Final Report

PILOT MARINE DEBRIS MONITORING AND ASSESSMENT PROJECT

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April 2012

EXECUTIVE SUMMARY

Developing standardized protocols to quantify marine debris is critical for the protection of natural resources and for evaluating debris removal programs and policies designed to reduce marine debris. The National Oceanic and Atmospheric Administration (NOAA) Marine Debris Division (MDD) developed a suite of sampling protocols to quantify marine debris on coastal shoreline habitats and in nearshore pelagic surface waters. We developed a large scale pilot project to test the ability of the protocols to quantify marine debris, monitor changes in debris density, and assess factors correlated with changes in debris density on short and long-term timescales. The overall goal of the pilot project was to provide feedback to the MDD on the level of sampling effort required to implement the protocols in a larger assessment program. Two sampling regions representing urban and rural land use in the coastal zone of the mid-Atlantic Bight were chosen to conduct the pilot project. Within the urban and rural regions, three locations consisting of three sampling sites each were sampled for marine debris along the shoreline and in the ocean using visual shoreline transect surveys and pelagic net sampling methods designed by the MDD. Each region was sampled bi-weekly from June 27th to December 08th, 2011 for a total of 12 sampling events per region over the 24 week survey.

MDD sampling protocols were successfully employed to sample debris and make estimates of debris densities. Debris was more common in the shoreline compared to the pelagic portion of the survey for each size class of debris. Plastic was the most common form of debris observed. Shoreline macrodebris varied over time and at each level of spatial resolution except for the region level. The urban and rural region had similar debris densities. Differences among shoreline locations were best explained by the sampling event on which the location was sampled, the number of people per site, and the total debris density. Shoreline macrodebris was weakly correlated with densities of people and the week of sampling. Both debris density and the number of people decreased over the course of the survey. Relative standard errors for shoreline macrodebris at the region, location, and site levels indicate that reasonably precise estimates were made (RSE<=30% in most instances). Pelagic macrodebris varied among locations but was similar between regions, among transects, and over time. Pelagic macrodebris was positively correlated with surface water temperature. Differences among pelagic locations were best explained by the sampling event during which the location was sampled and the surface water temperature. Relative standard errors for pelagic macrodebris at each spatial resolution indicate that estimates are imprecise due to high spatial and temporal variability of debris in the water. Sample size analyses indicate that sample size would have to increase exorbitantly to distinguish urban from rural due to the high degree of similarity between regions. Overall we found the sampling protocols employed in this survey are consistent and repeatable and based on our assessment would have the flexibility to serve as a guide for standardized methods for quantifying marine debris in small or large scale marine debris monitoring and assessment surveys. To further enhance these sampling protocols and future surveys we recommend (1) that a critical evaluation be conducted to determine the value of comparing differences in marine debris between land use types, (2) additional protocol testing be conducted in other shoreline habitat types, (3) readily available GIS and location specific data from U.S. regions be identified and compiled into a comprehensive GIS, and (4) that shoreline sampling continue in the location of the current pilot survey using a stratified random sampling rather than fixed sampling approach.

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1.0 INTRODUCTION

Marine debris is a problem that plagues the shorelines and coastal waters in the U.S. and around the world. It is now a source of prolonged economic hardship for coastal communities as it continues to accumulate and persist in the environment. Impacts from marine debris include degraded ocean habitats, imperiled marine and coastal wildlife, interference with navigation, and threatened human health and safety. It can physically ensnare individual animals and be ingested by fish, birds, mammals, and reptiles, potentially affecting growth, reproduction, and survivorship (Boerger et al. 2010; Gregory 2009). The problem is so great that the Scientific and Technical Advisory Panel (STAP) of the Global Environmental Facility (GEF) declared marine debris a global environmental problem and outlined a framework for the reduction of marine debris through the implementation of a product life-cycle approach to plastic-debris prevention (STAP 2011). Other known methods of reducing marine debris include direct debris clean-up activities, debris screening devices or other mechanical removal methods, and legislation designed to reduce or eliminate debris before it enters the environment.

Although marine debris awareness and prevention measures have become more common there is still a lack of standardized methodologies to assess the density and distribution of marine debris across multiple scales. Estimating the amount of debris that pollutes the nation's shorelines and adjacent waterways is critical to protecting our natural resources and for evaluating the effectiveness of debris removal programs or policies designed to reduce marine debris. The design of monitoring protocols has been difficult for resource agencies because of the breadth of factors related to debris densities and differing objectives of the agencies themselves. Nevertheless, developing standardized methods is necessary to compare marine debris abundance, distribution, movement, and impact on regional and national scales.

Working under the authority of the Marine Debris Research, Prevention, and Reduction Act (2006), the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Division (MDD) supports the research and development of methods to assess the status and impacts of marine debris. For several years the MDD has been developing a framework to implement a large-scale monitoring program designed to assess the quantity, type, and distribution of marine debris in the coastal zone. So far this initiative has included the development of standardized field methods to quantify debris on coastal shoreline habitats and in nearshore pelagic surface waters. Specifically, the MDD has compiled a suite of various field methodologies designed to quantify shoreline macro-debris ($\geq$ 2.5 cm), shoreline meso-debris (Between 5 mm and 2.5 cm), pelagic macro-debris ($\geq$ 5 mm), and pelagic micro-debris ($\leq<$ 0.33mm) debris. The MDD methods have been applied to a limited extent and require further application to test their validity and ability to characterize marine debris. We developed a pilot marine debris assessment project to further test the sampling protocols developed by the MDD. The specific objectives of the pilot project were to:

- Apply the monitoring protocols (shoreline and surface waters) to assess marine debris in a coastal region within the United States.
- Determine the baseline debris density in the study area using MDD assessment protocols.

- Monitor changes in debris density and assess factors correlated with changes in debris density on over time and space.
- Evaluate sample replication and statistical power required for valid statistical comparisons on temporal and spatial scales.

The pilot study was conducted for 24 weeks along two beaches and the adjacent ocean waters located in the mid-Atlantic Bight region of the United States. The entire suite of MDD field sampling protocols for shoreline and pelagic assessments were implemented in our survey; however micro-debris samples were not part of the final analysis. This report presents the methods that were used for sampling and the statistics used to evaluate the ability of the MDD protocols to monitor trends in marine debris density. The criteria used for final survey site selection is located in Appendix A, and the MDD protocols are located in Appendix E.

2.0 METHODS

2.1 SURVEY AREA AND SURVEY DESIGN

Two sampling regions in the coastal zone of the mid-Atlantic Bight were chosen for the marine debris survey. The first was the Delaware State Seashore Park (Figure 2-1). Located along the maritime coast of Delaware, this area is designated as urban because it is located at the mouth of the Delaware River which drains a highly urbanized watershed. The second was Assateague Island State Park located on the northern portion of Assateague Island in Maryland. This area was designated as rural because of its more remote location and distance away from urban centers. Within the urban and rural regions, three locations consisting of three sampling sites each were sampled for marine debris along the shoreline and in the ocean using visual shoreline transect surveys and pelagic sampling methods designed by the MDD. Each region was sampled bi-weekly from June 27th to December 08th, 2011 for a total of 12 sampling events per region over the 24 week survey.

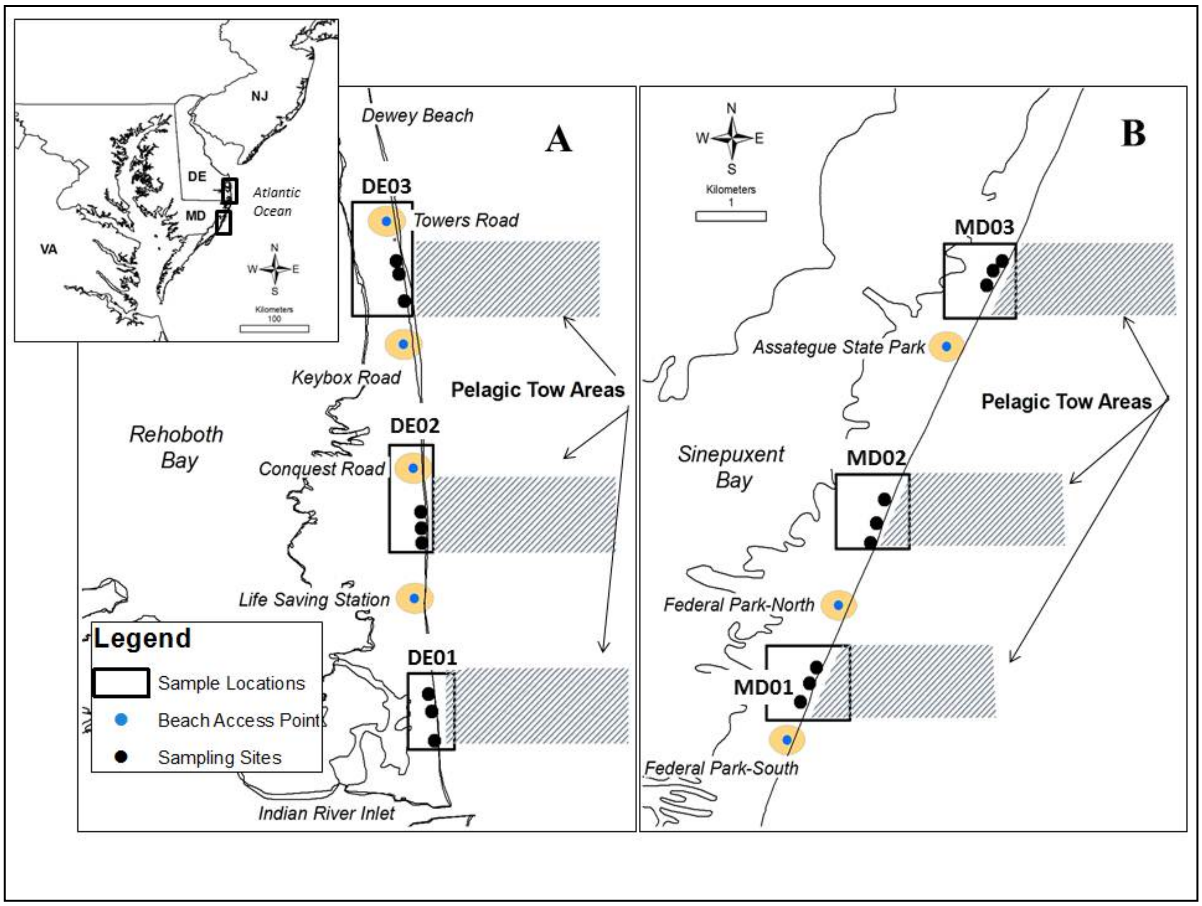


Figure 2-1. Maps depicting the sampling locations where shoreline and pelagic marine debris was assessed. A) The urban region located in the Delaware Seashore State Park in Delaware (urban) and B) the rural region located in the Assateague Island National Seashore and State Park in Maryland (rural).

Survey sampling sites were chosen through a desktop review of Geographic Information System (GIS) layers to identify all potential areas at Delaware State Seashore Park and the Assateague Island State Park that met sampling site selection criteria (see Appendix A for sample selection details). The final sampling locations were 1000 meters in length (in beach length units) and were partitioned into ten 100 m wide sample sites. This was the length of each sampling unit defined by MDD protocols. Each location was at least 1200 meters apart from the other two locations in that region to ensure each site represented an independent sample. Within each location three out of the ten potential shoreline sampling sites were randomly chosen for sampling and the location of those sites remained fixed for the duration of the survey so that within site variability could be examined. Each of the fixed 100 m sampling sites was further partitioned into 20 smaller 5 m wide sampling units following the MDD protocols (Figure 2-2). A total of four of these sampling units were randomly chosen and sampled at each site during a sampling event for a total of 12 transects sampled per location per event (Figure 2-3). Specific details of each sampling method are described in section 2.2.

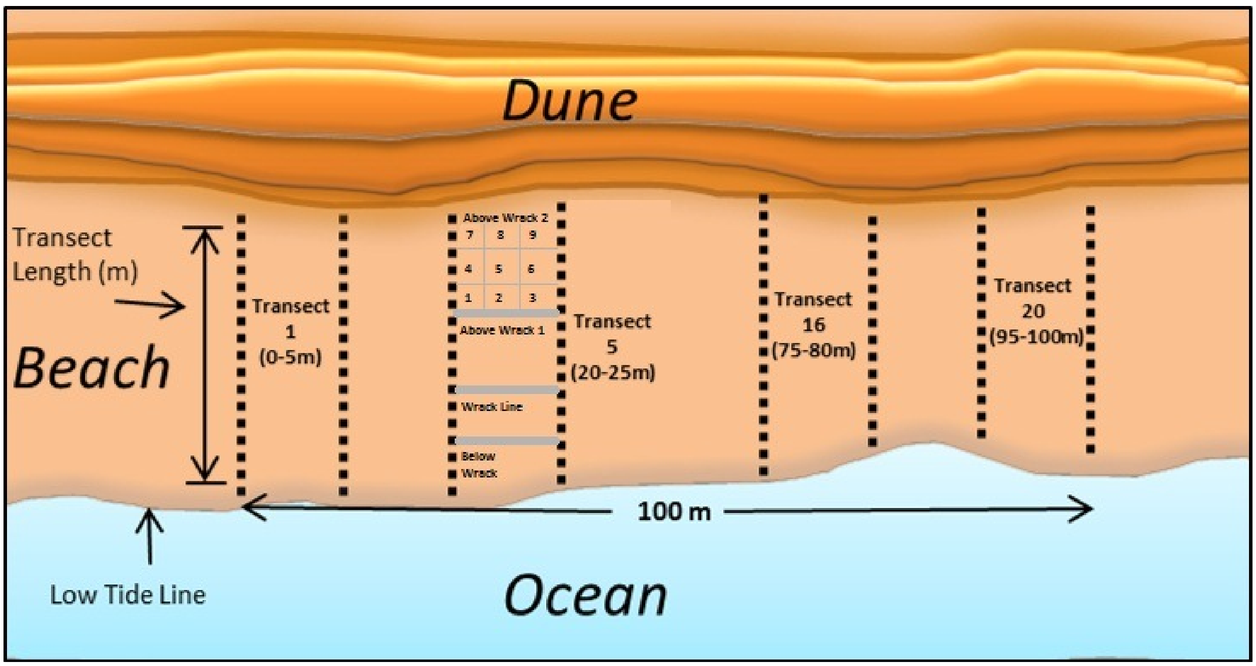


Figure 2-2. Shoreline section (100m) displaying perpendicular transects from water's edge at low tide to the first barrier (dune toe) at the back of the shoreline section. Transect five depicts how each transect was divided for meso-debris sampling.

Marine debris was also sampled in ocean surface waters adjacent to each of the regional beach locations. Pelagic debris sampling using a manta-net was conducted at the location level within 1 nm offshore of each beach location (1000 m) (Figure 2-1). Due to the length of each pelagic tow and other factors affecting tow direction and distance (i.e., wind and current) pelagic tows were not restricted to site level sampling. A total 9 sampling stations were randomly chosen within each of the three locations in each region during a sampling event (Figure 2-3). Specific details of each sampling method are described in section 2.2.

All site specific and debris data collected during the pilot project was documented on field data sheets. The MDD had a set of proposed datasheets that were included in the MDD sampling protocols. The datasheets for shoreline and pelagic sampling were slightly modified based on the specific needs of this project and suggested enhancements. Each datasheet used in our survey is presented in Appendix B. Datasheet modifications were performed to streamline the volume of data collected thereby reducing the number of datasheets required in the field. A list of items deleted from and added to the original MDD datasheets is presented in Appendix C.

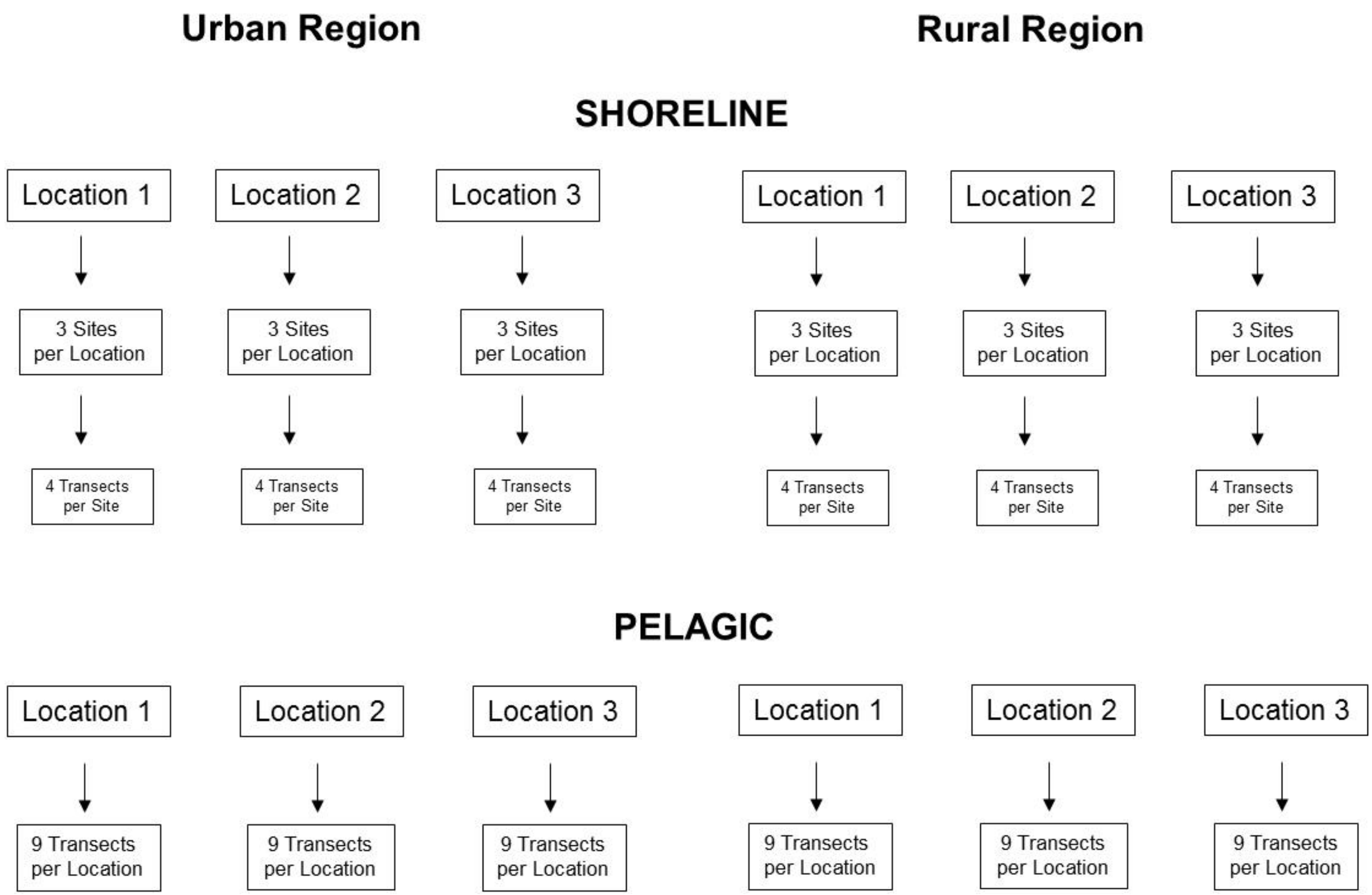


Figure 2-3. Sampling scheme for the shoreline and the pelagic portions of the survey.

2.2 SAMPLING MODES

2.2.1 Shoreline Macro-Debris (≥ 2.5 cm)

Four randomly selected transects within each site were sampled during each sampling event for a total of 36 sites sampled per region per event. Transects were 5m wide and ran perpendicular to the shoreline section from water's edge to the tow of the beach dune. Sampling events occurred at or near the daily low tide. During sampling events each sample site was located using a handheld Global Positioning System (GPS). Once a site was located the entire 100m site was demarcated using a surveyor's measuring wheel (Figure 2-4) and each randomly chosen 5m transect was marked using surveyors flagging. The length of each transect was measured and recorded along with the beginning and end GPS coordinates. The beach aspect and distance from the water's edge to the beginning of the wrack line were also recorded. Additional location and site specific information recorded included the time, season, date of last survey, description of recent storm activity, current weather conditions, primary substrate type, and the number of beach-goers present within the location, site and transect.

Figure 2-4. Picture of survey crew delineating site using a surveyor's wheel.

The amount of marine debris within each transect was counted by visually inspecting the substrate surface and tallying debris ≥ 2.5cm in size according to its material type and subcategory. Visual inspections were conducted by two or more trained technicians by walking and tallying debris on field datasheets. The width of each transect was divided by the number of technicians conducting the survey and each technician was responsible for visually inspecting and documenting debris located in a portion of the transect. For example, when two technicians were conducting the survey the transects were split in the middle and each technician was responsible for a 2.5m wide area of the transect. Inspections were conducted is straight lines from the water's edge to the dune line or vice versa. To avoid missing debris or double counting, technicians frequently discussed whether debris located at the edge of each technician's area had been documented.

When large debris items (> 30 cm) were encountered, a photo was taken, and data were entered on a separate datasheet. Debris items were classified based on MDD protocols using the Marine Debris Survey Photo Manual (2010) provided by the MDD as a field reference for debris identification and classification. On average, each site required 30 minutes (Range 20 to 42 minutes) to delineate transects and conduct all sampling and data collection.

2.2.2 Shoreline Meso-Debris (Between 5 mm and 2.5 cm)

Each transect was partitioned into four sections: one section between the wrack line and the water's edge, the wrack line, and two equally sized areas above the wrack line up to the end of each transect (Figure 2-5). One section per transect was randomly chosen to be sampled for meso-debris by rolling a 12 sided die. A PVC quadrat was tossed into the chosen section and the sand in that location was processed on the beach by sieving it through a stainless steel 5 mm mesh sieve to collect those debris items > 5 mm (Figure 2-5). A length measurement was taken for each piece of meso-debris. The type of meso-debris and length was recorded on the datasheet separate from the macro-debris counts.

Figure 2-5. Picture of sieve and scoop used to sample shoreline meso-debris.

2.2.3 Pelagic Macro-Debris (≥ 5mm)

Pelagic manta-net sampling occurred adjacent to each of the three large sampling locations located at the urban and rural regions (Figure 2-1). This includes the area of water adjacent to the 1000 m wide location out to 1 nm offshore from the low-tide line and within 1 nm to the north and south of the centerpoint of the shoreline site. Nine sampling stations were randomly selected for sampling within each location for a total of 27 samples per sampling event in a region. Pelagic debris samples were collected using a manta-net with a body composed of

0.330 mm nylon mesh and measuring approximately 3m in length. Navigation to each station was done using a differential GPS unit accurate to within 10 m. Once on site the net was deployed from the port side of the vessel and was positioned approximately 50m behind the vessel for the duration of the tow (Figure 2-6). To avoid tow direction bias, the direction of each tow was randomly chosen using a 12 sided die where each number corresponded to 30 degrees of the vessels compass. The net was towed for 15 min or a distance of 0.5 nm and towed at a speed of 1-2 knots. The beginning and ending DGPS coordinates were recorded to calculate the total distance of each tow. An analog flow meter was attached to the net frame and suspended in the center of the net mouth. A flow reading was recorded just prior to net deployment and immediately after the net was fully retrieved to calculate total volume of water sampled. Site specific information recorded included the time, season, date of last survey, description of recent storm activity, current weather conditions, site and transect number. Water quality was also recorded at shallow, middle, and deep water depths within each location. Depth classification was relative to the depth gradient at each location but overall depths were similar between all regional locations (Avg. MD-Shallow 6 m, MD-Middle 10 m, MD-Deep 13 m; DE-Shallow 7 m, DE-Middle 9 m, DE-Deep 11 m). An individual water quality cast was conducted at each of the depth locations to measure temperature, PH, dissolved oxygen, and salinity at the bottom and surface of the water.

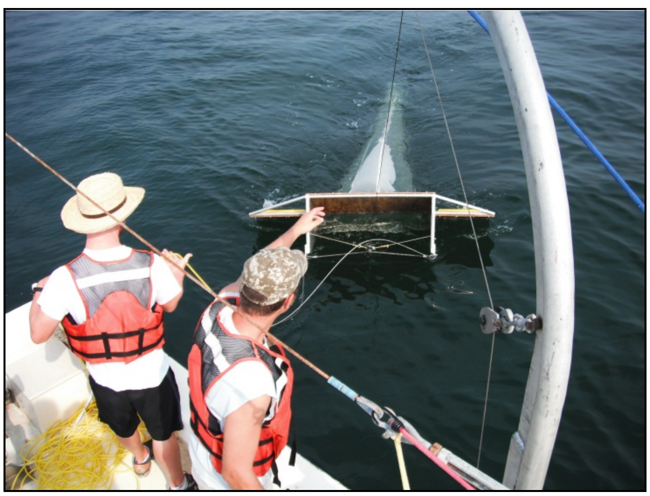


Figure 2-6. Picture of manta-net sample being retrieved.

Contents of the net were gently washed from the outside into the cod end with seawater. The cod end was then detached, and its entire contents were sieved through two screens (5 mm, 0.33 mm) to collect debris items (Figure 2-7). Obvious large natural items were recorded on the datasheet and then discarded. Large debris, items approximately > 20cm, were counted on a separate large debris datasheet for each site and then discarded appropriately. Sieved samples were sorted by size class on the vessel and all debris collected in the 5 mm size class was identified and processed on the vessel and tallied on debris datasheets. Any large debris items that were initially funneled into the net but were too large to be captured were noted on a separate datasheet.

Figure 2-7. Picture of pelagic sample being processed on research vessel.

2.2.4 Pelagic Meso-Debris (Between 0.33 mm and 5 mm)

Debris collected on the 0.33 mm mesh sieve were processed into glass sampling jars and preserved in formalin and retained for further analysis. Jars were labeled with the site ID, transect number, and date.

2.2.5 Quality Assurance and Control Methods

Quality Assurance and Control (QA/QC) of field collection methods was performed through initial training sessions conducted in collaboration with MDD personnel and through subsequent random visits to sites by designated quality control officers. A one-day training workshop on methods was conducted with the MDD several weeks prior to the first sampling event. The workshop consisted of reviewing sampling methodologies, discussing lessons learned from previous MDD projects, and implementing both shoreline and pelagic sampling methods at a local beach (Sandy Point, MD) and in the Chesapeake Bay. The techniques and lessons learned during this training session were applied during the project phase.

QA/QC of data collection activities was conducted through random site visits by QA/QC officers. During QA/QC operations, shoreline data collection methods were assessed by observing site and transect level delineations and by reviewing field data sheets. Debris detection and classification ability were also assessed during QA/QC site visits. The assessment consisted of comparing the debris documented from transects performed by the field crews to the debris documented by QA/QC officers within the same transect. Once the field crew completed a transect, the QA/QC officers inspected the transect and marked each piece of debris with a flag as they moved through the transect. Immediately afterwards, both groups went back through the transect to compare debris items documented on both data sheets. Our goal was 100% correspondence but 80% correspondence was deemed sufficient to meet our QA/QC standard.

QA/QC of pelagic tow operations was performed during the same site visits as the shoreline QA/QC. Pelagic tow operations were monitored for consistency, vessel and crew safety, technique and data quality. QA/QC officers reviewed data documented on field data sheets and debris processing methods. If discrepancies with preferred methods were observed, they were noted and corrected in the field.

3.0 STATISTICAL METHODS

Data are presented graphically throughout this report. Averages at the region, location, and site level were calculated by summing the number of debris in a transect or tow and then dividing by the actual area of the transect to calculate density for that transect. For shorelines, the average density per transect was calculated across transects at the desired level of spatial resolution. For surface waters, density was calculated by dividing the number of debris in a tow by the volume of water sampled using the equations below where net height=1.016m, the net width = 0.1778m, and the rotor constant=26,873m. (The denominator 999,999 refers to the total possible rotations of the flow meter). Error bars in graphs indicate ±1se in all cases.

$$Pelagic\ Density = \frac{\#\ of\ Debris}{Volume\ (m3)}$$

$$Volume = Net\ Height\ (m) * Net\ Width\ (m) * Distance\ (m)$$

$$Distance = \frac{[End\ Flowmeter\ Count - Start\ Flowmeter\ Count] * Rotor\ Constant}{999{,}999}$$

A mixed model analysis of variance (ANOVA) was used to examine differences in the density of marine debris at each spatial scale of resolution and over time. The main effects for the shoreline analysis included region (urban vs. rural), location nested within region, site nested within location, transect nested within site, and time. Time was defined as the paired sampling event number (Table 3-1). For the pelagic analysis, the same main effects were used except that transects were nested within locations because there were no sites in the pelagic sampling scheme. The paired sampling event number was derived by assigning the first sampling event at both urban and rural locations as 1, the second sampling event at urban and rural locations as 2, etc. (Table 3-1). Time was also crossed with each of the main effects to determine if there were significant temporal changes at each spatial scale. All of the main effects were considered to be random except for region which was considered to be a fixed effect. This analysis was conducted for shoreline macro-debris, shoreline large item debris, and pelagic macro-debris. Both shoreline meso-debris and pelagic large item debris were so rare, that no formal statistics were conducted for these types of debris. Shapiro-Wilkes test was used to determine whether data were normally distributed and Levene's test was used to test for homogeneous variances. Data were ln(x+1) transformed to meet the assumptions of ANOVA when necessary.

We calculated the Pearson's correlation coefficient to explore the correlative relationships between macro-debris density (the most common size class) and various environmental and human factors at the scales of site (shoreline) and location (shoreline and pelagic). Averages for debris density and each correlative variable were taken at the spatial scales of the site and location. For shoreline debris, these factors included the number of beach-goers at the location and at the site, wind speed, tidal range, transect, and paired sampling event number. For pelagic debris, these factors included wind speed, surface water temperature, surface water dissolved oxygen, surface water pH, surface water conductivity, tow length, and paired sampling event number. We also examined the correlation between pelagic and shoreline debris at the location and at the region level. When appropriate, data were ln(x+1) transformed.

Principal components analysis (PCA) was used to explore what factors might separate sampling locations from one another. For each sampling location and date, we examined the influence of each of the following: total debris density, wind speed, region, transect or tow length, paired sample event number, and in the case of pelagic locations we also considered surface dissolved oxygen, conductance, pH, and temperature. This analysis was conducted using location level data. Each of the response variables were averaged over the 24 weeks of the survey with the exception of debris density which was the total density of macro-debris over the entire survey. Region was coded as a numerical variable. Separate PCAs were conducted for shoreline and pelagic macro-debris. Data were ln(x+1) transformed to meet the assumption of normality for PCA when necessary.

Table 3-1. Sampling events and the specific week and date they were conducted. Superscripts denote the occurrence of a=Hurricane Irene and b=Tropical Storm Lee. Rural sampling was conducted on odd numbered weekly events and urban sampling was conducted on even numbered weeks.

Paired Sample Event	Individual Weekly Sampling Event	Dates
1	1	06/27-06/30
	2	07/05-07/08
2	3	07/11-07/13
	4	07/18-07/21
3	5	07/25-07/27
	6	08/01-08/03
4	7	08/08-08/10
	8	08/15-08/17
5[a]	9	08/22-08/24
	10	08/30-09/01
6[b]	11	09/06-09/07
	12	09/13-09/15
7	13	09/19-09/20
	14	09/28-10/05
8	15	10/04-10/06
	16	10/11-10/12
9	17	10/17-10/20
	18	10/24-10/26
10	19	10/31-11/02
	20	11/07-11/09
11	21	11/14-11/16
	22	11/18-11/19
12	23	11/28-11/30
	24	12/06-12/08

Power analysis was used to determine the number of transects required to distinguish an urban from a rural region. Statistical power can be defined as the probability of correctly rejecting a null hypothesis that is false (Sokal and Rohlf 1981). Power is a function of alpha (the Type I Error rate), sample size, and effect size of the survey design. Because there was a large amount of variation among sampling events, separate analyses were conducted for each sampling event. We used the power procedure in SAS with the two sample means option to carry out this analysis (SAS Institute, Inc. 2008). We entered the mean and standard deviation for each urban and rural based on the data set and designated various alpha levels (0.05, 0.1) and power (0.5, 0.65. 0.8, 0.99). The average used in the power analysis was calculated as the average among all transects per region for each sampling event. The standard deviation used in the power analysis was calculated as the median of the 9 site level standard deviations per region, per sampling event (i.e., standard deviations among transects within sites).

Bootstrap analysis was conducted to determine the number of samples required to minimize variability in order to make a reasonably precise estimate of debris density. For ecological survey data, a dataset with an RSE of 20-30% provides a reasonably precise estimate of the mean. The data showed that region and location level estimates of shoreline debris were below 30% in most instances; therefore, we focused our bootstrap analysis on site level data for shorelines and the location level data for surface waters. Bootstrap analysis is a statistical resampling method used to evaluate the statistical precision of sample estimates. For sites representing a range of variability in the estimate of debris, the dataset was resampled randomly with replacement 1,000 times using a fixed sample size to determine the empirical sampling distribution of the observed data using that sample size. The mean, variance, and relative standard error (RSE) was calculated for this distribution. This process was repeated for numerous sample sizes in order to determine the number of samples required to attain a reasonably precise coefficient of variation (20-30%). Separate analyses were run for individual sampling events in order to partition out differences due to sampling events. For the spatial resolution of site, a subset of sites spanning the range of variability was examined to reduce the computational intensity required for this portion of the analysis.

4.0 RESULTS

4.1 SURVEY SUMMARY STATISTICS

A total of 864 shoreline transects and 621 pelagic manta-net tows were successfully completed during the 12 week survey (Tables 4-1 and 4-2). No pelagic sampling occurred during the week of September 6 due to dangerous sea conditions caused by Tropical Storm Lee. The lengths of the shoreline transects from water's edge to the first physical barrier ranged from 42m to 52m in rural locations and 42m to 61m in urban locations. Among pelagic samples, manta-net tow lengths ranged from 903m to 906m in rural locations and from 894m to 914m in urban locations.

Table 4-1. Shoreline transect meta-data.

Area	Site Code	Location Name	N	Average Recorded Length (m)	SE Recorded Length
Rural	MD01	Federal Park North	144	42.382	0.611
Rural	MD02	Federal Park South	144	51.681	0.574
Rural	MD03	Assateague State Park	144	52.078	0.564
Rural Total			432	48.714	0.399
Urban	DE01	Life Saving Station	144	42.147	0.929
Urban	DE02	Conquest Road	144	53.925	0.775
Urban	DE03	Towers Road	144	60.965	0.749
Urban Total			432	52.346	0.603
Combined Total			864	50.530	0.367

Table 4-2. Pelagic manta-net tow meta-data.

Area	Location	Location Name	N	Average Tow Distance (m)	SE Tow Distance	Average Volume Filtered (m^3)	SE Volume Filtered (m^3)
Rural	MD01	Federal Park North	108	903.27	6.03	130.44	1.28
Rural	MD02	Federal Park South	108	908.69	12.56	132.14	1.30
Rural	MD03	Assateague State Park	108	906.26	3.62	132.15	1.33
Rural Total			324	906.07	4.79	131.58	0.75
Urban	DE01	Life Saving Station	99	894.42	10.22	136.66	4.43
Urban	DE02	Conquest Road	99	906.37	5.05	136.26	1.65
Urban	DE03	Towers Road	99	913.61	3.95	131.50	2.18
Urban Total			297	904.80	4.03	134.81	1.73
Combined Total			621	905.46	3.15	133.12	0.92

The number of recreational users present on the shoreline varied among sites and among locations (Table 4-3). Rural locations and sites generally had greater numbers of beach-goers than urban locations sites and locations.

Table 4-3. Sample number information, sampling dates, and beach-goer counts from the shoreline survey. Superscripts denote the occurrence of a=Hurricane Irene and b=Tropical Storm Lee.

Paired Sample Event #	Individual Sample Event #	Dates	A) Total # of People in the 3 Locations		B) Total # of People in the Sites Sampled					
			Rural	Urban	MD01	MD02	MD03	DE01	DE02	DE03
1	1	06/27-06/30		-				4	0	0
	2	07/05-07/08	520		24	69	0			
2	3	07/11-07/13		125				0	2	0
	4	07/18-07/21	249		53	0	0			
3	5	07/25-07/27		21				0	0	4
	6	08/01-08/03	954		92	41	0			
4	7	08/08-08/10		108				6	11	2
	8	08/15-08/17	930		46	26	0			
5[a]	9	08/22-08/24		0				0	0	0
	10	08/30-09/01	198		21	0	0			
6[b]	11	09/06-09/07		0				0	0	0
	12	09/13-09/15	105		7	8	0			
7	13	09/19-09/20		4				0	2	0
	14	09/28-10/05	27		12	0	0			
8	15	10/04-10/06		3				0	0	0
	16	10/11-10/12	8		0	0	0			
9	17	10/17-10/20		3				1	0	0
	18	10/24-10/26	9		0	0	0			
10	19	10/31-11/02		0				0	0	0
	20	11/07-11/09	21		2	0	0			
11	21	11/14-11/16		21				0	2	0
	22	11/18-11/19	0		0	0	0			
12	23	11/28-11/30		0				0	0	0
	24	12/06-12/08	0		0	0	0			
Total			3,021	285	257	144	0	11	17	6

Four random QA/QC site visits were performed (08/15, 09/19, 9-30 and 10-05) during the marine debris assessment. A total of seventeen transects were assessed for debris detection and classification accuracy. Two of the seventeen (~ 10%) transects failed (< 80% accuracy) debris detection accuracy when compared to transects conducted by QA/QC officers. Those instances occurred during the initial site visit and greater correspondence with QA/QC officers was attained during subsequent site visits. There was slightly greater misclassification of debris items between QA/QC officers and field crews; however this was primarily due to an unclear classification of food wrappers and plastic sheets. These discrepancies were also more prevalent during the first site visit and greater correspondence was attained during subsequent visits once the distinction between those two plastic items was more clear to staff. Actions to resolve misinterpretations were done in the field during QA/QC site visits. No detection or classification errors were witnessed during pelagic tow operations QA/QC.

The frequency with which debris occurred in transects was greatest for shoreline transects and pelagic tows for macro-debris (Table 4-4). Shoreline meso-debris and large item debris, both along shores and in pelagic tows, was less common.

Table 4-4. Percent of shoreline transects or pelagic tows containing each size-class of debris.

	Shoreline			**Pelagic**	
	Meso-Debris	**Macro-Debris**	**Large Item Debris**	**Macro-Debris**	**Large Item Debris**
Urban	1.9%	96.8%	10.2%	28.3%	0.34%
Rural	3.0%	94.9%	3.7%	20.4%	0.93%

4.2 MARINE DEBRIS DENSITY

4.2.1 Shoreline Macro-Debris

The density of shoreline macro-debris was significantly different among locations nested within region, among sites nested within location, and among transects nested within sites (Figures 4-1, Table 4-5). This reflects the wide range of variation in debris density at each of these levels of spatial resolution. Significant interactions between each of these factors and time indicate that there was a great deal of temporal variability at each level of spatial resolution as well. The effect of location nested within region was driven by the differences among the three rural locations (Figure 4-2). On average, MD-01 had four times as much debris as MD-03 and twice as much as MD-02. The significant interaction between location and time was influenced by the peaks in debris density at MD-01 during sampling events 5 and 6, where debris density was much greater than at any other locations during any other sampling events (Figure 4-3). This spike was coincident with Hurricane Irene and Tropical Storm Lee. The greatest variability among sites within locations, among transects within sites, and over time also occurred at location MD-01 (Figure 4-4). There was no significant difference in debris density between the urban and rural region (Table 4-5, Figure 4-5). Debris counts and debris density (#/100m2) for all shoreline transects conducted is presented in Appendix D.

Table 4-5. Results of ANOVA for shoreline macro-debris density. Den=the denominator used to calculate the F-ratio. 1=$MS_{Location(Region)}$=13.4; 2=$MS_{Site(Location)(Region)}$=0.76; 3=$MS_{Transect(Site)(Location)(Region)}$=0.23; 4=$MS_{Error}$=0.15. ns=not significant, * p<0.05, **p<0.01, *** p<0.001, ****p<0.0001.

Source	df	MS	F	p	Den
Region	1,4	2.77	0.21	ns	1
Location(Region)	4,12	13.4	17.7	****	2
Site(Location)(Region)	12,54	0.76	3.22	***	3
Transect(Site)(Location)(Region)	54,594	0.23	1.59	**	4
Time	11,594	6.48	44.0	****	4
Time X Region	11,594	1.93	13.1	****	4
Time X Location(Region)	44,594	0.59	4.03	****	4
Time X Site(Location)(Region)	132,594	0.26	1.79	****	4

The majority (79-88%) of debris at all locations, both urban and rural, was composed of plastics (Figure 4-6). Processed lumber contributed 8-13% of the debris. The predominance of plastics and processed lumber was consistent over time at all locations (Figure 4-7). The remaining major types of debris each comprised <4% of the debris. Among debris subtypes, plastics/polystyrene fragments, plastic sheets, cigarettes, and bottle/container caps were the most common (Figure 4-8).

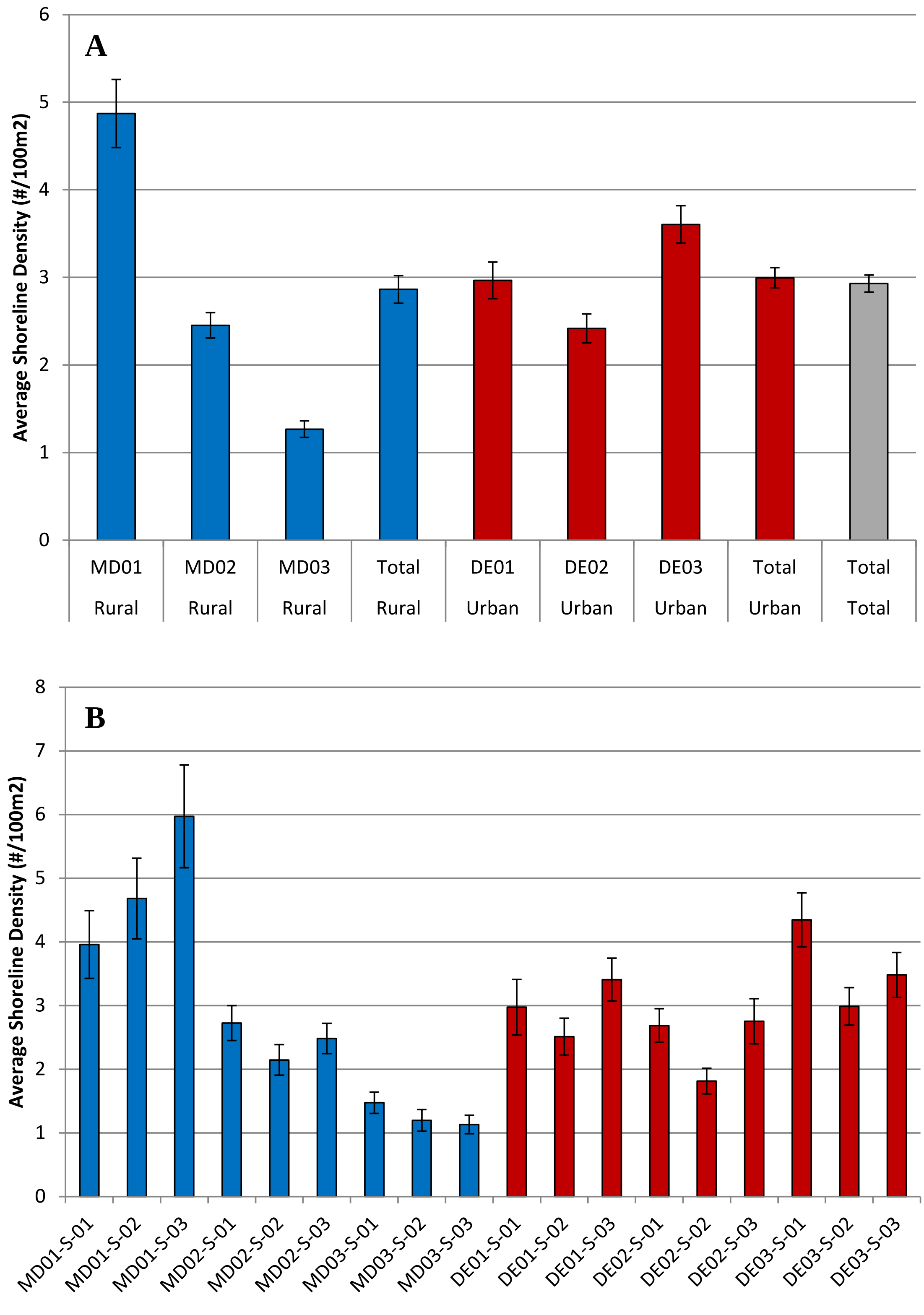


Figure 4-1. Average shoreline debris density per 100m^2 for each of the A) locations and B) sites sampled in the urban and rural regions. Error bars represent ±1se of the mean.

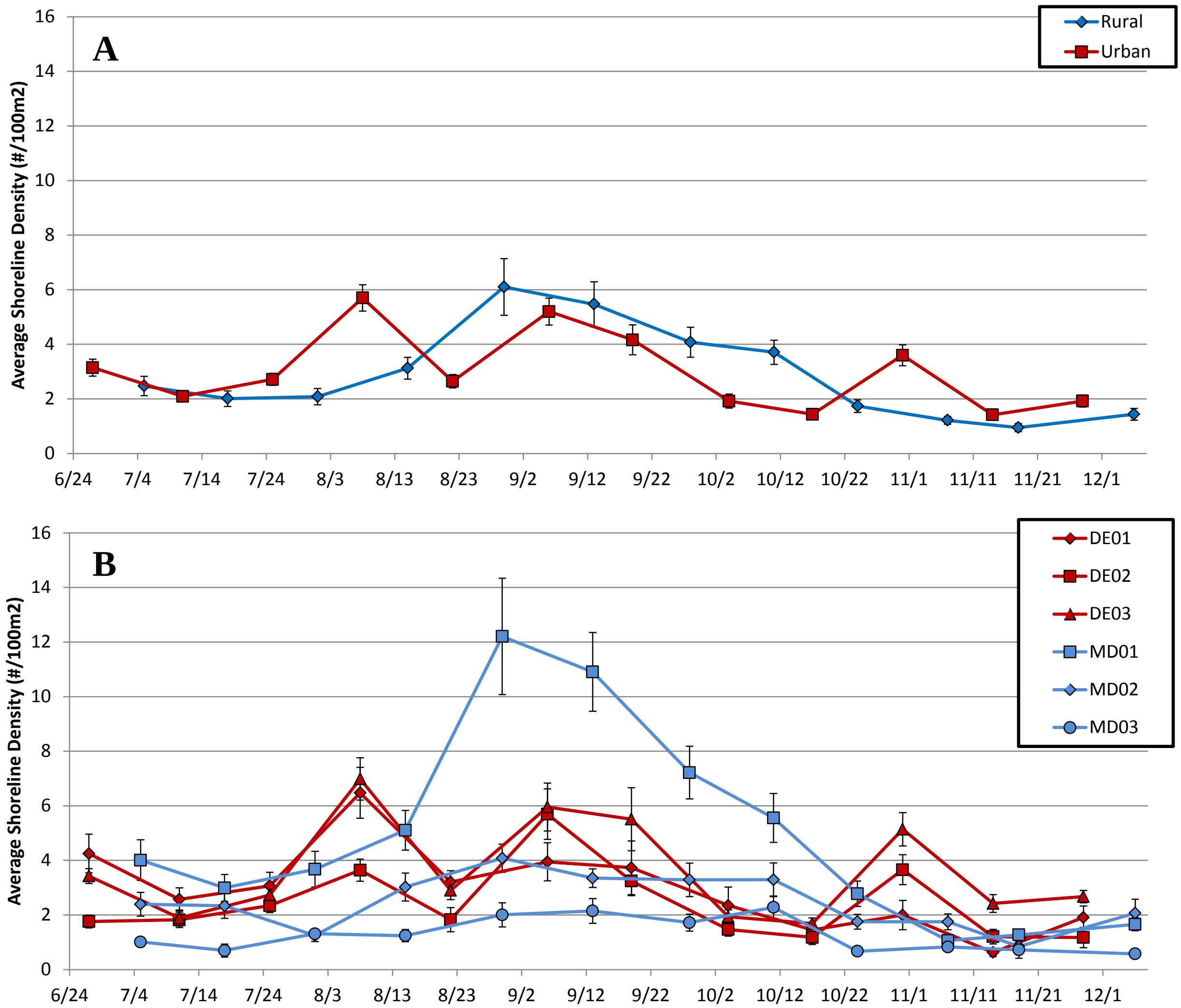


Figure 4-2. The average shoreline debris density per sampling event for each A) region and B) location sampled. Error bars represent ±1se of the mean.

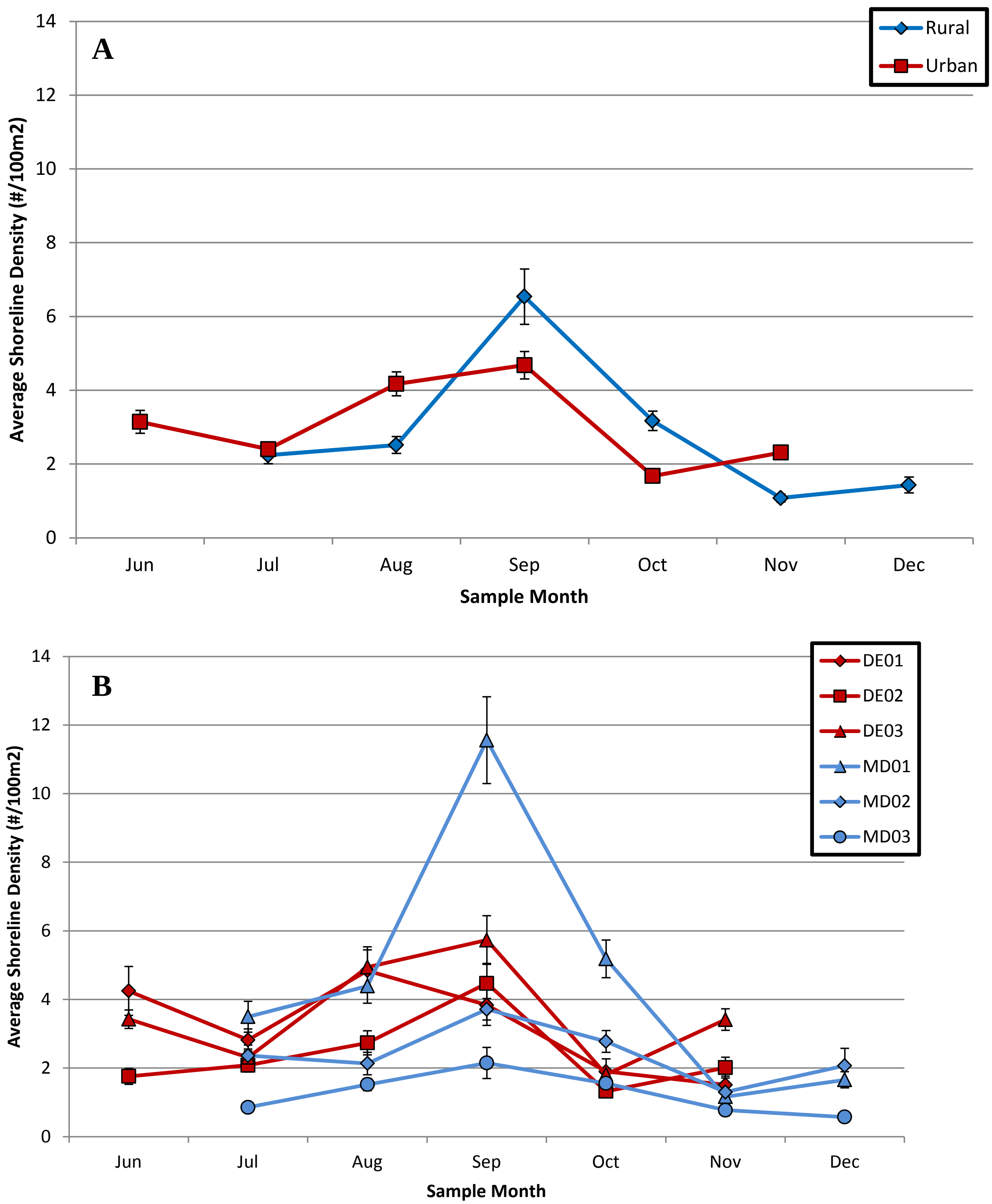


Figure 4-3. The average shoreline debris density per month for each A) region and B) location sampled. Error bars represent ±1se of the mean.

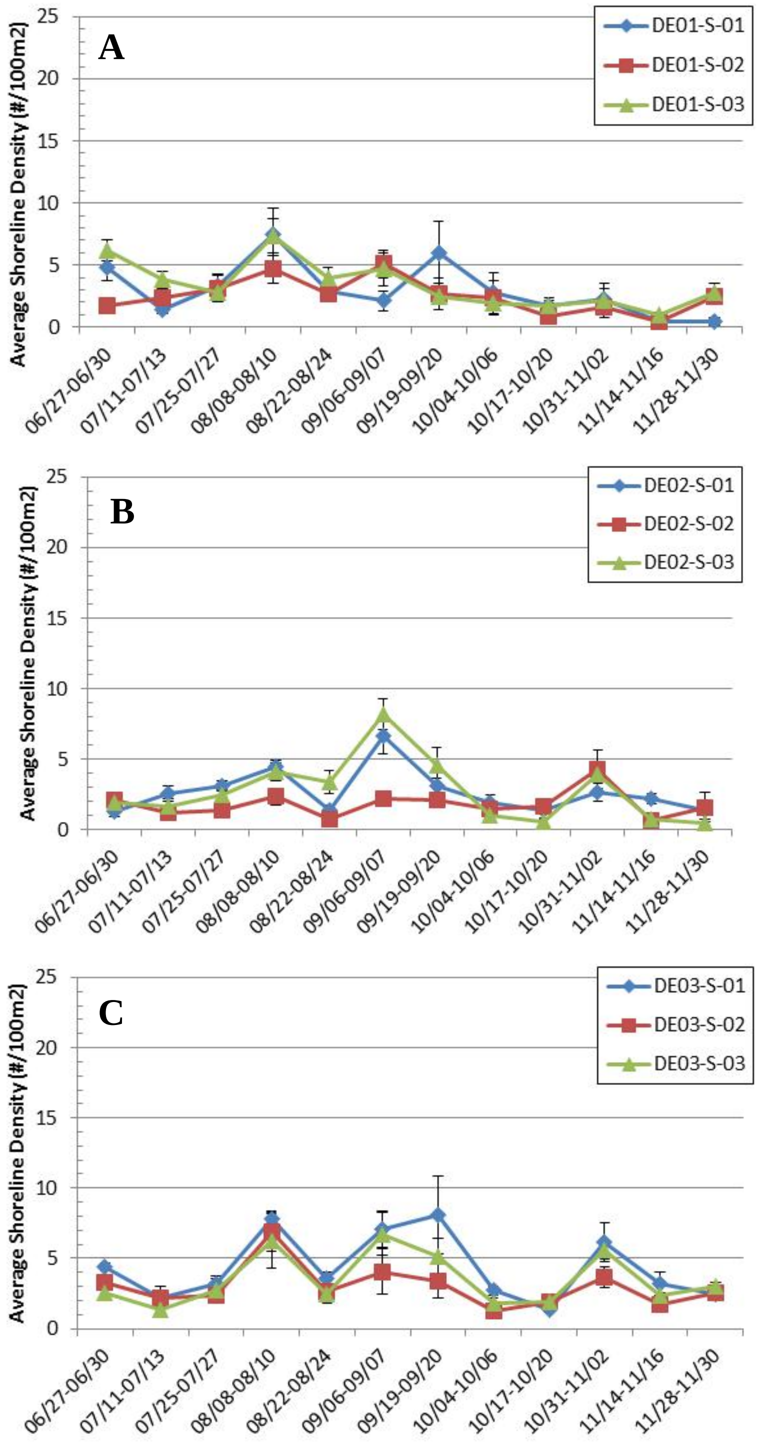


Figure 4-4. Average shoreline debris density per sampling event for each site sampled for each location A) DE01, B) DE02, C) DE03, D) MD01, E) MD02, and F) MD03.

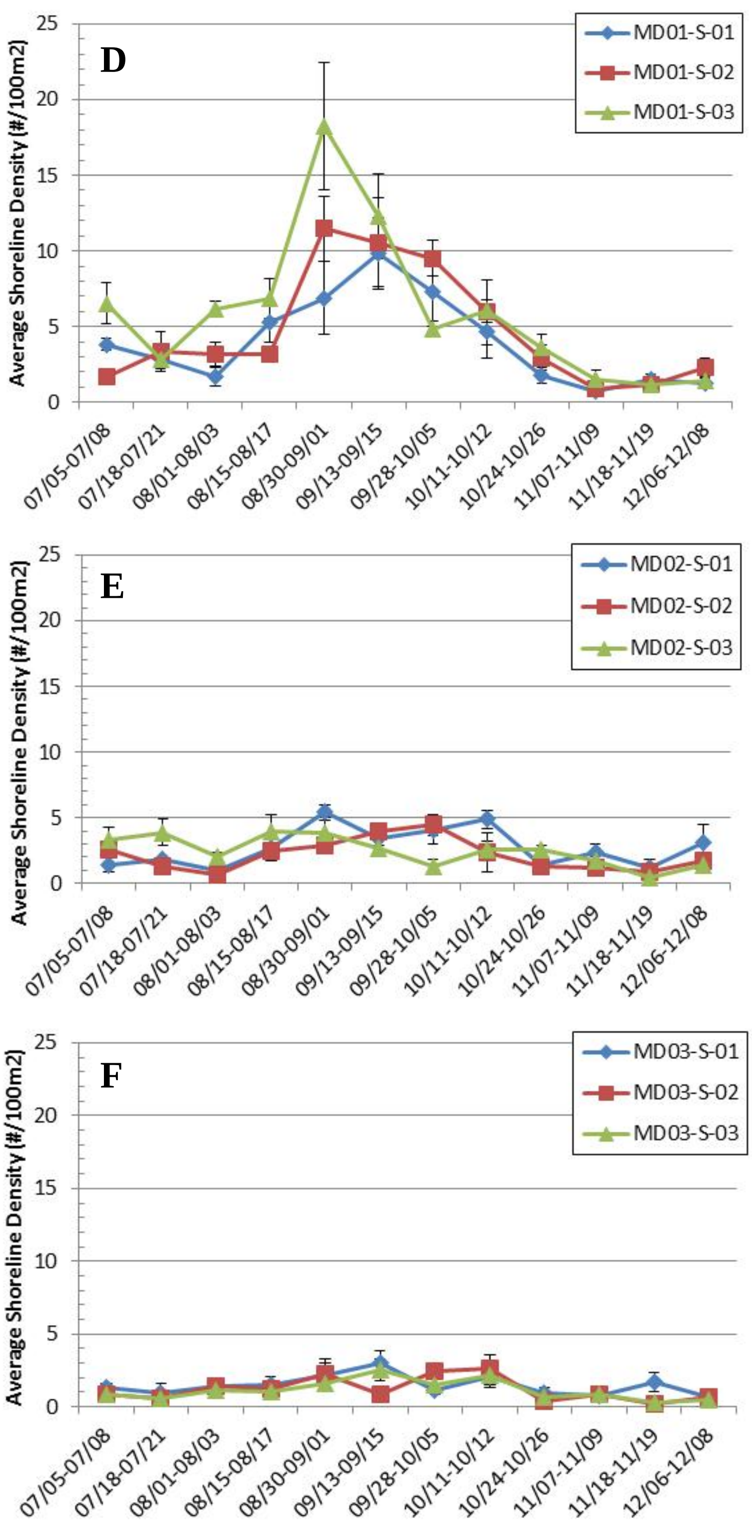
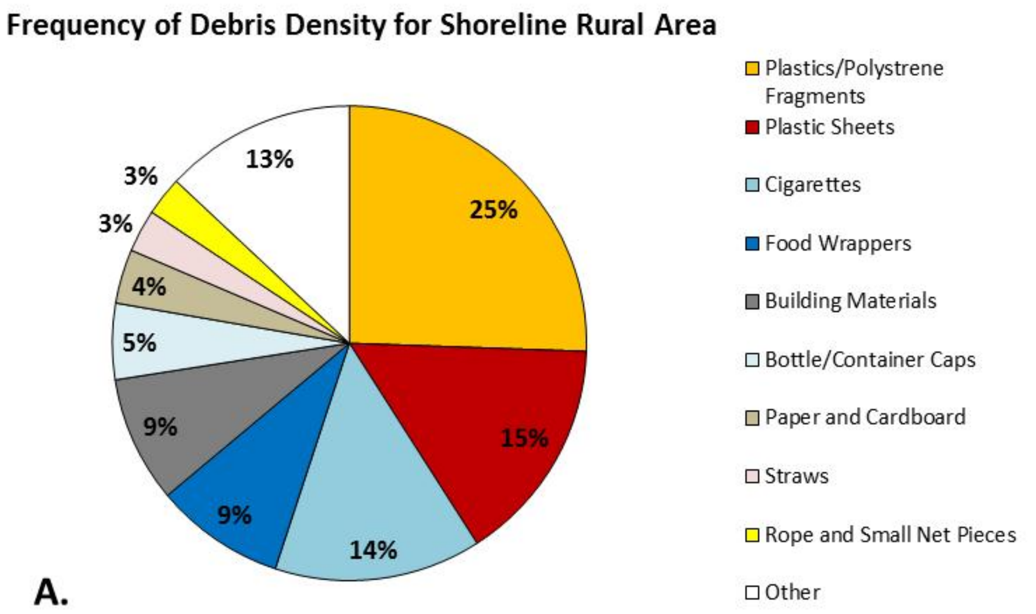


Figure 4-4. (Continued).



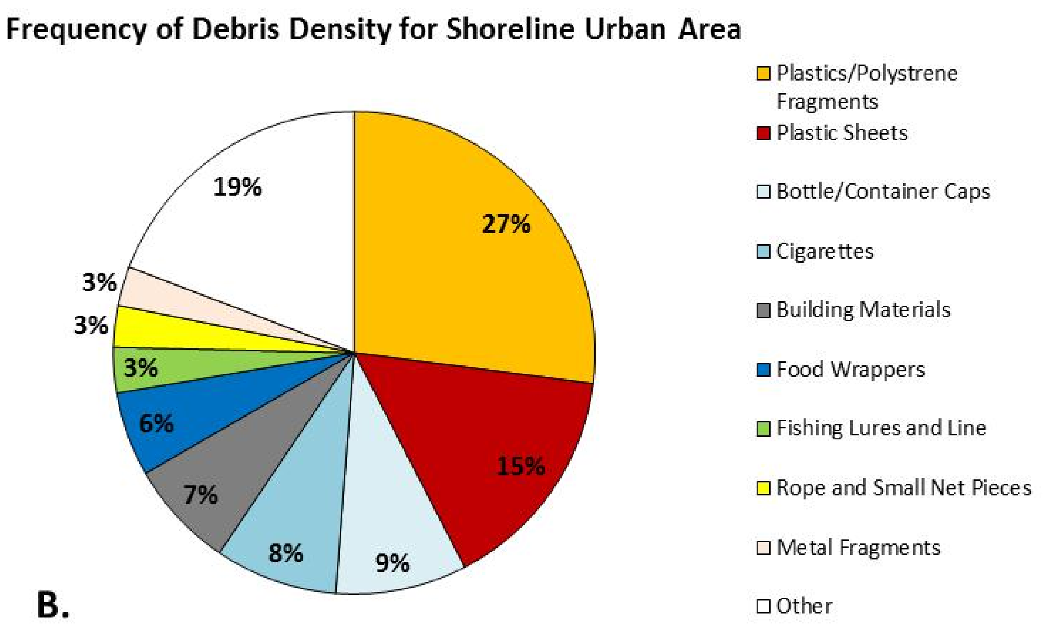


Figure 4-5. The frequency with which each type of shoreline debris was present by density in the A) rural region and B) urban regions.

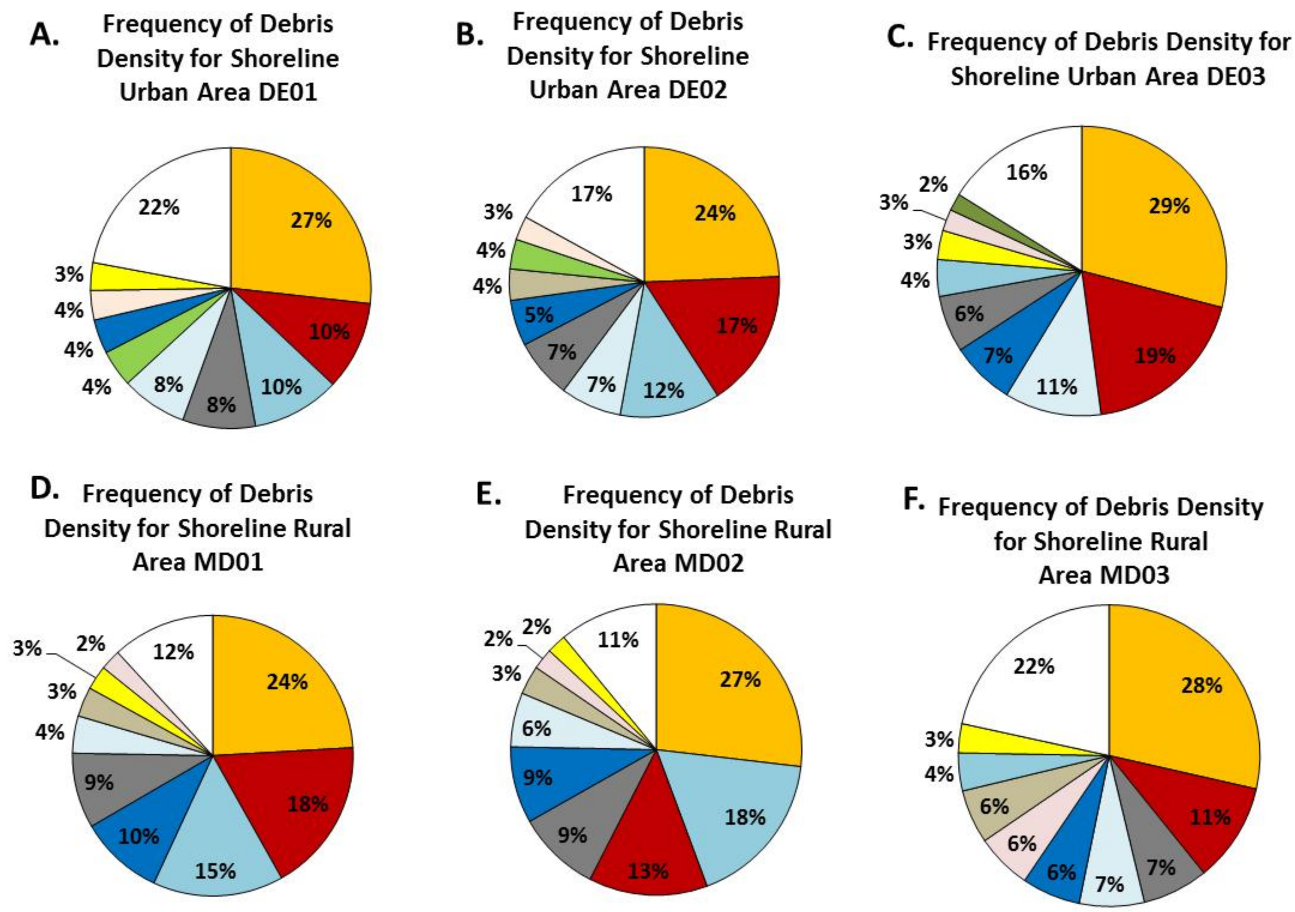


Figure 4-6. Frequency of each subtype of debris per location by density for each location A) DE01, B) DE02, C) DE03, D) MD01, E) MD02, and F) MD03. Orange=plastics/polystyrene fragments, Red=Plastic sheets, Aqua=Cigarettes, Dark Blue=Food Wrappers, Grey Building materials, Pale Blue=Bottle/Container caps, Tan=Paper and cardboard, Yellow=Rope and small net pieces, Pink=Straws, White=Other.

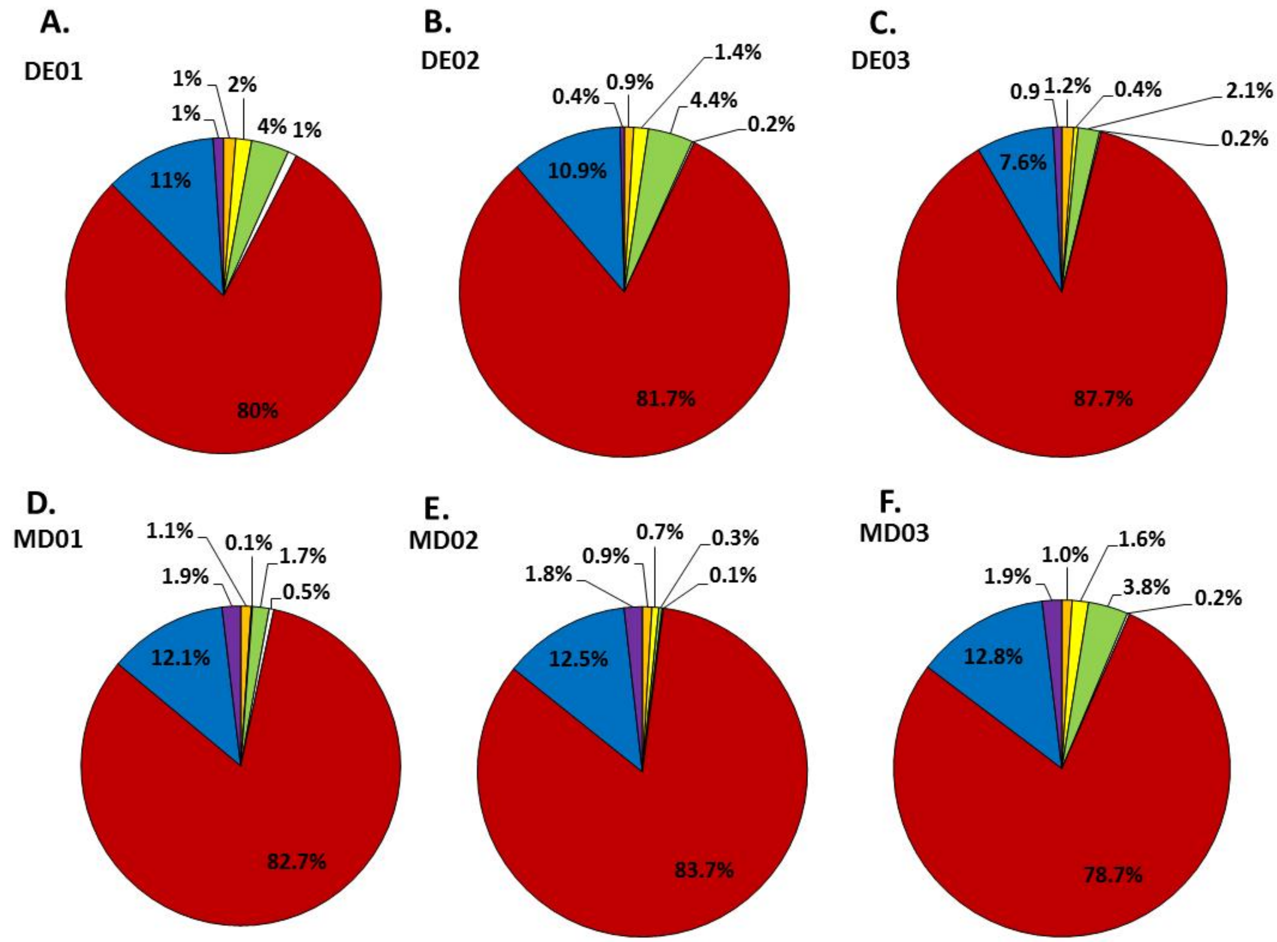
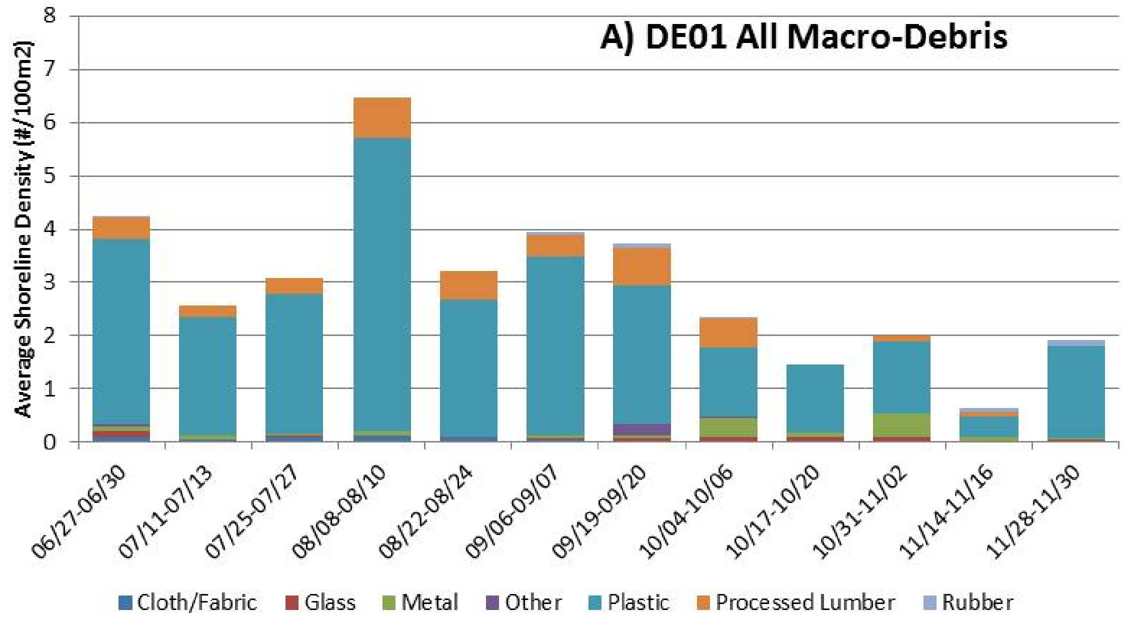


Figure 4-7. The frequency of major type of shoreline macro-debris per location by density for urban locations A) DE01, B) DE02, and C) DE03, and rural locations D) MD01, E) MD02, and F) MD03. Red=Plastics, Blue=Processed Lumber, Green=Metals, Orange=Cloth/Fabric, Yellow=Glass, Purple=Rubber, and White=Other.



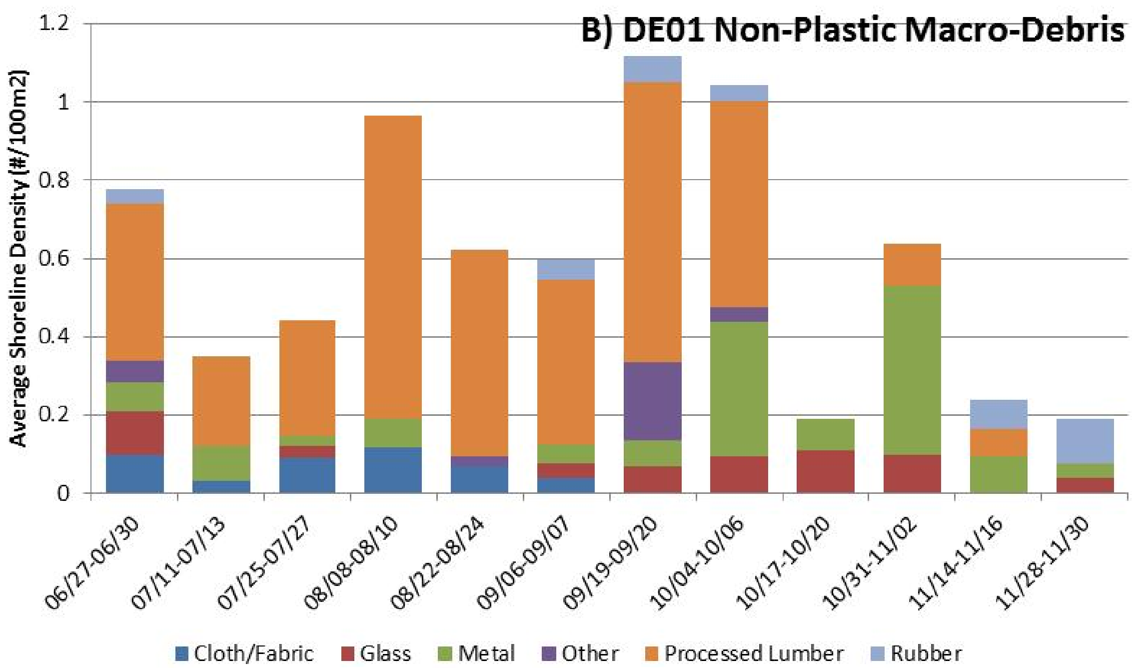
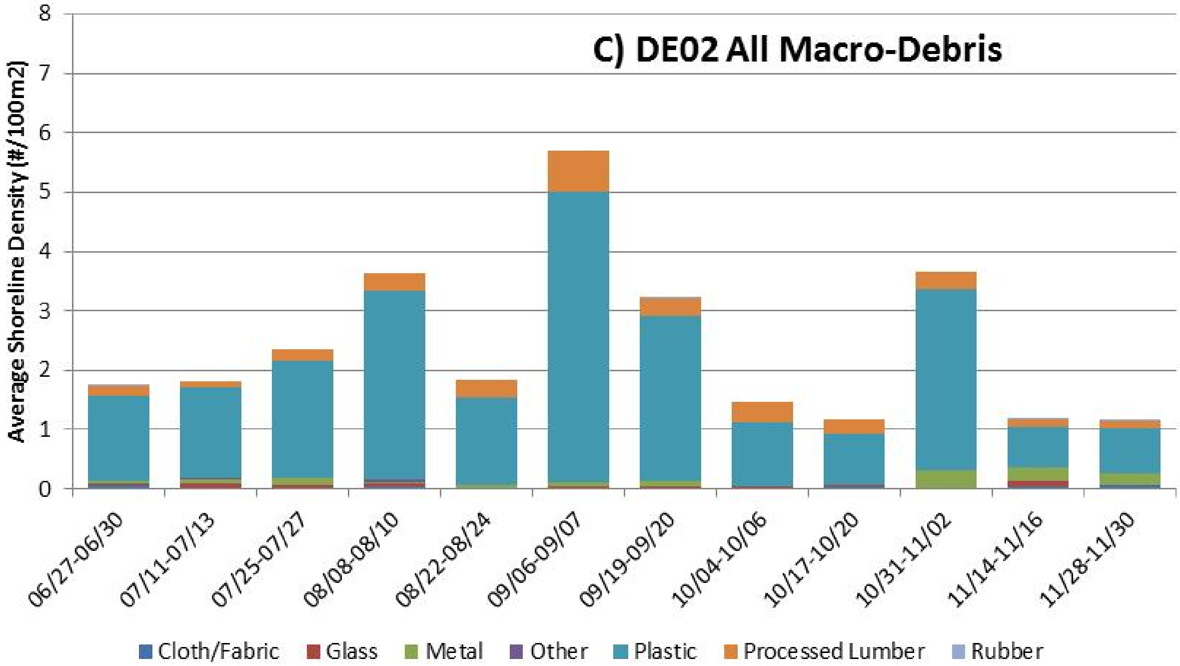


Figure 4-8. Average shoreline density of each major type of macro-debris per sampling events. Panel A) DE01 all macro-debris, B) DE01 non-plastic macro-debris, C) DE02 all macro-debris, D) DE02 non-plastic macro-debris, E) DE03 all macro-debris, F) DE03 non-plastic macro-debris, G) MD01 all macro-debris, H) MD01 non-plastic macro-debris, I) MD02 all macro-debris, J) MD02 non-plastic macro-debris, K) MD03 all macro-debris, and L) MD03 non-plastic macro-debris.



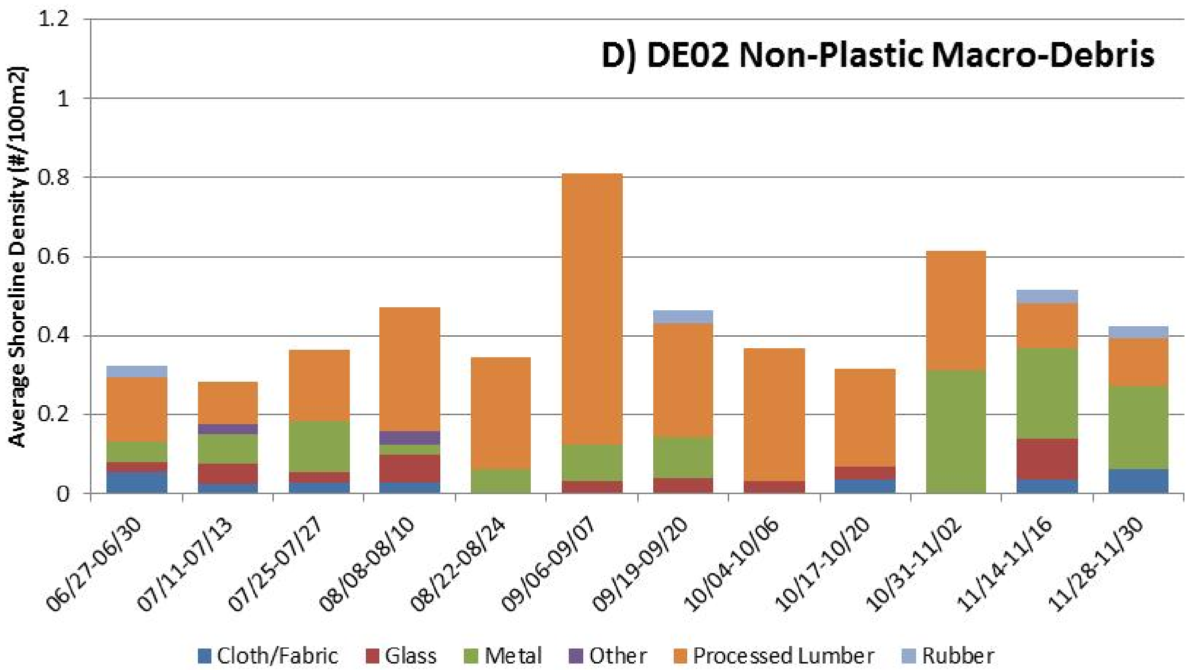
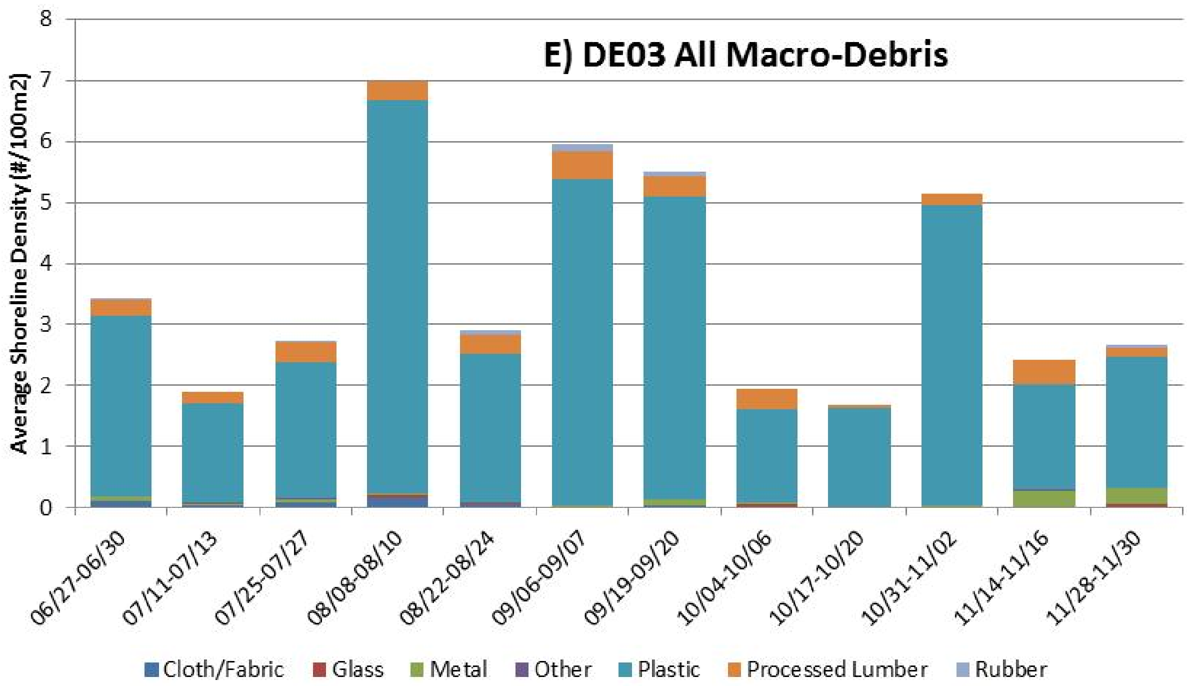


Figure 4-8. Continued.



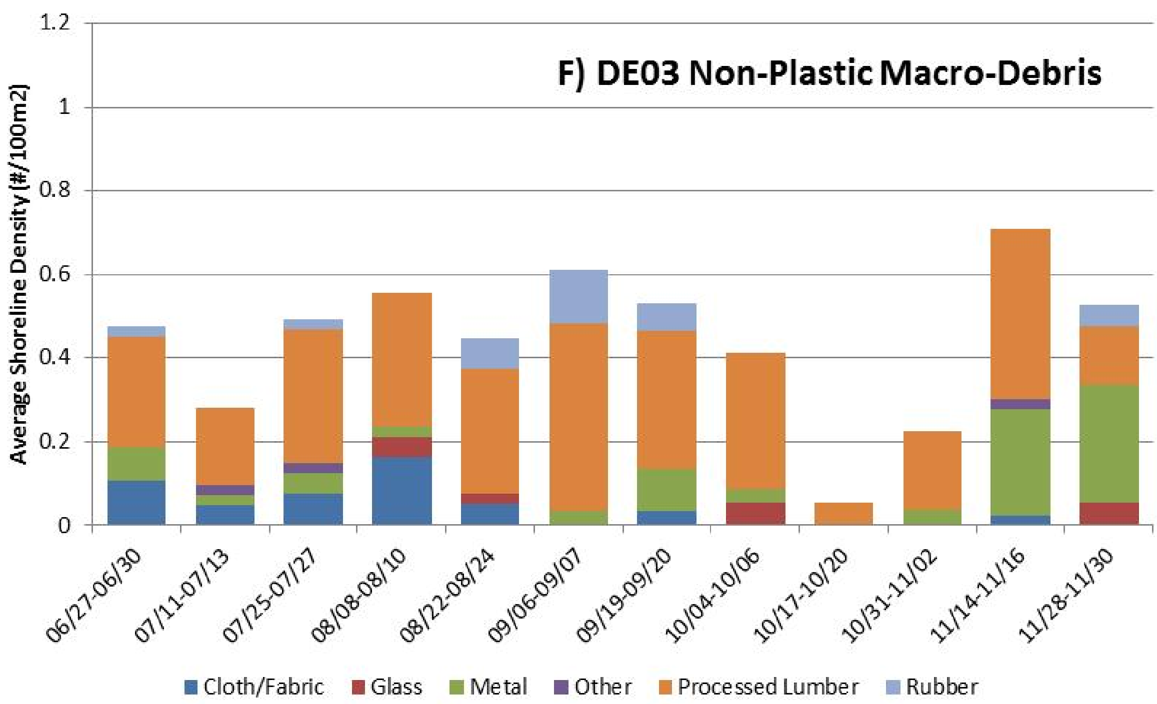
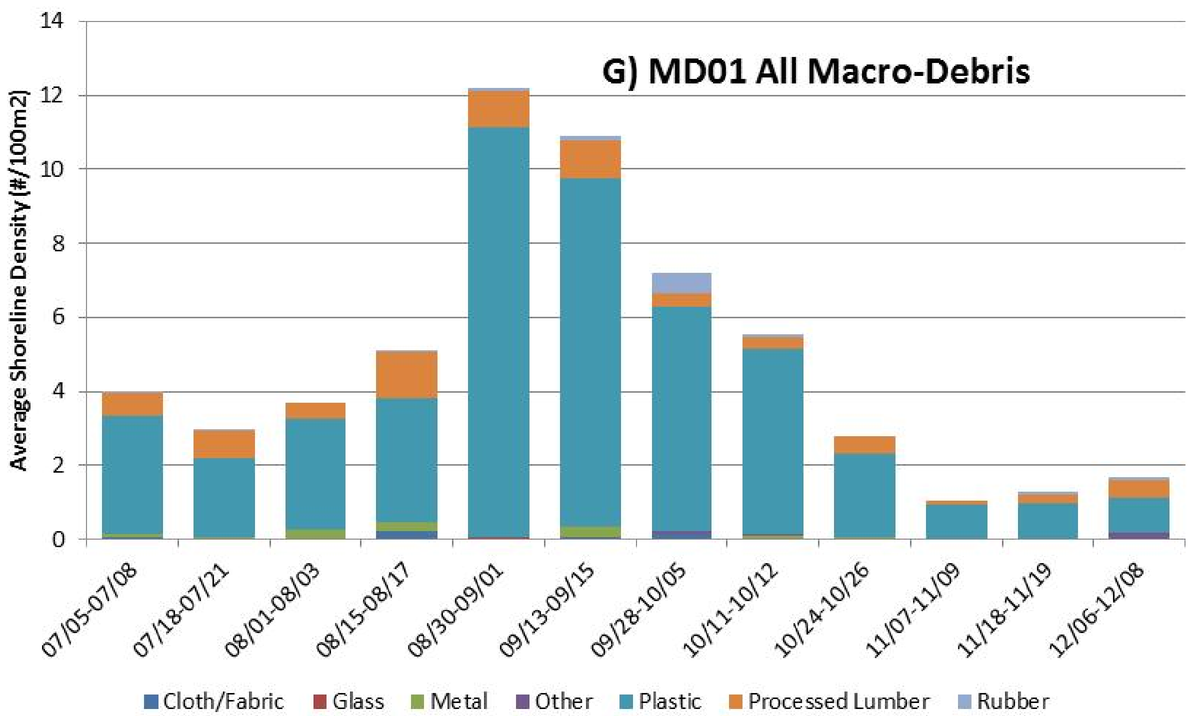


Figure 4-8. Continued.



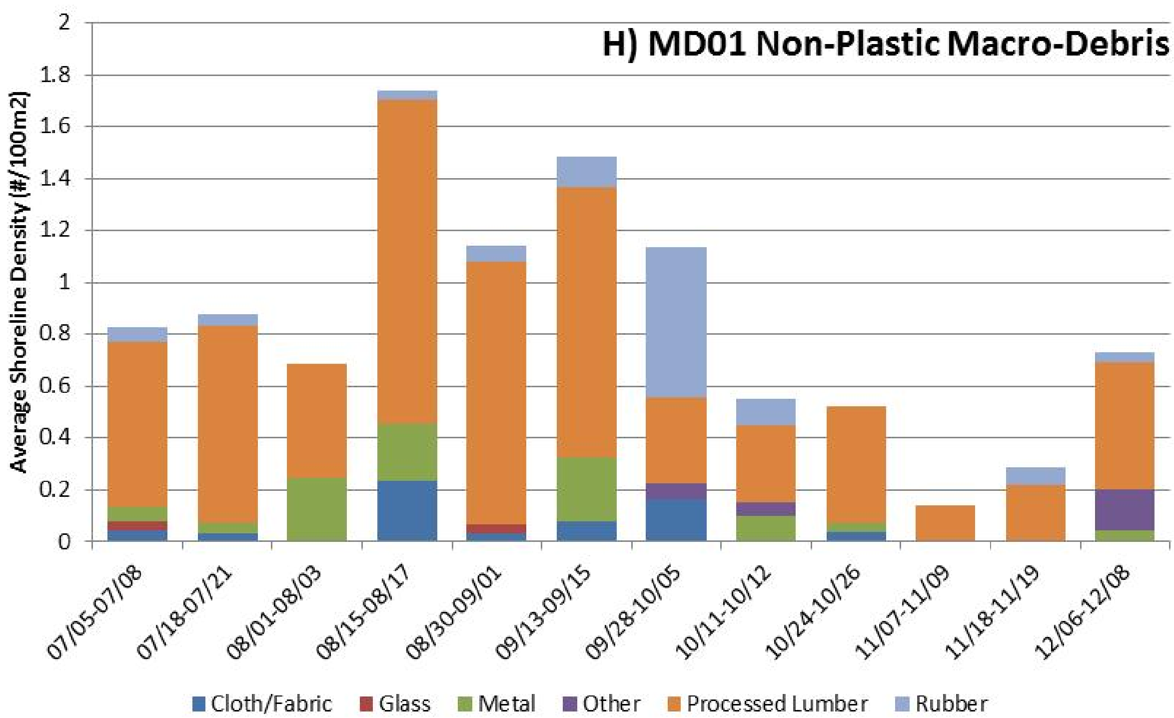


Figure 4-8. Continued.

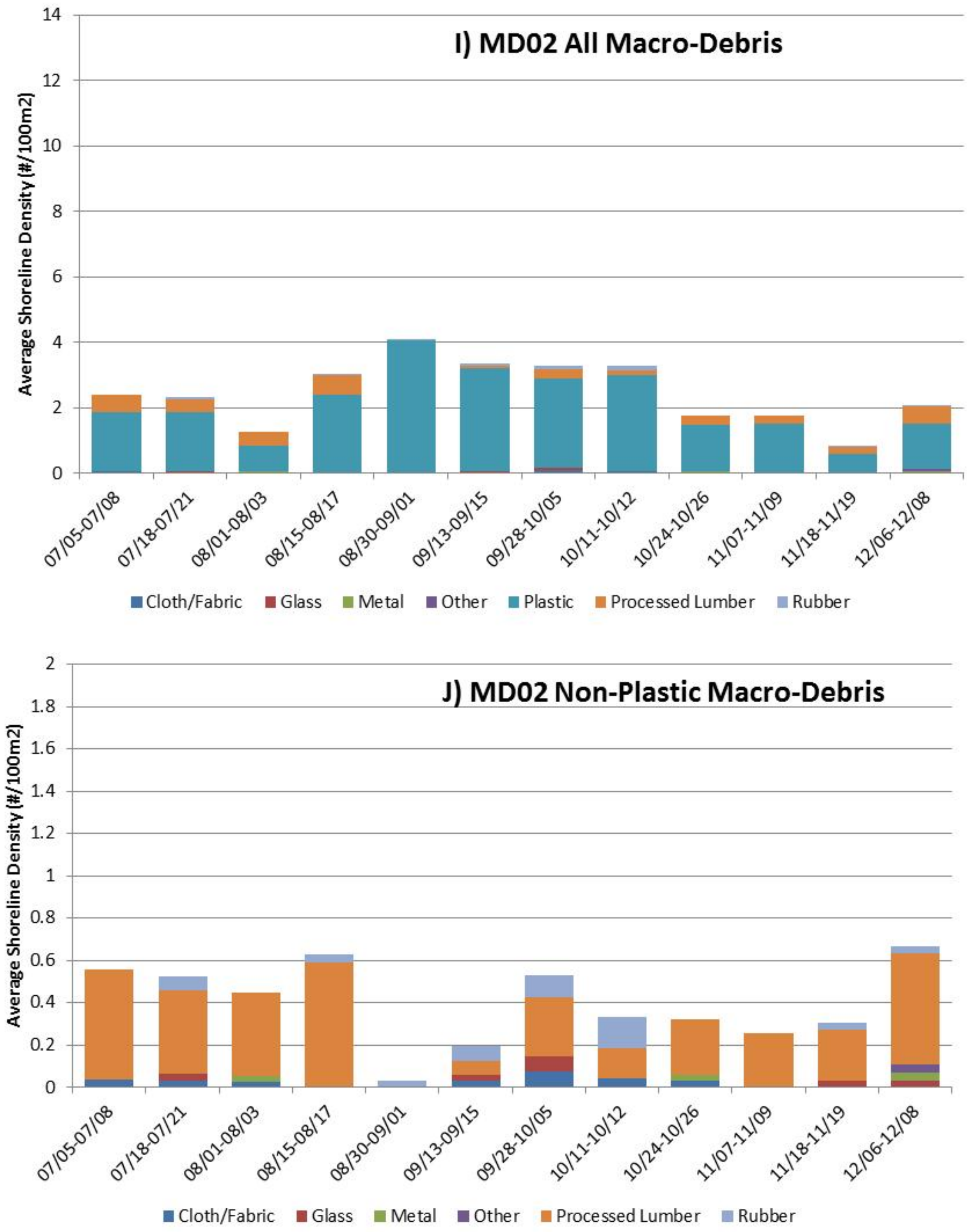


Figure 4-8. Continued.

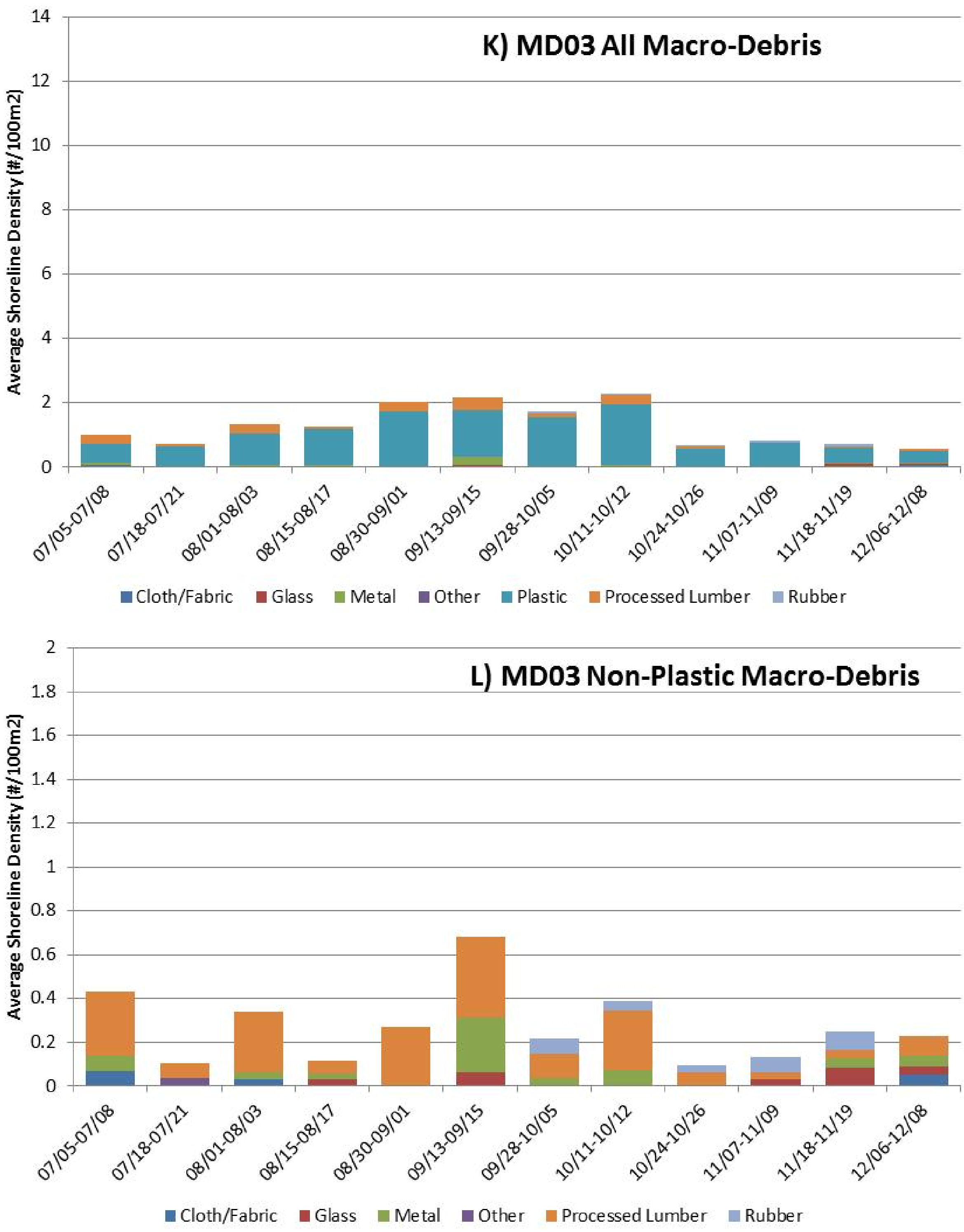


Figure 4-8. Continued.

4.2.2 Large Item Debris

Large item debris was less common compared to macro-debris along the shoreline (Table 4-6). The density of large item debris was generally greater in urban locations compared to rural locations, however this difference was not significant (p=0.09). There was a significant difference among locations nested within region. This statistical pattern was driven by location because DE-01 had had two to three times greater debris density compared to other locations and DE-03 had at least twice the debris density of other locations (Figures 4-9 and 4-10).

Table 4-6. Results of ANOVA for shoreline large item debris density. Den=the denominator used to calculate the F-ratio. 1=$MS_{Location(Region)}$=0.12; 2=$MS_{Site(Location)(Region)}$=0.02; 3=$MS_{Transect(Site)(Location)(Region)}$=0.03; 4=$MS_{Error}$=0.03. ns=not significant, * p<0.05, **p<0.01, *** p<0.001, ****p<0.0001.

Source	**df**	**MS**	**F**	**p**	**Den**
Region	1,4	0.58	4.99	ns	1
Location(Region)	4,12	0.12	5.20	*	2
Site(Location)(Region)	12,54	0.02	0.79	ns	3
Transect(Site)(Location) (Region)	54,594	0.03	0.82	ns	4
Time	11,594	0.04	1.22	ns	4
Time X Region	11,594	0.05	1.53	ns	4
Time X Location(Region)	44,594	0.04	1.17	ns	4
Time X Site(Location)(Region)	132,594	0.04	1.14	ns	4

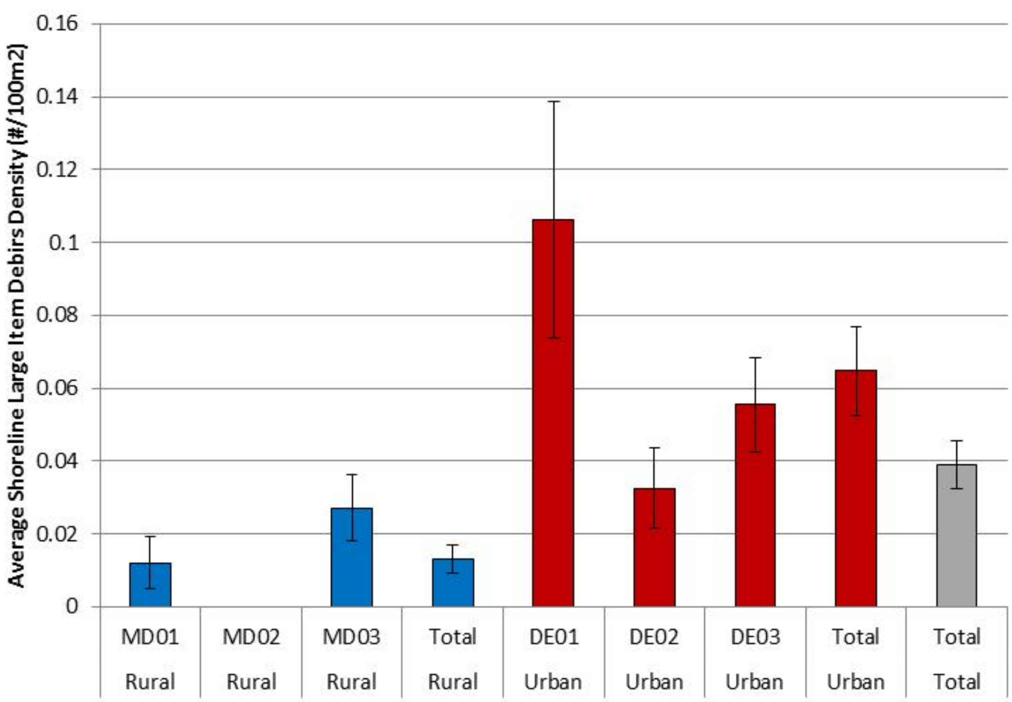


Figure 4-9. Average shoreline density of large item debris in urban and rural locations.

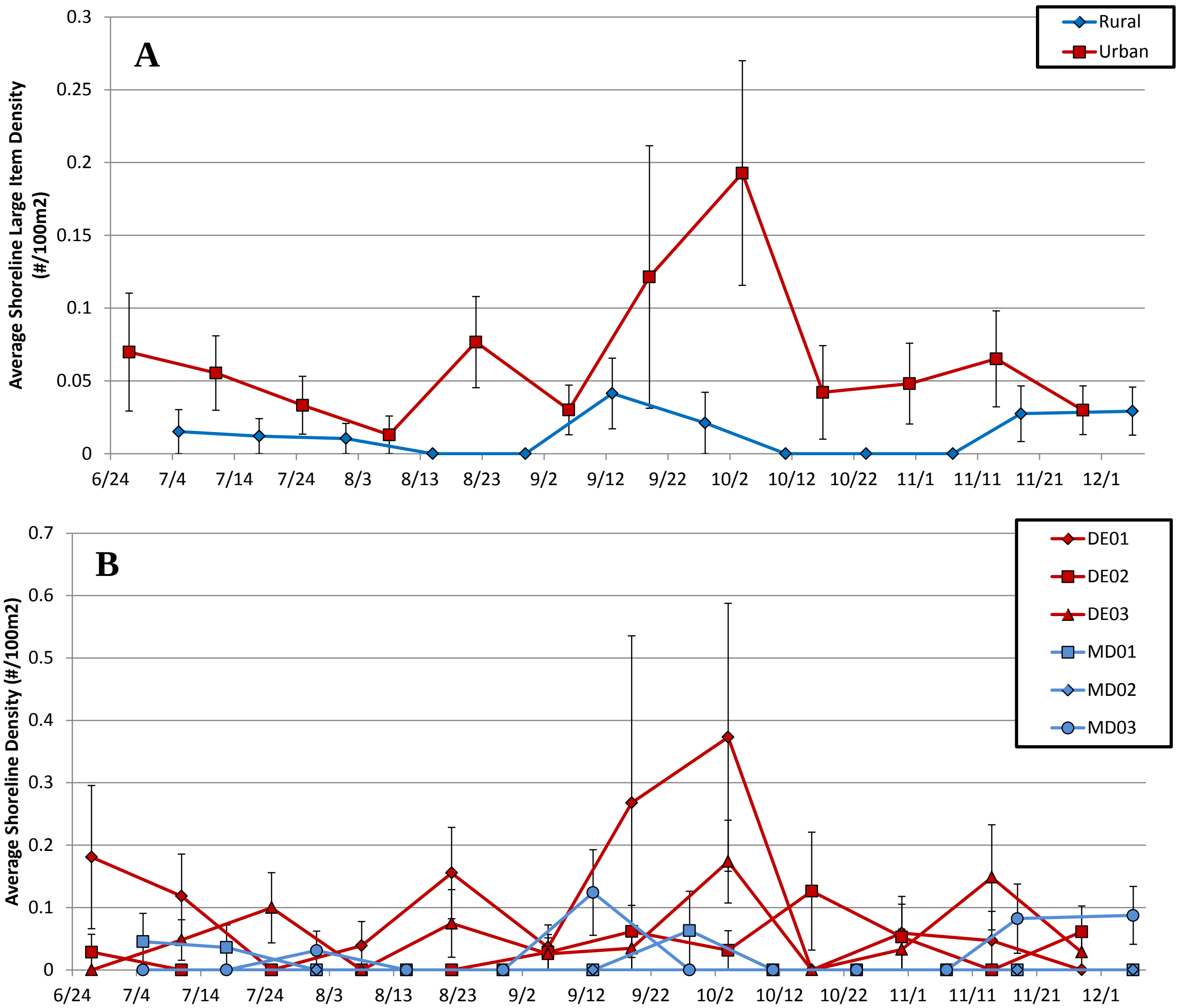


Figure 4-10. Average shoreline large item debris by A) region and B) location within region.

4.2.3 Shoreline Meso-Debris in Sieves

Shoreline meso-debris was rare (Table 4-4). A total of 25 pieces were found across all sampling dates and transects, occurring above wrack 1 and wrack 2, below wrack, and within wrack (Figure 4-11). There was noticeable temporal variation across sampling dates and sampling months but no clear cause of this variability was evident (Figures 4-12 and 4-13). Plastics/polystyrene fragments, cigarettes, rope and small net pieces, and fabric pieces were the most common in the urban and rural region (Figure 4-14). Because so few pieces of meso-debris were found, no formal statistical tests were performed. The largest number of meso-debris was found above wrack 2.

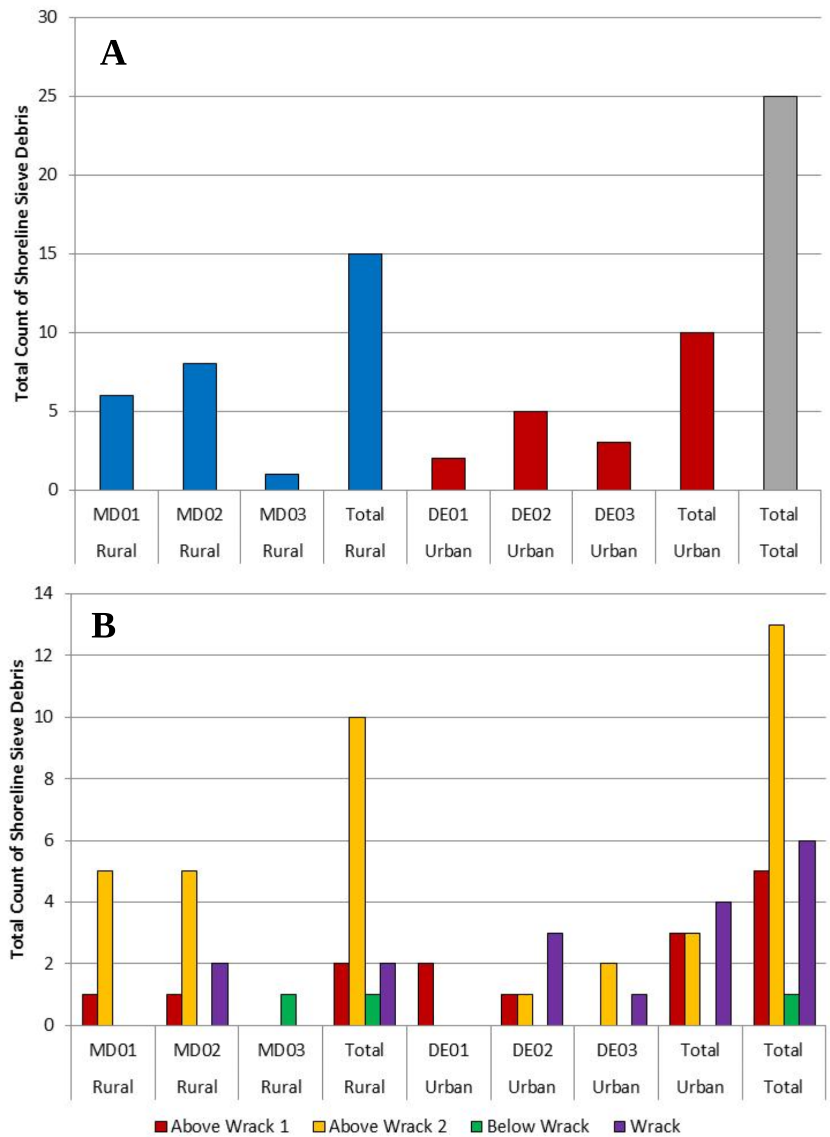


Figure 4-11. Total count of shoreline meso-debris sampled in sieves A) for urban and rural locations and B) relative to the wrack line for each urban and rural location.

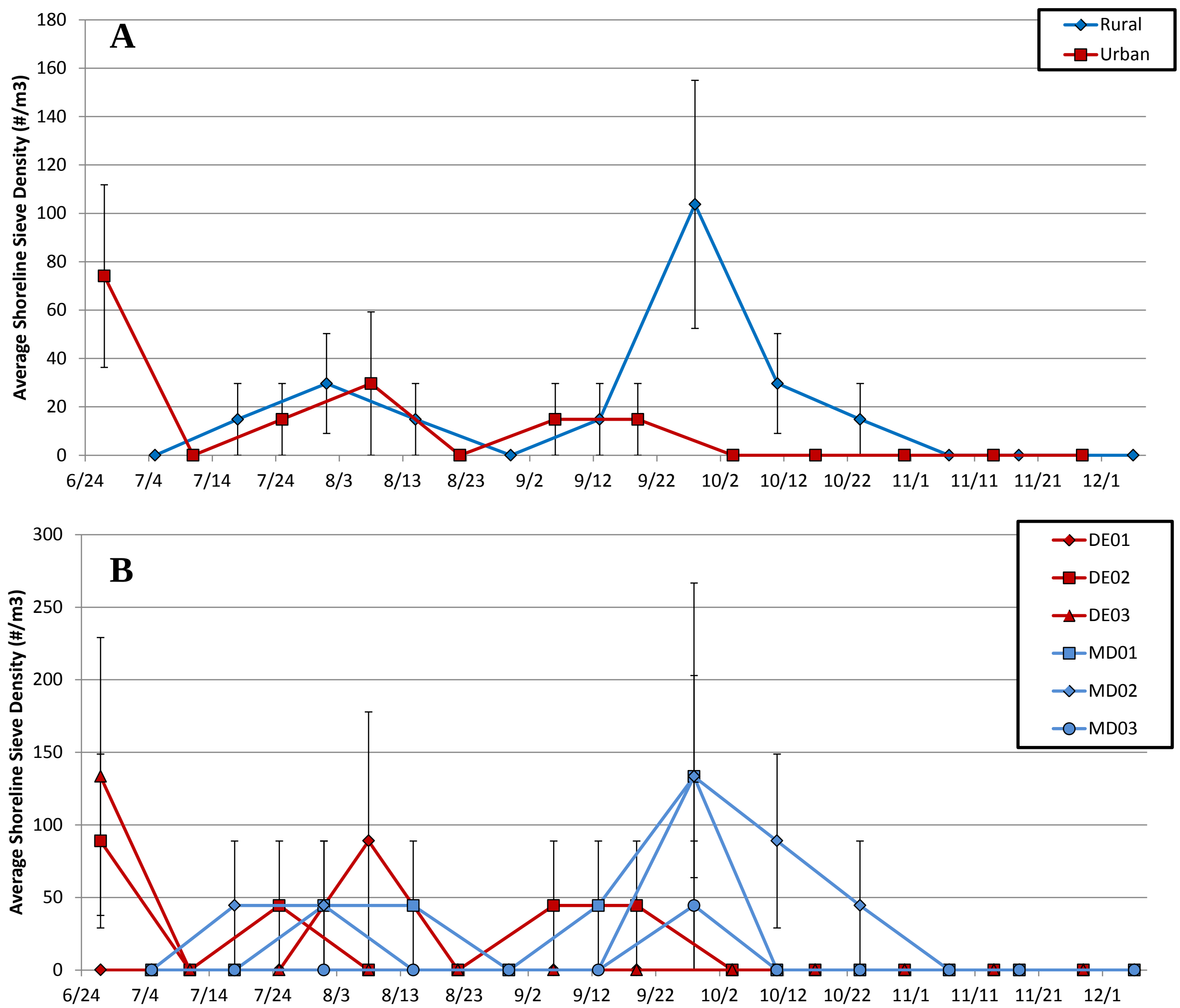


Figure 4-12. Total count of shoreline meso-debris collected in sieves per sampling event for A) each region and B) each location with the urban and rural regions.

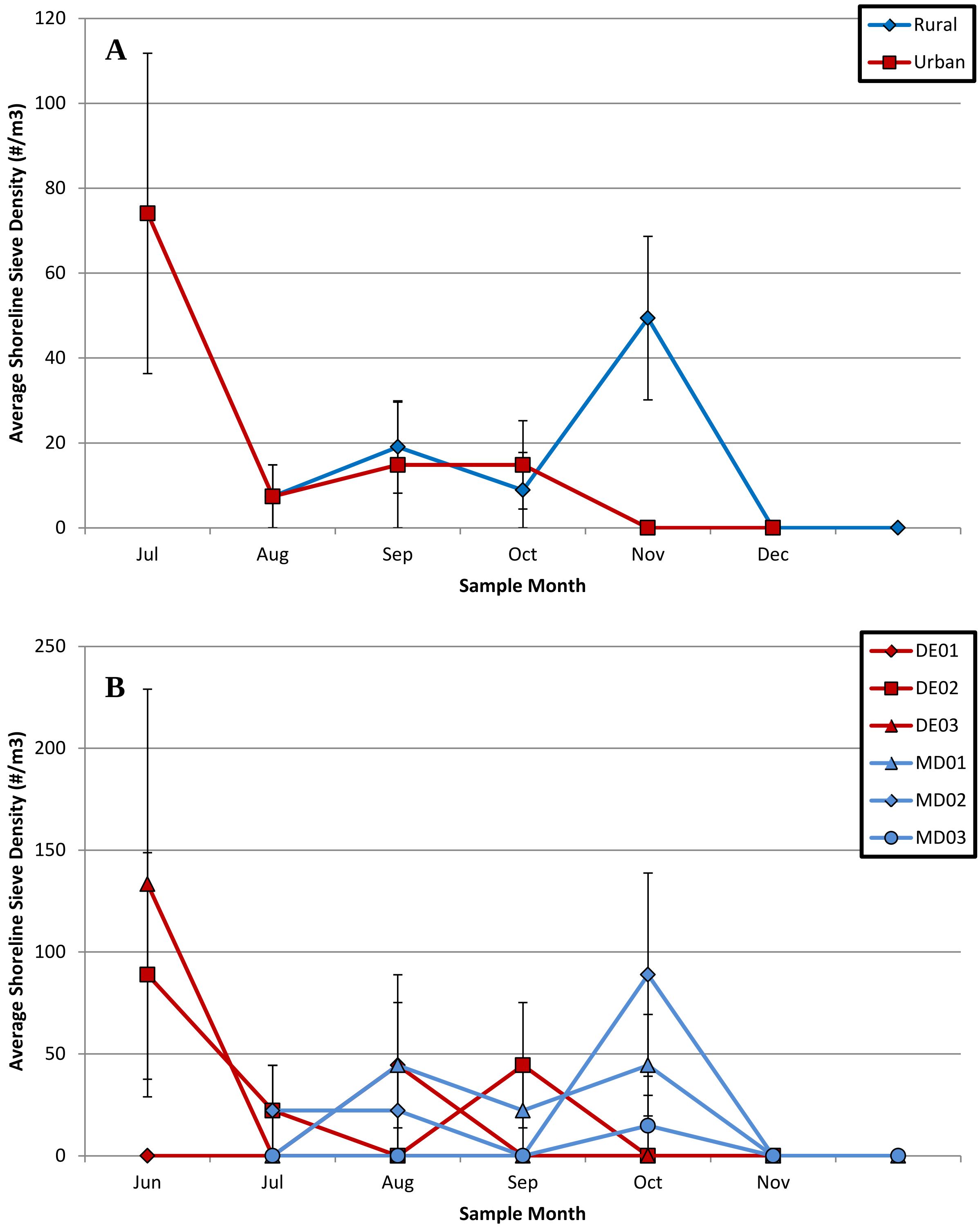
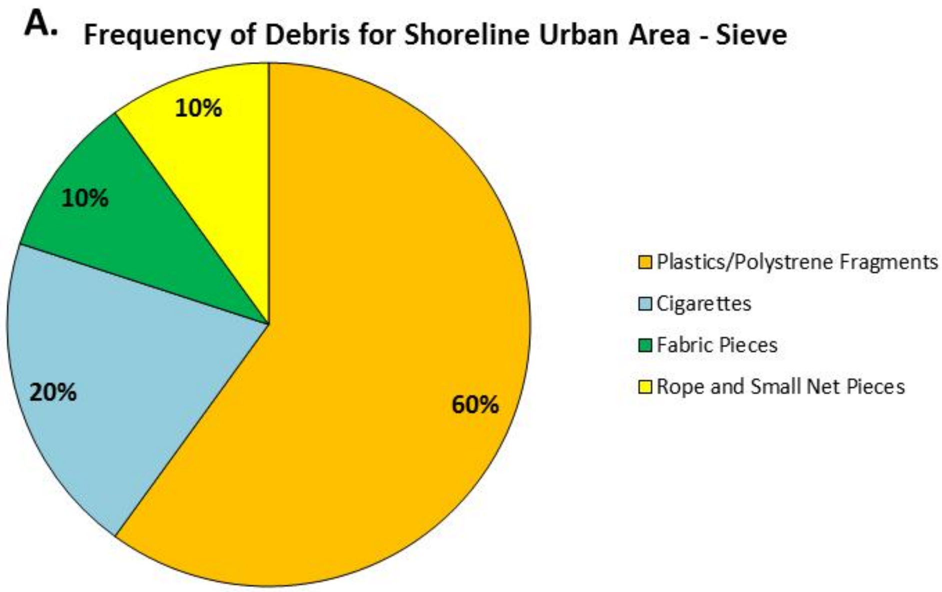


Figure 4-13. Average density (#/m3) of shoreline meso-debris collected in sieves per month for each A) region and B) each location within the urban and rural regions.



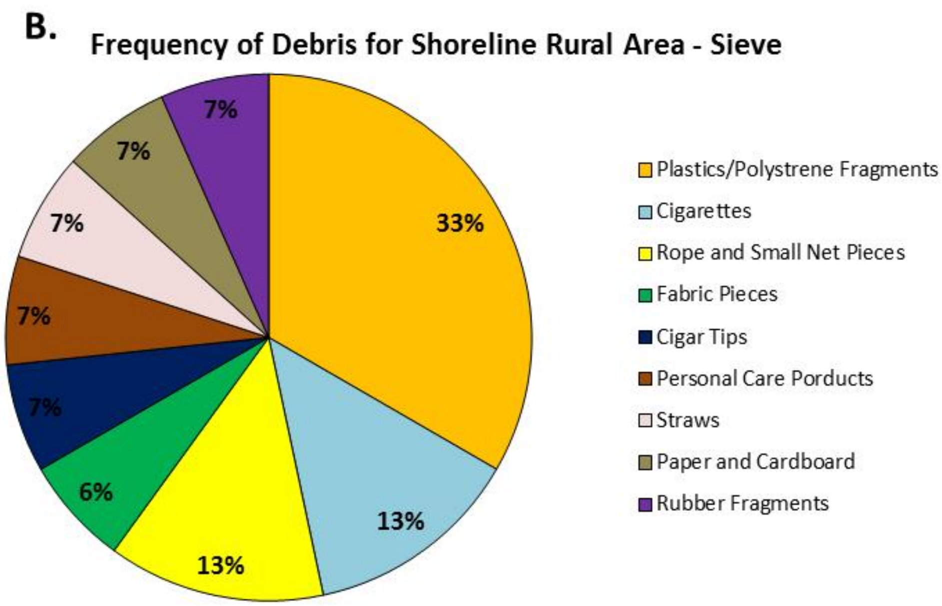


Figure 4-14. Frequency of each subtype of meso-debris in the A) urban region and B) rural region based on total count of meso-debris.

4.2.4 Pelagic Macro-Debris

Pelagic macro-debris was significantly different among locations nested within region and over time (Table 4-7). Significant differences were also found when time was crossed with region and location within region. There were no significant differences between the urban and rural region or among transects within locations.

Table 4-7. Results of ANOVA for pelagic macro-debris density. Den=the denominator used to calculate the F-ratio. $1=MS_{Location(Region)}=0.70$; $2=MS_{Transect(Region)(Location)}=0.15$; $3=MS_{Error}=0.14$. ns=not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$, **** $p<0.0001$.

Source	df	MS	F	p	Den
Region	1,4	0.93	1.33	ns	1
Location(Region)	4,48	0.73	4.89	*	2
Transect(Location)(Region)	48,504	0.15	1.09	ns	3
Time	44,504	1.45	10.66	****	3
Time X Region	10,504	1.57	11.54	****	3
Time X Location(Region)	42,504	0.27	1.97	***	3

Differences among locations were driven by the relatively high densities of debris at locations MD-03 and DE-03 compared to other locations. Temporal variation was notable throughout the study across sampling dates as well as sampling months (Figures 4-15 to 4-17). High densities of debris were most notable on sampling dates 4 and 5 at MD-03 and during sampling date ten at location DE-01 (Figure 4-16).

The major types of debris that were most common in pelagic samples included plastic sheets, plastics/polystyrene fragments, and rope and small net pieces (Figures 4-18 and 4-19). The remaining types of debris comprised ≤ 9% of debris at a given location. The predominance of plastics was consistent at each location throughout the course of the survey (Figure 4-20). The size distribution of pelagic debris was strongly skewed toward smaller pieces in the 0-20 mm size classes for both urban and rural locations (Figure 4-21).

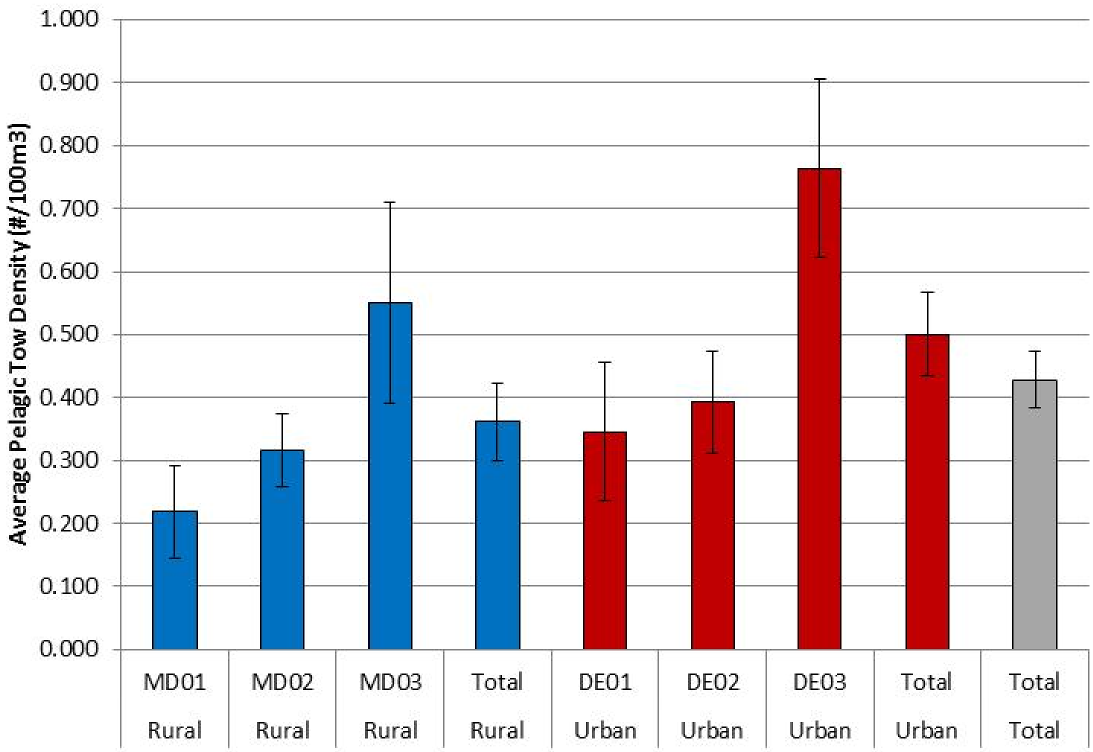


Figure 4-15. Average density per tow of macro-debris in each urban and rural location.

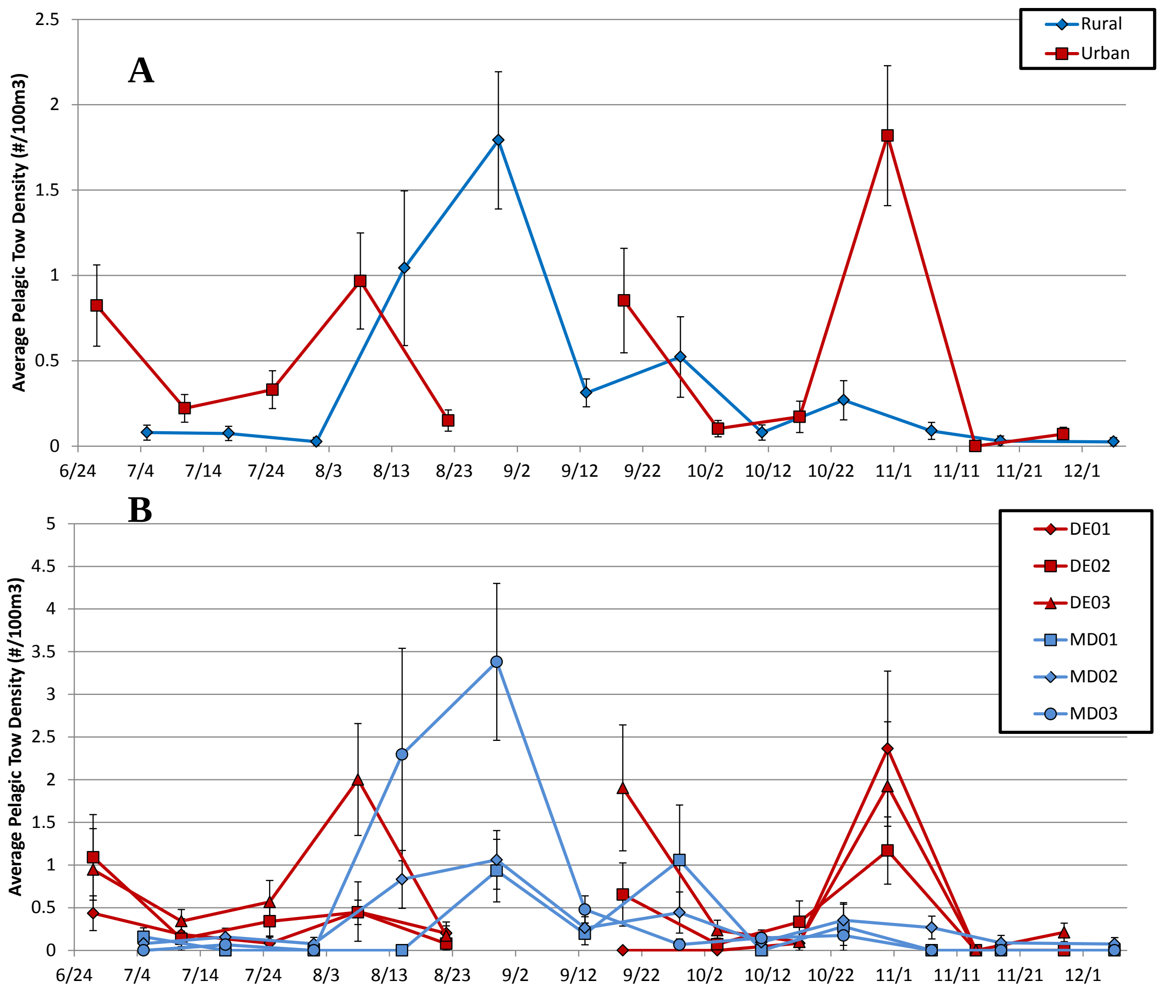


Figure 4-16. Average density of macro-debris per 100m^3 for each sampling date for A) each region and B) each urban and rural location.

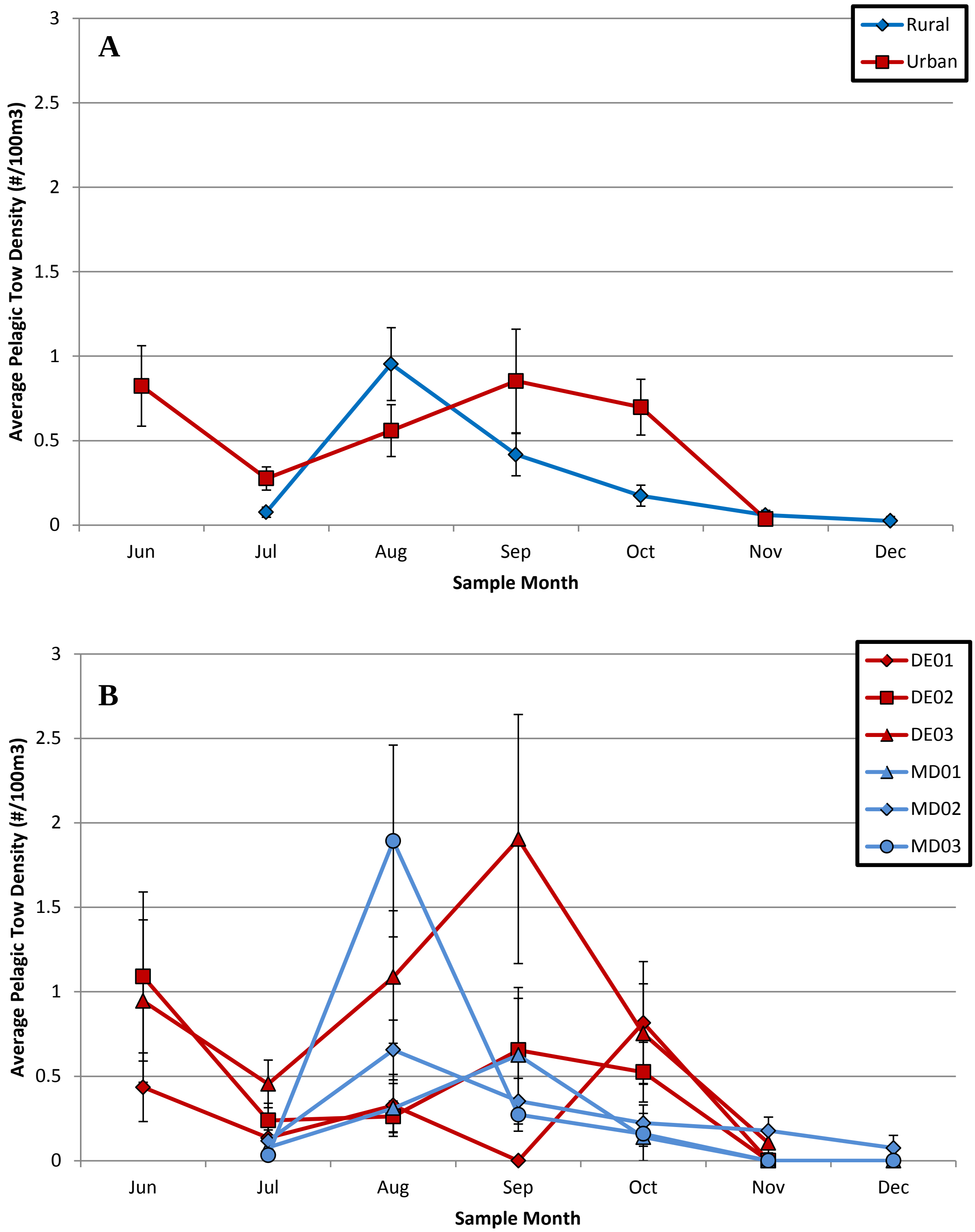


Figure 4-17. Average density of macro-debris per 100m^3 for each month for A) each region and B) each urban and rural location.

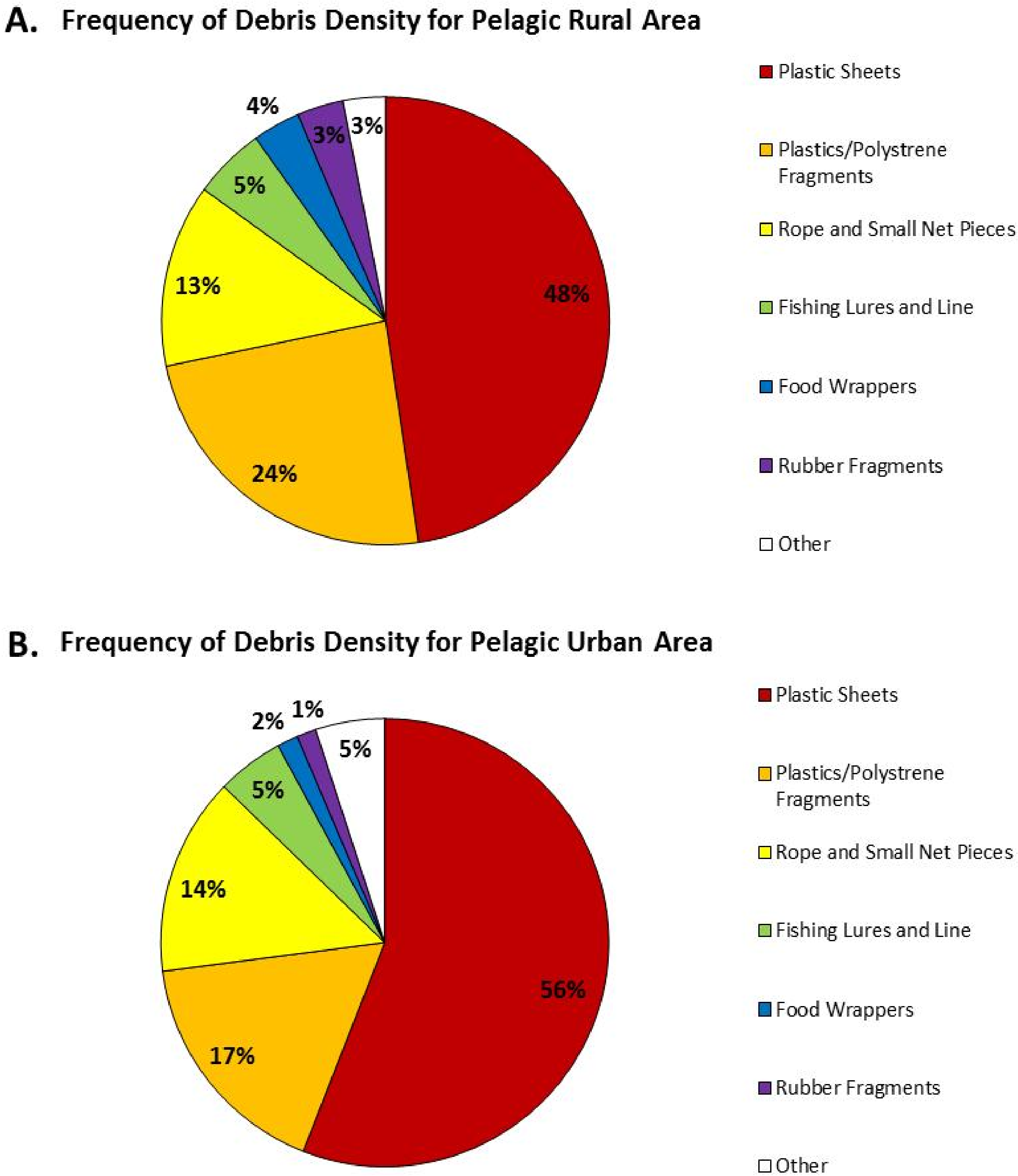


Figure 4-18. Frequency of each subtype of pelagic macro-debris by density for the A) rural region and B) urban region.

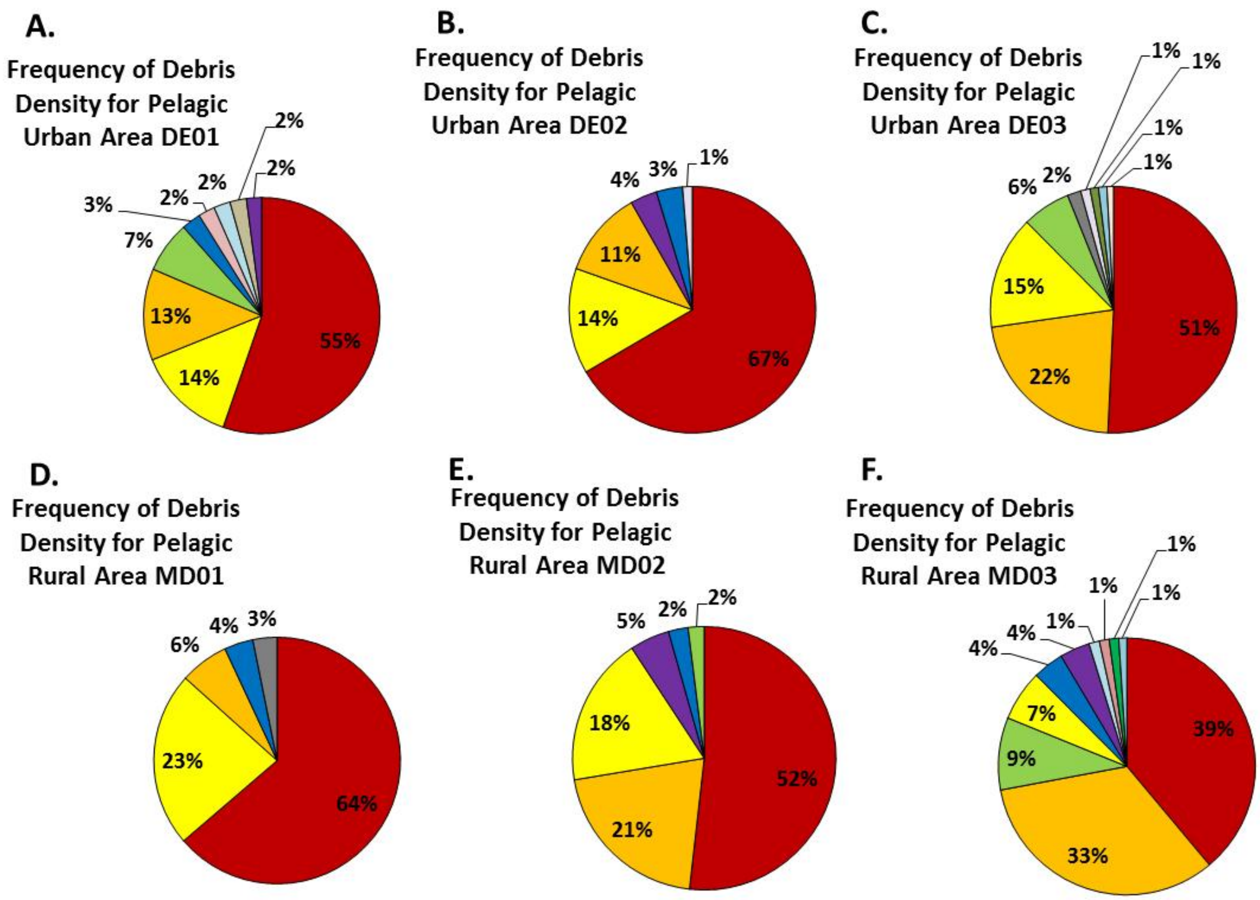


Figure 4-19. Frequency of each subtype of macro-debris in pelagic tows for urban locations A) DE01, B) DE02, C) DE03 and rural locations D) MD01, E) MD02, and F) MD03. Red=Plastic sheets, Orange=Plastics/polystyrene fragments, Yellow=Rope and small net pieces, Light Green=Fishing lures and line, Dark Blue=Food wrappers, Pink=Straws, Light Blue=Bottle/Container caps, Dark Green=Beverage bottles, Light Blue=cigarettes, Purple=Rubber fragments, Light Grey=Building materials, Dark Grey=Balloons, Tan=Paper and cardboard, Light Pink=Shotgun shells/wads.

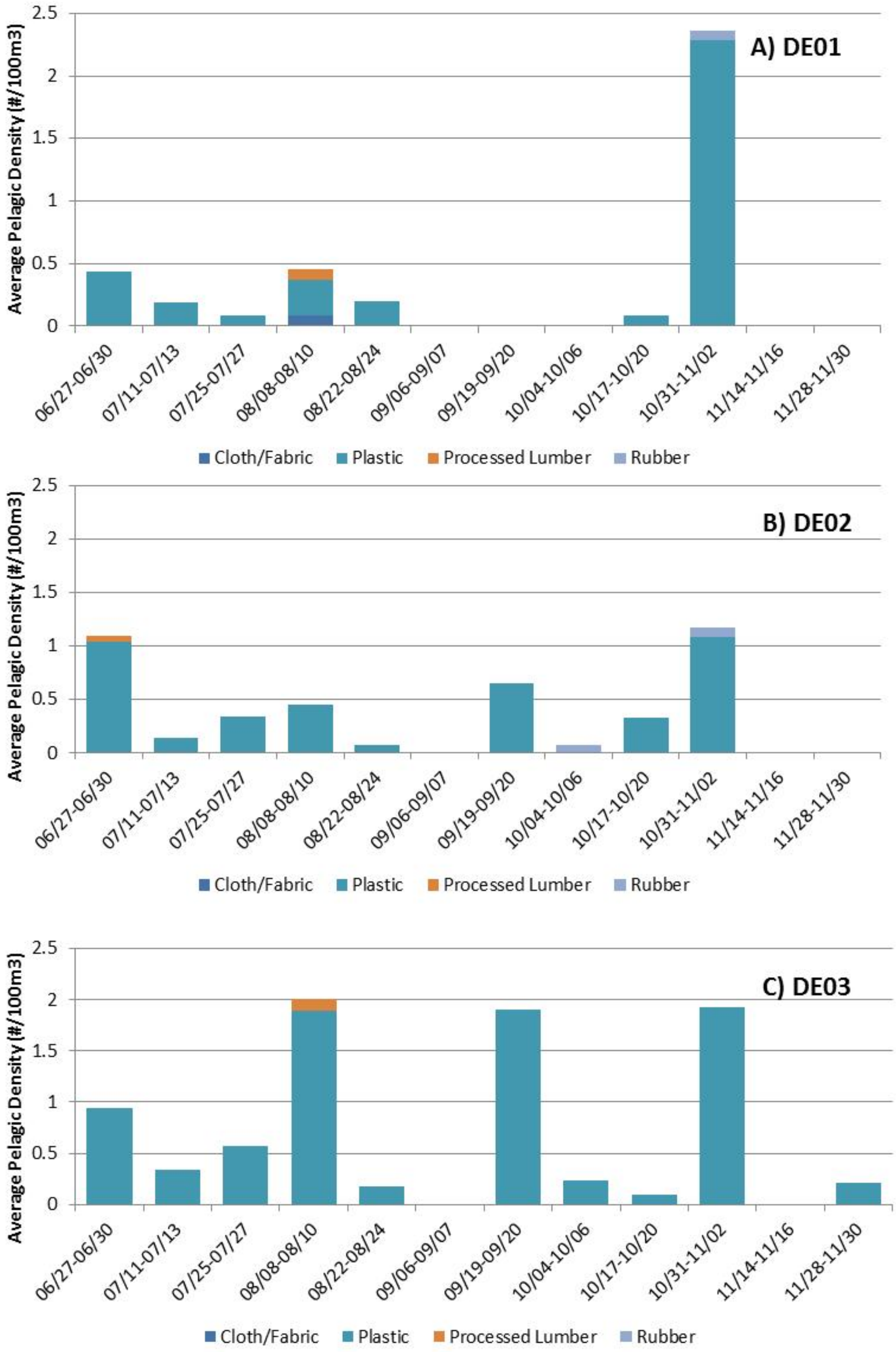


Figure 4-20. Average density of each major type of pelagic macro-debris per sampling data for urban locations A) DE01, B) DE02, and C) DE03 and for rural locations D) MD01, E) MD02, and F) MD03.

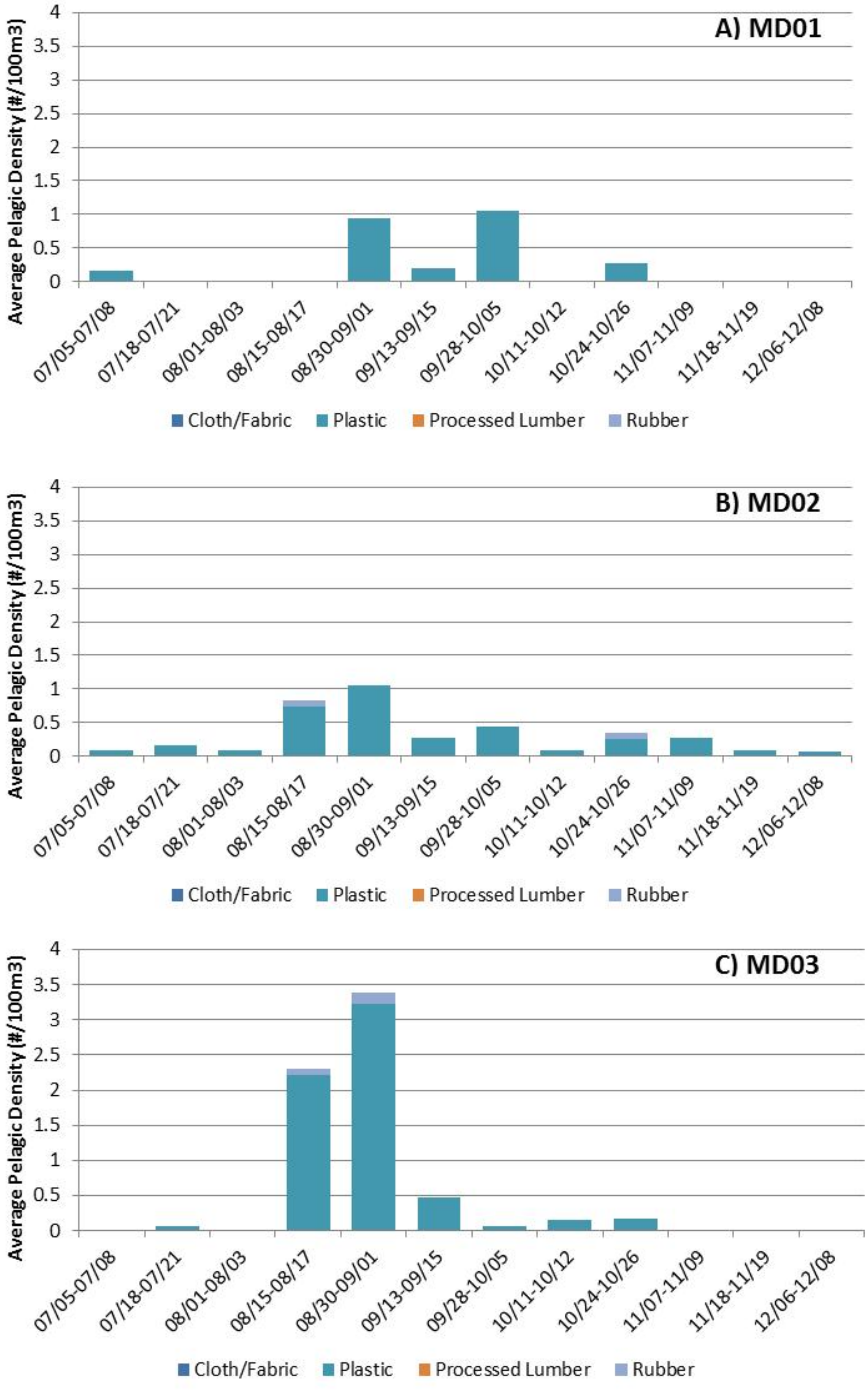


Figure 4-20. Continued.

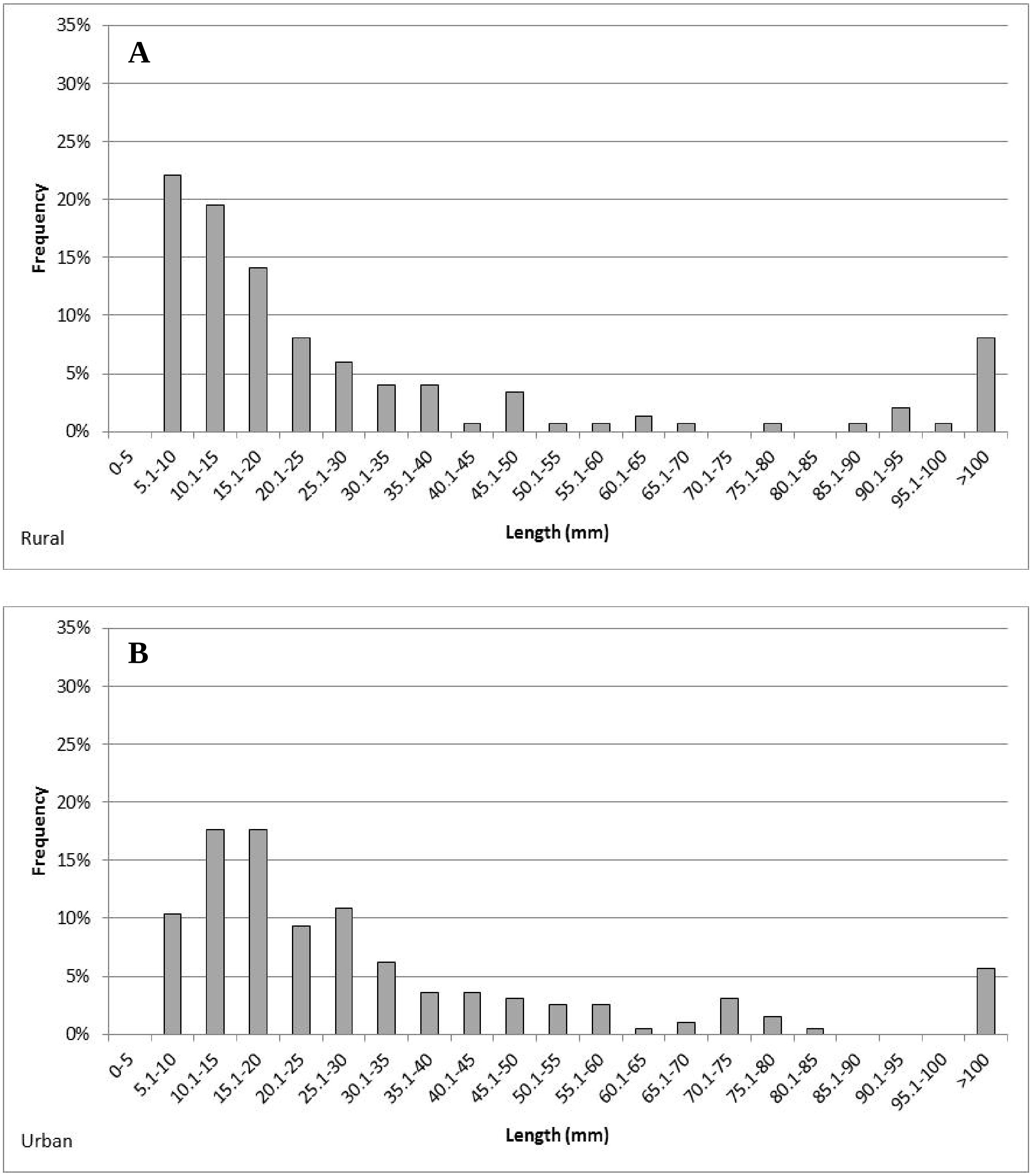


Figure 4-21. Size frequency of pelagic macro-debris in the A) rural region and B) urban region.

4.2.5 Pelagic Large Item Debris

Large item debris in pelagic tows was the most rare size class of debris sampled during the survey, occurring in less than 1% of tows (Table 4-4). Only plastic and processed lumber were found in both urban and rural locations (Figures 4-22 and 4-23). Because so few pieces of large item debris were collected in pelagic locations, no statistical analyses were conducted.

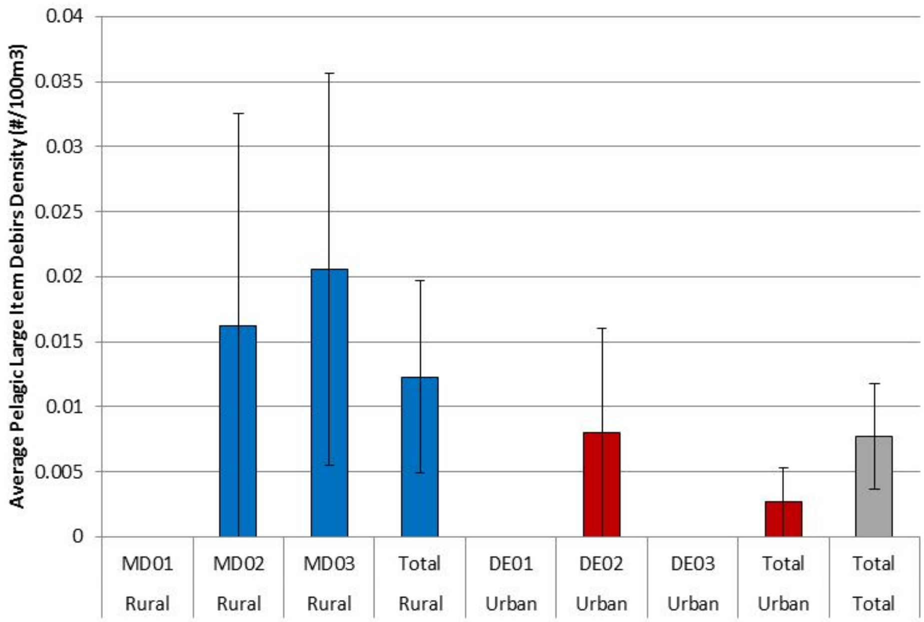


Figure 4-22. Average pelagic density of large item debris in urban and rural locations.

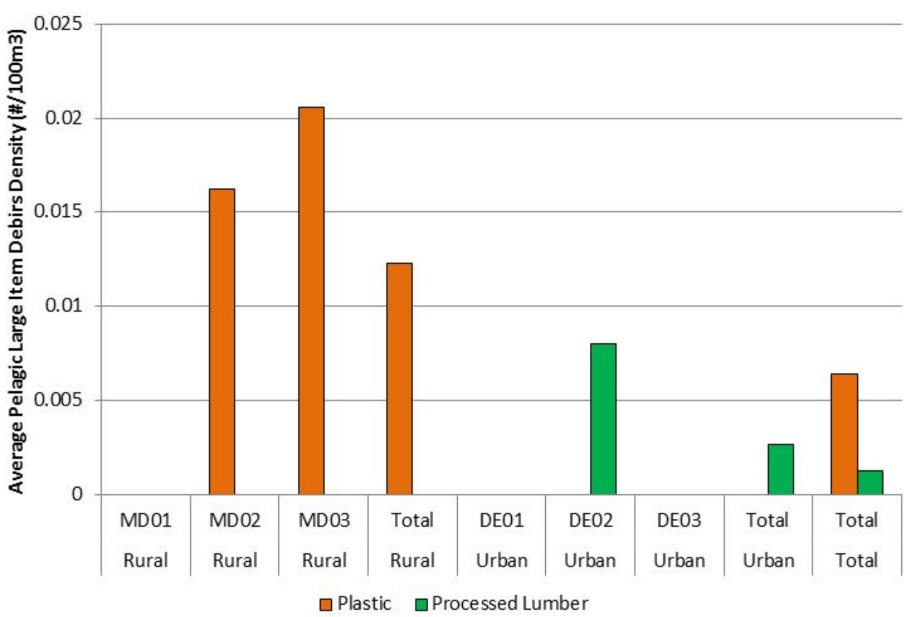


Figure 4-23. Average pelagic density of large item debris by type in urban and rural locations.

4.3 RELATIONSHIP OF ENVIRONMENTAL AND HUMAN FACTORS WITH MACRO-DEBRIS DENSITY

4.3.1 Shoreline Macro-Debris

At the location level, shoreline macro-debris density was weakly correlated with the number of beach-goers at the location, with the number of beach-goers at the site, and the paired sampling week number (Figures 4-24, Table 4-8). These correlations were still present when considering debris density at the site level (Table 4-9). In addition, transect length and tidal range was also weakly correlated with debris density at the site level. Larger tidal ranges and shorter transects were associated with higher debris density at this spatial resolution (Table 4-9).

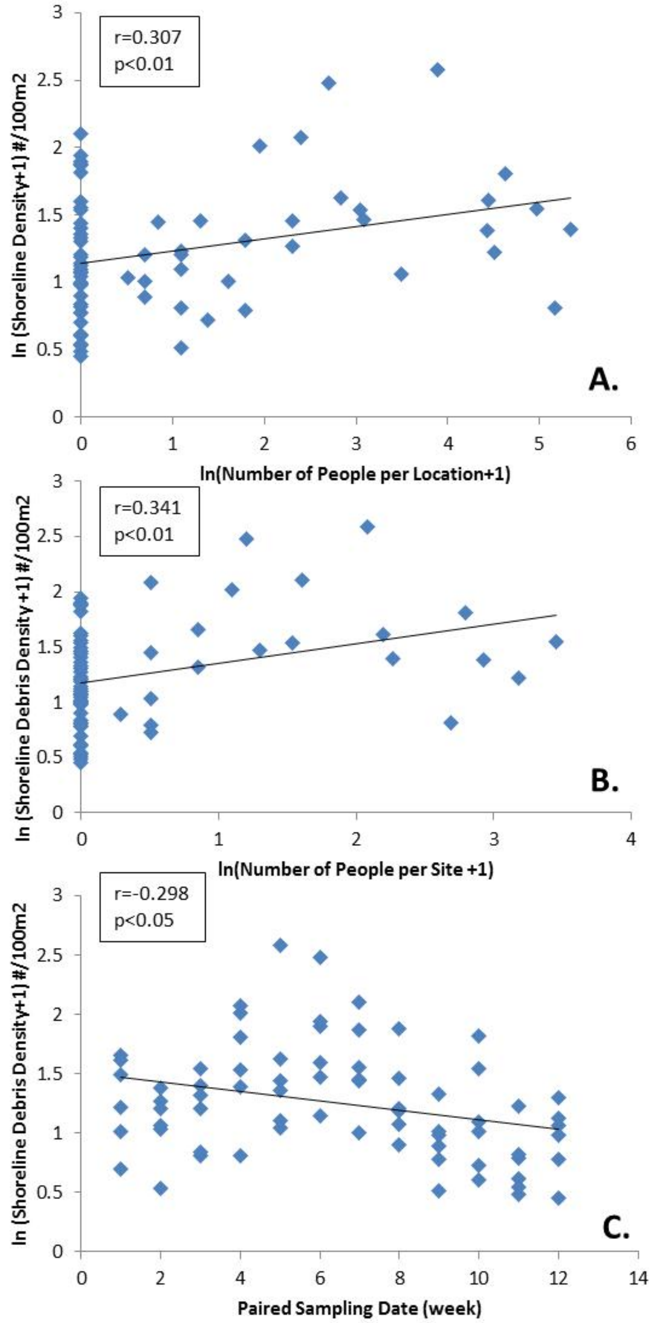


Figure 4-24. Pearson correlations of shoreline macro-debris density and A) number of people per location, B) number of people per site, and C) paired sampling date. Each point represents an average for a location during one sampling event (N=72 (3 locations X 2 regions X 12 sampling events).

Table 4-8. Pearson correlation coefficients describing the relationship between shoreline macro-debris and both environmental and human factors at the **Location** level. N=72 (3 locations X 2 regions X 12 sampling events). * p<0.05, **p<0.01

	Wind Speed	#People per Loc	#People per Site	Tidal Range	Transect Length	Sampling Week
Debris Density	0.002	0.307	0.341	0.151	-0.187	-0.298
	ns	**	**	ns	ns	*

Table 4-9. Pearson correlation coefficients describing the relationship between shoreline macro-debris and both environmental and human factors at the **Site** level. N=216 (3sites X 3 locations X 2 regions X 12 sampling events). * p<0.05, **p<0.01, ***p<0.001, ****p<0.0001

	Wind Speed	# People per Loc	#People per Site	Tidal Range	Transect Length	Sampling Week
Debris Density	0.024	0.278	0.241	0.150	-0.161	-0.265
	ns	****	***	*	*	****

4.3.2 Pelagic Macro-Debris

Pelagic macro-debris density was weakly correlated with the surface temperature of the water. There was no relationship with any of the other factors measured (Figure 4-25, Table 4-10).

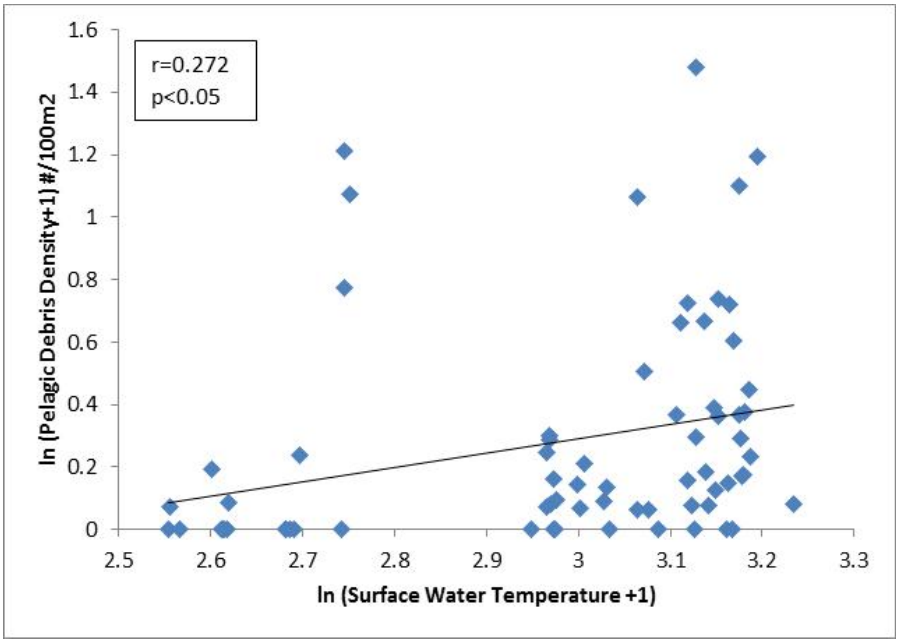


Figure 4-25. Pearson correlations of pelagic macro-debris density and sea surface temperature. Each point represents an average for a location during one sampling event.

Table 4-10. Pearson correlation coefficients describing the relationship between pelagic macro-debris and both environmental and human factors. Water quality variables examined are from surface waters. * p<0.05

	Wind Speed	Temp	DO	pH	Conductivity	Tow Length	Sampling Week
Debris Density	-0.014	0.272	-0.063	-0.028	-0.203	-0.011	-0.165
	ns	*	ns	ns	ns	ns	ns

4.3.3 Pelagic vs. Shoreline Macro-Debris

Pelagic macro-debris was weakly correlated with shoreline at two rural locations and two urban locations (Figure 4-26). This may be due either to shoreline sources of debris delivering more debris to nearby surface waters or ocean sources delivering more debris to the shoreline. At the region level, there was a weak correlation between pelagic and shoreline debris in the urban region only (Figure 4-27).

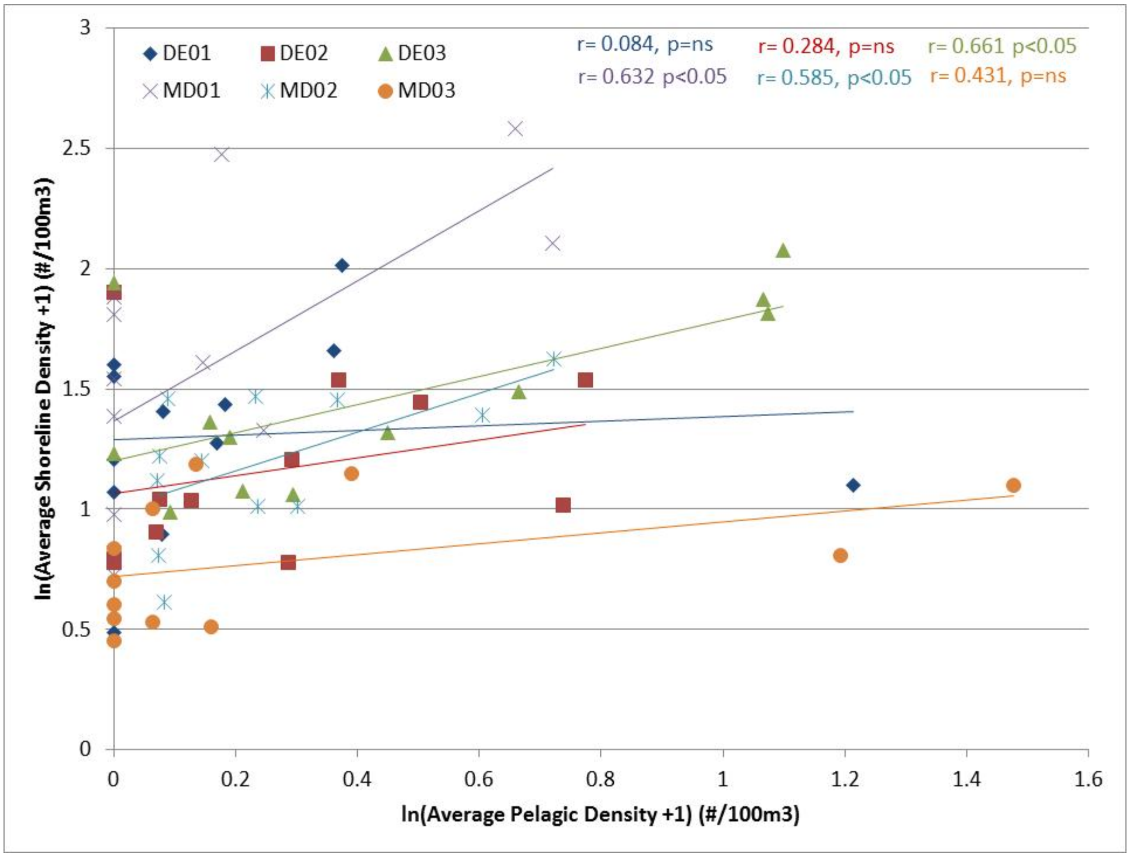


Figure 4-26. Pearson correlations of pelagic macro-debris density with shoreline macro-debris density. Points represent the 12 bi-weekly average measures of debris density at each location.

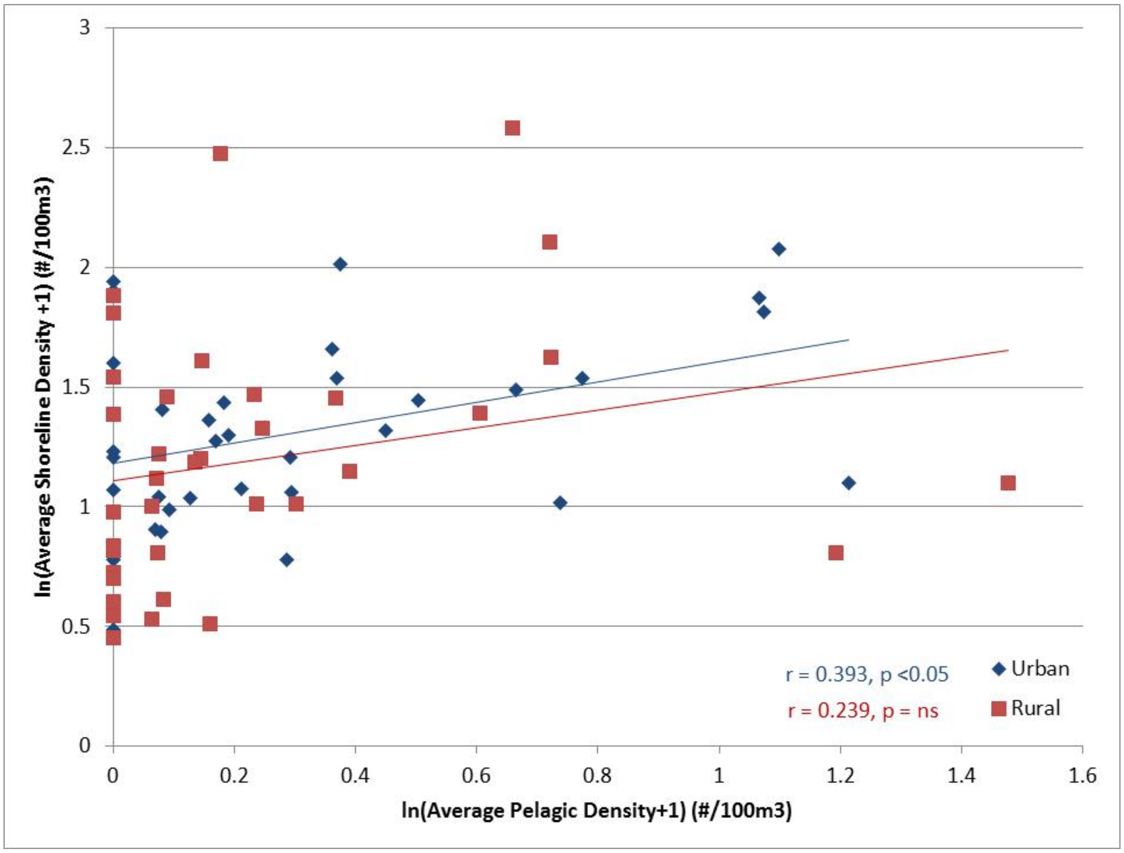


Figure 4-27. Pearson correlations of pelagic macro-debris density with shoreline macro-debris density. Points represent 36 bi-weekly (3 locations X 12 sampling events) sampling events in each region.

4.4 DIFFERENCES AMONG LOCATIONS USING MULTIVARIATE STATISTICS

4.4.1 Shoreline Macro-Debris

The first two principal components explained 53% of the variation among shoreline locations. The first principal component separated the locations MD01 and MD03 on particular sampling dates from the other locations and dates (Figure 4-28). Separation along the first principal component was driven by time of sampling, total debris density, and number of people per site (Table 4-11). This reflects a decrease in the number of people per site and in the total debris over the course of the study. Separation along the second principal component was driven by transect length. Locations with longer transects on particular sampling dates scored more negatively on PCA2.

Table 4-11. Loadings of explanatory variables on the first two principal components for shoreline samples.

Source	PCA1	PCA2
Time	-0.603	0.274
Wind Speed	-0.194	0.469
Transect Length	0.103	-0.702
Region	0.170	0.248
Total Debris Density	0.452	0.281
# People per Site	0.596	0.268

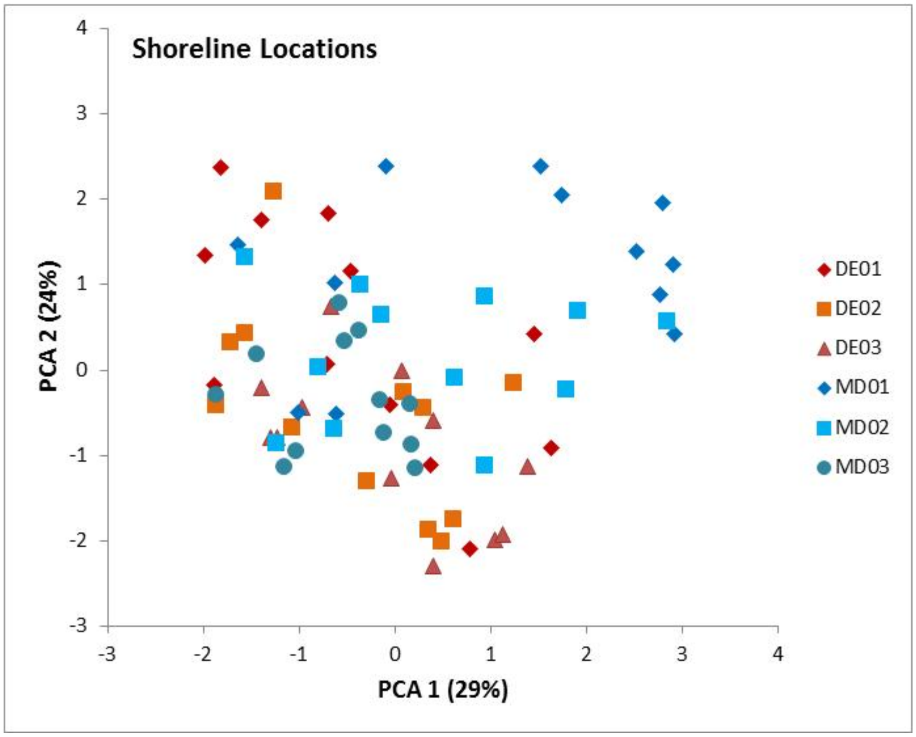


Figure 4-28. Ordination of shoreline locations by principal components analysis. Each point represents an individual location sampled during one sampling event (N=72).

4.4.2 Pelagic Macro-Debris

The first two principal components explained 48% of the variation among pelagic locations. Separation along the first principal component was driven by time of sampling and surface water temperature (Figure 4-29). This separation was due to relatively lower water temperature at certain urban and rural locations later in the survey (Table 4-12). The second principal component separated urban from rural locations and these differences were due to water quality differences. Rural locations in Maryland had relatively lower dissolved oxygen, pH, and relatively higher conductivity than urban locations in Delaware. Debris density did not strongly influence differences among locations.

Table 4-12. Loadings of explanatory variables on the first two principal components for pelagic samples.

Source	PCA1	PCA2
Surface Water Temperature	-0.597	-0.103
Surface Water pH	-0.281	0.450
Total Debris Density	-0.226	0.033
Region	0.077	-0.359
Wind Speed	0.110	0.417
Tow Length	0.213	-0.147
Surface Water Dissolved Oxygen	0.214	0.514
Surface Water Conductivity	0.299	-0.408
Time	0.562	0.173

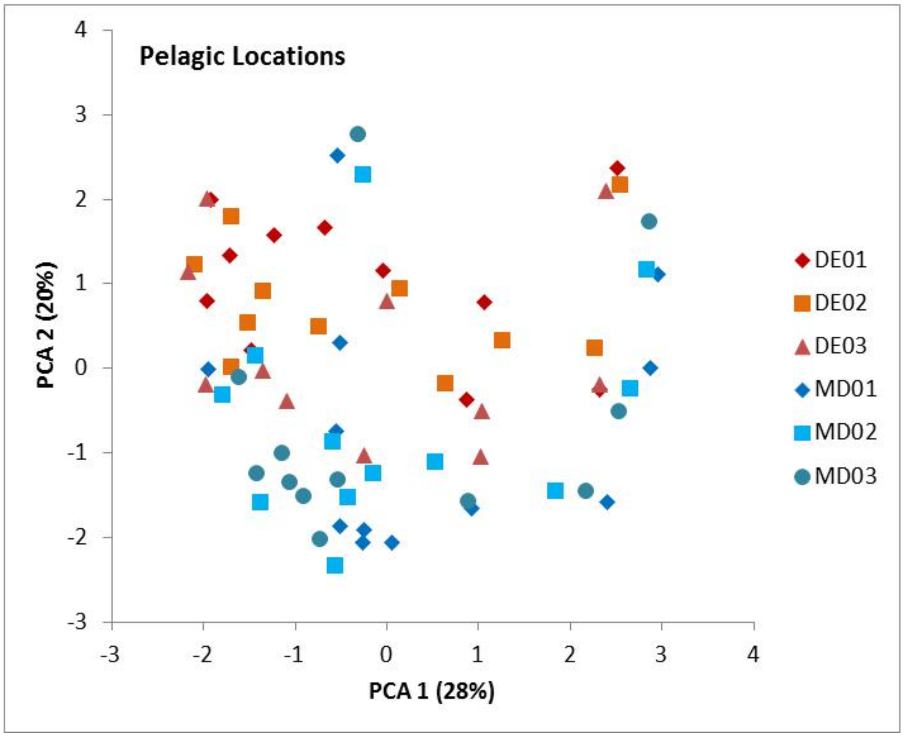


Figure 4-29. Ordination of pelagic locations by principal components analysis. Each point represents an individual location sampled during one sampling event (N=72).

4.5 SPATIAL VARIABILITY

4.5.1 Shoreline Macro-Debris

The relative standard error (RSE) for shoreline samples was below 20% in all instances when comparing the urban region to the rural region, and below 30% in most instances when comparing locations among regions (Figures 4-30 and 4-31). This pattern was consistent when examining the data on a weekly or on a monthly basis.

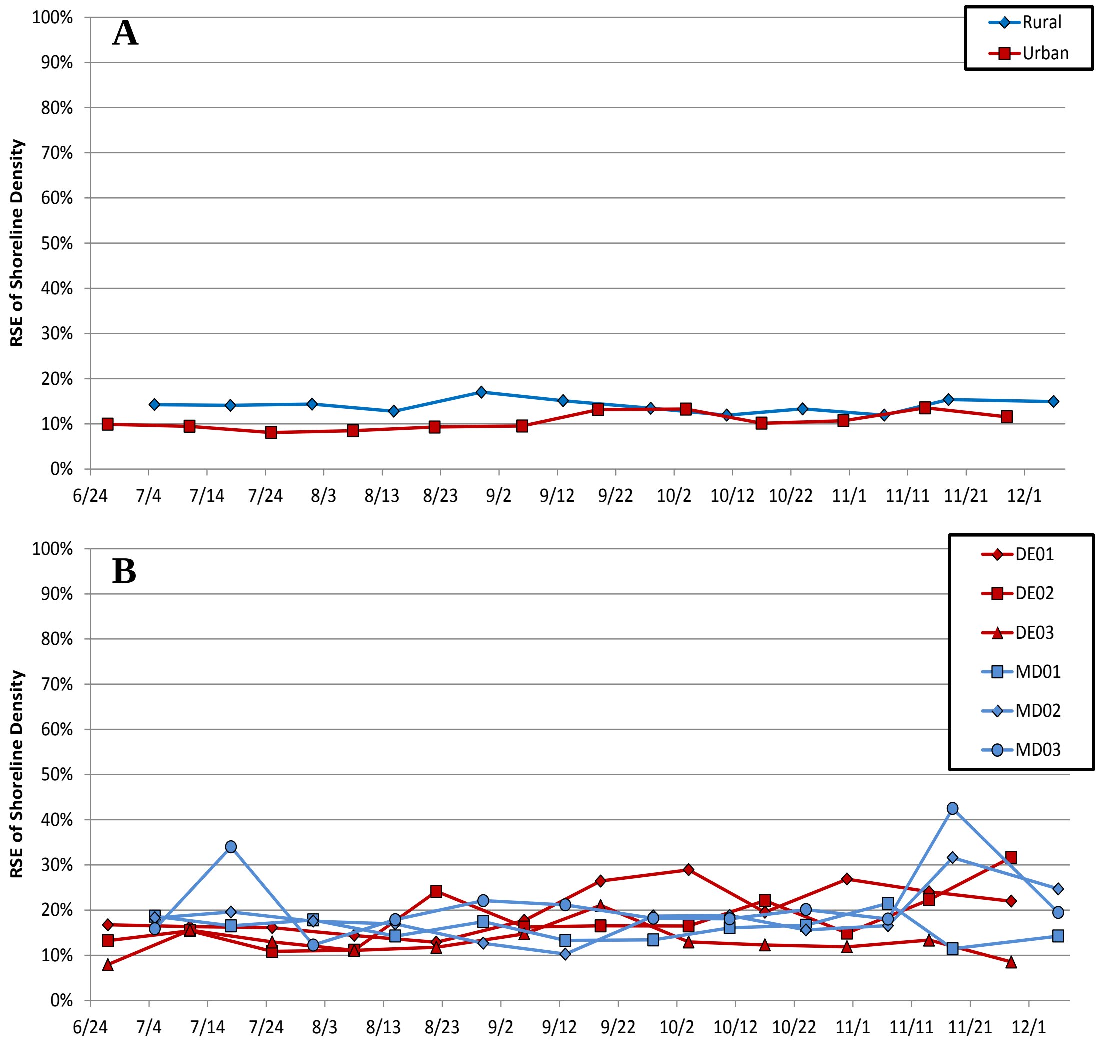


Figure 4-30. RSE for shoreline sampling by sampling event at the spatial resolutions of the A) region and B) locations within the urban region and rural region

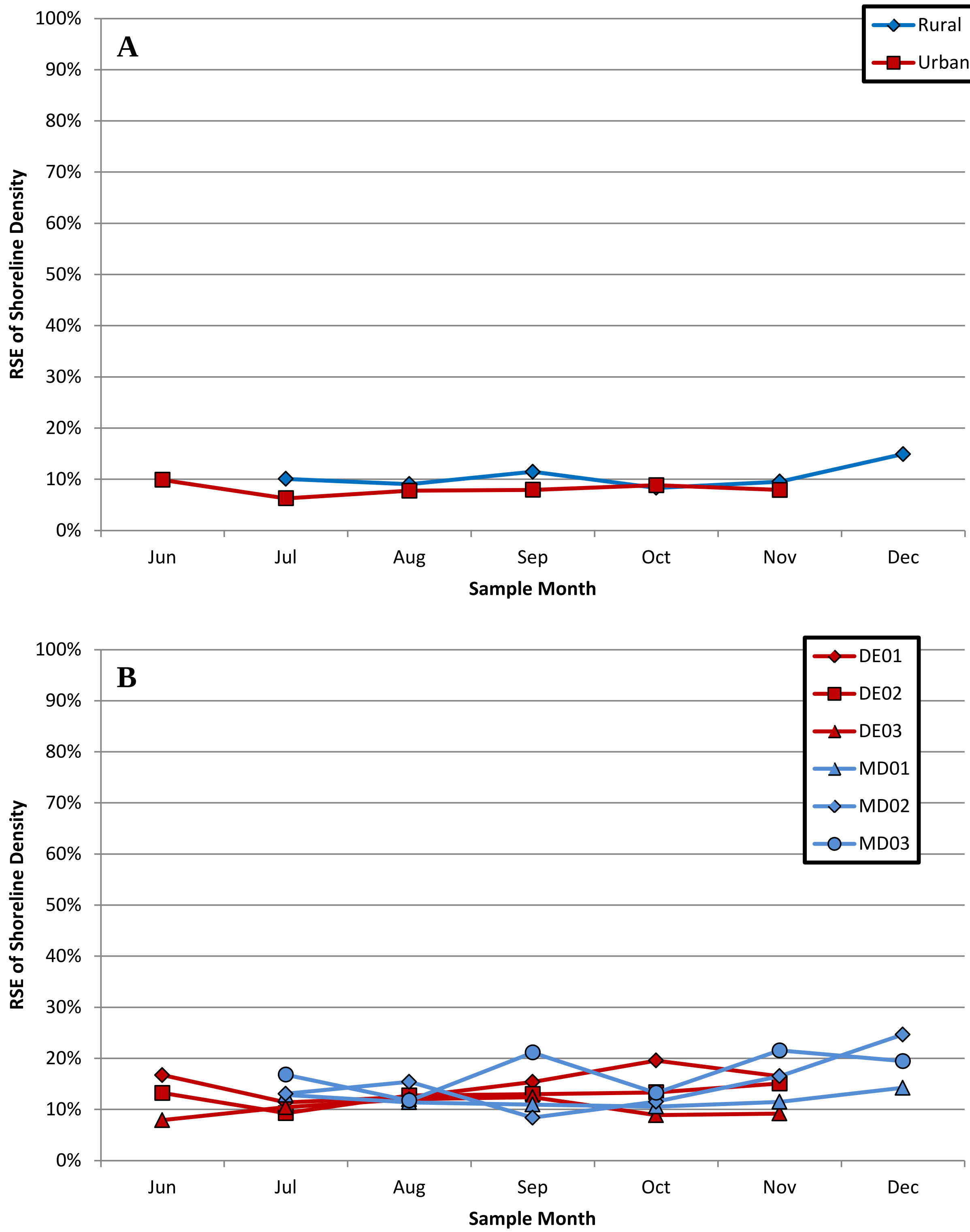


Figure 4-31. RSE for shoreline sampling by month at the spatial resolutions of the A) region and B) locations within the urban region and rural region

The RSE for transects within sites at urban sites was <30% at all sites at the beginning of the survey but RSEs increased by the end of the survey for most sites (Figure 4-32). Some sites at DE-01 and DE-02 had notably high RSEs during the latter half of the survey.

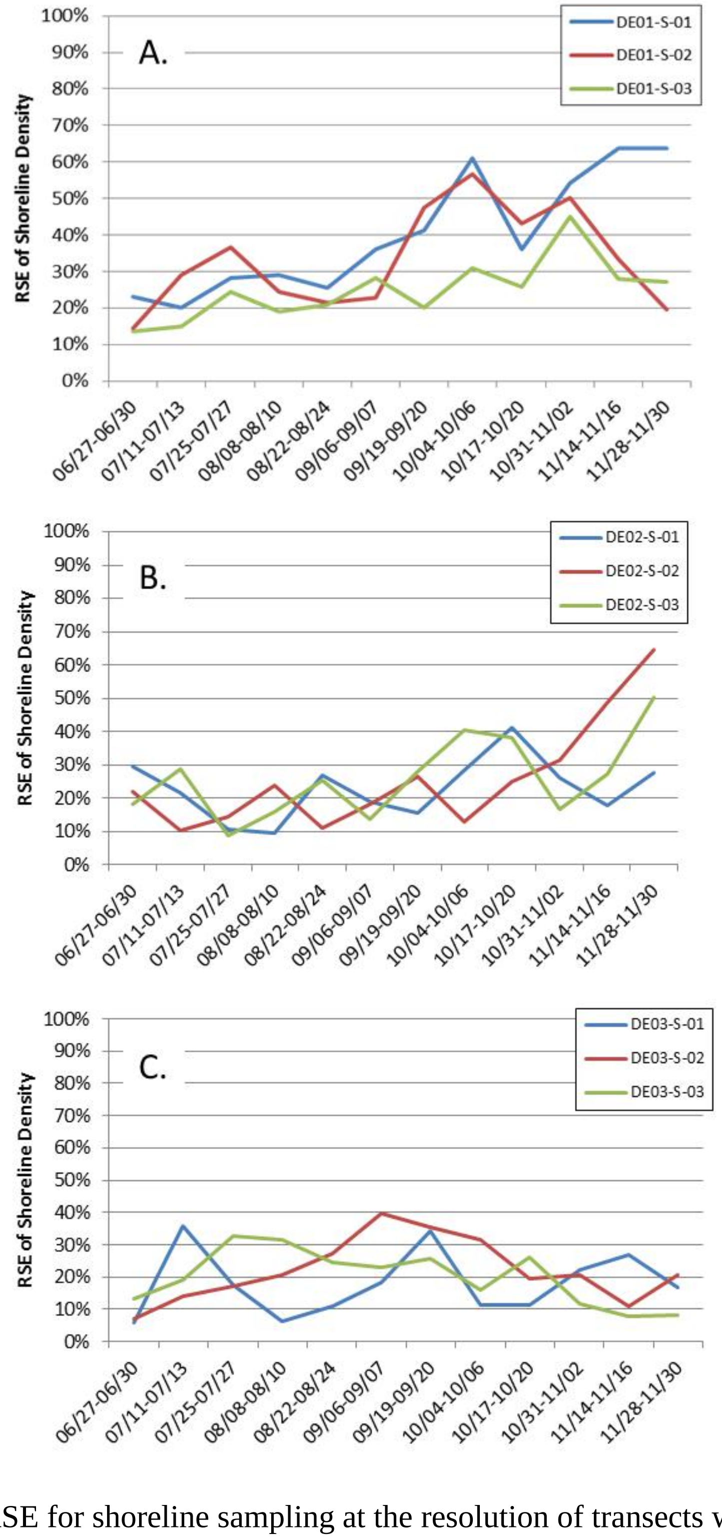


Figure 4-32. RSE for shoreline sampling at the resolution of transects within sites for sites at location A) DE01, B) DE02, C) DE03, D) MD01, E) MD02, and F) MD03.

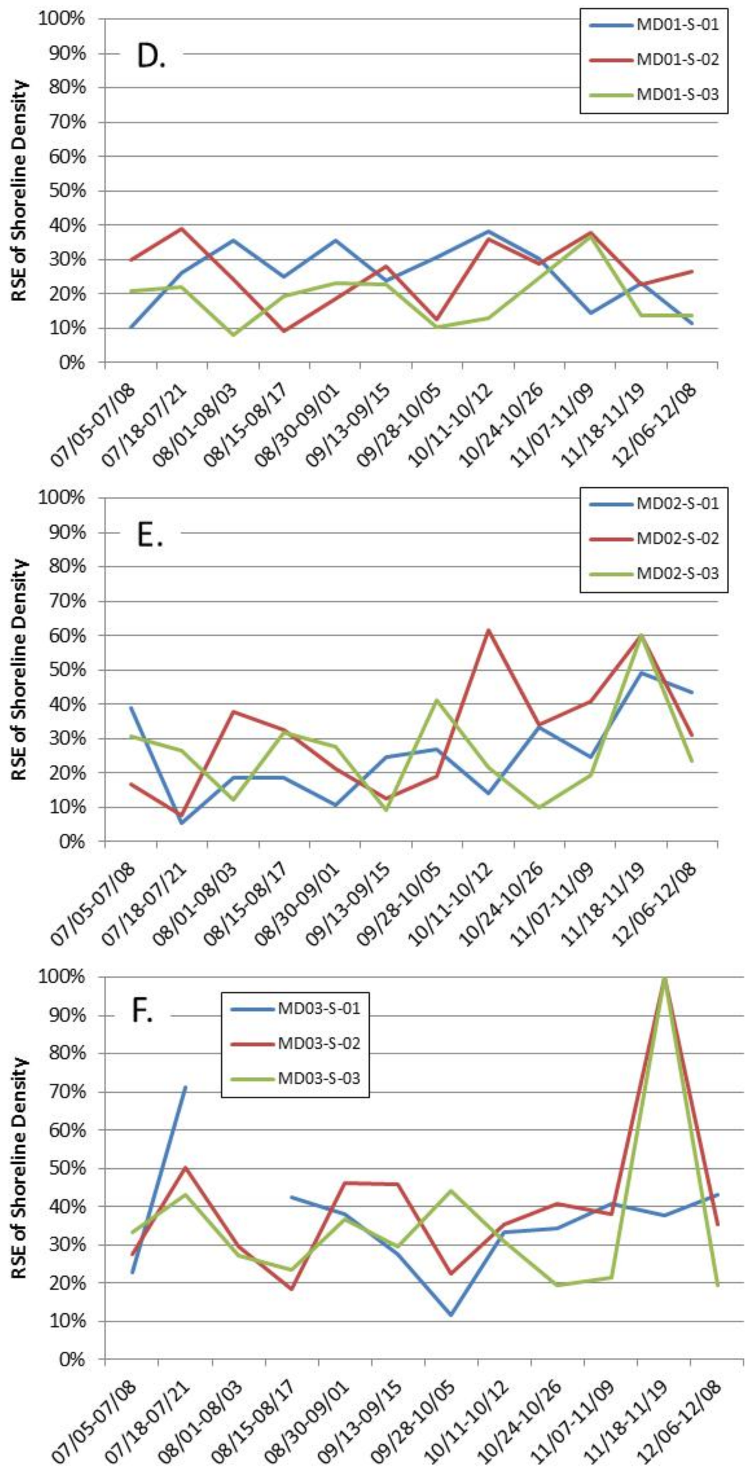


Figure 4-32. (Continued)

At the rural locations, RSEs among transects within a site were generally less than 40% throughout the survey with some notable exceptions such as all the sites in MD02 and two of the sites at MD03 in the latter portion of the survey.

4.5.2 Pelagic Macro-Debris

The RSE for pelagic sampling was variable over time and was quite high in several instances when comparing the urban region and rural region and when comparing locations among regions (Figures 4-33). This pattern was evident over both weekly and monthly time scales (Figures 4-33 and 4-34).

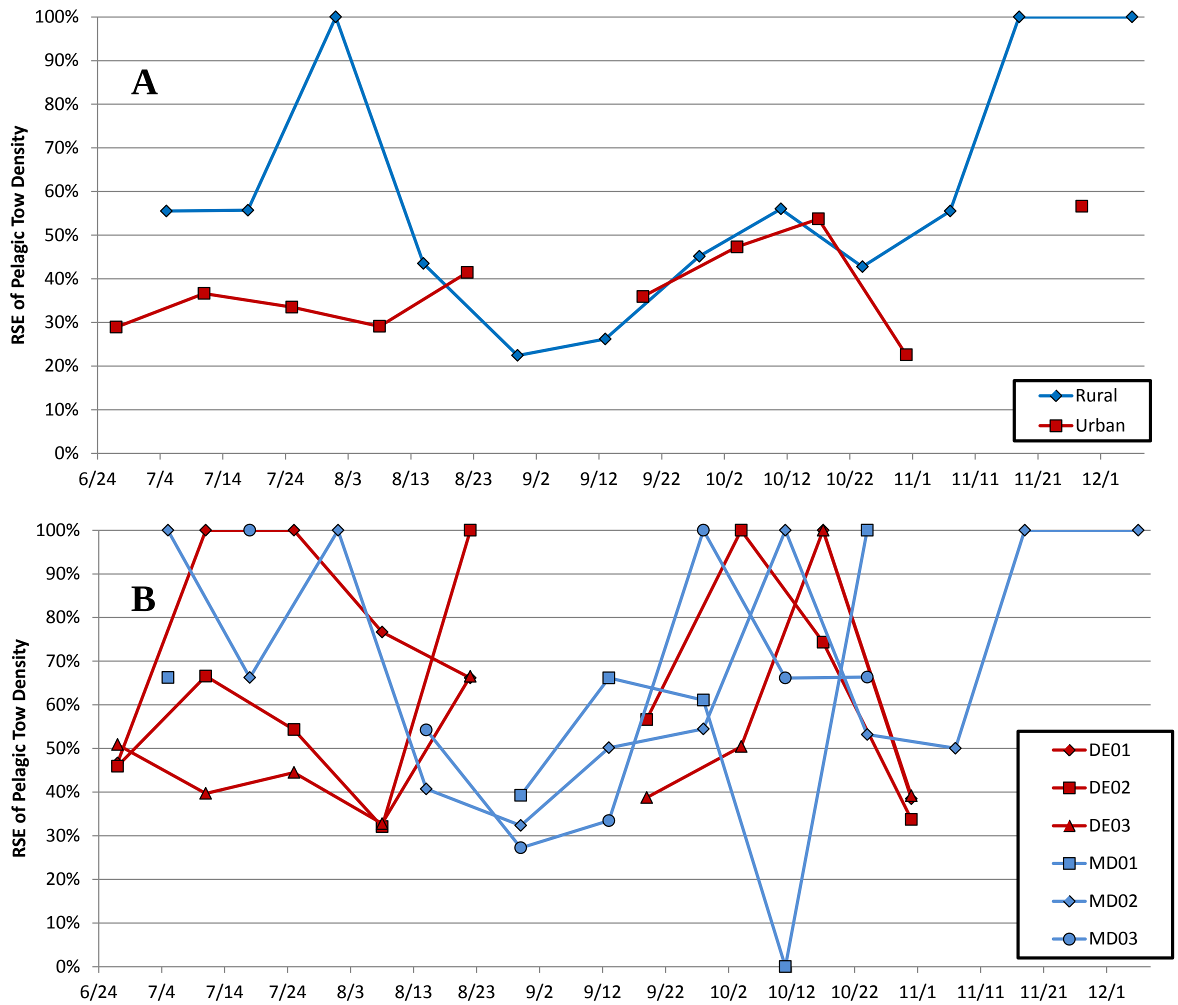


Figure 4-33. RSE for pelagic sampling by sampling event at the spatial resolution of the A) region and B) locations within the urban and the rural region

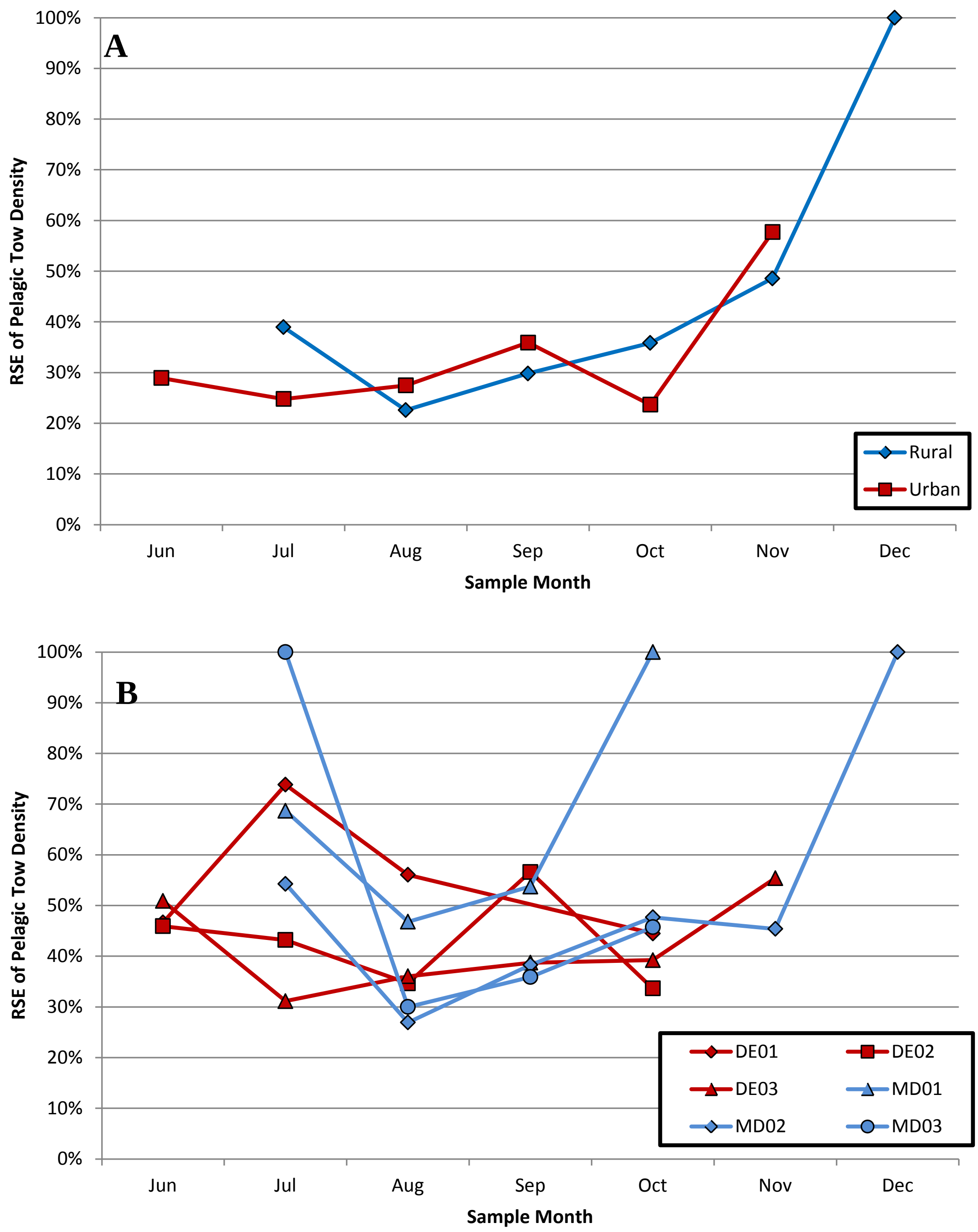


Figure 4-34. RSE for pelagic sampling by month at the spatial resolution of the A) region and B) locations within the urban and the rural region. Missing RSE values are due to zero debris density at certain location and month intervals.

4.6 OPTIMIZING THE SURVEY DESIGN FOR FUTURE SURVEY DEVELOPMENT

4.6.1 Optimizing Sample Size to Distinguish Urban from Rural

We conducted a power analysis to determine the number of samples (transects) required per region to distinguish an urban region from a rural region. Because there was a large amount of variation among sampling events, separate analyses were conducted for each paired sampling event. The analyses were conducted using a mean and standard deviation estimated from the dataset and multiple levels of alpha and power. Reducing the power (the probability of rejecting a false null hypothesis) and/or increasing the alpha value (the probability of rejecting the null hypothesis when the null hypothesis is true) also reduces the number of samples needed to show a difference.

The results of the power analyses indicate that the number of samples required depend highly upon the sampling event (Figure 4-35 and 4-36). For shoreline sampling, during weeks that were more variable (particularly U03-R04, U11-R12, U13-R14, and U17-R18, where U indicates urban and R indicates rural), the number of samples required to detect a difference were much higher than the 36 samples taken per region per sampling event during the survey (4 transects X 3 sites X 3 locations per region per sampling event). However, for the power analyses where power was designated to be ≤0.8, the number of samples is attainable for most of the paired sampling events. For pelagic sampling, there were again weeks that were extremely variable (especially U7-R8, U13-R14, U15-R16, U17-R18). Power analysis indicated these weeks would require an exorbitant number of samples to distinguish urban from rural, i.e., much greater than the 27 samples per region taken during the survey (9 tows X 3 locations per region). However, for the power analyses in which power was designated to be ≤0.8, the samples sizes required were attainable for the remaining paired sample events.

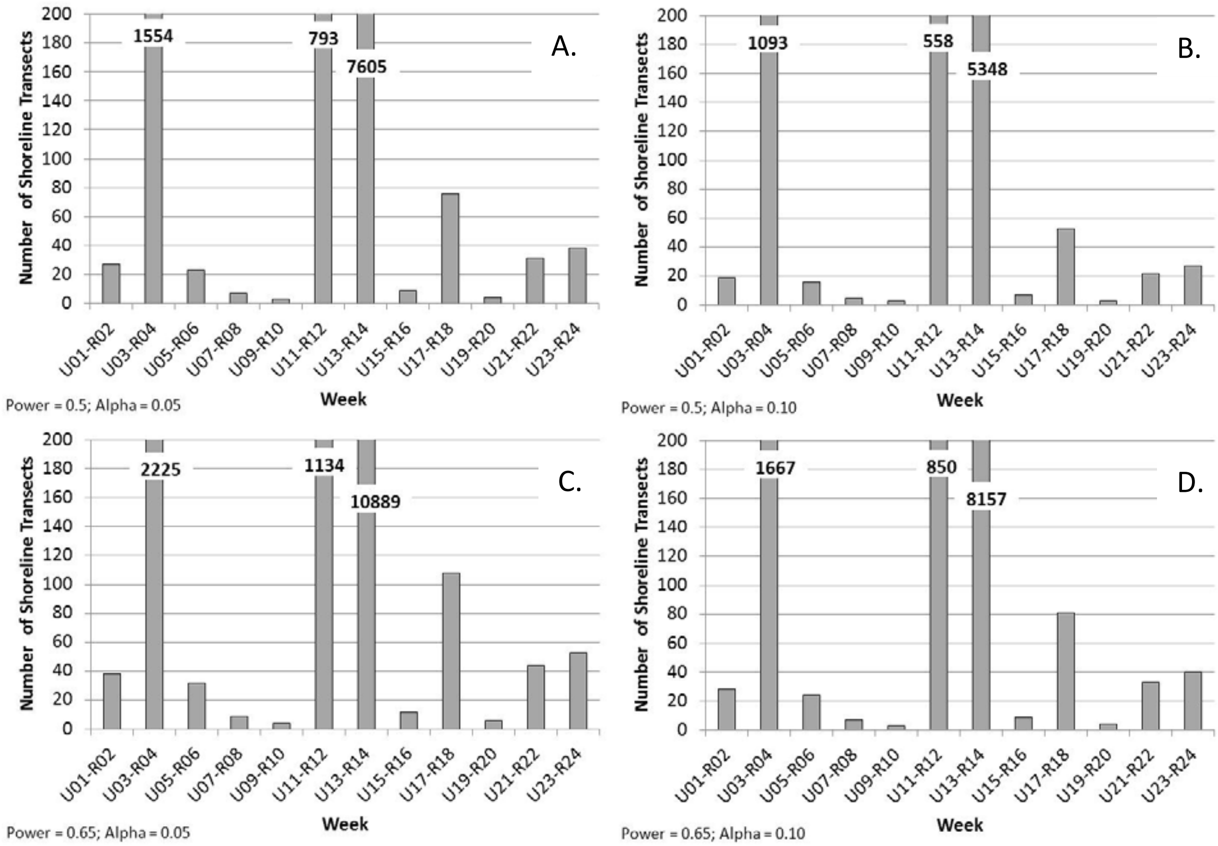


Figure 4-35. The number of transects needed per region to distinguish an urban region from a rural region along shorelines using A) Power=0.5, alpha=0.05 and B) Power=0.5, alpha=0.1, C) Power=0.65, alpha=0.05, D) Power=0.65, alpha=0.10, E) Power=0.8, alpha=0.05, F) Power=0.8, alpha=0.1, G) Power=0.99, p=0.05, and H) Power=0.99, p=0.1. The number of tows needed to distinguish an urban region from a rural region in surface waters using I) Power=0.5, alpha=0.05 and J) Power=0.5, alpha=0.1, K) Power=0.65, alpha=0.05, L) Power=0.65, alpha=0.10, M) Power=0.8, alpha=0.05, N) Power=0.8, alpha=0.1, O) Power=0.99, p=0.05, and P) Power=0.99, p=0.1. The x-axis indicates the sampling week number and whether the urban (U) or rural (R) region was sampled during that week number.

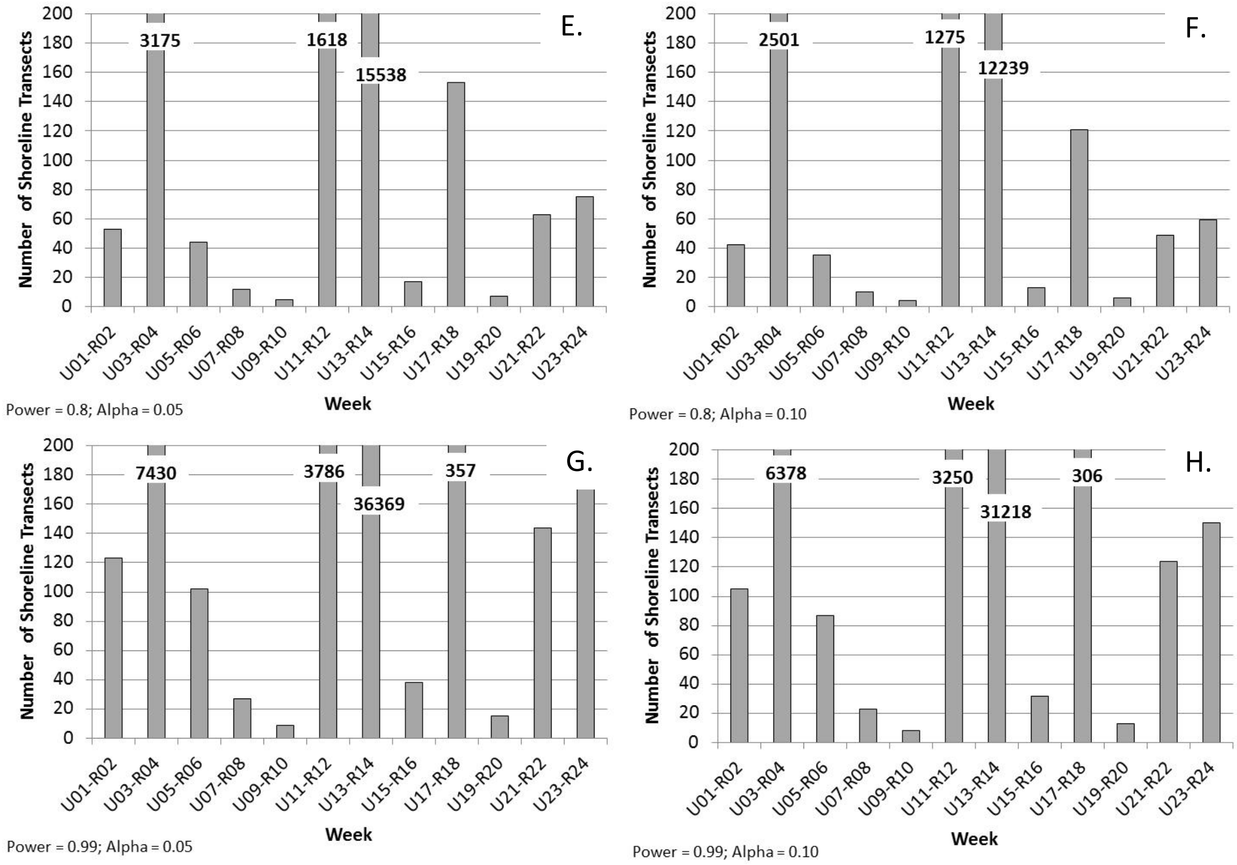


Figure 4-35. (Continued)

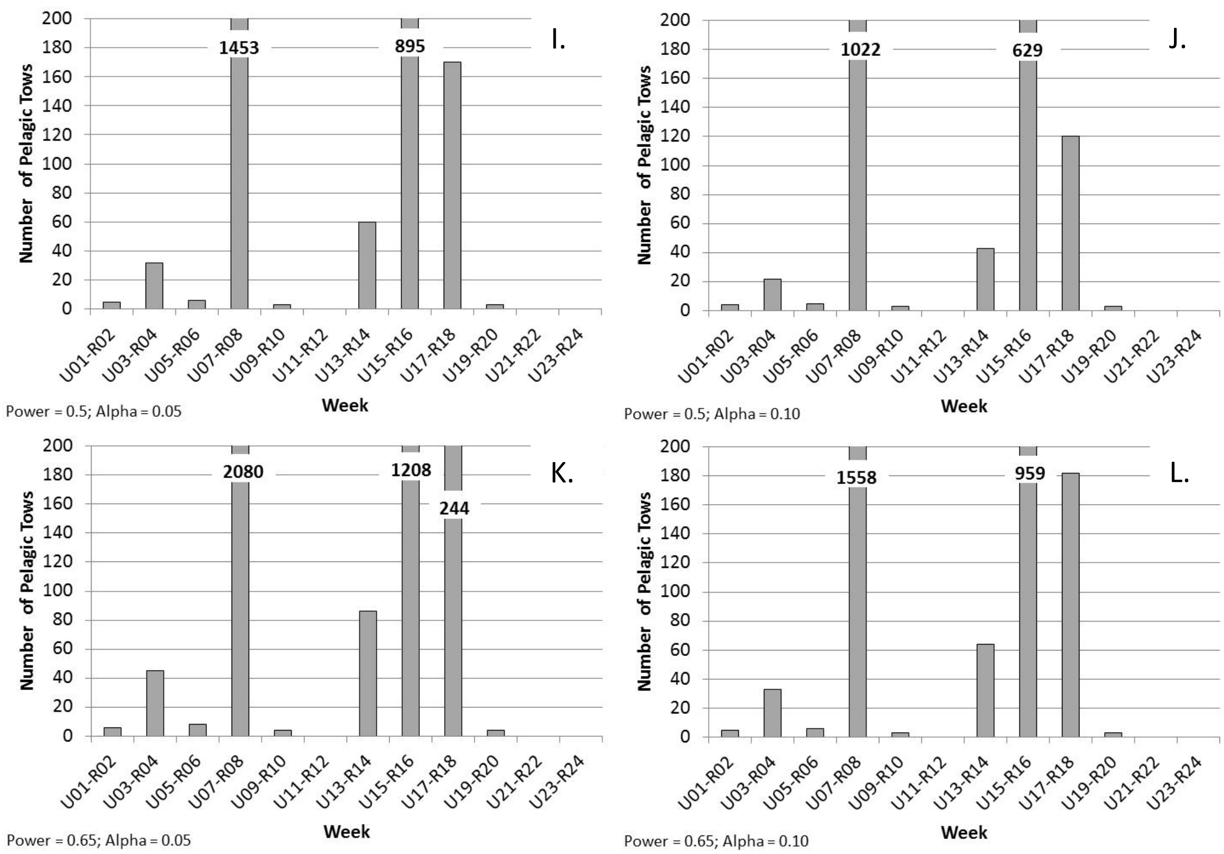


Figure 4-36. The number of tows needed to distinguish an urban region from a rural region in surface waters using I) Power=0.5, alpha=0.05 and J) Power=0.5, alpha=0.1, K) Power=0.65, alpha=0.05, L) Power=0.65, alpha=0.10, M) Power=0.8, alpha=0.05, N) Power=0.8, alpha=0.1, O) Power=0.99, p=0.05, and P) Power=0.99, p=0.1. The x-axis indicates the sampling week number and whether the urban (U) or rural (R) region was sampled during that week number. For the surface water analyses, no comparison could be made for U11-R12 because there was no sampling during week 11. Likewise, no comparisons were made for U21-R22 or U23-R24 because no surface water debris was collected during those weeks.

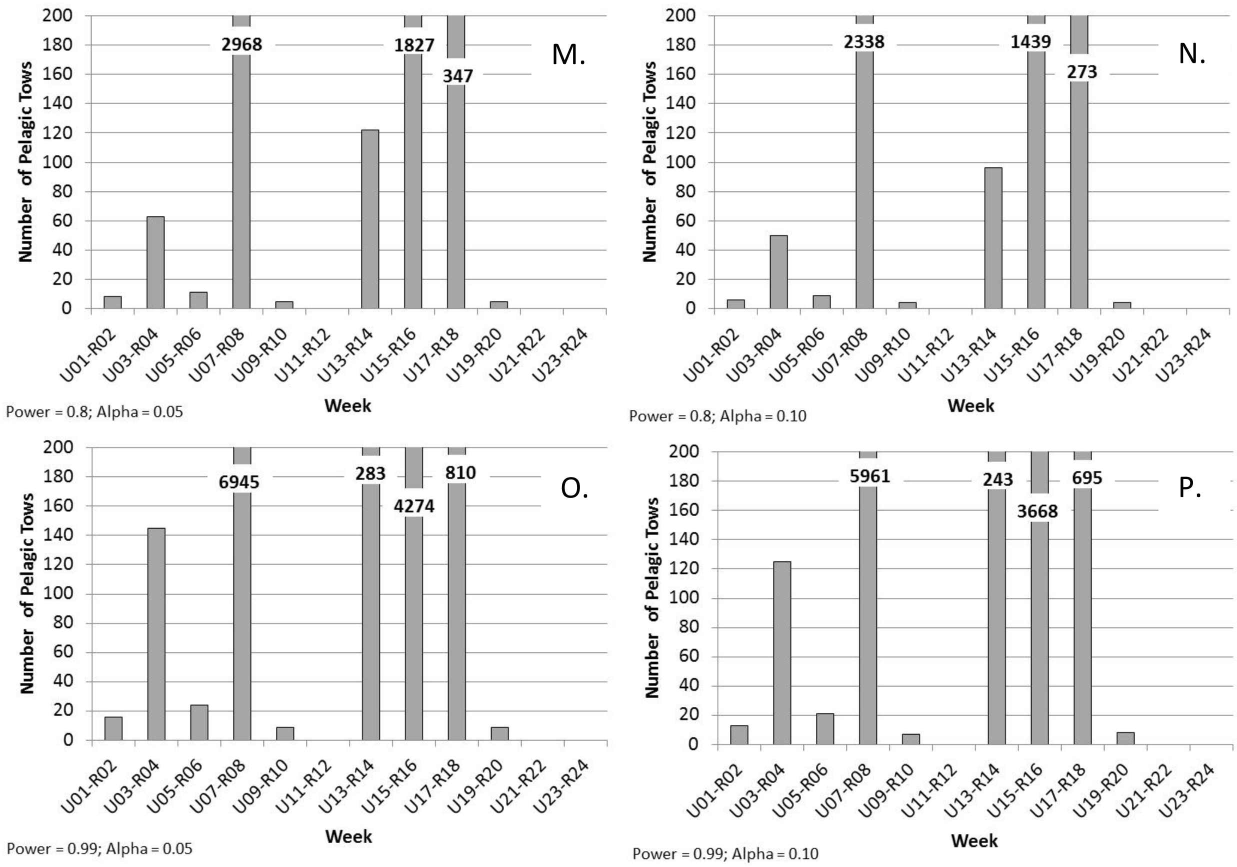


Figure 4-36. (Continued)

4.7 OPTIMIZING SAMPLE SIZE TO ATTAIN PRECISE ESTIMATES

4.7.1 By Region

For shoreline debris, the actual relative standard error of the estimates for macro-debris density were less than 30% in the majority of cases at both the region and location levels (Figures 4-28 and 4-29). The sample sizes used in this survey therefore are thought to be sufficient to attain reasonably precise estimates of shoreline macro-debris. At the region level, bootstrap analysis indicates that sampling about 20 transects in a region per sampling date would provide estimates with RSEs in the 20-30% range (Figure 4-37). This is fewer but comparable to the 36 samples per region per event that were conducted during the survey.

In contrast, pelagic macro-debris density estimates were quite variable with RSEs ranging from 22% to 100% at spatial scales of region and location. Bootstrap analysis was used to determine how many tows would need to be sampled in order to minimize the RSE at the spatial scale of a region to a reasonably precise level. For the rural region, the RSE for most sampling dates remained higher than 40% even after the resampled sample size was close to n=200 (Figure 4-38). There were two sampling dates (weeks 10 and 12) during which the bootstrap indicated that the RSE could be reduced below 30%. On two sampling dates in the rural region (weeks 22 and 24), the RSE actually increased with increasing resampled sample size. This was an artifact of having only 1 non-zero data point in the rural pelagic data set during those weeks. In urban regions, the variability and thus the RSEs attainable by increasing sample size, depended upon the week of sampling. Three sampling dates (weeks 1, 7, and 19) attained an RSE below 30% when using a re-sampled sample size ranging from 20 to 50. The variability during the remaining sampling weeks was sufficiently high to prevent RSEs below 30%, even when nearly 200 samples were re-sampled.

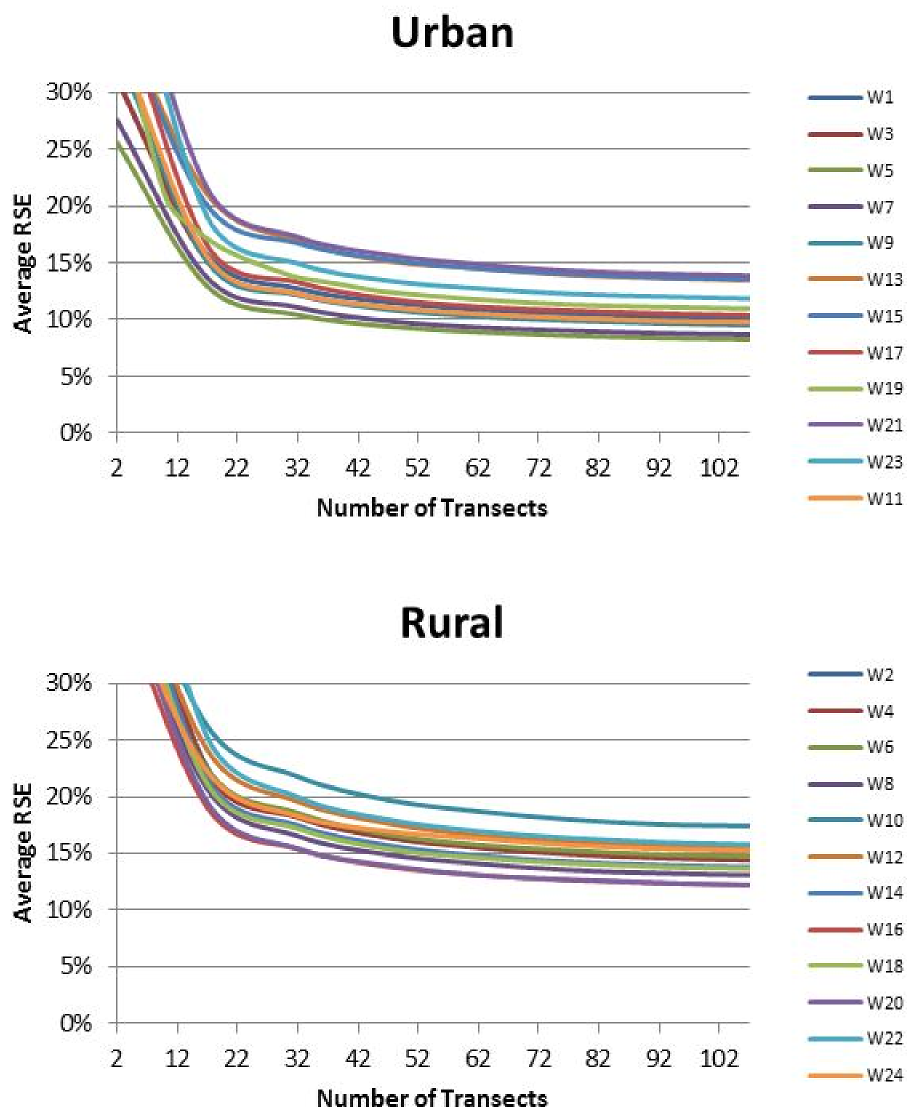


Figure 4-37. The results of the bootstrap analysis for shorelines indicating sample size (i.e., number transects) required to attain reduced RSEs for an A) urban region and a B) rural region. Each line represents an individual sampling week.

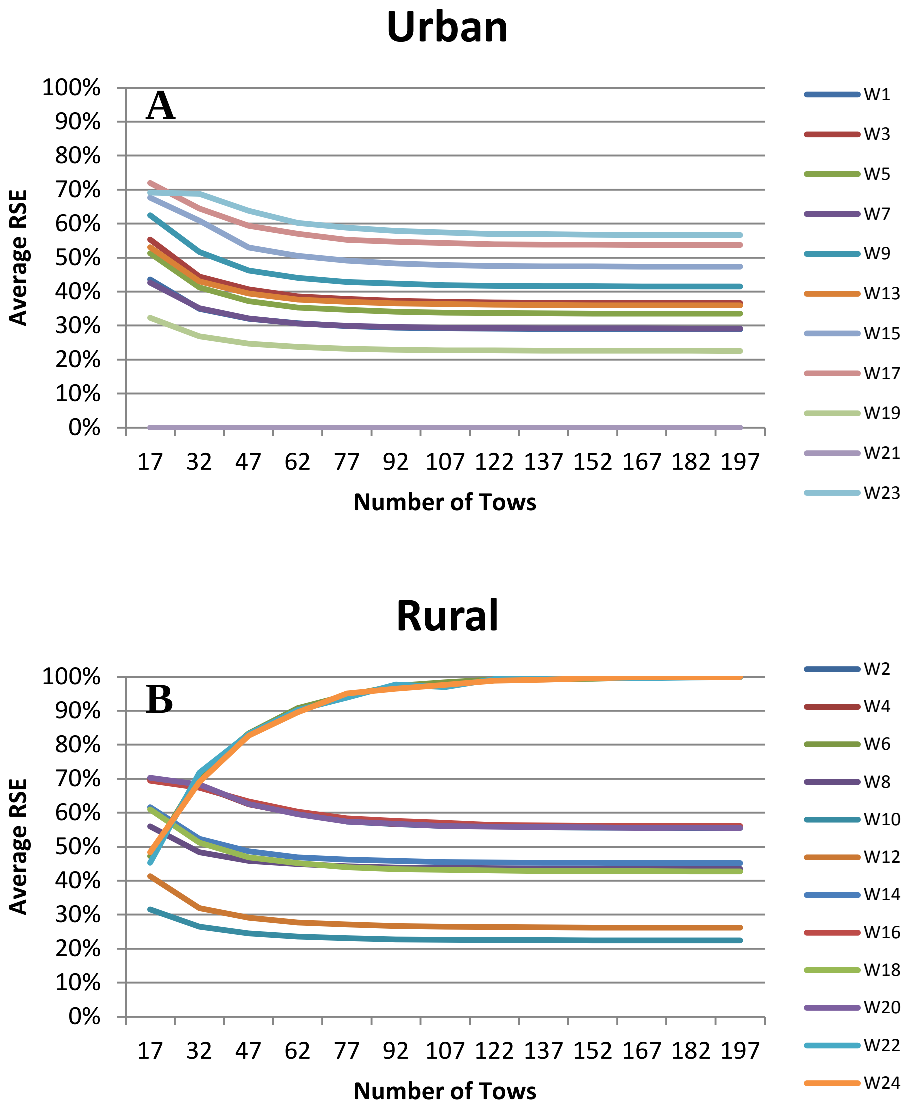


Figure 4-38. The results of the bootstrap analysis for surface waters indicating sample size (i.e., number of pelagic tows) required to attain reduced RSEs for an A) urban region and a B) rural region. Each line represents an individual sampling week.

4.7.2 By Location

The number of shoreline transects required to attain an estimate with RSEs in the 20-30% range depended on the sampling date (Figure 4-39). For the least variable sample dates at each location represented by the blue lines in Figure 4-39, 10 transects per location appears to attain RSEs in the 10-20% range. For the most variable sampling date at each location represented by the red lines in Figure 4-39, 20-30 transects at a location attained RSEs ≤30%. The one exception was week 22 at MD-03 where RSEs did not decrease below 40% for any sample size considered. However, this is just one sampling date at one location and therefore represents an uncommon pattern.

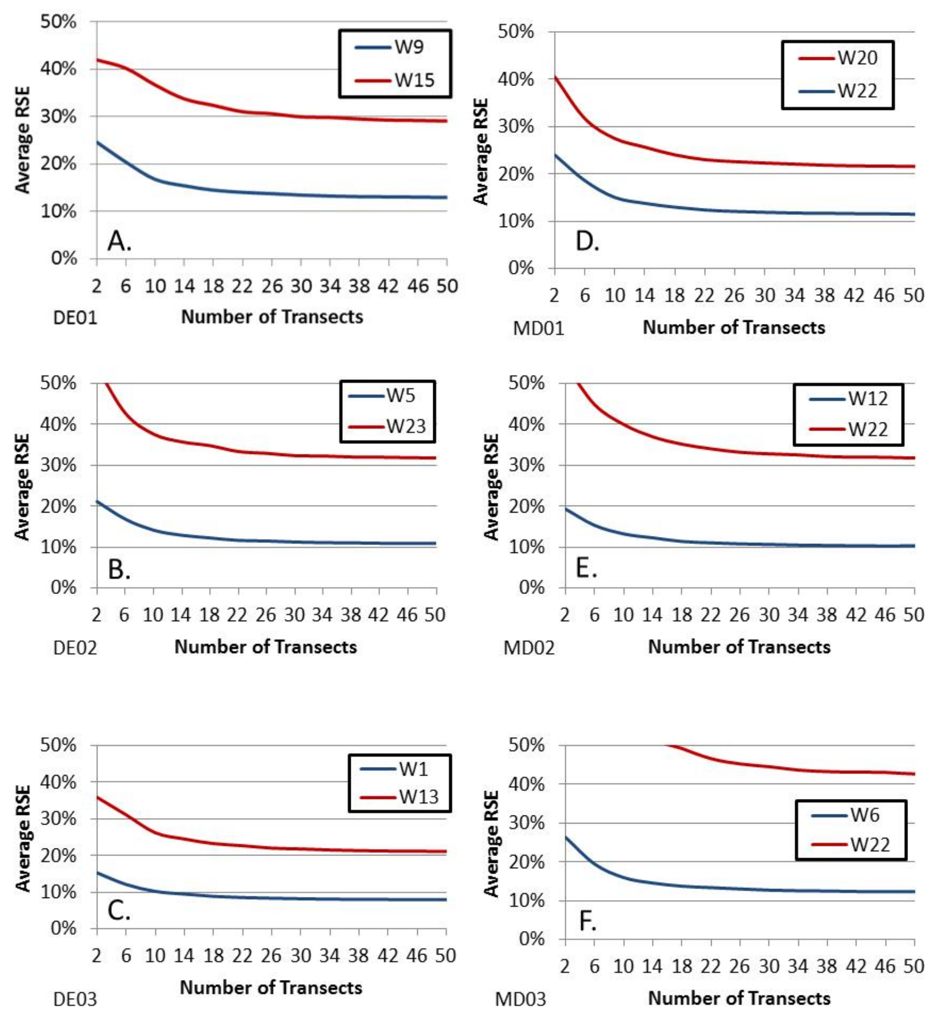


Figure 4-39. The results of the bootstrap analysis indicating sample size (i.e., number of transects) required on shorelines to attain reduced RSEs for the urban locations A) DE-01, B) DE-02, and C) DE-03 and the rural locations D) MD-01, E) MD-02, and F) MD03. The two lines on each graph represent the bootstrapped RSEs for the sampling events at that location that had the highest and the lowest variability.

4.7.3 By Site

A survey data set with an RSE of 30% is typically considered to be able to make a reasonably precise estimate. For the site level at each sampling event, 32% of the RSEs were < 30% (Figure 4-40). At the location level for shoreline sampling, the precision of the estimates was better with 75% of the RSEs below 30% whereas for pelagic locations, only 2% of RSEs were below 30%. We conducted bootstrap analyses for 8 selected sites that represented instances in which RSEs were > 30%, to determine the number of samples (i.e., transects) that would need to be sampled in order to increase the level of precision at those representative sites (Table 4-13). For these sites, using a sample size of n=20, the maximum number of 5m transects in a 100m site, did not reduce the RSE below30% (Figure 4-41). This demonstrates that there may be some sites during a survey that are so variable that precise estimates of debris cannot be made.

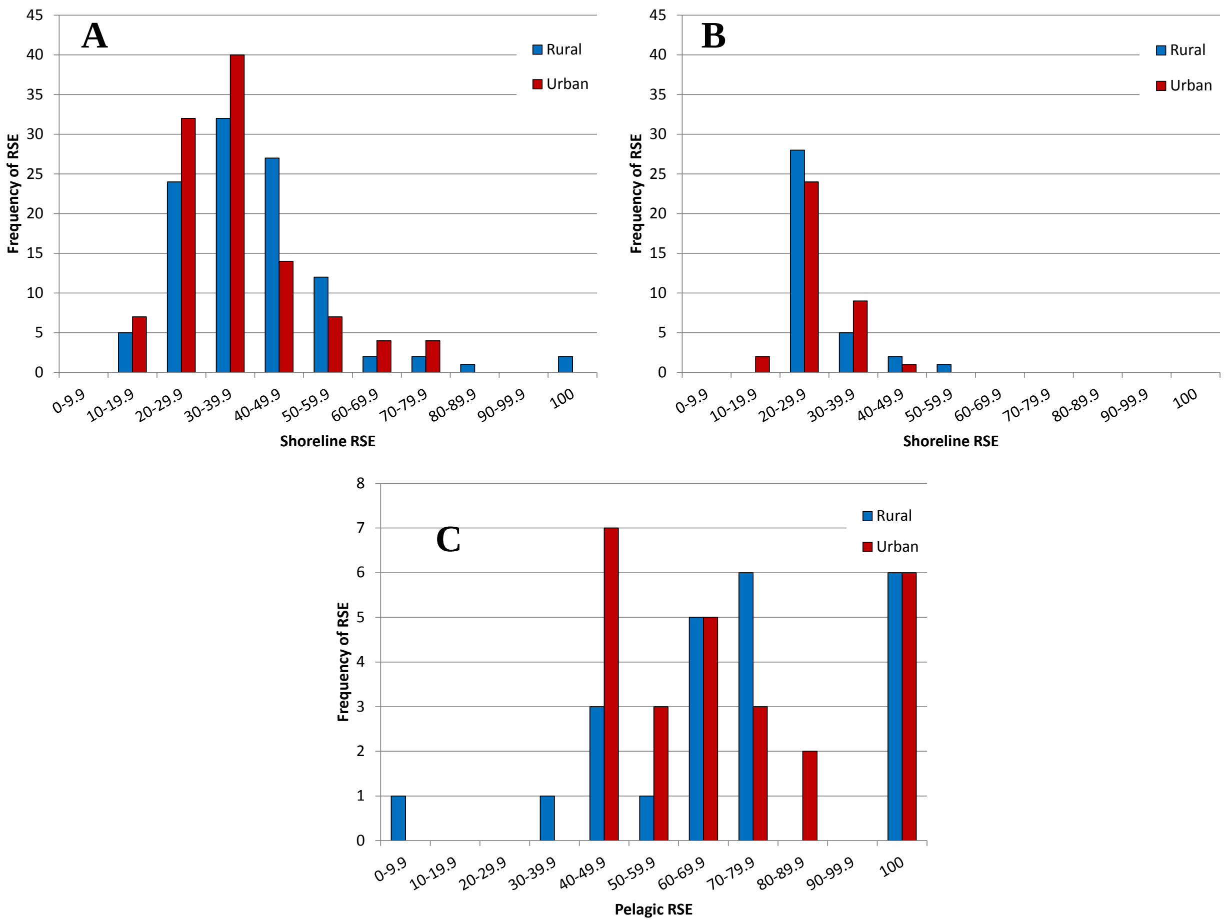


Figure 4-40. Histograms representing the frequency distribution of RSEs at A) the site level for shoreline sampling, i.e., the variability of among transects within sites for shoreline sampling at each sampling event, B) the location level, i.e., the variability among sites within location at each sampling event, and C) at the location level for pelagic samples, i.e., the variability among transects within locations at each sampling event.

Table 4-13. Sites selected for resampling with bootstrapping methods. RSEs at these sites ranged from 34.4% to 100%.					
Week#	**Dates**	**Area**	**Location**	**Site**	**RSE Density**
13	09/19-09/20	Urban	DE03	DE03-S-01	34.4%
18	10/24-10/26	Rural	MD03	MD03-S-01	34.4%
14	09/28-10/05	Rural	MD02	MD02-S-03	41.2%
17	10/17-10/20	Urban	DE02	DE02-S-01	41.3%
4	07/18-07/21	Rural	MD03	MD03-S-02	50.3%
19	10/31-11/02	Urban	DE01	DE01-S-01	54.3%
15	10/04-10/06	Urban	DE01	DE01-S-01	61.0%
16	10/11-10/12	Rural	MD02	MD02-S-02	61.6%

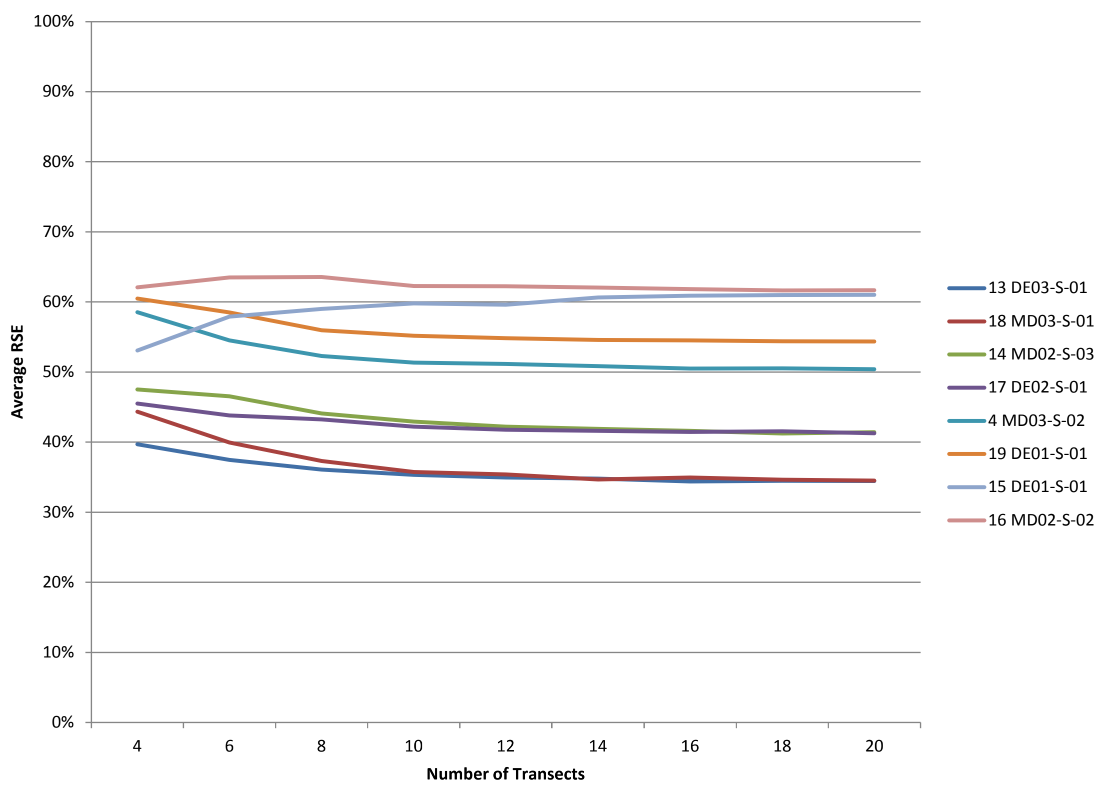


Figure 4-41. Results from bootstrap analysis indicating the average RSE expected for a given sample size. Each line represents an individual site sampled during one sampling event. Sites are identified in the legend by the week during which they were sampled, the state, location number, and site for shoreline samples.

4.8 OPTIMAL SAMPLING FREQUENCY

Figures 4-42 and 4-43 depicts both the monthly average and the individual sampling events within each month in order to compare the trends at each of these temporal scales. For the shoreline survey, in most instances, individual sampling events tracked the monthly averages closely (although there were some exceptions, e.g., August in DE01). This suggests that sampling just one of these dates within a month could provide an accurate snapshot of the patterns of debris in that month. For the pelagic survey, there were some sampling events during which the variability was notably high due to the spatial and temporal patchiness of pelagic macro-debris.

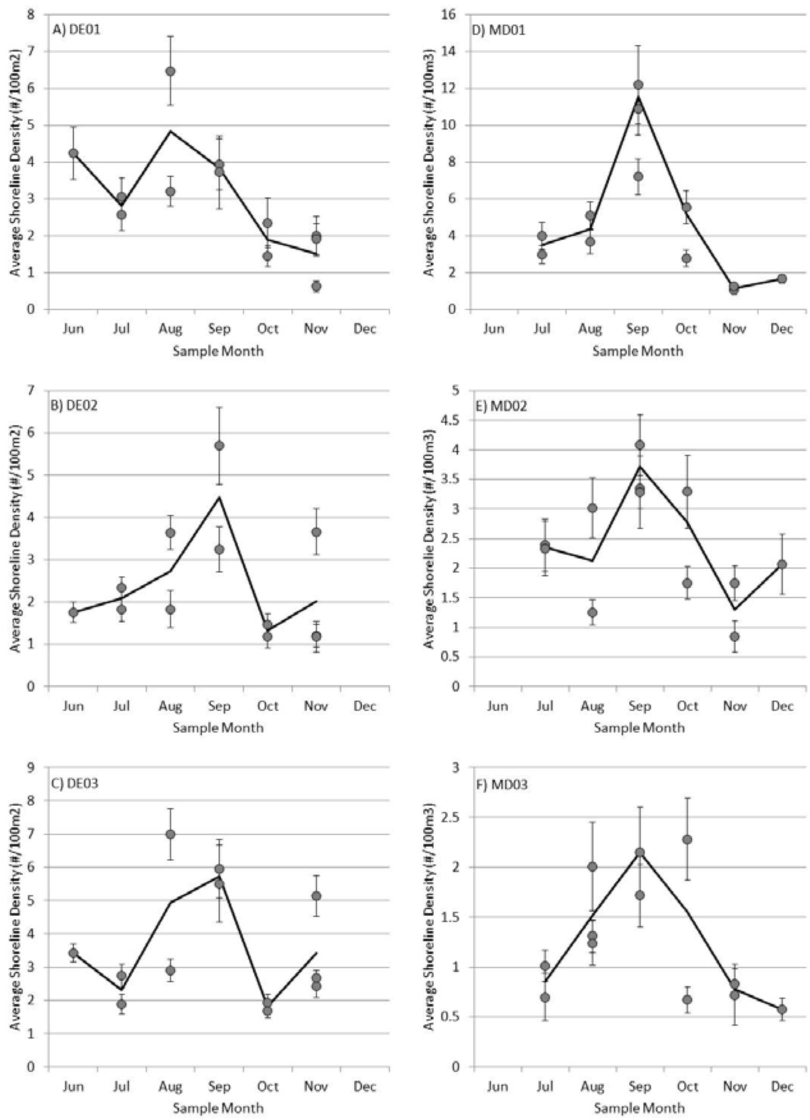


Figure 4-42. Comparison of monthly and weekly averages for macro-debris on shorelines at urban locations A) DE01, B) DE02, and C) DE03 and at rural locations D) MD01, E) MD02, and F) MD03.The line represents the monthly average and points represent the individual sampling events for the location within that month.

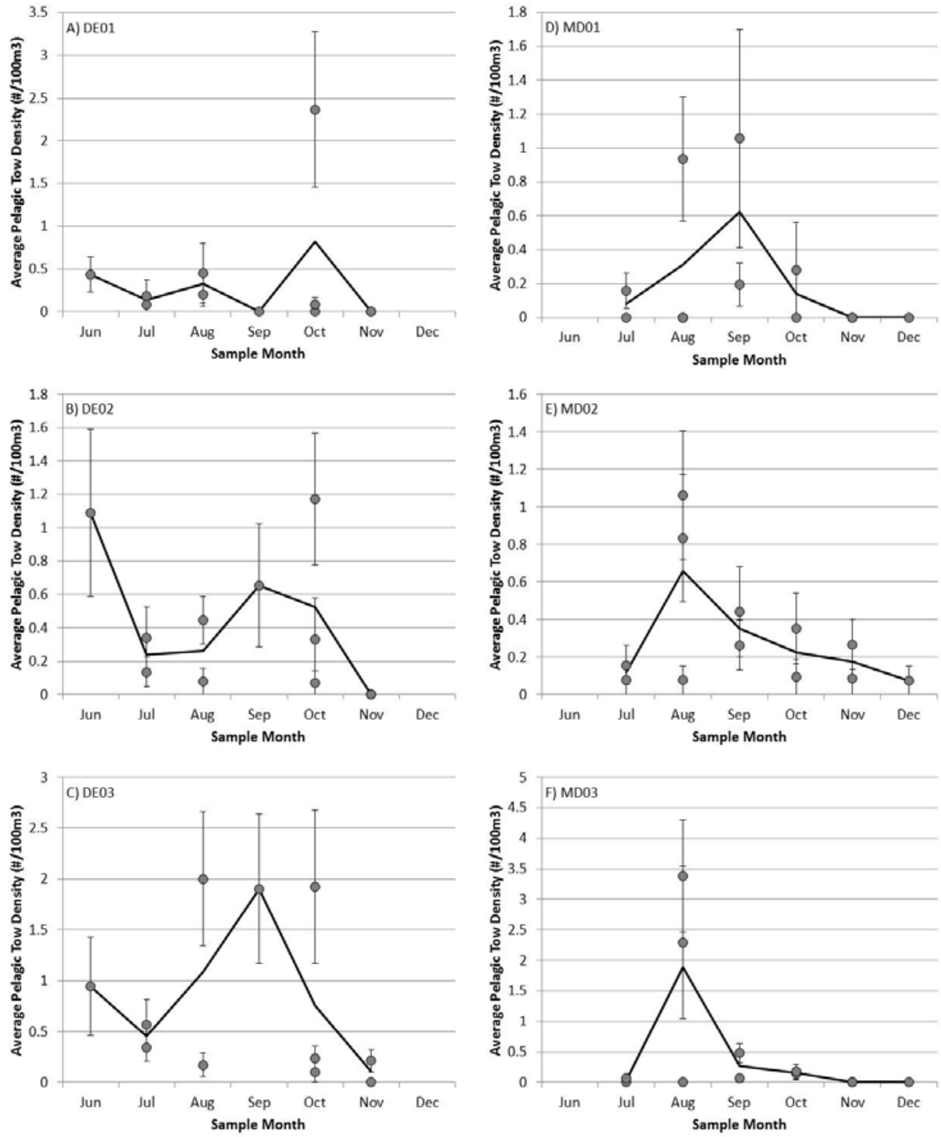


Figure 4-43. Comparison of monthly and weekly averages for pelagic macro-debris at urban locations A) DE01, B) DE02, and C) DE03 and at rural locations D) MD01, E) MD02, and F) MD03. The line represents the monthly average and points represent the individual sampling events within each month.

5.0 CONCLUSIONS & RECOMMENDATIONS

In this section, we examine our findings in the context of the stated goals for this project laid out in Section 1. We address our success in achieving these goals and offer conclusions and recommendations based on our findings.

Goal 1: Apply the monitoring protocols (shoreline and surface waters) to assess marine debris in a coastal region within the United States

To implement the sampling protocols established by MDD, we designed and conducted a survey which quantified marine debris in the coastal area of the mid-Atlantic Bight. The marine debris survey was conducted weekly on beaches and in ocean surface waters for 24 consecutive weeks. In designing a survey to distinguish an urban region from a rural region, we considered three underlying factors to be important for the distribution of debris: proximity to the debris source, location relative to regional hydrology (i.e., upstream or downstream of a plume), and local hydrodynamics. At more refined spatial scales, local factors such as beach-goer traffic are also acting on debris and just as important to consider during the design phase. A suite of site selection criteria were developed to minimize the variability within regions (urban and rural) with regard to human and environmental influences and to maximize the variability between regions with regard to degree of urban-ness, while keeping in mind the logistical constraints of field sampling (e.g., gaining access to the site, driving distance between sites, etc.). Overall we found the MDD sampling protocols were easy to implement for both shoreline and pelagic sampling; they were flexible, repeatable, and practical for use in the setting of our survey.

While straightforward to implement, the meso-debris survey on beaches turned up very little marine debris. There was an intense amount of sampling effort for a very small return in terms of data. To improve the efficiency of this approach, MDD may consider focusing meso-debris sampling in the "above wrack 2" zone where meso-debris was found more frequently. While meso-debris was rare on the sand beaches where this survey was conducted, the shorelines of the U.S. contain a variety of habitats with differing grain size, vegetation, and topography which may influence the retention of meso-debris. Large item debris was also rarely encountered but the amount of effort required to monitor this type of debris was far less.

Surface water debris was much less common than shoreline debris and much more temporally variable. The high variability associated with pelagic debris density was due to large numbers of samples with no debris during each sampling event. In fact, 72% of urban tows and 80% of rural tows contained zero debris. Even in tows that contained debris, the counts were low, ranging from 0-0.8 pieces per $100m^3$ in the urban region and 0-0.9 pieces per $100m^3$ in the rural region. As an additional piece of information, we recorded the presence of debris lines (conglomeration of debris generated by currents) and found that only 4.8% of all tows intercepted a debris line. The fact that few debris lines or other floating debris were witnessed during our survey may indicate that little debris was present in our sampling area or that other factors such as wave turbulence were keeping debris from the surface. Pelagic sampling occurred in areas that were just seaward of the surf zone where turbulence from waves and currents occurred. The surf zone could have acted as barrier pushing land derived debris back toward the beach through wave action. In addition, surface water could have continuously been pushed away from this area by prevailing offshore winds taking surface debris further out to sea.

We have no means to compare if the manta-net was sampling efficiently or if higher densities of debris occurred in areas that are less turbulent. Pelagic debris is dynamic in the environment and could occur in high densities in certain locations or be very patchy for unknown site specific reasons. It is difficult to account for all site specific factors and we expect that repeating this survey design in surface waters of the type in our survey will yield similar results. In traditional fisheries survey data, it is not uncommon to encounter large numbers of zero catch tows and fisheries scientists have developed methods to cope with this issue.

Modifying collection methods to enhance the efficiency of sampling gear is one way to cope with zero catch. In our survey, surface debris was collected by towing a manta-net for 15 minutes across a ~1.79 km^2 area. The manta-net is effective for surface water sampling and aside from making the sampled area larger (i.e. increasing the size of the net opening); increasing or decreasing the tow duration is the only modification that would change the effectiveness of the net to capture debris. This type of modification actually changes the sample unit size rather than the efficiency of the net itself. Without data collected from varying tow durations, we have no basis to recommend an increase or decrease to the tow duration used in this study; however, research of trawl tow duration for fisheries sampling has been conducted and can be used to discuss the value of certain tow durations. Pennington and Volstad (1991; 1994) determined that 15 minute trawls was a sufficient sampling unit to precisely estimate fish densities when compared to 30 or 60 minute tows. Their research focused on optimizing overall survey performance and suggests that the time saved from conducting shorter individual tows allows the survey to sample at more locations overall which could yield even more precise population estimates. While increasing tow duration might increase overall catch of marine debris due to a larger area sampled it would also increase the time spent sampling one particular area and possibly sacrifice time required to collect samples from more locations.

Another approach uses analytical methods to account for lack of debris in samples. Fletcher et al. (2005) describes a common method in which the skewed data with many zeroes are separated into two datasets: The first indicates whether the species (or debris in our case) is present or absent and the other contains just those samples where abundance was greater than zero. Using the first data set, this method would use logistic regression to model the probability that debris is present and then with the second data set, this method would use ordinary regression to model the abundance of debris. This approach then goes on to combine the two models to predict debris density for a given set of predictor variables.

Goal 2: Determine the baseline debris density in the study area using MDD assessment protocols

The survey established a range of baseline densities for shoreline and surface water debris in an urban region and a rural region. Overall, marine macro-debris ranged from 0-27.5 per 100m2 on rural shorelines and 0-15.4 per 100m2 on urban shorelines. Macro-debris in surface waters was less common, ranging from 0-11.6 pieces per 100m3 in surface waters offshore of a rural region and 0-8.6 in the surface waters offshore of an urban region. Shoreline meso-debris was rare ranging from 0-3 pieces in a transect on rural beaches and 0-2 on urban beaches. Large item debris along beaches ranged from 0-0.757 per 100m2 in the rural region and from 0-0.803 in the urban region. Pelagic large item debris occurred in densities ranging from 0-0.878 per 100m3 in the rural region and from 0-0.791 per 100m3 in the urban region These baseline densities can provide the basis for future comparisons.

Macro-debris was the most common size class of debris found on shorelines or in surface waters. Plastic materials which commonly included plastic/polystyrene fragments, plastic sheets, bottle/container caps and cigarettes were by far the most frequent type of debris in both the shoreline and pelagic environments. This may be because plastics are deposited into the environment more frequently and/or because plastic degrades more slowly than other natural produces such as paper or wood.

Goal 3: Monitor changes in debris density and assess factors correlated with changes in debris density over time and space

The marine debris survey commenced for 24 consecutive weeks beginning in June 2011 and finishing in December 2011. In addition to measuring debris densities, we also monitored multiple factors that were thought to potentially influence the density of debris. This provided an opportunity to track the change in marine debris over time and to determine whether any of these potentially contributing factors were correlated with debris density.

Explaining the driving forces behind spatial and temporal differences in marine debris is perhaps a greater challenge than estimating its standing stock. We found weak correlations between shoreline debris density and human densities which indicated a decline in shoreline debris coincident with the decrease in beach-goers as the beach season drew to a close. If this pattern reflects a true signal between debris density and humans, then it would suggest that in the region we sampled a large portion of shoreline debris originates locally rather than being imported from the ocean. It is very important to note, however, that correlation does not denote causation. The correlation we detected may indeed be a spurious one, e.g., perhaps some set of conditions that create a nice tourist beach also increase debris. A more in-depth study of the linkage between human density and debris density would be required to determine whether or not this relationship is real. Likewise, we detected a weak positive correlation between surface water temperature and pelagic debris. Some factor that is correlated with surface water temperature may be driving up debris densities in surface waters. Future studies could be directed to study this question. We also found weak correlations between pelagic and shoreline debris for some urban and rural locations and for the urban region overall. The vast majority of debris that was counted in the survey was shoreline macro-debris which appeared to be land derived. Correlations between pelagic and shoreline debris could be due to areas with more shoreline debris delivering more debris into surface waters.

Humans could potentially increase marine debris through their activities but they may also reduce the amount and types of debris that are found by selectively removing certain types of debris. We conducted sampling in locations that were accessible to field crews and to the general public, but there were areas on Assateague Island with limited public access. During our survey we were granted access to this portion of the island and observed higher abundance of large item debris on that beach (H. Ward Slacum Jr. personal observation). The most common items were buoys, fishing net debris and tires. These items would be unsightly for beach-goers on the public portions of Assateague and would be easy to remove. Buoy's and fishing net pieces were not documented on the urban and rural beaches in our study suggesting those debris items were probably removed by beach-goers.

Storm events can have a significant impact on patterns of debris, but they are unpredictable and difficult to account for. Two major storms, Hurricane Irene and Tropical Storm Lee, occurred during this survey. The largest peaks in debris occurred immediately after these storms. Storms cannot be predicted very far in advance so some thought should be given to how storms will be treated by the survey during the survey design process. A study of the impacts of storm events on marine debris can be integrated into the study by developing specific adaptive sampling protocols when a storm occurs in the study region. One option is to conduct intense pre and post storm sampling if such a sampling event is not scheduled as part of the original survey design. Alternatively, impacts from storms could be minimized by choosing sampling seasons during which storms are historically rare.

One of the rural locations sampled, MD-01, had a much more variable pattern of debris over the course of the survey compared to other locations. This location peaked at 12 pieces of debris per 100m2 in early September, and debris remained relatively higher there compared to all other locations for four consecutive bi-weekly sampling events. The initial spike in debris density coincided with extreme weather events, yet other locations in the same region did not have as dramatic of a response. One possible explanation for this pattern is the greater accessibility of MD-01 to recreational beachgoers and campsites. MD-01 was the southern-most location in Maryland and was located between the two major beach access points in Assateague Island National Seashore Park. To the south, MD-01 was within 300m of the Federal Park South access point, and to the north, MD-01 was within 600m of the Federal Park North access point. MD-01 was also adjacent to visitor campsites. The beginning of September marks the end of the summer season and is a time when many families go camping before the school year begins. Although we do not have the actual numbers of campers in the park during that timeframe, it is plausible that increases in campers directly adjacent to the MD-01 site could be responsible for the increase in debris deposition. It is also conceivable that additional debris from campsites was transported onto the beach during the two extreme weather events. Both weather events had high winds and rainfall, thus debris that was normally contained within a campsite could have been transported to the beach. The pattern of debris densities documented at MD-01 is consistent with what one might expect in such an anomalous weather event. Since the survey is designed to monitor the standing stock of debris, it was sensitive enough to initially detect an increase in debris and then monitor its change over time while debris was either removed by beachgoers or transported away from the site through other means.

Another set of factors that influence the patterns of debris are scheduled citizen clean up events. Mechanized and volunteer beach clean-up was considered during site selection and we specifically chose sites that were not influenced by regular clean-ups. However, in the fall of every year, the Ocean Conservancy organizes a coastal clean-up event that occurs nationally. In 2011 the clean-up occurred at our study beaches on September 17th. Because the clean-up occurred at all of our survey beach locations, we treated the clean-up as an inherent part of the urban and rural locations and did not factor the event into our analysis. However, we note that the spike in debris that was measured at the rural location MD-01 right after Tropical Storm Lee was considerably reduced after the clean-up event. The presence of clean-up events may pose unique opportunities for marine debris surveys to conduct pre and post clean-up surveys and study factors such as debris accumulation and loading rates or even the effectiveness of the clean-up. An additional factor to consider would be the tidal range. Tides that are wider in amplitude could potentially deliver/remove debris higher up on the shoreline and therefore affect a larger proportion of the shore overall.

Future surveys which have the goal of explaining the distribution of debris would be improved by considering/measuring additional human, environmental, and oceanographic factors that might be influencing the debris patterns. Accounting for all factors acting on patterns of debris would be impossible, but attempts should be made to document all known factors and incorporate that knowledge into the initial site selection process of the survey. We developed site selection criteria to account for known human and environmental factors and chose sites in the urban region and rural region where those factors were either absent or equally among locations.

The bi-weekly temporal interval used for the survey was the finest that was logistically possible. In addition to allowing us to evaluate changes in debris density over short time scales, it also allowed us to consider the tradeoff between sampling frequency and information gain. There were statistically significant effects of time (i.e., paired sampling event number) which were largely driven by the distinct pattern of debris at location MD-01. However, in general, the survey found that average bi-weekly debris on shorelines was qualitatively similar to the average monthly estimate. This suggests that the same general temporal trends could be detected if a monthly as opposed to a bi-weekly sampling scheme was used. For pelagic debris, however, there was so much spatial and temporal variability that data collected even on a bi-weekly basis were not able to make precise estimates. We did not look at seasonal sampling scenarios since our survey only overlapped with summer and fall seasons

Goal 4: Evaluate sample replication and statistical power required for valid statistical comparisons on temporal and spatial scales.

The sampling design was hierarchical in that transects were nested within sites, sites were nested within locations which in turn were nested within regions. This design provided an opportunity to explore variability at multiple scales of resolution. Our analysis revealed a high degree of variability at finer spatial scales (among transects within sites for shorelines, among sites within locations for shorelines, and among locations within a region for pelagic) but less variability at coarser spatial scales (i.e., among locations within a region for shorelines). However, no significant differences were detected in marine debris densities between the urban and the rural region either on the beaches or in ocean surface waters. This reflects the more uniform distribution of marine debris at coarse scales and the more patchy distribution at finer scales. Although we chose our survey sites based on their proximity to the Delaware River mouth, it is likely that debris being transported by the Delaware becomes diluted and is dispersed more evenly once it enters the ocean environment. Results from the pelagic survey were also highly variable at all scales which is a reflection of the dataset being heavily weighted by zero debris tows with the occasional tow with some debris (72% or urban tows and 80% of rural tows contained no debris). Also, there were no obvious trends in greater densities of pelagic debris in one region or another indicating that surface water debris is distributed similarly across land-use types.

Throughout the survey the relative standard errors for shoreline debris were small enough at the region and location levels in most instances to make reasonably precise estimates of debris standing stock. There were, however, sampling dates at site level on which attaining precise estimates would have required a logistically infeasible sample size. For surface water samples, there was a tremendous amount of variability at the location and region level. Any well designed survey should consider the spatial distribution of sampling within an area of interest and balance that against the amount of replication required at the sample site level. This is particularly important for sampling marine debris because it is spatially and temporally patchy in the environment. Spreading sample sites throughout the area of interest will assist in capturing the variability of marine debris and providing greater confidence in estimates of debris. Sampling sites were spread across the beaches of interest in our survey and care was taken to reduce confounding factors (e.g., human and environmental influences) through the use of site selection criteria. The results from shoreline sampling indicate there was enough sample replication and spatial distribution at the region scale and also at the location scale for the majority of sampling events. Future survey development should consider the amount of sample replication in our survey as a guide for regional shoreline marine debris assessments on sandy beaches. However, for pelagic debris, MDD may need to consider alternative approaches to sampling and/or data analysis to develop precise estimates.

Evaluation of shoreline RSEs from the survey indicate that in most instances, sample sizes smaller than those used in the survey would provide precise estimates of debris per region and per location. However, to distinguish an urban from a rural region on shorelines, power analyses indicated that greater sample sizes at these spatial resolutions would be required. This is not due to the variability at these coarser scales, but rather this is due to the similarity in the debris estimates at the urban and rural region scale. For surface waters, greater sample sizes would be required both to attain precise estimates of debris and to distinguish urban from rural. Increased sample sizes may be possible logistically if monthly or bi-monthly sampling is conducted.

Integrating both systematic and random sampling methods provided a powerful approach for sampling marine debris on the shoreline. At coarse spatial scales, the survey used a systematic (non-random) approach to choose sampling locations that met the site selection criteria. Fixed sampling locations provided the added advantage of allowing us to examine temporal changes at each location. Although sites were initially chosen randomly, they remained fixed throughout the survey, allowing us to also examine temporal fluctuations at fine scales. Understanding variability at the site level is important to fully develop a probabilistic survey design for future marine debris assessments. Choosing transects randomly for each site allowed for a completely unbiased sample at the finest resolution of sampling.

Random selection of transects at coarse spatial scales may be one way to increase the efficiency of the survey. The within-location variability was relatively low during the survey suggesting that sites and/or transects within the location could potentially be chosen randomly for each sampling event without sacrificing precision in the estimate. The sort of spatial variability observed there is to be expected and can only be captured by sampling multiple locations within the larger area of interest. Although this one location exhibited unique patterns of debris, spatial variability of debris was uniform within a location in most instances. Locations were 1000m in beach length and sampling 12 transects (4 transects X 3 sites per location) on each sampling date resulted in covering 60m or 6% of the location. The vast majority of RSEs at the location level were below 30%. Randomizing transect selection within locations in our survey design would give precise estimates per location and would be logistically feasible. A completely random transect selection component at the region level could also reduce the level of sampling required to attain precise estimates of marine debris although this was not tested in our analysis. Both fixed site and random sampling should be considered when developing future marine debris assessments.

Major Conclusions:

- Sample sizes similar to those used at the location level in this survey may be used to provide reasonable estimates of density for shoreline debris on sandy beaches of the mid-Atlantic and possibly on other shoreline types.
- Monthly to bi-weekly shoreline sampling can provide sufficient sampling frequency to establish trends in marine debris on sandy beaches in the mid-Atlantic.
- Additional site selection factors may be considered for future surveys such as proximity to campsites, citizen clean-up activities, and restrictions to public access.
- The sampling design used here which integrated systematic and random sampling methods can provide a powerful standardized approach for future surveys on a nationwide scale.

5.1 RECOMMENDATIONS

The MDD sampling protocols employed in this survey were consistent and repeatable and based on our assessment, would have the flexibility to serve as a guide for standardized methods for quantifying marine debris in small or large scale marine debris monitoring and assessment surveys. With the goal of further enhancing the MDD protocols, we make the following recommendations for immediate adjustments and future work.

- Reassess the value of comparing the densities of marine debris between urban and rural land use areas along the coast. We found no statistical differences between regions, and it is hard to imagine a situation where large differences in debris density would be found on coastal U.S. beaches given the tremendous number of scenario driven factors influencing debris movement in this environment. We may need to ask ourselves whether such a comparison provides useful information, or if it is more meaningful to focus on developing robust estimates of marine debris densities from sites spanning a large geographic area. Our survey sacrificed both logistical and statistical flexibility in order to identify sites with similar human and environmental factors that were represented in both urban and rural land use classes. It would seem the foremost goal for a nationwide survey is to develop robust estimates of marine debris densities. Potentially influential factors should also be monitored to determine which, if any including land use type, is/are influencing debris densities. Focusing on urban/rural differences, which may in fact not be measureable along coastlines, could lead us to ignore other potentially important factors. For example, we found significant correlations between debris density and human density and much of the debris encountered on beaches appeared to be related to recreational activities. However, human density on beaches was not necessarily related to land use type, because recreational users seek areas for their activities using their own set of criteria. Perhaps they chose areas that are easier to drive to, that are less inhabited, have better fishing or have the best surfing waves. MDD's purpose may be better served by focusing on making good debris estimates and then mining the data after the fact to determine what environmental, human, or other factors may play a role in its distribution.

- Consider increasing the size of a site from 100m of beach length to 1000m of beach length for shoreline sampling. Variability among transects within sites and among sites within locations were both relatively greater than the variation among locations within a region. Seventy-five percent of the RSEs calculated for locations within regions were below 30%. Given this, location or coarser scale monitoring should provide precise estimates of debris.

- Focus shoreline meso-debris sampling on the "above wrack 2" zone. Intensely sampling the entire beach for meso-debris provided little data. Focusing efforts in "above wrack 2" should at least optimize sampling effort. U.S. shorelines contain a variety of habitat types with differing grain sizes, vegetation, and topography. It is possible that meso-debris may be more common in habitats other than sand beaches where this survey occurred. Therefore, we recommend keeping this portion of the survey and focusing on upper shoreline areas.

- Consider using a monthly survey interval. This would reduce the cost and logistical complication of travel for the survey while providing estimates similar to those made on a bi-weekly basis.

- Use a stratified-random or completely randomized sampling approach for shoreline and surface water sampling. A randomized approach was used for the tows in the pelagic survey and for transects within sites in the shoreline survey. Sites within locations were also selected randomly initially but remained fixed throughout the survey. The value in keeping sites fixed within a location for the duration of the survey was to monitor for temporal trends. While variation was high at sites within locations, no clear temporal trends were noted. Given that sites level data were variable with no clear temporal trends, selecting random sites to survey within a location may be just as good as maintaining fixed sites. Random selection of sample points could be achieved in a GIS after removing any unsampleable areas from the survey area.

- Combine the concepts of sampling 1000m sites, using a monthly sampling interval, and applying a stratified random sampling method. This would allow MDD to increase sample size per sampling event without increasing survey cost. For shorelines, power analyses indicated that on most sampling dates up to 60 samples per region should be able to distinguish an urban from a rural region (Power $\leq$0.8, p=0.1 or 0.05). Moreover, the RSE evaluation indicated that about 20-30 samples per location per event would provide precise estimates in most instances. Stratifying a region by location and randomly allocating 20-30 samples to each location would be possible if monthly rather than bi-weekly sampling were conducted per region. Alternatively, all 60 samples could be randomly chosen within the region for a completely randomized design.

- An analytical approach that separately models the probability of debris being present and the abundance of debris (Fletcher et al. 2005) could be used to cope with a highly skewed dataset with many zeroes.

- The size threshold for large item debris should be standardized between shoreline and surface water debris surveys. There is no good justification for maintaining a 30cm breakpoint for shoreline and a 20cm breakpoint for pelagic large item debris, particularly in light of the fact that much of the debris censured appears to be derived from the same types of land based sources. Given that large item debris is everything over and above this threshold (a potentially huge size range), we recommend using 30cm as the standardized threshold.

- For MDD protocols to become standardized, they must be tested in a multitude of scenarios and modified appropriately. The MDD should continue testing their shoreline sampling protocols over different habitat types. Our survey sampled sandy beaches in the mid-Atlantic and the shoreline methods were perfectly suited for that terrain. Marine debris occurs on every shoreline type and sampling protocols may have to be modified to account for factors unique to certain terrains.

- Locate and compile GIS and other readily available location specific data from U.S. regions. There are so many factors influencing patterns of debris and many of these factors are specific to a particular region and may be well documented. We were able to gather useful GIS and other location specific information through readily available electronic clearinghouses and by contacting helpful agency representatives who were willing to provide site specific information. This approach could be applied to most regions in the U.S. prior to the implementation of marine debris surveys and would provide upfront insight into location specific factors such as shoreline access, land use practices, primary currents, etc. These data could be compiled in a GIS and be used not just for planning marine debris surveys, but also for other marine debris related activities or for tracking expected debris loadings from disasters and what the impacts might be to natural environments. Some recognized data sets that could be useful include the NOAA Environmental Sensitivity Index (ESI) GIS layers, USGS

Land Use Maps, and NOAA Digitized nautical charts. There are also countless other State and local GIS data accessible for this type of planning.

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APPENDIX A

Final Survey Design and Site Selection Methods

FINAL SURVEY DESIGN AND SITE SELECTION METHODS

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June 14, 2011

General Approach to Site Selection

Sampling site selection is a crucial component of developing a robust survey design. For marine debris, numerous factors including hydrology, hydrodynamics, and proximity to the debris source interact to influence the distribution and amount of debris on shorelines and near shore waters. Disparities among sites or lack of knowledge about other factors such as debris clean-up and the magnitude and frequency of human activity can affect the ability of an assessment to quantify marine debris standing stock precisely. We developed a standardized approach to document and evaluate factors expected to influence marine debris quantity at specific sites in Region 2. The final proposed sampling plan is based upon this evaluation.

Several large stretches of shoreline were evaluated in Delaware, Maryland, and Virginia to identify potential study locations. The initial evaluation included a desktop review using multiple sources of information and mapping tools. A GIS was developed that included data layers for federal lands, urban areas, state, local, and national parks, wildlife refuges, management areas, shoreline type, boat ramps, marinas, and roads. These data provided insight into land use, accessibility, and potential departure points for research vessels. The relative numbers of recreational users and vehicles along the shoreline were also evaluated using satellite imagery from GoogleEarth. GoogleMaps provided an additional source of road access data and other visual information to assist with site evaluation.

To gather more detailed site specific information, Versar conducted phone calls with appropriate representatives from each of the potential locations and made site visits to each of the potential survey locations. Table 4-1 lists the individuals who were Versar's points of contact:

Table 4-1. Points of contact at each location considered for the survey.

Name	Ms. Maria Sadler	Mr. Bill Hulslander	Mr. Kevin Holcomb
Position	Environmental Scientist	Chief, Resource Management	Supervisory Wildlife Biologist
Address	DNREC 25039 Coastal Highway Rehoboth Beach, DE 19971	Assateague Island NS 7206 National Seashore Lane Berlin, MD 21811	U.S. Fish and Wildlife Service Chincoteague NWR 8231 Beach Road PO Box 62 Chincoteague, VA 23336
Phone	302-739-9921	410-629-6061	757-336-6122 x319
Email	Maria.Sadler@state.de.us	bill_hulslander@nps.gov	Kevin_Holcomb@fws.gov

The goal of the survey is to provide estimates of marine debris standing stock and to inform the design of future surveys around the nation. To that end, the survey was designed with statistical robustness, field logistics, and several site selection criteria in mind. A robust survey design is achieved through replicated sampling at multiple levels of spatial resolution (Figure 4-1). This approach ensures that the survey will capture the patterns of variability at each scale. Given that increased replication tends to decrease the variability in the estimate, this information will guide the distribution of replicates and overall design of future surveys.

The coarsest level of spatial resolution in the survey is the land-use region (Figure 4-1). *Two regions* which contrasted urban land use and rural land use were chosen for study under the assumption that the proximity to denser human populations and their associated activities will contribute to greater debris densities. Within each of the two regions, *three locations* were identified. Each location was required to be 1000 meters long (in beach length units) and at least 1200 meters apart from the other locations in that region (Criterion 1). Locations are an important scale for study because they will tell us how much coarse-scale variation there is within a region. Within each location, *three 100m stretches of beach or sites* were identified systematically. At each site, *four 5m transects* were chosen randomly. Transects run perpendicular to the coastline from the low tide mark to the back of the beach. At each site, three 0.5nm pelagic transects will be conducted within 1nm of the shoreline. Data from the pelagic component of the survey will provide information on the source pool of debris that is distributed on the beach and on micro-plastics occurring in ocean surface waters.

In addition to satisfying the requirements for a robust statistical design, many aspects of field logistics and ecological sensitivity were considered closely during the survey design process. Sites were required to be reasonably accessible for the field crew by vehicle or by boat (Criteria 2 and 7). Given that there appeared to be some recreational use at all locations, sites were required to have only minimal recreational users or at least similar levels of recreational use among locations and regions (Criterion 3). Recreational users may make it difficult to physically observe debris and they may also deposit additional debris that could confound the survey results. Removal of debris from the beach by means of regular mechanized cleaning was also avoided because this would directly affect debris counts. Given that beach clean-up activities were present at all locations, sites were required to have only minimal manual beach clean-up (Criterion 4). Locations with mechanized clean-up were eliminated. Beaches in Region 2 and around the nation provide important nesting and feeding grounds for protected species. Therefore, careful consideration was given to the potential for and timing of beach closures and the NEPA concerns associated with protected species (Criteria 5 and 6). Unique characteristics of locations or sites were also evaluated in order to avoid introducing sources of variability into the survey that the design might not be able to identify (Criterion 8).

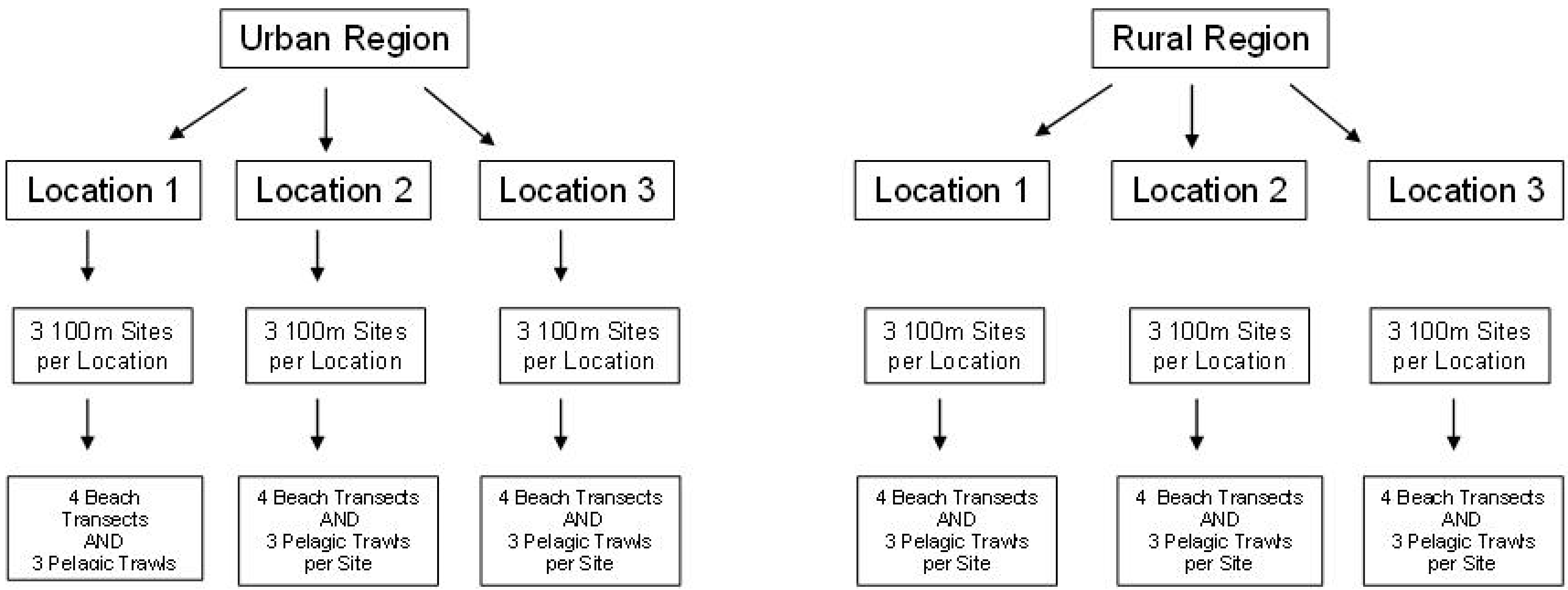

Figure 4-1. Sampling design. Sites are 100m stretches of beach. Transects are each 5m wide and run perpendicular to the water from the low tide mark to the back of the beach. Trawls are 0.5 nautical miles long.

Site Selection Criteria:

1) **Beach Area.** The amount area at each potential beach location was examined through evaluation of maps from GIS, State, and Googlemaps. Each shoreline location required 3 separate 100m stretches of beach. Sites at each location were required to be sufficiently spaced apart to insure that they represent independent samples.

2) **Accessibility.** Road accessibility was assessed by looking at GIS and Googlemap layers depicting state and local roads as well as park access roads. Other potential entry points including hiking and biking trails were also examined. Boat access was evaluated by mapping all local marinas and boat ramps which could be used as departure points. To be selected for sampling, sites were required to have adequate access.

3) **Recreational Use.** The beaches of Delaware, Maryland and Virginia are popular vacation destinations for beach bathing and fishing, so we also considered the potential order of magnitude of beach-goers and vehicle traffic that may be encountered on the beaches. To do this, we measured the distance between potential study locations at access points with the assumption that recreational beach users would tend to cluster near points of beach access. We further evaluated satellite imagery which depicted snapshots of densities of people and vehicles on the beaches. To be selected for sampling, sites had to have minimal recreational activities or at least similar levels of recreational use among locations and regions.

4) **Beach Clean-Up.** Information on beach clean-up activities and closures was gathered through park websites and through conversations with points of contacts at each potential study location. To be selected for sampling, sites had to have no mechanized beach clean-up activities. Nearly every beach considered had some form of clean-up activities; therefore, beaches with minimal clean-up were given priority.

5) **Closures.** Periodic short term and long term closures are possible along Region 2 beaches due to the activities (e.g., nesting, migration stopovers) of protected species. Sites within locations that have already experienced closures were excluded from the site selection process.

6) **NEPA Concerns.** The National Environmental Policy Act requires federal agencies to fully consider and disclose the impact of their funded or permitted activities on the natural and human environment. This criterion of the site selection process describes the activities of protected species at potential sites and addresses how the sampling crew would avoid interfering with those species. Potentially affected taxa include piping plover and loggerhead turtles in Region 2. On a nationwide scale, other species of turtles, birds, and plants could also be affected. The permitting process required by each of the state or local parks that were considered required a precise explanation of the sampling activities and when they would occur. This allows the permitting agency to prevent any undesired activity on the beaches. The beaches considered for sampling were regularly accessed by the public and monitored by government agencies for the presence of protected species and any negative effects on those species. If a protected species is

detected, the responsible agency closes the beach to all activities including scientific study.

7) **Proximity to Versar/Other Survey Locations.** To address travel time considerations, we considered the geographic location of the potential study location relative to Versar and to other study locations. Greater distance between locations would increase travel time and cost for the project. Sites that were in closer proximity to either Versar or other sampling sites were given priority during the site selection process over sites that did not meet these criteria.

8) **Similarity to Other Locations.** Some sampling locations had unique physical or geographic attributes or patterns of recreational use. In order to reduce the influence of unmeasured sources of variation that might affect marine debris, locations that did not have unusual characteristics were given preference.

4.1.2 Urban Areas Considered

Three general areas along the Delaware shoreline in the vicinity of the Delaware River mouth were identified for close scrutiny as potential urban study locations. These areas were Broadkill Beach/Plum Island, Cape Henlopen State Park, and Delaware State Seashore Park.

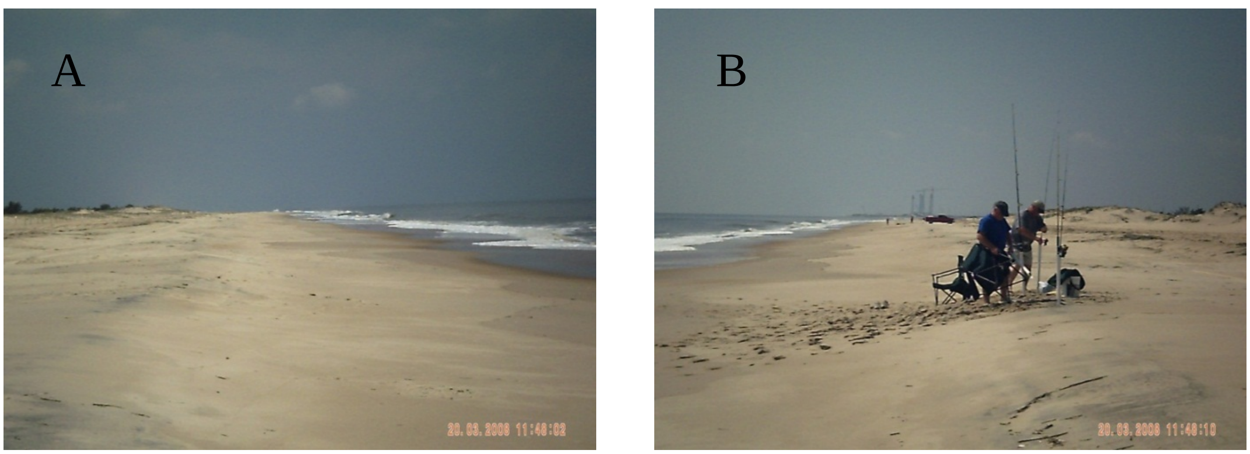

Figure 4-2. Pictures of Delaware Seashore State beach during reconnaissance visit in May 2011. Inset A shows the stretch of beach facing north. Inset B is facing southward and shows recreational fishermen on the beach and a truck parked on the beach further down the beach.

4.1.2.1 The Broadkill Beach/Beach Plum Island. This location was the northern most potential location considered (Table 4-2). It is located within Delaware Bay approximately 10 miles from the ocean coastline of Delaware. This potential site is located within the Prime Hook National Wildlife Refuge (NWF). The wetlands of Prime Hook NWF are important stop-over sites for spring and fall migrating shorebirds and wading birds. Habitat for endangered and threatened species such Delmarva fox squirrels, nesting bald eagles and migrating peregrine falcons are also present at Prime Hook NWR.

Table 4-2. Broadkill Beach/Beach Plum Island		
Attribute	**Positives**	**Negatives**
Beach Area	Sufficient amount of shoreline	
Accessibility	Good accessibility.	Back road usage required which will increase travel time.
Recreational Use	Less crowded than other Delaware sites.	
Beach Clean Up	No mechanized clean-up.	Manual volunteer clean-up activities may occur (Figure 4-3). In 2010, statewide volunteer clean-up day was Sept. 25. The date for 2011 has not been set yet.
Closures		Beach Plum Island may have periodic closures because of piping plover and other protected species.
NEPA Concerns		Piping plovers and loggerhead turtles may nest at Beach Plum Island. State agencies monitor the beaches and instate closures when these species are detected.
Proximity to Versar/Other Locations		This site is the farthest north and geographically the most distant from both Versar and other potential rural sites.
Similarity to Other Locations		Because this site is located in Delaware Bay, it will likely have unique factors influencing debris that are absent from the other locations, such as those at ocean beaches.

4.1.2.2 Cape Henlopen State Park. This location occurs at the mouth of Delaware Bay and so it borders both the Delaware Bay and the Delaware ocean coastline (Table 4-3). The potential for unique hydrodynamic patterns exist on the Bay side of the hook due to its morphology and proximity to the Delaware Bay mouth. These unique hydrodynamic patterns could influence marine debris deposition and quantity in a way that is much different than any of the other potential sampling locations. Therefore, the most likely sites available for sampling occur in the marine coastal portion of the park.

Table 4-3. Cape Henlopen State Park		
Attribute	**Positives**	**Negatives**
Beach Area	Sufficient amount of shoreline	
Accessibility	Good accessibility; Beach driving permissible.	
Recreational Use		High recreational traffic from late spring through early fall; Both foot traffic and vehicle traffic occur on beach.
Beach Clean Up	No mechanized clean-up.	Manual volunteer clean-up activities may occur (Figure 4-3). In 2010, volunteer clean-up day was Sept. 25. The date for 2011 has not been set yet.
Closures		Seasonally restricted areas due to piping plover and other protected species.
NEPA Concerns		Piping plovers, other birds, and loggerhead turtles may nest at Beach Plum Island. State agencies monitor the beaches and instate closures when these species are detected.
Proximity to Versar/Other Locations	This location is the second closest geographically to Versar and to potential rural locations.	
Similarity to Other Locations		The potential for unique hydrodynamic pattern patterns exist on the Bay side of the hook do to its natural morphology and proximity to the Delaware Bay mouth. This could be a factor influencing marine debris deposition and quantity that would not be similar to any of the other potential sampling locations.

4.1.2.3 Delaware Seashore State Park. This was the southernmost location considered for urban sites. The coastline is entirely marine and easily accessible by vehicle and by boat (Table 4-4). Portion of the beach may be closed periodically due to nesting piping plovers.

Table 4-4. Delaware Seashore State Park		
Attribute	**Positives**	**Negatives**
Beach Area	Sufficient amount of shoreline (6-7 miles).	
Accessibility	Good accessibility for vehicles; Beach driving permissible; Good accessibility for the boat.	
Recreational Use		Recreational use potentially heavy in public areas.
Beach Clean Up	No mechanized clean-up.	Manual statewide volunteer clean-up activities may occur (Figure 4-3). In 2010, volunteer clean-up day was Sept. 25. The date for 2011 has not been set yet. In addition to the statewide clean-up, local volunteer cleanup activities occur 1-3 times per year on some beaches.
Closures	Any closures are most likely to have been instated prior to the start of field work.	Periodic closures due to piping plovers and other protected species possible but not likely.
NEPA Concerns		Piping plovers and loggerhead turtles may nest at Beach Plum Island. State agencies monitor the beaches and instate closures when these species are detected.
Proximity to Versar/Other Locations		Heavy vehicle traffic between Ocean City and Rehoboth will increase travel time between sites.
Similarity to Other Locations	All potential sites within this stretch of beach will have similar factors influencing marine debris quantity and will also have similar factors as the Assateague Islands sites.	Factors may vary seasonally.

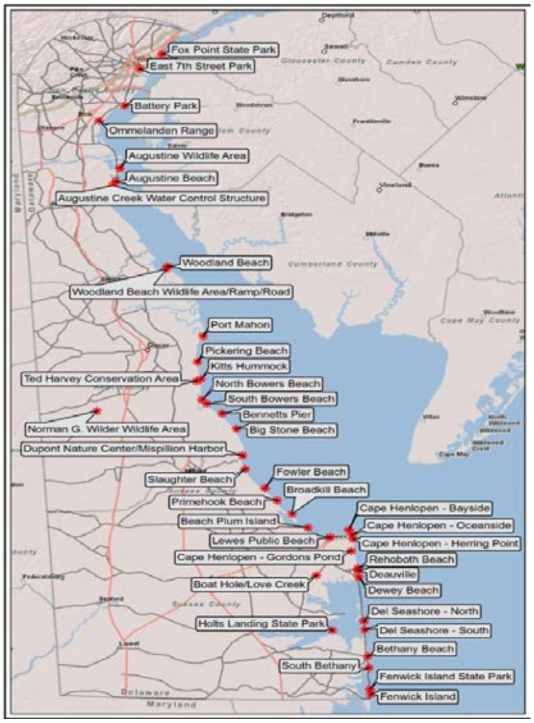

Figure 4-3. A map of the 40 sites at which volunteer clean-up activities occur in Delaware. In 2010, statewide beach clean-up occurred on Sept. 25. As of June 2011, the clean-up date for 2011 not been set. Potential marine debris survey sites occur from Dewey Beach southward. This map was produced by DNREC.

4.1.3 Rural Areas Considered

Two general areas along the Maryland/Virginia shoreline were identified for close scrutiny as potential rural study locations. These areas were Assateague Island National Seashore in Maryland and Chincoteague National Wildlife Refuge in Virginia both of which are located on Assateague Island.

Figure 4-4. A picture of a portion of Chincoteague Island beach taken during a reconnaissance visit in June 2011. The picture shows a stretch of beach just south of the visitor parking lot with a beach closure sign on the beach in the middle of the picture.

4.1.3.1 Assateague Island National Seashore (Maryland). This location is the more northern location considered for rural sites and therefore would be closer to any of the urban sites evaluated for Delaware (Table 4-5).

Table 4-5. Assateague Island National Seashore, Maryland		
Attribute	**Positives**	**Negatives**
Beach Area	Sufficient amount of shoreline (4 miles).	
Accessibility	Good road accessibility; Boat accessible, 11 nm from boat launch to northernmost sampling location.	Accessibility could contribute to more people using the Assateague Parks throughout the week.
Recreational Use		Recreational traffic high on weekends and possibly during the week due to camping; Recreational use may occur year round due to proximity to Ocean City (fishing tournys, Sunfest events, vehicle shows, etc.).
Beach Clean Up	Only one scheduled known beach clean-up day in the fall of the year. No mechanized clean-up on State or Federal side.	Voluntary beach clean-ups may occur, but the dates and frequency areunknown.
Closures	Any closures are most likely to have been instated prior to the start of field work.	Closures to protect piping plover and other protected species are possible.
NEPA Concerns		Piping plovers and loggerhead turtles may nest at Beach Plum Island. State agencies monitor the beaches and instate closures when these species are detected.
Proximity to Versar/Other Locations	Closer to potential urban sites in DE which would reduce travel between study areas.	Closer to Ocean City Inlet and DE beaches so it may be considered less rural than Chincoteague.
Similarity to Other Locations	All potential sites within this stretch of beach will have similar factors influencing marine debris quantity and will also have similar factors as the Delaware Seashore sites.	Factors may vary seasonally.

4.1.3.2 Chincoteague National Wildlife Refuge (Virginia). This location is the more southward of the two locations considered for the rural sites (Table 4-6).

Table 4-6. Chincoteague National Wildlife Refuge, Virginia		
Attribute	**Positives**	**Negatives**
Beach Area	Sufficient amount of shoreline (5 miles)	
Accessibility	Boat accessible, 12 nm from boat launch to northernmost sampling location.	Walk-in access only on some beaches; distance is significant. Research permit and pass for after-hours work may be required.
Recreational Use	Minimal recreational use during off season.	Recreation traffic high at beach access point. In the summer of 2011, recreational use was expected to be concentrated to just a 1.5 miles of beach due to closures. Annual pony swim may disrupt schedule.
Beach Clean Up	No mechanized clean up.	Daily manual clean up by volunteers occurs regularly by park staff throughout the year. In the summer of 2011, only 1.5 mile of beach was open for clean-up, so clean-up activities were expected to be intense.
Closures		Periodic beach closures due to piping plovers around Tom's Cove. In the summer of 2011, only 1.5 miles of beach were available for sampling. Closures for other protected species are possible.
NEPA Concerns		Piping plovers and loggerhead turtles may nest at Beach Plum Island. State agencies monitor the beaches and instate closures when these species are detected.
Proximity to Versar/Other Locations		Greater distance from Ocean City (56 mi) and Versar (167 mi), increasing travel time.
Similarity to Other Locations		Higher density recreational use because of the smaller size of accessible beach.

4.1.4 Final Sampling Site Selection

Urban Locations

Delaware State Seashore Park (DSSP) was chosen for sampling out of the three locations that were considered (Figure 4-4). Like each of the rural locations considered, the coastline of DSSP is entirely marine and likely to have similar environmentally to either rural location. DSSP also has a large amount of beach available for sampling all of which is accessible by vehicles. Pelagic sites are also easy to access due to the proximity to Indian River Inlet. Some clean-up activities do occur, but they are infrequent and manual. Although closures for piping plover do occur in the park, this species tends to establish nesting areas by the spring. Therefore, the nesting areas for 2011 are already established and the closures that are in effect can be avoided. Stretches of beach more heavily used by recreational users can be avoided by walking some distance from the entry point to the beach. Broadkill Beach/Beach Plum Island and Cape Henlopen had similar drawbacks with regards to manual clean-up activities, recreational use, and closures. However, each of these two sites had unique characteristics that could potentially introduce additional sources of variation into the survey design. The Broadkill Beach/Beach Plum Island location is located in Delaware Bay and would have a much different physical regime than either of the rural locations. The area on the inside of the hook of Cape Henlopen could potentially exhibit unique hydrodynamic conditions not present at the other rural locations.

Rural Locations

The Assateague Island National Seashore (AINS) was chosen for the rural portion for the survey from the two locations that were considered (Figure 4-4). Both beach and pelagic sites are accessible at AINS and there is sufficient beach available for sampling. Recreational use is limited and AINS has only one known day of volunteer clean-up that corresponds to the annual Coastal clean-up day that occurs in the fall. The AINS is also located closer to all locations in Delaware. Although closures for piping plover do occur in the park, this species tends to establish nesting areas by the spring. The Chincoteague National Wildlife Refuge (CNWR) had several issues which prevented us from choosing this location. The primary concern was that significant areas were closed at the CNWR for piping plover during the development of the survey design (Spring 2011) which left only approximately 1.5 miles of beach open for sampling. This is not enough beach area to accommodate the design of the survey. This restriction would also concentrate beach clean-up activities in the small amount of area available to be sampled. Compounding these issues is that sites at CNWR are logistically more difficult to reach and they are further away from all Delaware sampling sites.

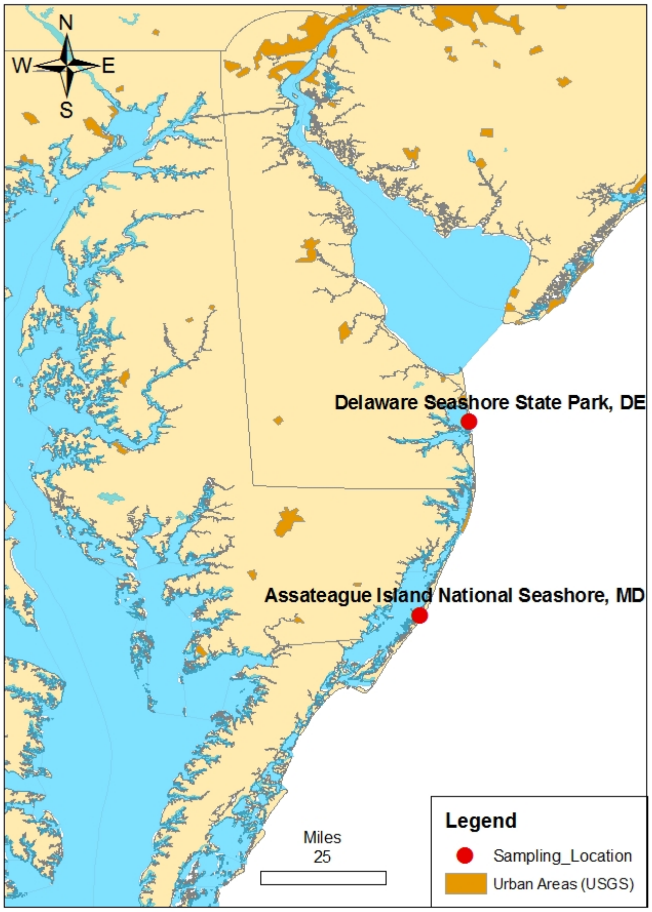

Figure 4-4. The proposed survey locations in relation to urban environments.

4.1.5 Fixed and Random Sampling

A combination of fixed and random sampling methods will be used in order to satisfy the requirements of a robust sampling design, to maximize sampling efficiency, and to accommodate the space limitations at each of the sample locations. The sampling design calls for three 100m stretches of beach at each of three locations for both urban and rural sampling. Locations and the stretches of beach (i.e., sites) within locations must be sufficiently spaced apart in order to represent independent samples. Desktop review of GIS layers was used to identify all potential areas at DSSP and the AINS that were sampleable. Within the sampleable area, three fixed locations that were at least 1200 meters apart were systematically chosen. At each location, 3 sites were systematically chosen for sampling. The random component of sampling will be implemented when selecting individual transects at each site. For beach sampling, four 5m transects will be randomly selected for each site before arriving at the site. For pelagic sampling, the coordinates for three 0.5nm transects for each site will be selected adjacent to each 100m stretch of beach sampled at that location and pelagic tows will be conducted perpendicular to the shoreline.

The final sampling scheme was created in a GIS to assist with the development of the final survey design and final site selection process. The scheme was developed by first identifying all beach access points at each sampling location (Figure 4-5 and 4-6). A 400 m buffer was then placed over the center of each access point to exclude these areas as potential sampleable locations because it is anticipated that high densities of recreational beach-goers would be located in these areas. Three 1000 meter wide locations were then delineated near access areas to visualize the amount of beach available for sampling. Each location was spaced at least 1200 meters apart to ensure that locations were independent from each other. A systematic grid of 100 m x 100 m blocks was then created over the extent of each final sampling site to show the number of potential 100 m transects available to sample within each sampling site. This GIS will be used to select the final three 100 m stretches of beach within each sampling site that will be sampled during the course of the survey.

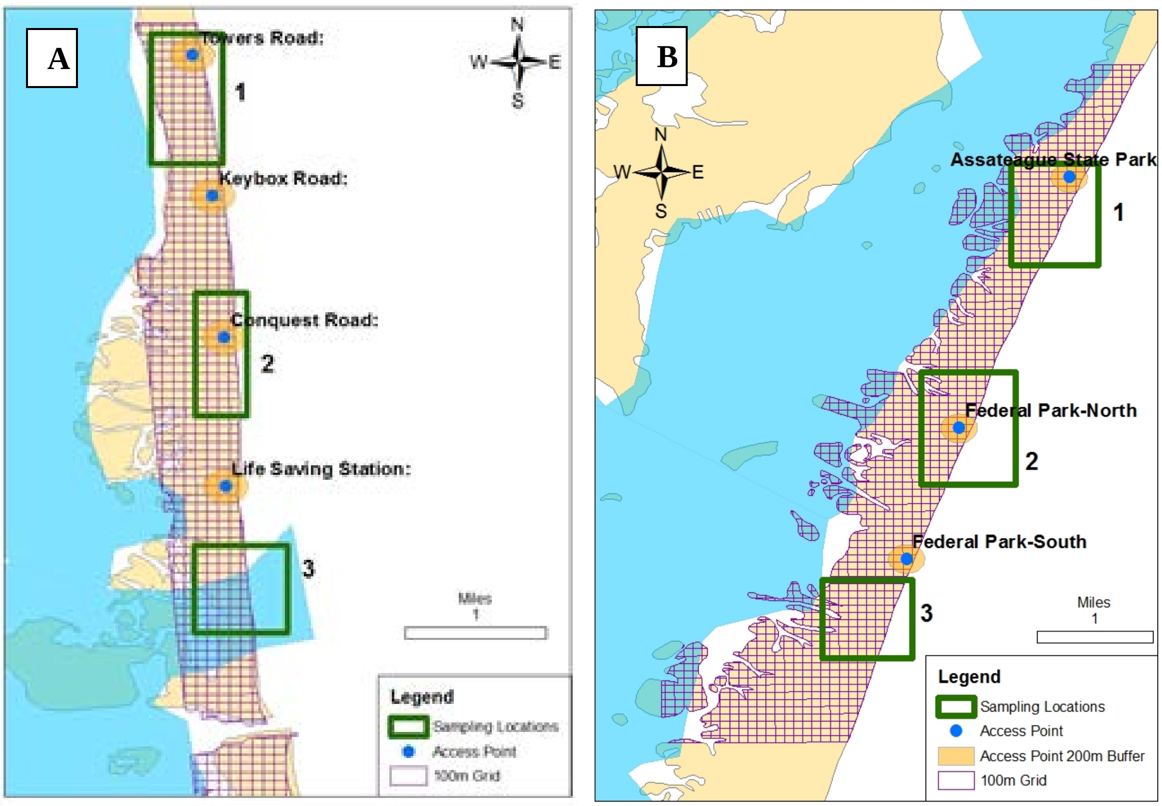

Figure 4-5. The proposed survey site locations and sampling scheme for sampling urban (A) and rural (B) locations.

APPENDIX B

Field Data Sheets

VERSAR

Shoreline Marine Debris Datasheet - Site Characterization

				Crew	
Date		Site Picture #		Arrival Time	
Site ID				Departure Time	
Past Week Storm Activity	Y / N	Storm Comments			

Current Weather

Beaufort Wind Force	
Wind Direction (degrees)	
% Cloud Cover	
Current Weather	
Time of Low Tide	

Site Comments

Site Characterization

Length of Site if Less than 100m		Reason Shortened
Substratum Type (Circle one or write in)	Fine Sand / Medium Sand / Coarse Sand / Gravel /	
Primary Substrate Uniformity (%)		
Back of Shoreline Type (Circle one or write in)	Dune / Parking Lot / Rock Wall /	
Min and Max Vertical Height of Tidal Range (m)		
Horizontal Distance from Low to High Tidal Range (m)		
Aspect - direction perpendicular to beach facing water (degrees)		

# of People - Location		- Site		# of Boats	

Large Item Debris Recorded: Y / N

Transect #				
Length of Transect (m)				
Picture #				
Start Latitude				
Start Longitude				
End Latitude				
End Longitude				
Debris Found	Y / N	Y / N	Y / N	Y / N
Sieve Location and #				
Latitude				
Longitude				
Debris Found	Y / N	Y / N	Y / N	Y / N

Page __________ of ___________

Shoreline Marine Debris Datasheet - Site Characterization

To be filled out prior to sampling or first time visiting site

Shoreline Name	
Body of Water Name	
State / County	

	At Water's Edge		At Back of Shoreline	
	Latitude	Longitude	Latitude	Longitude
Northern Extent of 100m Site				
Southern Extent of 100m Site				

Location and Major Usage		
	Urban	
	Peri-Urban	
	Rural	

Select one and determine major usage (recreation, boat access, remote, etc...)

Access	
Nearest Town	
Nearest Town-Distance (m)	
Nearest Town-Direction (degrees)	
Nearest River	
Nearest River-Distance (m)	
Nearest River-Direction (degrees)	

River/Creek Input to Beach	Y / N	Pipes or Drains Input	Y / N

Page __________ of ___________

Pelagic Marine Debris Datasheet - Site Characterization

Crew			
Date		Site Picture #	
Site ID			
Past Week Storm Activity	Y / N	Storm Comments	

Current Weather	
Beaufort Wind Force	
Wind Direction (degrees)	
Cloud Cover %	
Current Weather	
Time of Low Tide	
Large Item Debris Recorded	Y / N
# of Boats	

Water Quality — Location: Shallow / Mid Depth / Deep Depth

	Start of Trawl			End of Trawl		
	Surface	Mid	Bottom	Surface	Mid	Bottom
Depth (m)						
Temperature (C)						
Salinity (ppt)						
Conductivity (mS/cm)						
DO (mg/L)						
pH						

Trawl #				
Course (degrees)				
Vessel Speed (knots)				
Picture #				
Pass Through Debris Line	Y / N	Y / N	Y / N	Y / N
Time Net Deployed				
Initial Flowmeter Reading				
Start Latitude				
Start Longitude				
End Latitude				
End Longitude				
Final Flowmeter Reading				
Time Net Recaptured				
Debris Found	Y / N	Y / N	Y / N	Y / N

Comments

Page ____ of ____

Pelagic Marine Debris Datasheet - Site Characterization

To be filled out prior to sampling or first time visiting site

Shoreline Name	
Body of Water Name	
State / County	

	At Water's Edge		1 Nautical Mile from Shoreline	
	Latitude	Longitude	Latitude	Longitude
Northern Extent of 100m Site				
Southern Extent of 100m Site				

Location and Major Usage		
	Urban	
	Peri-Urban	
	Rural	

Select one and determine major usage (recreation, boat access, remote, etc...)

Access	
Nearest Town	
Nearest Town-Distance (m)	
Nearest Town-Direction (degrees)	
Nearest River	
Nearest River-Distance (m)	
Nearest River-Direction (degrees)	

River/Creek Input	Y / N	Pipes or Drains Input	Y / N

Page ____ of ____

Marine Debris Datasheet - Debris Data

☐ Shoreline ☐ Pelagic

Page ____ of ____

Date | | Site ID | | Trawl or Transect # |

	Item	Tally (non-sieve) and Total		Sieve - Lengths (mm) and Total Count	
PLASTICS	6 Pack Rings				
	Bags				
	Balloons				
	Beverage Bottles				
	Bottle/Container Caps				
	Bouys and Floats				
	Cigar Tips				
	Cigarettes (whole and filters only)				
	Cups				
	Disposable Cigarette Lighters				
	Fishing Lures and Line				
	Food Wrappers				
	Other Jugs/Containers				
	Pellets				
	Personal Care Products				
	Plastics/Polystyrene (foam) Frags				
	Plastic Sheets				
	Plastic Toys				
	Rope and Small Net Pieces				
	Shotgun Shells / Wads				
	Straws				
	Utensils				
METALS	Aerosol Cans				
	Aluminum/Tin Cans				
	Bottle Caps				
	Metal Fragments				
GLASS	Beverage Bottles				
	Glass Fragments				
	Jars				
RUBBER	Flip-Flops				
	Gloves				
	Rubber Fragments				
	Tires				
PROCESSED LUMBER	Building Materials				
	Cardboard Cartons				
	Paper and Cardboard				
	Paper Bags				
CLOTH/FABRIC	Clothing and Shoes				
	Fabric Pieces				
	Gloves (non-rubber)				
	Rope and Net Pieces (non-synthetic)				
	Towels and Rags				
OTHER					

Page ____ of ____

Item		Tally (non-sieve) and Total		Sieve - Lengths (mm) and Total Count	
OTHER					

Large Item Marine Debris Datasheet

Crew

Date

Site ID

☐ Shoreline ☐ Pelagic

Item Type	Status	Transect / Trawl #	Latitude	Longitude	Approximate Area		Photo #	Description
					Length (m)	Width (m)		

Status: For Shoreline = Sunken, Stranded, or Buried. For Pelagic = Captured (in net) or Excluded (from net in ship path)

Page _____ of _____

VERSAR

APPENDIX C

Data Sheet Modifications

Datasheet Modifications

Shoreline Debris Data Sheet

- The Shoreline Characterization Sheet and first sheet of the Debris Data Sheet were combined into a one page "Shoreline Marine Debris Datasheet – Site Characterization" datasheet. One datasheet will be completed per site and will include information for up to four transects.

Deleted from initial MDD Datasheet:

- **Organization –** deleted because only Versar staff will be working on the project and can automatically fill this in.
- **Phone number –** deleted because only Versar staff will be working on project and can automatically fill this in.
- **Season –** deleted because this can easily be queried once the data is entered.
- **Date of last survey –** deleted because this can be determined from database.
- **Number of Persons –** deleted because it will be determined from the "Crew" field.

Added to initial MDD Datasheet:

- **Surveyor Name –** retitled "Crew".
- **Beaufort Wind Force –** added Beaufort Wind Force at time of sampling.
- **Wind Direction –** added Wind Direction at time of sampling.
- **% Cloud Cover –** added percent cloud cover at time of sampling.
- **Current Weather –** added current weather code at time of sampling (1=Sunny; 2=Partly Cloudy; 3=Cloudy; 4=Rain; 5=Snow; 6=Fog; 7=Dark).
- **Time of Low Tide** - added location for time of low tide on sampling day.
- **Absolute count of People** - added counts of people category at sampling site and in locations (# people).

Debris Item Added

- Added metal bottle caps

Pelagic Debris Datasheet

- The Site Characterization datasheet was modified from the first page of the Pelagic Debris Datasheet. One datasheet per site (and information up to four trawls).

Deleted from initial MDD Datasheet:

- **Organization –** deleted because only Versar staff will be working on the project and can automatically fill this in in the database.
- **Phone number –** deleted because only Versar staff will be working on project and can automatically fill this in in the database.
- **Body of water/Location –** deleted because this is included in the site id.
- **Date of last survey –** deleted because this can be determined from database.
- **Number of Persons –** deleted because it will be determined from the Crew field.

- **Time (adjusted) –** deleted because when the net is deployed is essentially the same time that the flowmeter starts.

Added to initial MDD Datasheet:

- **Surveyor Name –** retitled “Crew”
- **Wind direction (degrees) –** added to datasheet to determine the wind direction at time of sampling.
- **Current Weather –** added current weather code at time of sampling (1=Sunny; 2=Partly Cloudy; 3=Cloudy; 4=Rain; 5=Snow; 6=Fog; 7=Dark).
- **Time of Low Tide** - added time of low tide on sampling day.
- **Boating Activity** - added density of boats in water at sampling site (Low=># boats; Med = # to # boats; High = > # boats).

Large Item Marine Debris Datasheet

- Two datasheets were combined (one for Shoreline and one for Pelagic) into one dataasheet. One sheet will be completed per site sampled (for all transects or trawls sampled at that site/date)

Deleted from initial MDD Datasheet:

- **Organization –** deleted because only Versar staff will be working on the project and can automatically fill this in.
- **Phone number –** deleted because only Versar staff will be working on project and can automatically fill this in.

Added to initial MDD Datasheet:

- **Surveyor Name –** retitled “Crew”
- **Shoreline Name –** retitled Site ID
- **Check Box for Site Type –** added a check box for the crew to select whether or not the Site ID is shoreline or pelagic

APPENDIX D

Summary Statistics Table

Appendix D-1. Marine debris count and density (#/100m2) in shoreline transects for each sampling event

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
1	06/27-06/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-06-27-01	20	7.843137255
1	06/27-06/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-06-27-02	13	5.098039216
1	06/27-06/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-06-27-14	8	3.137254902
1	06/27-06/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-06-27-18	8	3.137254902
1	06/27-06/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-06-27-07	4	1.31147541
1	06/27-06/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-06-27-12	4	1.31147541
1	06/27-06/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-06-27-15	7	2.295081967
1	06/27-06/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-06-27-18	6	1.967213115
1	06/27-06/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-06-27-01	11	4.888888889
1	06/27-06/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-06-27-06	19	8.444444444
1	06/27-06/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-06-27-10	15	6.666666667
1	06/27-06/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-06-27-17	11	4.888888889
1	06/27-06/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-06-29-05	1	0.342465753
1	06/27-06/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-06-29-08	5	1.712328767
1	06/27-06/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-06-29-17	6	2.054794521
1	06/27-06/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-06-29-18	3	1.02739726
1	06/27-06/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-06-29-07	9	3
1	06/27-06/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-06-29-08	3	1
1	06/27-06/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-06-29-12	5	1.666666667
1	06/27-06/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-06-29-16	8	2.666666667
1	06/27-06/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-06-29-03	10	2.941176471
1	06/27-06/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-06-29-12	5	1.470588235
1	06/27-06/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-06-29-15	5	1.470588235
1	06/27-06/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-06-29-19	6	1.764705882
1	06/27-06/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-06-29-01	13	3.880597015
1	06/27-06/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-06-29-02	15	4.47761194
1	06/27-06/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-06-29-14	17	5.074626866
1	06/27-06/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-06-29-18	14	4.179104478
1	06/27-06/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-06-29-07	8	2.653399668
1	06/27-06/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-06-29-12	11	3.648424544
1	06/27-06/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-06-29-15	11	3.648424544
1	06/27-06/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-06-29-18	10	3.316749585
1	06/27-06/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-06-29-01	6	1.98019802
1	06/27-06/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-06-29-06	6	1.98019802
1	06/27-06/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-06-29-10	9	2.97029703
1	06/27-06/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-06-29-17	10	3.300330033

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
2	07/05-07/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-06-09	9	4.891304348
2	07/05-07/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-06-10	6	3.260869565
2	07/05-07/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-06-12	7	3.804347826
2	07/05-07/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-06-18	6	3.260869565
2	07/05-07/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-06-03	5	1.941747573
2	07/05-07/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-06-04	4	1.553398058
2	07/05-07/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-06-05	1	0.430107527
2	07/05-07/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-06-16	6	2.891566265
2	07/05-07/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-06-06	12	8
2	07/05-07/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-06-11	4	3.2
2	07/05-07/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-06-18	8	5.517241379
2	07/05-07/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-06-19	14	9.333333333
2	07/05-07/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-06-04	1	0.32
2	07/05-07/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-06-08	8	2.56
2	07/05-07/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-06-10	2	0.64
2	07/05-07/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-06-14	6	1.92
2	07/05-07/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-07-04	8	3.67816092
2	07/05-07/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-07-07	6	2.666666667
2	07/05-07/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-07-18	5	1.886792453
2	07/05-07/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-07-19	5	1.886792453
2	07/05-07/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-07-05	2	0.821355236
2	07/05-07/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-07-13	6	2.464065708
2	07/05-07/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-07-14	12	4.928131417
2	07/05-07/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-07-15	12	4.928131417
2	07/05-07/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-08-04	3	1.071428571
2	07/05-07/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-08-07	2	0.714285714
2	07/05-07/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-08-08	6	2.142857143
2	07/05-07/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-08-11	4	1.428571429
2	07/05-07/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-08-04	3	1.411764706
2	07/05-07/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-08-05	2	0.941176471
2	07/05-07/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-08-14	1	0.470588235
2	07/05-07/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-08-17	1	0.470588235
2	07/05-07/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-08-13	3	1.165048544
2	07/05-07/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-08-14	1	0.388349515
2	07/05-07/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-08-15	1	0.388349515
2	07/05-07/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-08-16	4	1.553398058

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
3	07/11-07/13	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-11-11	5	1.886792453
3	07/11-07/13	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-11-18	2	0.754716981
3	07/11-07/13	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-11-19	3	1.132075472
3	07/11-07/13	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-11-20	5	1.886792453
3	07/11-07/13	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-11-01	6	1.986754967
3	07/11-07/13	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-11-06	13	4.304635762
3	07/11-07/13	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-11-10	7	2.317880795
3	07/11-07/13	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-11-18	3	0.993377483
3	07/11-07/13	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-11-06	8	2.898550725
3	07/11-07/13	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-11-08	13	4.710144928
3	07/11-07/13	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-11-09	14	5.072463768
3	07/11-07/13	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-11-17	8	2.898550725
3	07/11-07/13	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-12-09	7	2.243589744
3	07/11-07/13	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-12-10	13	4.166666667
3	07/11-07/13	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-12-16	7	2.243589744
3	07/11-07/13	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-12-17	5	1.602564103
3	07/11-07/13	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-12-07	3	0.911854103
3	07/11-07/13	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-12-08	4	1.215805471
3	07/11-07/13	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-12-10	5	1.519756839
3	07/11-07/13	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-12-14	4	1.215805471
3	07/11-07/13	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-12-06	10	2.93255132
3	07/11-07/13	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-12-08	6	1.759530792
3	07/11-07/13	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-12-11	2	0.586510264
3	07/11-07/13	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-12-12	5	1.46627566
3	07/11-07/13	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-12-06	6	1.606425703
3	07/11-07/13	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-12-07	12	3.212851406
3	07/11-07/13	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-12-08	1	0.267737617
3	07/11-07/13	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-12-09	14	3.74832664
3	07/11-07/13	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-12-01	7	2.02020202
3	07/11-07/13	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-12-02	8	2.308802309
3	07/11-07/13	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-12-16	10	2.886002886
3	07/11-07/13	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-12-18	5	1.443001443
3	07/11-07/13	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-12-02	5	1.443001443
3	07/11-07/13	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-12-03	5	1.443001443
3	07/11-07/13	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-12-05	6	1.731601732
3	07/11-07/13	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-12-09	2	0.577200577

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
4	07/18-07/21	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-18-09	8	4.24403183
4	07/18-07/21	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-18-10	7	3.713527851
4	07/18-07/21	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-18-12	2	1.061007958
4	07/18-07/21	Rural	MD01	MD01-S-01	MD01-S-01-2011-07-18-18	4	2.122015915
4	07/18-07/21	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-18-03	8	3.455723542
4	07/18-07/21	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-18-04	2	0.863930886
4	07/18-07/21	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-18-05	5	2.159827214
4	07/18-07/21	Rural	MD01	MD01-S-02	MD01-S-02-2011-07-18-16	16	6.911447084
4	07/18-07/21	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-18-06	6	2.352941176
4	07/18-07/21	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-18-11	5	1.960784314
4	07/18-07/21	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-18-18	12	4.705882353
4	07/18-07/21	Rural	MD01	MD01-S-03	MD01-S-03-2011-07-18-19	6	2.352941176
4	07/18-07/21	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-21-05	4	1.509433962
4	07/18-07/21	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-21-07	5	1.886792453
4	07/18-07/21	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-21-16	5	1.886792453
4	07/18-07/21	Rural	MD02	MD02-S-01	MD02-S-01-2011-07-21-17	5	1.886792453
4	07/18-07/21	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-21-10	3	1.224489796
4	07/18-07/21	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-21-13	3	1.224489796
4	07/18-07/21	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-21-16	3	1.224489796
4	07/18-07/21	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-21-17	4	1.632653061
4	07/18-07/21	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-21-06	4	1.632653061
4	07/18-07/21	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-21-09	8	3.265306122
4	07/18-07/21	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-21-10	16	6.530612245
4	07/18-07/21	Rural	MD02	MD02-S-03	MD02-S-03-2011-07-21-20	10	4.081632653
4	07/18-07/21	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-19-01	1	0.416666667
4	07/18-07/21	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-19-02	1	0.416666667
4	07/18-07/21	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-19-14	0	0
4	07/18-07/21	Rural	MD03	MD03-S-01	MD03-S-01-2011-07-19-15	7	2.916666667
4	07/18-07/21	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-19-03	0	0
4	07/18-07/21	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-19-07	1	0.434782609
4	07/18-07/21	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-19-11	1	0.434782609
4	07/18-07/21	Rural	MD03	MD03-S-02	MD03-S-02-2011-07-19-13	3	1.304347826
4	07/18-07/21	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-19-07	1	0.408163265
4	07/18-07/21	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-19-12	3	1.224489796
4	07/18-07/21	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-19-14	0	0
4	07/18-07/21	Rural	MD03	MD03-S-03	MD03-S-03-2011-07-19-16	2	0.816326531

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
5	07/25-07/27	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-25-01	12	4.615384615
5	07/25-07/27	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-25-02	13	5
5	07/25-07/27	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-25-15	3	1.153846154
5	07/25-07/27	Urban	DE01	DE01-S-01	DE01-S-01-2011-07-25-16	6	2.307692308
5	07/25-07/27	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-25-11	7	2.201257862
5	07/25-07/27	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-25-13	6	1.886792453
5	07/25-07/27	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-25-14	21	6.603773585
5	07/25-07/27	Urban	DE01	DE01-S-02	DE01-S-02-2011-07-25-18	6	1.886792453
5	07/25-07/27	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-25-03	6	2.094240838
5	07/25-07/27	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-25-09	13	4.537521815
5	07/25-07/27	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-25-11	4	1.396160558
5	07/25-07/27	Urban	DE01	DE01-S-03	DE01-S-03-2011-07-25-16	9	3.141361257
5	07/25-07/27	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-27-02	12	3.755868545
5	07/25-07/27	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-27-06	7	2.190923318
5	07/25-07/27	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-27-07	10	3.129890454
5	07/25-07/27	Urban	DE02	DE02-S-01	DE02-S-01-2011-07-27-10	11	3.442879499
5	07/25-07/27	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-27-06	6	1.877934272
5	07/25-07/27	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-27-07	3	0.938967136
5	07/25-07/27	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-27-11	4	1.251956182
5	07/25-07/27	Urban	DE02	DE02-S-02	DE02-S-02-2011-07-27-16	5	1.564945227
5	07/25-07/27	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-27-04	10	3.110419907
5	07/25-07/27	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-27-06	7	2.177293935
5	07/25-07/27	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-27-10	7	2.177293935
5	07/25-07/27	Urban	DE02	DE02-S-03	DE02-S-03-2011-07-27-16	8	2.488335925
5	07/25-07/27	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-27-02	17	4.795486601
5	07/25-07/27	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-27-08	8	2.256699577
5	07/25-07/27	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-27-12	10	2.820874471
5	07/25-07/27	Urban	DE03	DE03-S-01	DE03-S-01-2011-07-27-14	10	2.820874471
5	07/25-07/27	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-27-01	10	2.989536622
5	07/25-07/27	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-27-03	9	2.69058296
5	07/25-07/27	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-27-13	4	1.195814649
5	07/25-07/27	Urban	DE03	DE03-S-02	DE03-S-02-2011-07-27-16	8	2.391629297
5	07/25-07/27	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-27-06	9	2.786377709
5	07/25-07/27	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-27-15	2	0.619195046
5	07/25-07/27	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-27-16	16	4.953560372
5	07/25-07/27	Urban	DE03	DE03-S-03	DE03-S-03-2011-07-27-20	8	2.476780186

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
6	08/01-08/03	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-01-01	4	1.673640167
6	08/01-08/03	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-01-06	2	0.836820084
6	08/01-08/03	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-01-08	8	3.347280335
6	08/01-08/03	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-01-18	2	0.836820084
6	08/01-08/03	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-01-01	3	1.428571429
6	08/01-08/03	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-01-04	5	2.380952381
6	08/01-08/03	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-01-10	11	4.782608696
6	08/01-08/03	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-01-15	9	4.090909091
6	08/01-08/03	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-01-01	9	4.736842105
6	08/01-08/03	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-01-05	13	6.842105263
6	08/01-08/03	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-01-06	13	6.842105263
6	08/01-08/03	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-01-11	12	6.315789474
6	08/01-08/03	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-01-01	3	0.872093023
6	08/01-08/03	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-01-05	2	0.581395349
6	08/01-08/03	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-01-07	4	1.162790698
6	08/01-08/03	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-01-12	5	1.453488372
6	08/01-08/03	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-01-01	4	1.154401154
6	08/01-08/03	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-01-02	3	0.865800866
6	08/01-08/03	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-01-16	2	0.577200577
6	08/01-08/03	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-01-19	0	0
6	08/01-08/03	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-01-05	7	2.127659574
6	08/01-08/03	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-01-10	6	1.823708207
6	08/01-08/03	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-01-12	9	2.760736196
6	08/01-08/03	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-01-18	5	1.587301587
6	08/01-08/03	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-03-05	4	1.444043321
6	08/01-08/03	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-03-09	4	1.444043321
6	08/01-08/03	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-03-11	4	1.444043321
6	08/01-08/03	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-03-17	4	1.444043321
6	08/01-08/03	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-03-08	6	2.242990654
6	08/01-08/03	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-03-11	3	1.121495327
6	08/01-08/03	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-03-12	1	0.373831776
6	08/01-08/03	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-03-18	5	1.869158879
6	08/01-08/03	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-03-05	5	1.818181818
6	08/01-08/03	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-03-13	3	1.090909091
6	08/01-08/03	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-03-15	1	0.363636364
6	08/01-08/03	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-03-18	3	1.090909091

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
7	08/08-08/10	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-08-01	24	11.1627907
7	08/08-08/10	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-08-02	24	11.1627907
7	08/08-08/10	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-08-03	9	4.186046512
7	08/08-08/10	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-08-18	7	3.255813953
7	08/08-08/10	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-08-01	6	2.727272727
7	08/08-08/10	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-08-08	17	7.727272727
7	08/08-08/10	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-08-16	11	5
7	08/08-08/10	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-08-18	7	3.181818182
7	08/08-08/10	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-08-06	13	6.046511628
7	08/08-08/10	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-08-08	24	11.1627907
7	08/08-08/10	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-08-09	16	7.441860465
7	08/08-08/10	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-08-15	10	4.651162791
7	08/08-08/10	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-10-04	15	4.792332268
7	08/08-08/10	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-10-09	10	3.194888179
7	08/08-08/10	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-10-10	15	4.792332268
7	08/08-08/10	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-10-11	16	5.111821086
7	08/08-08/10	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-10-04	4	1.632653061
7	08/08-08/10	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-10-09	3	1.224489796
7	08/08-08/10	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-10-12	9	3.673469388
7	08/08-08/10	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-10-18	7	2.857142857
7	08/08-08/10	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-10-08	10	3.571428571
7	08/08-08/10	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-10-09	17	6.071428571
7	08/08-08/10	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-10-17	9	3.214285714
7	08/08-08/10	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-10-18	10	3.571428571
7	08/08-08/10	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-10-05	26	7.647058824
7	08/08-08/10	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-10-11	29	8.529411765
7	08/08-08/10	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-10-12	22	6.470588235
7	08/08-08/10	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-10-19	29	8.529411765
7	08/08-08/10	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-10-05	9	3.071672355
7	08/08-08/10	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-10-11	25	8.532423208
7	08/08-08/10	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-10-14	19	6.484641638
7	08/08-08/10	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-10-18	28	9.556313993
7	08/08-08/10	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-10-06	4	1.298701299
7	08/08-08/10	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-10-10	28	9.090909091
7	08/08-08/10	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-10-14	30	9.74025974
7	08/08-08/10	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-10-19	15	4.87012987

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
8	08/15-08/17	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-15-02	9	3.870967742
8	08/15-08/17	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-15-07	14	6.021505376
8	08/15-08/17	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-15-08	20	8.602150538
8	08/15-08/17	Rural	MD01	MD01-S-01	MD01-S-01-2011-08-15-11	6	2.580645161
8	08/15-08/17	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-15-01	9	3.488372093
8	08/15-08/17	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-15-03	10	3.875968992
8	08/15-08/17	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-15-05	7	2.713178295
8	08/15-08/17	Rural	MD01	MD01-S-02	MD01-S-02-2011-08-15-19	7	2.713178295
8	08/15-08/17	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-15-06	21	7.984790875
8	08/15-08/17	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-15-07	8	3.041825095
8	08/15-08/17	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-15-14	19	7.224334601
8	08/15-08/17	Rural	MD01	MD01-S-03	MD01-S-03-2011-08-15-18	24	9.125475285
8	08/15-08/17	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-15-04	4	1.509433962
8	08/15-08/17	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-15-05	8	3.018867925
8	08/15-08/17	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-15-08	10	3.773584906
8	08/15-08/17	Rural	MD02	MD02-S-01	MD02-S-01-2011-08-15-13	6	2.264150943
8	08/15-08/17	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-15-01	2	0.759013283
8	08/15-08/17	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-15-11	7	2.65654649
8	08/15-08/17	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-15-16	5	1.897533207
8	08/15-08/17	Rural	MD02	MD02-S-02	MD02-S-02-2011-08-15-18	12	4.554079696
8	08/15-08/17	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-15-02	3	1.282051282
8	08/15-08/17	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-15-03	6	2.564102564
8	08/15-08/17	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-15-12	16	6.837606838
8	08/15-08/17	Rural	MD02	MD02-S-03	MD02-S-03-2011-08-15-18	12	5.128205128
8	08/15-08/17	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-16-02	1	0.34904014
8	08/15-08/17	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-16-13	2	0.698080279
8	08/15-08/17	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-16-14	5	1.745200698
8	08/15-08/17	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-16-17	9	3.141361257
8	08/15-08/17	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-16-02	3	1.071428571
8	08/15-08/17	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-16-09	2	0.714285714
8	08/15-08/17	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-16-16	4	1.428571429
8	08/15-08/17	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-16-18	5	1.785714286
8	08/15-08/17	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-16-04	4	1.32231405
8	08/15-08/17	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-16-10	1	0.330578512
8	08/15-08/17	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-16-13	4	1.32231405
8	08/15-08/17	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-16-17	3	0.991735537

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
9	08/22-08/24	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-22-04	7	3.16027088
9	08/22-08/24	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-22-07	7	3.16027088
9	08/22-08/24	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-22-08	2	0.902934537
9	08/22-08/24	Urban	DE01	DE01-S-01	DE01-S-01-2011-08-22-09	10	4.514672686
9	08/22-08/24	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-22-02	6	2.108963093
9	08/22-08/24	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-22-09	11	3.866432337
9	08/22-08/24	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-22-14	4	1.405975395
9	08/22-08/24	Urban	DE01	DE01-S-02	DE01-S-02-2011-08-22-17	10	3.514938489
9	08/22-08/24	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-22-01	12	4.642166344
9	08/22-08/24	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-22-05	15	5.80270793
9	08/22-08/24	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-22-10	5	1.934235977
9	08/22-08/24	Urban	DE01	DE01-S-03	DE01-S-03-2011-08-22-18	9	3.481624758
9	08/22-08/24	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-23-01	3	1.034482759
9	08/22-08/24	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-23-02	2	0.689655172
9	08/22-08/24	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-23-03	7	2.413793103
9	08/22-08/24	Urban	DE02	DE02-S-01	DE02-S-01-2011-08-23-06	4	1.379310345
9	08/22-08/24	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-23-04	3	0.972447326
9	08/22-08/24	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-23-09	2	0.648298217
9	08/22-08/24	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-23-11	2	0.648298217
9	08/22-08/24	Urban	DE02	DE02-S-02	DE02-S-02-2011-08-23-13	2	0.648298217
9	08/22-08/24	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-23-06	5	1.779359431
9	08/22-08/24	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-23-15	6	2.135231317
9	08/22-08/24	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-23-17	12	4.270462633
9	08/22-08/24	Urban	DE02	DE02-S-03	DE02-S-03-2011-08-23-18	15	5.338078292
9	08/22-08/24	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-23-13	16	4.507042254
9	08/22-08/24	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-23-14	11	3.098591549
9	08/22-08/24	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-23-17	10	2.816901408
9	08/22-08/24	Urban	DE03	DE03-S-01	DE03-S-01-2011-08-23-20	14	3.943661972
9	08/22-08/24	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-23-05	4	1.251956182
9	08/22-08/24	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-23-09	5	1.663893511
9	08/22-08/24	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-23-11	11	3.442879499
9	08/22-08/24	Urban	DE03	DE03-S-02	DE03-S-02-2011-08-23-17	14	4.294478528
9	08/22-08/24	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-23-02	5	1.481481481
9	08/22-08/24	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-23-03	14	4.148148148
9	08/22-08/24	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-23-06	8	2.37037037
9	08/22-08/24	Urban	DE03	DE03-S-03	DE03-S-03-2011-08-23-20	6	1.777777778

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
10	08/30-09/01	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-01-05	30	13.79310345
10	08/30-09/01	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-01-07	7	3.218390805
10	08/30-09/01	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-01-10	15	6.896551724
10	08/30-09/01	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-01-13	8	3.67816092
10	08/30-09/01	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-01-04	32	13.5881104
10	08/30-09/01	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-01-05	14	5.944798301
10	08/30-09/01	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-01-09	25	10.61571125
10	08/30-09/01	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-01-10	37	15.71125265
10	08/30-09/01	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-01-01	72	27.5334608
10	08/30-09/01	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-01-04	37	14.14913958
10	08/30-09/01	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-01-05	59	22.56214149
10	08/30-09/01	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-01-14	23	8.79541109
10	08/30-09/01	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-01-10	11	4.772234273
10	08/30-09/01	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-01-13	13	5.639913232
10	08/30-09/01	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-01-16	10	4.338394794
10	08/30-09/01	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-01-19	16	6.94143167
10	08/30-09/01	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-01-02	7	2.554744526
10	08/30-09/01	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-01-08	6	2.189781022
10	08/30-09/01	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-01-12	6	2.189781022
10	08/30-09/01	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-01-13	13	4.744525547
10	08/30-09/01	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-01-02	16	6.926406926
10	08/30-09/01	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-01-04	5	2.164502165
10	08/30-09/01	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-01-05	9	3.896103896
10	08/30-09/01	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-01-16	6	2.597402597
10	08/30-09/01	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-31-04	12	3.827751196
10	08/30-09/01	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-31-09	1	0.318979266
10	08/30-09/01	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-31-11	10	3.189792663
10	08/30-09/01	Rural	MD03	MD03-S-01	MD03-S-01-2011-08-31-12	4	1.275917065
10	08/30-09/01	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-31-07	0	0
10	08/30-09/01	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-31-13	11	3.636363636
10	08/30-09/01	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-31-14	13	4.297520661
10	08/30-09/01	Rural	MD03	MD03-S-02	MD03-S-02-2011-08-31-16	3	0.991735537
10	08/30-09/01	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-31-03	3	0.978792822
10	08/30-09/01	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-31-04	9	2.936378467
10	08/30-09/01	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-31-06	7	2.283849918
10	08/30-09/01	Rural	MD03	MD03-S-03	MD03-S-03-2011-08-31-20	1	0.326264274

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
11	09/06-09/07	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-06-01	7	4.204204204
11	09/06-09/07	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-06-02	3	1.801801802
11	09/06-09/07	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-06-03	3	1.801801802
11	09/06-09/07	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-06-13	1	0.600600601
11	09/06-09/07	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-06-05	6	2.708803612
11	09/06-09/07	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-06-08	18	8.126410835
11	09/06-09/07	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-06-09	12	5.417607223
11	09/06-09/07	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-06-18	9	4.063205418
11	09/06-09/07	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-06-04	8	3.463203463
11	09/06-09/07	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-06-06	13	5.627705628
11	09/06-09/07	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-06-07	4	1.731601732
11	09/06-09/07	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-06-09	18	7.792207792
11	09/06-09/07	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-07-02	30	10.23890785
11	09/06-09/07	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-07-04	17	5.802047782
11	09/06-09/07	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-07-08	13	4.436860068
11	09/06-09/07	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-07-20	18	6.14334471
11	09/06-09/07	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-07-03	8	2.744425386
11	09/06-09/07	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-07-05	8	2.744425386
11	09/06-09/07	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-07-16	3	1.02915952
11	09/06-09/07	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-07-18	7	2.401372213
11	09/06-09/07	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-07-02	20	7.448789572
11	09/06-09/07	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-07-06	31	11.54562384
11	09/06-09/07	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-07-07	19	7.076350093
11	09/06-09/07	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-07-10	18	6.703910615
11	09/06-09/07	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-07-04	30	9.216589862
11	09/06-09/07	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-07-08	29	8.9093702
11	09/06-09/07	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-07-13	21	6.451612903
11	09/06-09/07	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-07-20	12	3.686635945
11	09/06-09/07	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-07-02	9	3.481624758
11	09/06-09/07	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-07-10	9	3.481624758
11	09/06-09/07	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-07-13	22	8.510638298
11	09/06-09/07	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-07-14	2	0.773694391
11	09/06-09/07	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-07-01	13	4.868913858
11	09/06-09/07	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-07-12	30	11.23595506
11	09/06-09/07	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-07-14	12	4.494382022
11	09/06-09/07	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-07-18	17	6.367041199

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
12	09/13-09/15	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-14-05	35	16.01830664
12	09/13-09/15	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-14-12	24	10.98398169
12	09/13-09/15	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-14-13	14	6.407322654
12	09/13-09/15	Rural	MD01	MD01-S-01	MD01-S-01-2011-09-14-18	13	5.949656751
12	09/13-09/15	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-14-05	37	17.78846154
12	09/13-09/15	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-14-08	12	5.769230769
12	09/13-09/15	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-14-10	12	5.769230769
12	09/13-09/15	Rural	MD01	MD01-S-02	MD01-S-02-2011-09-14-15	27	12.98076923
12	09/13-09/15	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-14-07	11	5.82010582
12	09/13-09/15	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-14-09	20	10.58201058
12	09/13-09/15	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-14-16	36	19.04761905
12	09/13-09/15	Rural	MD01	MD01-S-03	MD01-S-03-2011-09-14-19	26	13.75661376
12	09/13-09/15	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-15-03	4	1.393728223
12	09/13-09/15	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-15-08	8	2.787456446
12	09/13-09/15	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-15-09	12	4.181184669
12	09/13-09/15	Rural	MD02	MD02-S-01	MD02-S-01-2011-09-15-13	15	5.226480836
12	09/13-09/15	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-15-14	8	3.354297694
12	09/13-09/15	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-15-15	9	3.773584906
12	09/13-09/15	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-15-16	13	5.450733753
12	09/13-09/15	Rural	MD02	MD02-S-02	MD02-S-02-2011-09-15-20	8	3.354297694
12	09/13-09/15	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-15-02	5	2.538071066
12	09/13-09/15	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-15-10	6	3.045685279
12	09/13-09/15	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-15-17	6	3.045685279
12	09/13-09/15	Rural	MD02	MD02-S-03	MD02-S-03-2011-09-15-18	4	2.030456853
12	09/13-09/15	Rural	MD03	MD03-S-01	MD03-S-01-2011-09-13-05	13	5.078125
12	09/13-09/15	Rural	MD03	MD03-S-01	MD03-S-01-2011-09-13-11	3	1.171875
12	09/13-09/15	Rural	MD03	MD03-S-01	MD03-S-01-2011-09-13-12	6	2.34375
12	09/13-09/15	Rural	MD03	MD03-S-01	MD03-S-01-2011-09-13-19	9	3.515625
12	09/13-09/15	Rural	MD03	MD03-S-02	MD03-S-02-2011-09-13-08	4	1.74291939
12	09/13-09/15	Rural	MD03	MD03-S-02	MD03-S-02-2011-09-13-11	3	1.307189542
12	09/13-09/15	Rural	MD03	MD03-S-02	MD03-S-02-2011-09-13-12	0	0
12	09/13-09/15	Rural	MD03	MD03-S-02	MD03-S-02-2011-09-13-17	1	0.435729847
12	09/13-09/15	Rural	MD03	MD03-S-03	MD03-S-03-2011-09-13-02	4	1.403508772
12	09/13-09/15	Rural	MD03	MD03-S-03	MD03-S-03-2011-09-13-09	13	4.561403509
12	09/13-09/15	Rural	MD03	MD03-S-03	MD03-S-03-2011-09-13-10	4	1.403508772
12	09/13-09/15	Rural	MD03	MD03-S-03	MD03-S-03-2011-09-13-19	8	2.807017544

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
13	09/19-09/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-19-01	4	3.212851406
13	09/19-09/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-19-09	2	1.606425703
13	09/19-09/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-19-10	8	6.425702811
13	09/19-09/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-09-19-11	16	12.85140562
13	09/19-09/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-19-08	1	0.561797753
13	09/19-09/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-19-09	11	6.179775281
13	09/19-09/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-19-11	2	1.123595506
13	09/19-09/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-09-19-13	5	2.808988764
13	09/19-09/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-19-02	6	3.519061584
13	09/19-09/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-19-07	2	1.173020528
13	09/19-09/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-19-17	5	2.93255132
13	09/19-09/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-09-19-18	4	2.346041056
13	09/19-09/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-20-02	12	4.444444444
13	09/19-09/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-20-10	7	2.592592593
13	09/19-09/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-20-17	9	3.333333333
13	09/19-09/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-09-20-18	6	2.222222222
13	09/19-09/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-20-04	8	3.47826087
13	09/19-09/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-20-05	5	2.173913043
13	09/19-09/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-20-07	4	1.739130435
13	09/19-09/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-09-20-15	2	0.869565217
13	09/19-09/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-20-01	3	1.428571429
13	09/19-09/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-20-06	9	4.285714286
13	09/19-09/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-20-14	16	7.619047619
13	09/19-09/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-09-20-17	10	4.761904762
13	09/19-09/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-19-02	6	2.312138728
13	09/19-09/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-19-08	15	5.780346821
13	09/19-09/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-19-10	23	8.863198459
13	09/19-09/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-09-19-12	40	15.41425819
13	09/19-09/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-19-05	7	2.910602911
13	09/19-09/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-19-08	1	0.471698113
13	09/19-09/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-19-14	9	3.742203742
13	09/19-09/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-09-19-15	15	6.237006237
13	09/19-09/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-19-03	6	2.494802495
13	09/19-09/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-19-04	12	4.98960499
13	09/19-09/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-19-05	10	4.158004158
13	09/19-09/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-09-19-15	21	8.731808732

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
14	09/28-10/05	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-05-03	15	9.090909091
14	09/28-10/05	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-05-05	21	12.72727273
14	09/28-10/05	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-05-11	6	3.636363636
14	09/28-10/05	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-05-17	6	3.636363636
14	09/28-10/05	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-05-04	21	11.53846154
14	09/28-10/05	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-05-06	18	9.89010989
14	09/28-10/05	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-05-09	8	6.060606061
14	09/28-10/05	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-05-15	14	10.60606061
14	09/28-10/05	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-05-02	9	5.142857143
14	09/28-10/05	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-05-09	9	5.142857143
14	09/28-10/05	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-05-17	10	5.714285714
14	09/28-10/05	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-05-18	6	3.428571429
14	09/28-10/05	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-05-03	8	3.636363636
14	09/28-10/05	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-05-06	5	2.272727273
14	09/28-10/05	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-05-07	16	7.272727273
14	09/28-10/05	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-05-08	7	3.181818182
14	09/28-10/05	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-05-06	11	4.545454545
14	09/28-10/05	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-05-12	14	5.785123967
14	09/28-10/05	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-05-13	13	5.371900826
14	09/28-10/05	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-05-18	5	2.066115702
14	09/28-10/05	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-05-01	1	0.447427293
14	09/28-10/05	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-05-10	7	2.60707635
14	09/28-10/05	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-05-15	5	1.862197393
14	09/28-10/05	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-05-19	1	0.386847195
14	09/28-10/05	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-05-04	3	1.395348837
14	09/28-10/05	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-05-07	2	0.930232558
14	09/28-10/05	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-05-09	2	0.930232558
14	09/28-10/05	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-05-16	3	1.395348837
14	09/28-10/05	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-05-05	3	1.324503311
14	09/28-10/05	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-05-06	4	1.766004415
14	09/28-10/05	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-05-08	7	2.972399151
14	09/28-10/05	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-05-12	8	3.712296984
14	09/28-10/05	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-05-01	8	3.305785124
14	09/28-10/05	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-05-05	4	1.652892562
14	09/28-10/05	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-05-15	3	1.239669421
14	09/28-10/05	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-05-16	0	0

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
15	10/04-10/06	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-06-04	12	7.741935484
15	10/04-10/06	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-06-06	2	1.290322581
15	10/04-10/06	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-06-08	2	1.290322581
15	10/04-10/06	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-06-17	1	0.64516129
15	10/04-10/06	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-06-06	1	0.473933649
15	10/04-10/06	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-06-13	5	2.369668246
15	10/04-10/06	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-06-17	1	0.473933649
15	10/04-10/06	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-06-20	13	6.161137441
15	10/04-10/06	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-06-03	4	1.818181818
15	10/04-10/06	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-06-11	2	0.909090909
15	10/04-10/06	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-06-12	3	1.363636364
15	10/04-10/06	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-06-16	8	3.636363636
15	10/04-10/06	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-06-03	6	2.112676056
15	10/04-10/06	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-06-07	1	0.352112676
15	10/04-10/06	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-06-18	7	2.464788732
15	10/04-10/06	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-06-19	8	2.816901408
15	10/04-10/06	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-06-07	4	1.523809524
15	10/04-10/06	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-06-08	3	1.142857143
15	10/04-10/06	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-06-09	5	1.904761905
15	10/04-10/06	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-06-20	3	1.142857143
15	10/04-10/06	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-06-07	5	1.886792453
15	10/04-10/06	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-06-09	4	1.509433962
15	10/04-10/06	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-06-17	2	0.754716981
15	10/04-10/06	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-06-18	0	0
15	10/04-10/06	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-06-13	8	2.62295082
15	10/04-10/06	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-06-14	7	2.295081967
15	10/04-10/06	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-06-18	11	3.606557377
15	10/04-10/06	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-06-19	7	2.295081967
15	10/04-10/06	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-06-06	5	1.949317739
15	10/04-10/06	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-06-07	2	0.779727096
15	10/04-10/06	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-06-13	5	1.949317739
15	10/04-10/06	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-06-17	1	0.389863548
15	10/04-10/06	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-06-05	7	2.707930368
15	10/04-10/06	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-06-11	4	1.547388781
15	10/04-10/06	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-06-14	4	1.547388781
15	10/04-10/06	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-06-20	4	1.547388781

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
16	10/11-10/12	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-12-02	13	8.387096774
16	10/11-10/12	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-12-09	11	7.096774194
16	10/11-10/12	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-12-17	2	1.290322581
16	10/11-10/12	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-12-18	3	1.935483871
16	10/11-10/12	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-12-04	21	12.20930233
16	10/11-10/12	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-12-12	5	2.906976744
16	10/11-10/12	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-12-16	9	5.23255814
16	10/11-10/12	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-12-17	6	3.488372093
16	10/11-10/12	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-12-06	7	4.402515723
16	10/11-10/12	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-12-07	8	5.031446541
16	10/11-10/12	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-12-10	8	7.339449541
16	10/11-10/12	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-12-13	8	7.339449541
16	10/11-10/12	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-12-10	13	6.666666667
16	10/11-10/12	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-12-11	7	3.58974359
16	10/11-10/12	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-12-12	10	5.128205128
16	10/11-10/12	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-12-13	8	4.102564103
16	10/11-10/12	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-12-01	1	0.416666667
16	10/11-10/12	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-12-04	5	2.083333333
16	10/11-10/12	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-12-09	1	0.416666667
16	10/11-10/12	Rural	MD02	MD02-S-02	MD02-S-02-2011-10-12-16	16	6.666666667
16	10/11-10/12	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-12-04	3	1.304347826
16	10/11-10/12	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-12-05	5	2.173913043
16	10/11-10/12	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-12-07	9	3.913043478
16	10/11-10/12	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-12-08	7	3.043478261
16	10/11-10/12	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-12-01	6	2.727272727
16	10/11-10/12	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-12-02	2	0.909090909
16	10/11-10/12	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-12-11	2	0.909090909
16	10/11-10/12	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-12-12	8	3.636363636
16	10/11-10/12	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-12-07	12	5.333333333
16	10/11-10/12	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-12-08	3	1.333333333
16	10/11-10/12	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-12-09	3	1.333333333
16	10/11-10/12	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-12-17	6	2.666666667
16	10/11-10/12	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-12-05	2	1
16	10/11-10/12	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-12-06	3	1.5
16	10/11-10/12	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-12-12	8	4
16	10/11-10/12	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-12-17	4	2

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
17	10/17-10/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-19-03	2	1.960784314
17	10/17-10/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-19-07	0	0
17	10/17-10/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-19-08	3	2.941176471
17	10/17-10/20	Urban	DE01	DE01-S-01	DE01-S-01-2011-10-19-19	2	1.960784314
17	10/17-10/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-19-04	1	0.600600601
17	10/17-10/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-19-06	2	1.201201201
17	10/17-10/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-19-08	0	0
17	10/17-10/20	Urban	DE01	DE01-S-02	DE01-S-02-2011-10-19-16	3	1.801801802
17	10/17-10/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-19-01	3	2.076124567
17	10/17-10/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-19-02	4	2.76816609
17	10/17-10/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-19-05	2	1.384083045
17	10/17-10/20	Urban	DE01	DE01-S-03	DE01-S-03-2011-10-19-09	1	0.692041522
17	10/17-10/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-20-02	2	0.725952813
17	10/17-10/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-20-05	1	0.362976407
17	10/17-10/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-20-08	8	2.903811252
17	10/17-10/20	Urban	DE02	DE02-S-01	DE02-S-01-2011-10-20-12	4	1.451905626
17	10/17-10/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-20-04	1	0.409836066
17	10/17-10/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-20-13	5	2.049180328
17	10/17-10/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-20-14	5	2.049180328
17	10/17-10/20	Urban	DE02	DE02-S-02	DE02-S-02-2011-10-20-18	5	2.049180328
17	10/17-10/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-20-05	1	0.426439232
17	10/17-10/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-20-07	2	0.852878465
17	10/17-10/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-20-09	2	0.852878465
17	10/17-10/20	Urban	DE02	DE02-S-03	DE02-S-03-2011-10-20-16	0	0
17	10/17-10/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-19-04	5	1.533742331
17	10/17-10/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-19-05	4	1.226993865
17	10/17-10/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-19-07	3	0.920245399
17	10/17-10/20	Urban	DE03	DE03-S-01	DE03-S-01-2011-10-19-13	5	1.533742331
17	10/17-10/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-19-03	5	1.788908766
17	10/17-10/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-19-04	8	2.862254025
17	10/17-10/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-19-05	5	1.788908766
17	10/17-10/20	Urban	DE03	DE03-S-02	DE03-S-02-2011-10-19-18	3	1.073345259
17	10/17-10/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-19-01	2	0.677966102
17	10/17-10/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-19-02	5	1.694915254
17	10/17-10/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-19-13	9	3.050847458
17	10/17-10/20	Urban	DE03	DE03-S-03	DE03-S-03-2011-10-19-19	6	2.033898305

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
18	10/24-10/26	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-25-01	2	1.194029851
18	10/24-10/26	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-25-03	5	2.985074627
18	10/24-10/26	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-25-09	4	2.388059701
18	10/24-10/26	Rural	MD01	MD01-S-01	MD01-S-01-2011-10-25-14	1	0.597014925
18	10/24-10/26	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-25-08	3	1.295896328
18	10/24-10/26	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-25-09	5	2.159827214
18	10/24-10/26	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-25-11	7	3.023758099
18	10/24-10/26	Rural	MD01	MD01-S-02	MD01-S-02-2011-10-25-17	12	5.183585313
18	10/24-10/26	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-25-04	8	3.516483516
18	10/24-10/26	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-25-07	5	2.197802198
18	10/24-10/26	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-25-18	14	6.153846154
18	10/24-10/26	Rural	MD01	MD01-S-03	MD01-S-03-2011-10-25-19	6	2.637362637
18	10/24-10/26	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-25-06	4	1.451905626
18	10/24-10/26	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-25-08	1	0.362976407
18	10/24-10/26	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-25-12	7	2.540834846
18	10/24-10/26	Rural	MD02	MD02-S-01	MD02-S-01-2011-10-25-16	3	1.08892922
18	10/24-10/26	Rural	MD02	MD02-S-02	MD02-S-02-2011-12-30-14	5	1.865671642
18	10/24-10/26	Rural	MD02	MD02-S-02	MD02-S-02-2011-12-30-15	6	2.23880597
18	10/24-10/26	Rural	MD02	MD02-S-02	MD02-S-02-2011-12-30-16	2	0.746268657
18	10/24-10/26	Rural	MD02	MD02-S-02	MD02-S-02-2011-12-30-18	1	0.373134328
18	10/24-10/26	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-25-06	6	2.48447205
18	10/24-10/26	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-25-13	8	3.3126294
18	10/24-10/26	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-25-14	6	2.48447205
18	10/24-10/26	Rural	MD02	MD02-S-03	MD02-S-03-2011-10-25-16	5	2.070393375
18	10/24-10/26	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-26-01	0	0
18	10/24-10/26	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-26-02	4	1.384083045
18	10/24-10/26	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-26-15	3	1.038062284
18	10/24-10/26	Rural	MD03	MD03-S-01	MD03-S-01-2011-10-26-18	4	1.384083045
18	10/24-10/26	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-26-01	0	0
18	10/24-10/26	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-26-06	1	0.428265525
18	10/24-10/26	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-26-10	1	0.428265525
18	10/24-10/26	Rural	MD03	MD03-S-02	MD03-S-02-2011-10-26-18	2	0.856531049
18	10/24-10/26	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-26-02	1	0.419287212
18	10/24-10/26	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-26-08	2	0.838574423
18	10/24-10/26	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-26-10	2	0.838574423
18	10/24-10/26	Rural	MD03	MD03-S-03	MD03-S-03-2011-10-26-13	1	0.419287212

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
19	10/31-11/02	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-01-06	2	1.652892562
19	10/31-11/02	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-01-12	7	5.785123967
19	10/31-11/02	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-01-13	0	0
19	10/31-11/02	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-01-17	2	1.652892562
19	10/31-11/02	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-01-01	6	3.488372093
19	10/31-11/02	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-01-05	4	2.325581395
19	10/31-11/02	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-01-08	0	0
19	10/31-11/02	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-01-19	1	0.581395349
19	10/31-11/02	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-01-02	1	0.706713781
19	10/31-11/02	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-01-07	2	1.413427562
19	10/31-11/02	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-01-09	2	1.413427562
19	10/31-11/02	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-01-14	7	4.946996466
19	10/31-11/02	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-01-03	5	3.164556962
19	10/31-11/02	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-01-04	1	0.632911392
19	10/31-11/02	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-01-08	5	3.164556962
19	10/31-11/02	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-01-14	6	3.797468354
19	10/31-11/02	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-01-01	5	2.985074627
19	10/31-11/02	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-01-03	4	2.388059701
19	10/31-11/02	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-01-12	6	3.582089552
19	10/31-11/02	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-01-15	14	8.358208955
19	10/31-11/02	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-01-03	4	2.53164557
19	10/31-11/02	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-01-10	5	3.164556962
19	10/31-11/02	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-01-12	8	5.063291139
19	10/31-11/02	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-01-20	8	5.063291139
19	10/31-11/02	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-02-02	14	5.490196078
19	10/31-11/02	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-02-08	26	10.19607843
19	10/31-11/02	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-02-09	10	3.921568627
19	10/31-11/02	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-02-15	13	5.098039216
19	10/31-11/02	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-02-07	11	5.326876513
19	10/31-11/02	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-02-08	6	2.905569007
19	10/31-11/02	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-02-12	9	4.358353511
19	10/31-11/02	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-02-18	4	1.937046005
19	10/31-11/02	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-02-01	9	4.128440367
19	10/31-11/02	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-02-04	12	5.504587156
19	10/31-11/02	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-02-08	12	5.504587156
19	10/31-11/02	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-02-13	16	7.339449541

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
20	11/07-11/09	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-07-13	1	0.422832981
20	11/07-11/09	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-07-14	2	0.845665962
20	11/07-11/09	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-07-16	2	0.845665962
20	11/07-11/09	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-07-19	2	0.845665962
20	11/07-11/09	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-07-07	4	1.6
20	11/07-11/09	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-07-12	3	1.2
20	11/07-11/09	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-07-13	2	0.8
20	11/07-11/09	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-07-18	0	0
20	11/07-11/09	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-07-01	7	2.702702703
20	11/07-11/09	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-07-09	2	0.772200772
20	11/07-11/09	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-07-14	6	2.316602317
20	11/07-11/09	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-07-19	1	0.386100386
20	11/07-11/09	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-09-08	8	3.036053131
20	11/07-11/09	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-09-10	2	0.759013283
20	11/07-11/09	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-09-15	9	3.415559772
20	11/07-11/09	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-09-17	6	2.277039848
20	11/07-11/09	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-09-02	4	1.587301587
20	11/07-11/09	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-09-08	6	2.380952381
20	11/07-11/09	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-09-12	1	0.396825397
20	11/07-11/09	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-09-16	1	0.396825397
20	11/07-11/09	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-09-05	7	2.621722846
20	11/07-11/09	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-09-08	3	1.123595506
20	11/07-11/09	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-09-12	4	1.498127341
20	11/07-11/09	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-09-16	4	1.498127341
20	11/07-11/09	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-09-08	2	0.772200772
20	11/07-11/09	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-09-09	0	0
20	11/07-11/09	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-09-13	4	1.544401544
20	11/07-11/09	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-09-14	2	0.772200772
20	11/07-11/09	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-09-07	2	0.787401575
20	11/07-11/09	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-09-08	3	1.181102362
20	11/07-11/09	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-09-11	4	1.57480315
20	11/07-11/09	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-09-15	0	0
20	11/07-11/09	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-09-05	3	1.10701107
20	11/07-11/09	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-09-06	3	1.10701107
20	11/07-11/09	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-09-14	2	0.73800738
20	11/07-11/09	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-09-18	1	0.36900369

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
21	11/14-11/16	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-16-01	1	0.655737705
21	11/14-11/16	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-16-02	2	1.31147541
21	11/14-11/16	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-16-03	0	0
21	11/14-11/16	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-16-11	0	0
21	11/14-11/16	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-16-07	1	0.563380282
21	11/14-11/16	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-16-10	1	0.563380282
21	11/14-11/16	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-16-11	0	0
21	11/14-11/16	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-16-13	1	0.563380282
21	11/14-11/16	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-16-03	2	0.858369099
21	11/14-11/16	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-16-04	4	1.716738197
21	11/14-11/16	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-16-05	1	0.429184549
21	11/14-11/16	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-16-06	2	0.858369099
21	11/14-11/16	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-14-06	3	1.382488479
21	11/14-11/16	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-14-08	4	1.843317972
21	11/14-11/16	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-14-10	7	3.225806452
21	11/14-11/16	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-14-11	5	2.304147465
21	11/14-11/16	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-14-08	2	0.792079208
21	11/14-11/16	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-14-10	0	0
21	11/14-11/16	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-14-11	1	0.396039604
21	11/14-11/16	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-14-16	4	1.584158416
21	11/14-11/16	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-14-01	3	1.257861635
21	11/14-11/16	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-14-06	1	0.419287212
21	11/14-11/16	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-14-07	1	0.419287212
21	11/14-11/16	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-14-15	2	0.838574423
21	11/14-11/16	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-14-03	23	5.735660848
21	11/14-11/16	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-14-11	9	2.244389027
21	11/14-11/16	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-14-16	9	2.244389027
21	11/14-11/16	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-14-17	10	2.493765586
21	11/14-11/16	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-14-03	6	1.809954751
21	11/14-11/16	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-14-04	4	1.206636501
21	11/14-11/16	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-14-06	6	1.809954751
21	11/14-11/16	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-14-10	7	2.111613876
21	11/14-11/16	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-14-11	8	2.275960171
21	11/14-11/16	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-14-12	10	2.844950213
21	11/14-11/16	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-14-17	7	1.991465149
21	11/14-11/16	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-14-18	8	2.275960171

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
22	11/18-11/19	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-19-06	4	1.818181818
22	11/18-11/19	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-19-07	1	0.454545455
22	11/18-11/19	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-19-12	4	1.818181818
22	11/18-11/19	Rural	MD01	MD01-S-01	MD01-S-01-2011-11-19-17	4	1.818181818
22	11/18-11/19	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-19-03	3	1.234567901
22	11/18-11/19	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-19-06	1	0.411522634
22	11/18-11/19	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-19-07	4	1.646090535
22	11/18-11/19	Rural	MD01	MD01-S-02	MD01-S-02-2011-11-19-12	3	1.234567901
22	11/18-11/19	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-19-05	4	1.6
22	11/18-11/19	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-19-06	2	0.8
22	11/18-11/19	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-19-11	3	1.2
22	11/18-11/19	Rural	MD01	MD01-S-03	MD01-S-03-2011-11-19-14	3	1.2
22	11/18-11/19	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-19-01	2	0.747663551
22	11/18-11/19	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-19-03	8	2.990654206
22	11/18-11/19	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-19-05	1	0.373831776
22	11/18-11/19	Rural	MD02	MD02-S-01	MD02-S-01-2011-11-19-07	2	0.747663551
22	11/18-11/19	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-19-02	7	2.372881356
22	11/18-11/19	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-19-04	1	0.338983051
22	11/18-11/19	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-19-05	1	0.338983051
22	11/18-11/19	Rural	MD02	MD02-S-02	MD02-S-02-2011-11-19-19	1	0.338983051
22	11/18-11/19	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-19-05	2	0.769230769
22	11/18-11/19	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-19-06	0	0
22	11/18-11/19	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-19-10	0	0
22	11/18-11/19	Rural	MD02	MD02-S-03	MD02-S-03-2011-11-19-17	3	1.153846154
22	11/18-11/19	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-19-06	3	1.481481481
22	11/18-11/19	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-19-07	5	2.469135802
22	11/18-11/19	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-19-11	6	2.962962963
22	11/18-11/19	Rural	MD03	MD03-S-01	MD03-S-01-2011-11-19-16	0	0
22	11/18-11/19	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-19-06	0	0
22	11/18-11/19	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-19-11	0	0
22	11/18-11/19	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-19-15	2	0.718132855
22	11/18-11/19	Rural	MD03	MD03-S-02	MD03-S-02-2011-11-19-16	0	0
22	11/18-11/19	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-19-05	0	0
22	11/18-11/19	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-19-12	0	0
22	11/18-11/19	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-19-16	3	1.022146508
22	11/18-11/19	Rural	MD03	MD03-S-03	MD03-S-03-2011-11-19-17	0	0

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
23	11/28-11/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-29-06	1	0.653594771
23	11/28-11/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-29-08	0	0
23	11/28-11/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-29-16	2	1.307189542
23	11/28-11/30	Urban	DE01	DE01-S-01	DE01-S-01-2011-11-29-17	0	0
23	11/28-11/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-29-06	7	3.263403263
23	11/28-11/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-29-08	3	1.398601399
23	11/28-11/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-29-10	7	3.263403263
23	11/28-11/30	Urban	DE01	DE01-S-02	DE01-S-02-2011-11-29-18	4	1.864801865
23	11/28-11/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-29-05	6	2.684563758
23	11/28-11/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-29-10	11	4.921700224
23	11/28-11/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-29-11	3	1.342281879
23	11/28-11/30	Urban	DE01	DE01-S-03	DE01-S-03-2011-11-29-18	5	2.237136465
23	11/28-11/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-29-12	6	2.259887006
23	11/28-11/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-29-15	2	0.753295669
23	11/28-11/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-29-16	2	0.753295669
23	11/28-11/30	Urban	DE02	DE02-S-01	DE02-S-01-2011-11-29-19	5	1.883239171
23	11/28-11/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-29-01	3	1.071428571
23	11/28-11/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-29-05	0	0
23	11/28-11/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-29-13	13	4.642857143
23	11/28-11/30	Urban	DE02	DE02-S-02	DE02-S-02-2011-11-29-16	2	0.714285714
23	11/28-11/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-29-12	1	0.401606426
23	11/28-11/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-29-13	1	0.401606426
23	11/28-11/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-29-14	3	1.204819277
23	11/28-11/30	Urban	DE02	DE02-S-03	DE02-S-03-2011-11-29-17	0	0
23	11/28-11/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-30-02	10	2.958579882
23	11/28-11/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-30-09	5	1.479289941
23	11/28-11/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-30-15	7	2.071005917
23	11/28-11/30	Urban	DE03	DE03-S-01	DE03-S-01-2011-11-30-19	11	3.25443787
23	11/28-11/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-30-06	7	2.385008518
23	11/28-11/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-30-12	12	4.088586031
23	11/28-11/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-30-16	6	2.044293015
23	11/28-11/30	Urban	DE03	DE03-S-02	DE03-S-02-2011-11-30-19	5	1.703577513
23	11/28-11/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-30-13	10	3.267973856
23	11/28-11/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-30-15	11	3.594771242
23	11/28-11/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-30-18	8	2.614379085
23	11/28-11/30	Urban	DE03	DE03-S-03	DE03-S-03-2011-11-30-19	8	2.614379085

Appendix D-1. (Continued)

Sample Event #	Sampling Dates	Area	Location	Site	Transect ID	Total Count	Density (#/100m2)
24	12/06-12/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-12-30-07	3	1.526717557
24	12/06-12/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-12-30-08	3	1.526717557
24	12/06-12/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-12-30-11	2	1.017811705
24	12/06-12/08	Rural	MD01	MD01-S-01	MD01-S-01-2011-12-30-15	2	1.017811705
24	12/06-12/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-12-07-03	5	2.398081535
24	12/06-12/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-12-07-11	8	3.836930456
24	12/06-12/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-12-07-15	2	0.959232614
24	12/06-12/08	Rural	MD01	MD01-S-02	MD01-S-02-2011-12-07-16	4	1.918465228
24	12/06-12/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-12-07-08	3	1.425178147
24	12/06-12/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-12-07-13	4	1.90023753
24	12/06-12/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-12-07-15	2	0.950118765
24	12/06-12/08	Rural	MD01	MD01-S-03	MD01-S-03-2011-12-07-17	3	1.425178147
24	12/06-12/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-12-07-01	2	0.740740741
24	12/06-12/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-12-07-05	5	1.851851852
24	12/06-12/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-12-07-14	19	7.037037037
24	12/06-12/08	Rural	MD02	MD02-S-01	MD02-S-01-2011-12-07-18	8	2.962962963
24	12/06-12/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-01-01	4	1.593625498
24	12/06-12/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-01-04	8	3.187250996
24	12/06-12/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-01-15	2	0.796812749
24	12/06-12/08	Rural	MD02	MD02-S-02	MD02-S-02-2011-07-01-20	3	1.195219124
24	12/06-12/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-12-07-08	2	0.909090909
24	12/06-12/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-12-07-10	3	1.363636364
24	12/06-12/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-12-07-15	5	2.272727273
24	12/06-12/08	Rural	MD02	MD02-S-03	MD02-S-03-2011-12-07-16	2	0.909090909
24	12/06-12/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-12-08-04	3	1.260504202
24	12/06-12/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-12-08-05	2	0.840336134
24	12/06-12/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-12-08-16	1	0.420168067
24	12/06-12/08	Rural	MD03	MD03-S-01	MD03-S-01-2011-12-08-19	0	0
24	12/06-12/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-12-08-01	2	0.628930818
24	12/06-12/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-12-08-06	1	0.314465409
24	12/06-12/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-12-08-12	1	0.314465409
24	12/06-12/08	Rural	MD03	MD03-S-02	MD03-S-02-2011-12-08-14	4	1.257861635
24	12/06-12/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-12-08-03	2	0.617283951
24	12/06-12/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-12-08-06	1	0.308641975
24	12/06-12/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-12-08-09	2	0.617283951
24	12/06-12/08	Rural	MD03	MD03-S-03	MD03-S-03-2011-12-08-19	1	0.308641975

APPENDIX E

Marine Debris Monitoring and Assessment Protocols

In recent years, research efforts in the marine debris field have significantly increased knowledge of the topic. However, significant gaps still remain in standardized monitoring practices. While numerous past debris studies have been conducted, currently a single best method is not available to estimate total densities in the environment, including: water column, subsurface, and shoreline. As such, the MDD is in the process of establishing a long-term monitoring and assessment program with four main objectives:

- Assess the quantity of debris at a location and expand to regional characterization according to associated land use or other correlating parameter
- Determine types and density of debris present by material category (plastic, metal, glass, rubber, processed lumber, cloth/fabric, other)
- Examine spatial distribution and variability of debris
- Investigate temporal trends in debris amounts

This monitoring and assessment program will incorporate five types of data collection including: (1) shoreline assessments for coastal debris, (2) underwater assessments for benthic submerged debris, (3) pelagic trawls for both large debris and micro-debris (≤5mm in length), (4) at-sea visual surveys of floating debris, and finally (5) sediment cores and sand samples to analyze for micro-debris items.

This report contains details on two of the five survey methods developed and/or modified by the MDD:

1. **<u>Shoreline Methods</u>**: Recommended shoreline method to be used when assessing coastline segments for debris density.

2. **<u>Pelagic Trawl Methods</u>**: Recommended surface water sampling method for the analysis of floating debris densities.

These methods were developed and tested by NOAA MDD staff as a pilot project in the Chesapeake Bay region during summer/fall 2009. For initial method development and testing purposes, the MDD focused only on assessments of beaches and rocky shorelines and nearshore waters. Shoreline survey locations included: Gibson Island (rural), Fort Smallwood (peri-urban), and Calvert Cliffs (rural). Each of the locations was visited once in July or August, with the exception of Fort Smallwood which was sampled again in October. Pelagic trawl methods were tested in the Patapsco River (urban) and the near shore waters of Chesapeake Bay at the mouth of the Patapsco River. Based on ease of sampling methodology and results, methods were modified after each sampling event. Visual survey methods were also developed with this pilot project but continue to require modification. Therefore, this method is not included in this report.

I. Shoreline Methods

Background

There are numerous and varied shoreline monitoring programs already in existence throughout the world. However, these studies each have unique objectives and therefore have slightly different methodologies. These differences in methodologies make comparisons of debris estimates difficult. In an attempt to standardize debris density methodologies and minimize the duplication of efforts, our first task was to compile a list of relevant shoreline studies, compare and contrast them, and analyze for strengths and weaknesses. These included published studies from peer-reviewed literature, federal reports, technical memoranda, and monitoring projects previously funded by the MDD.

Upon review, there were four projects that were similar to the objectives for this monitoring program. One of the first selected for further analysis and consideration was U.S. EPA's National Marine Debris Monitoring Program (NMDMP). The purposes of this volunteer-implemented national study were to estimate the amount of debris on U.S. coastlines changing over a five-year period and to identify the major sources of debris using indicator items (Sheavly 2007). This program in which volunteers collected debris and tallied it according to source indicator item was established in 2001 and ended in 2006 with surveys conducted monthly (Sheavly 2007).

Another study looked at in greater detail was Israel's Clean Coast Index (Alkalay *et al*. 2006). This index is used as a tool for evaluation of the actual cleanliness of a beach in response to the launch of the nation's Clean Coast Program by estimating plastic debris densities. Surveyors walk beach transects perpendicular to the water counting plastic debris items without removal. Instead, debris collection is done routinely by local authorities. The authors of this study came to the conclusion that not only was it a good evaluation of the Clean Coast Program, it was also an effective outreach and education tool (Alkalay *et al*. 2006).

Two regional marine debris projects were considered. The first was conducted by the Southern California Coastal Water Resource Project (SCCWRP), and analyzed composition and distribution of debris on beaches in Orange County, California (Moore *et al*. 2001). Sites were stratified by shoreline type (sandy beach and rocky shoreline) and debris was collected from walked transects perpendicular to the water. Additionally, one bucket of sand was sieved at each beach location to quantify small debris items not visible to the eye. Debris was then sorted in a lab according to material category and divided further into item subcategories (Moore *et al*. 2001).

The second regional project reviewed was conducted by the University of New Hampshire. This project examined the New Hampshire community marine debris cleanup and reduction volunteer efforts. It established a baseline, implemented new debris cleanup efforts, and measured impacts and outcomes. This project coordinated with the Blue Ocean Society to conduct monitoring and clean up of New Hampshire beaches. Volunteers tallied debris into three generalized source categories similar to those used by the International Coastal Cleanup (Jambeck *et al*. 2009).

This shoreline method takes into consideration lessons learned from these previous monitoring efforts. Additionally, these methods were sent to an established advisory group for comments and review. The advisory group consisted of researchers in the debris monitoring field, other federal agencies involved in marine debris efforts, and internal MDD staff (Appendix B). Datasheets modified here were adapted from the United Nations Environment Programme and the Intergovernmental Oceanographic Commission (UNEP/IOC) guidelines (Cheshire *et al*. 2009).

Equipment

The following items are suggested to conduct the shoreline assessments:

- Digital camera
- Hand-held GPS unit
- Extra batteries (suggest rechargeable batteries)
- Surveyor's measuring wheel
- Flag markers/stakes
- Calipers
- 100' fiberglass measuring tape
- First aid kit (including sunscreen, bug spray)
- Work gloves
- Quadrat kit (1m^2)
- Small folding shovel
- Sturdy 12in. ruler
- 5mm stainless steel sieve
- Tweezers/forceps
- 32 oz. Amber glass sample bottles
- Wide-mouth funnel (stainless steel) to fit bottles
- Clipboards for each person
- Data sheets (on waterproof paper)
- Waterproof paper for labels in jars
- Pencils
- Permanent markers
- Buckets (two 5-gal)

Site Selection

Previous studies have shown that varying amounts and types of marine debris accumulate on shorelines depending on geographical location, oceanographic and meteorological conditions, and proximity to land-based or ocean-based sources (Sheavly 2007). Therefore, to provide a more statistically relevant dataset, selected sites should be stratified by land use (*e.g.*, urban, rural), fishing activities, and storm water or sewage outfalls where possible and selected randomly from each stratum. Additionally, sites should have the following characteristics:

- Clear, direct, year-round access or seasonal access depending on physical conditions of the site
- No breakwaters or jetties to accumulate or inhibit debris deposition
- At least 100m in length parallel to the water
- No regular cleanup activities

These characteristics should be met where possible, but should be analyzed on a case-by-case basis and modified if appropriate for a particular region/location. Length of shoreline was selected based on UNEP recommendations for rapid assessment (Cheshire *et al*. 2009). This protocol may be adapted or modified to monitor all shoreline types and lengths.

Pre-Survey Shoreline Characterization

Before any sampling begins, shoreline characterization should be completed for each 100m site. Each survey site should be measured and marked for accuracy and repeatability using a surveyor's measuring wheel. This includes recording GPS coordinates in decimal degree format (nnn.nnnn N/W) at the start and end of each 100m segment. If shoreline width is greater than 6m, GPS coordinates at all four corners of the shoreline section may be possible. Additionally, a shoreline ID should be created based on the initials of the shoreline name (ex. Fort Smallwood = FS).

Shoreline characteristics and surrounding land use characteristics (*e.g.* primary land use, nearest town, nearest river, etc.) should also be noted on the datasheets prior to sampling. Shoreline characteristics include identification and uniformity of the primary substrate type (sand, cobble, etc.), if applicable the tidal range and distance, a description of the first barrier at the back of the shoreline section (dunes, vegetation, etc.), and the aspect of the shoreline. Unless major changes occur to the shoreline, shoreline characterization only needs to be completed once per site per year.

Density Survey Methodology for Macro-Debris (>2.5cm)

In order to analyze the maximum width of the shoreline section, sampling needs to be conducted at low tide. Before arriving on site, surveyors should select four numbers from the random number table to eliminate any bias from visual inspection of the shoreline section. These four numbers correspond with four transects of 5m in width that will be sampled that day within the shoreline section. Transects run perpendicular to the shoreline section from water's edge at the time of sampling to the back of the shoreline (Figure 1). The back of the shoreline is defined as where the primary substrate changes or at the first barrier. The number of transects chosen for each sampling event correspond with a twenty percent coverage of the shoreline section. Thus, on any sampling day 20m of the 100m shoreline section is analyzed for debris. In order to analyze for seasonal and inter-year variation in debris densities, shoreline sections should be revisited quarterly with random 5m transects selected at each sampling event.

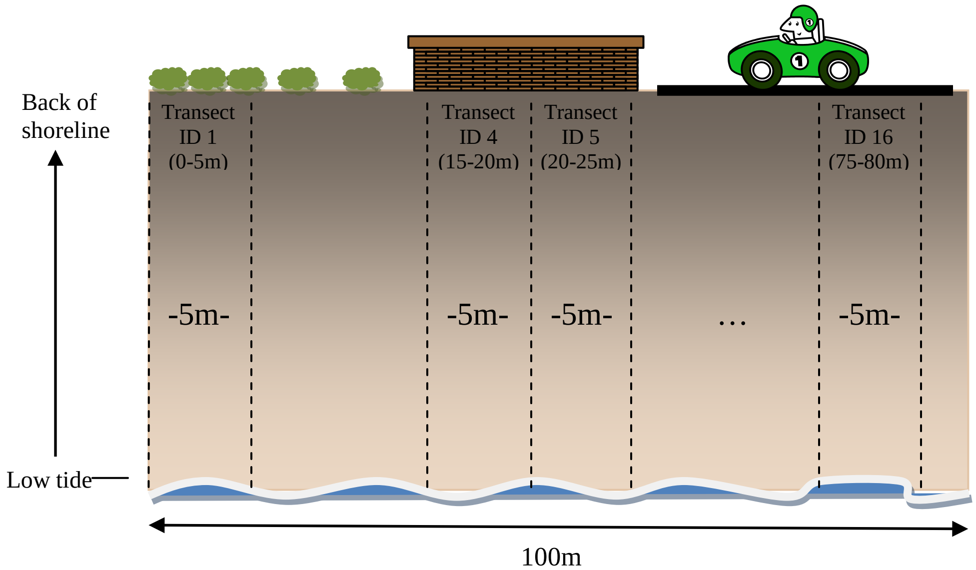

Figure 1. Shoreline section (100m) displaying perpendicular transects from water's edge at low tide to the first barrier at the back of the shoreline section.

Once arrived on site at low tide, surveyors can use the surveyor's measuring wheel to mark the selected transects with flags and record GPS coordinates in decimal degree format. Depending on the width of the shoreline section, the coordinate information can be recorded either at one point in the middle of each transect (shoreline width <6m) or at two points at the water's edge and back of each transect by the first barrier (shoreline width >6m) (Figure 2). This designation is due to the error associated with handheld GPS units. Additionally, for each transect surveyors should record ancillary data which include the length of each transect from water's edge to first barrier, the time, season, date of last survey, description of recent storm activity, current weather conditions, and the number of individuals conducting the transect survey. For each sampling event, transect ID numbers should be recorded as follows: State initials_Shoreline ID_year-month-date_transect number (Ex. MD_FS_2010-01-07_1).

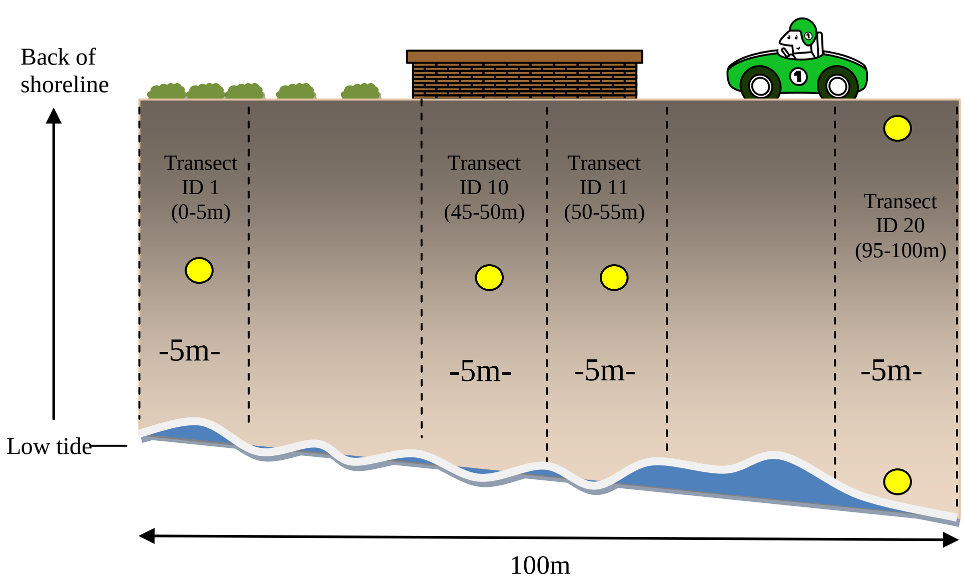

Figure 2. Example of a shoreline section (100m) with yellow circles indicating marked GPS coordinates. Width determines location of GPS coordinates.

Once ancillary data are complete, surveyors should walk each transect tallying debris items according to material type and subcategory (see appendix) that are greater than or equal to 2.5cm in size on the longest dimension (Figure 3). This standard length (approximately bottle cap size) was chosen to ensure that surveyors count the same size items and for maintaining consistency in survey results. Items that are found on the survey that do not fall under a specific subcategory can be entered into the other category at the end of each material section. If a surveyor is unsure of a material item, the unknown can be placed in the other/non-classifiable category at the end of the sheet with a brief description of the item. Pictures should be taken of unidentifiable items, as well as other debris items of interest.

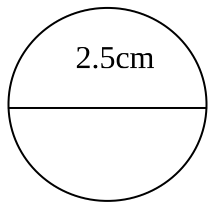

Figure 3. Minimum debris size to be counted

For large items such as nets (those larger than 30cm; approximate forearm length-base of palm to elbow) and vessels, a separate data sheet should be used. Nets that are shorter than 30cm should be counted in the plastics or cloth/fabric category and not entered with the large items. If any part of the item is within the sample transect, it should be included. Information recorded should include the status of the large item (sunken, stranded, or partially buried), the latitude and longitude of the item, as well as the approximate debris size. This information is important in determining the footprint of large debris items.

During data analysis, density (number of debris items/m^2) for macro-debris items should be calculated as follows:

$D = n / (w \times l)$

- n = # of macro-debris items observed
- w = width (m) of shoreline section recorded during sampling
- l = length (m) of shoreline = 100m (unless stated otherwise)

Sampling for Micro-Debris Items (≤5mm)

If the sample location is primarily sandy beach, surveyors should collect random sand samples in each sampled transect for micro-debris analysis. To do so, surveyors should randomly place a $1m^2$ quadrat within a sampled transect by selecting a number from the random number table. The placement of the number on the random number table determines location of sample. For example if random number 7 was chosen, the placement of the quadrat would be on the right side of the transect in the wrack line). After removing any pieces of debris from the surface that are larger than 2.5cm and which were counted in the transect survey, surveyors should collect the top 3cm of sand using a small stainless steel shovel from a sixteenth of the quadrat ($0.0625m^2$). This can be done by dividing the quadrat in fourths and then dividing one of the quarters into fourths (Figure 4). The collected sand should be sieved through a stainless steel 5mm mesh sieve with a bucket underneath to collect the two size fractions (those debris items <5mm and those >5mm). If the sand is wet, the sample may need to be rinsed with pre-sieved water to facilitate sieving. Separate size samples should be placed in labeled amber glass jars using a funnel and returned to the lab where they can be identified and counted under a microscope if necessary. This process should be repeated for each of the four sampled transects.

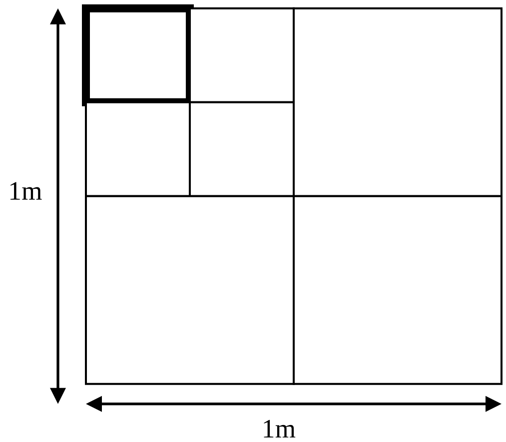

Figure 4. Randomly placed $1m^2$ quadrat with area of sand to be sieved ($0.0625m^2$) in bold.

During data analysis, density (number of micro-debris items/m^3) for micro-debris items should be calculated as follows:

D = n / (a x h)

- n = # of micro-debris items observed
- a = area sampled = $0.0625m^2$
- h = depth of sample = 0.03m

Quality Control

To ensure surveyors are recording all of the appropriate sized debris items within a transect, a second surveyor should conduct a quality control estimate by reassessing a transect BEFORE the collection of the random sand sample. This should be done for 20% of the samples per site (Ex. One site if visited quarterly will have a total of 3 QA/QC samples). Reported values should be within 30%.

II. Pelagic Trawl Methods

Introduction to Pelagic Surface Water Sampling Methods

Floating marine debris has been unofficially noted by research vessels since the 1970's and perhaps earlier. However, few systematic surveys have been conducted throughout the oceans to develop a cohesive understanding of the extent and degree of pollution from floating marine debris. Coastal and oceanic pollution is perhaps most notable nearshore, but no standard exists for determining debris densities in nearshore or offshore environments. Without a standard method for assessing and reporting debris densities, true comparisons of the extent of pollution are not possible. These comparisons are necessary to determine debris hotspots, which will eventually allow researchers and policymakers to work together to understand and address the most polluted areas in a timely manner.

It is the goal of this project to develop standardized methodologies for assessing the amount of floating anthropogenic debris in coastal waters. As with most scientific methods, one procedural standard will likely not fit the myriad of physical environments and coastal habitats present globally, but these methodologies will serve as a baseline starting point that may be slightly changed to suit varied field conditions. While developing these methods, care was taken to ensure that potentially small adjustments could make these methodologies applicable to offshore assessments as well. Also, it is the hope of the authors to identify appropriate monitoring programs that are in the practice of doing similar surface trawl studies in order to leverage data from ongoing projects.

Background Research

Floating debris has been documented across the world in the open ocean and in coastal waters. However, this has been done in a fairly ad-hoc manner, with many word-of-mouth reports, occasionally a scientific expedition that also includes some form of floating debris sighting surveys, and rarely a scientific expedition dedicated to collection and quantification of floating marine debris samples. The goal of this work is to provide insight into development of a robust sampling scheme for scientific expeditions to survey coastal waters, as well as potentially offshore waters, in a standardized manner. Also a goal is the intention to provide information that can be used by organizations that routinely use similar surface trawl techniques to (1) standardize collection and assessment methods, with perhaps only slight modifications to existing protocols, so that results may be comparable among coastlines and global oceans, and (2) increase the amount of marine debris data that can be leveraged from tangentially-related organizations and projects.

Sources of floating marine debris in the oceans can be difficult to determine. Often sources fall into one of four categories: (1) larger pieces from land-based runoff or actual release; (2) larger pieces from ocean-based dumping or accidental release; (3) smaller pieces that result from the degradation of larger marine debris in the environment; and (4) small debris, for example, micro- and nano-plastics used in consumer products that are made to enter the waste stream and are likely discharged with wastewater. Obtaining data on the direct sources of marine debris can be difficult. For example, source in the open ocean cannot be attributed to manufacturing origin or country of likely consumption, which can occasionally be determined based on writings and symbols and object identification, because there is no way to know the exact point-of-loss. Occurrence data is somewhat easier to procure, but often does not have the power of peer review. Also, much occurrence information from the open ocean is documented from marine debris sighting surveys where debris in a vessel's path is tallied but is not collected for quality control of the sighted objects.

This study identified and evaluated the few known studies that have performed robust field sampling of surface waters for marine debris. The studies were informally evaluated for robust field procedures, and the methods outlined in the next section reflect input from these studies.

Historically, the first surface water trawls conducted and subsequently published in peer-reviewed literature were described by Carpenter *et al.* (1972) in the early 1970's. Since then efforts to monitor oceanic marine debris have been ad-hoc and have not been sustained long-term.

The earliest efforts often were in conjunction with other planned pelagic sampling projects. Carpenter *et al.* (1972) used oblique plankton tows with a reference net, 0.5 m diameter with 0.333 mm mesh, and a flowmeter attached to the net mouth to record volume of water sampled during the plankton tows. Further analyses on the plastic particles were completed, including determination of bacterial, polychlorinated biphenyl, and polymer content of the particles. In a separate study, Carpenter and Smith (1972) sampled *Sargassum* in pelagic surface waters of the Sargasso Sea with 1 m long, 0.33 mm mesh neuston nets. Samples were manually sorted for plastic debris, weighed, and investigated to determine condition and presence of attached organisms. A couple of years later, Colton *et al.* (1974) published compelling results of widespread plastic pollution from MARMAP ichthyoplankton surveys in the North Atlantic from Cape Cod to the Caribbean. A neuston net, 2x1 m with 0.947 mm mesh, sampled surface waters for 10 min at 5 knots. Colton *et al.* (1974) provide perhaps the only discussion of sampling bias based on the larger net mesh size used and vessel speed of 5 knots.

Day and Shaw (1987) collected data on large debris (>2.5 cm) by conducting visual transects in the North Pacific Ocean and data on smaller debris by conducting horizontal surface tows with a 1.3 m long, 0.33 – 3.0 mm mesh ring net used as a neuston sampler for 10 min at an average speed of 5.6 km/h. This project re-sampled an area of the North Pacific that had been previously investigated for large plastics a year previously and for small plastics nine years previously. However, it was not noted that all methods were standard among sampling efforts so it is uncertain if data are directly comparable. Plastics were sorted, dried, and weighed. This study provided the first published temporal and spatial analysis of plastic in the North Pacific.

More recently, Thompson *et al.* (2004) determined plastic fragment concentrations in archived samples collected with a continuous plankton recorder, at 10 m depth, onto 0.280 mm mesh. A time series from the 1960's to 1990's was investigated, using microscopy and Fourier Transform Infrared Spectroscopy (FT-IR) to characterize the plastic fragments found. Yamashita and Tanimura (2007) investigated floating plastic in the Kuroshio Current near Japan by conducting surface water tows using a 3 m long neuston net with 0.33 mm mesh for 10 minutes at a speed of 2 knots. Moore *et al.* (2001, 2002) also investigated floating plastic concentrations in the Pacific, but use a 3.5 m manta net with 0.33 mm mesh and vary the distance covered. The advantage of this net is the two paravanes that attach to the frame and allow the net mouth to skim the surface of the water and was first described by Brown and Cheng (1981).

The longest time series of debris data comes from the Sea Education Association, which has approximately 22 years of data from a summer sampling effort each year in the North Atlantic Ocean. These data have not yet been published in a peer-reviewed format, but some preliminary findings were recently presented (Law *et al.* 2010, presentation). The method uses neuston nets with 0.33 mm mesh for up to 30 min to conduct plankton tows in surface waters (Law *et al.* 2010, presentation). Another long-running plankton survey, the California Cooperative Ocean and Fisheries Investigations (CalCOFI), have approximately 50 years of archived plankton samples. Recently marine debris has been investigated in some new and archived surface water plankton tow samples, using a manta net equipped with 0.505 mm mesh for 15 min at a speed of 0.5-0.75 m/s (Gilfillan *et al.* 2009). A flowmeter was attached to the mouth and debris was recorded in number per volume of water filtered, or density. This is preferred to reporting number per area, as different sampling methods – for example, obtaining water samples in cylinders at depth or obtaining debris density estimates on beaches or in sand and sediments – will also report number per volume.

Each of these studies informed the methods outlined below. In order to encourage participation in future marine debris sampling efforts by organizations that do similar plankton and at-sea sampling, the parameters listed below are suggestions that should be relatively easy to implement. Standardization of tow times, tow speeds, and the method of towing are key elements that will allow for the maximum amount of comparison among studies conducted in surface waters close to shore or in the open ocean. Please note that our sampling efforts were only conducted in nearshore waters. Also extremely important is the reporting unit, with count per volume giving the most accurate densities. This is a departure from most historic and present-day conventions, but is commonly used in marine plankton studies, is fairly simple to obtain, and allows for comparison of debris densities in other matrices such as sand and sediments.

Equipment

The following equipment is suggested to perform surface trawls for floating marine debris:

- Nautical charts
- Digital camera
- Hand-held GPS unit
- Extra batteries (rechargeable)
- Manta net
- Detachable cod end (+ one spare)
- Bridle for manta net
- Weights to attach to frame, if in offshore or choppy waters
- Flowmeter
- Stopwatch
- Squirt bottles
- 5 gallon buckets
- 5mm stainless steel sieves
- Digital calipers, ~6”

- First aid kit (sunscreen, bug spray, etc.)
- Work gloves (cotton / rubber / leather) for hauling the net
- Latex (or appropriate alternative) for handling the sample
- Stainless steel forceps, 6", angled tip, for picking out larger debris items
- 32 oz. (~1 L) amber glass sample bottles
- Wide-mouth funnel (stainless steel) to fit mouth of sample jars
- Clipboards
- Datasheets on waterproof paper
- Waterproof labels in jars, pre-labeled and inserted into jars prior to trawls
- Pencils
- Permanent markers
- White trays, 12" square (or equivalent) for sorting debris
- Stainless steel spatula, ~8" in length, with tapered and rounded ends for sorting debris

Site Selection

Previous studies have shown a wide variety of marine debris amounts and types in coastal and oceanic waters. However, few studies have re-sampled an area in a statistically valid way, so spatial and temporal comparisons are very difficult. This makes it also difficult to determine which environmental factors, or covariates, are the most important in determining debris density in surface waters.

Therefore, to provide a statistically robust dataset, selected sites for coastal surface water sampling should be stratified by land use (*e.g.*, urban, rural) associated with nearby shorelines, by fishing activities, and by storm water or sewage outfalls where possible and selected randomly from each stratum. Additionally, sites should have the following characteristics:

- Direct, seasonal or year-round access, depending on location
- Within one mile from shore
- No stationary or transient in-water barriers to ship transect path
- Preferably areas that have not seen recent changes in hydrographic patterns
- Stratified by land use into

These characteristics should be met where possible, but should be analyzed on a case-by-case basis and modified if appropriate for a particular region/location. This protocol may be adapted or modified to monitor all shoreline types and lengths.

Pre-Survey Site Characterization

Before any sampling begins, shoreline characterization should be completed for each 100m site. See above section for more information. This should be completed before any in-water sampling at a site.

It is ideal to complete a survey of the surrounding surface waters before any sampling begins. The ID created for each shoreline site should also be used for accompanying in-water surveys. Any pertinent information on hydrography and in-water barriers should be described in the "notes" section of the shoreline characterization datasheet.

Surface Water Trawl Survey Methodology

Current bathymetric maps should be obtained for the area within two nautical miles of the chosen shoreline site. Chose several potential sites for trawls based on ease of access and strata described above. Approximately ten transects should be identified and numbered. Select numbers from a random number table to determine which transects will be sampled. At least three transects should be completed within two nautical miles of the accompanying shoreline site (Figure 5). This should be done before arriving at the site. On the day of sampling, or one day before, review and fill in the appropriate ancillary data on the pelagic debris datasheet. Each trawl transect will have a unique identification for labeling purposes, in the following format: State initials_Shoreline ID_year-month-date_transect number (Ex. MD_FS_2010-01-07_1).

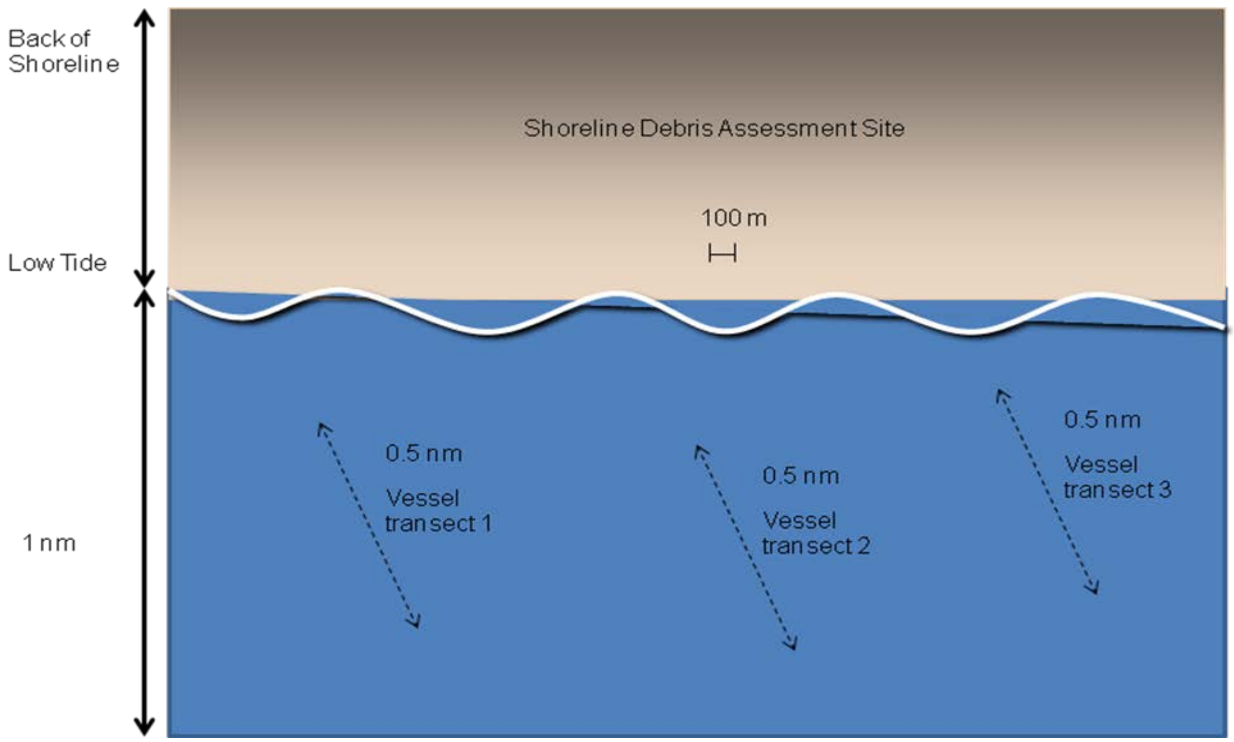

Figure 5. Shoreline and pelagic sampling will be coordinated so that the pelagic trawl transects occur within two nautical miles of the shoreline assessment sites. Three trawls, each approximately 0.5nm, will be conducted at each site.

All ancillary and pre-trawl data should be completed on one datasheet per trawl. GPS coordinates should be recorded in degree decimal format at the beginning and ending point of each trawl transect. However, if obstructions are present in the area and require a curvilinear vessel path, GPS coordinates should be recorded when the vessel changes its heading (Figure 6).

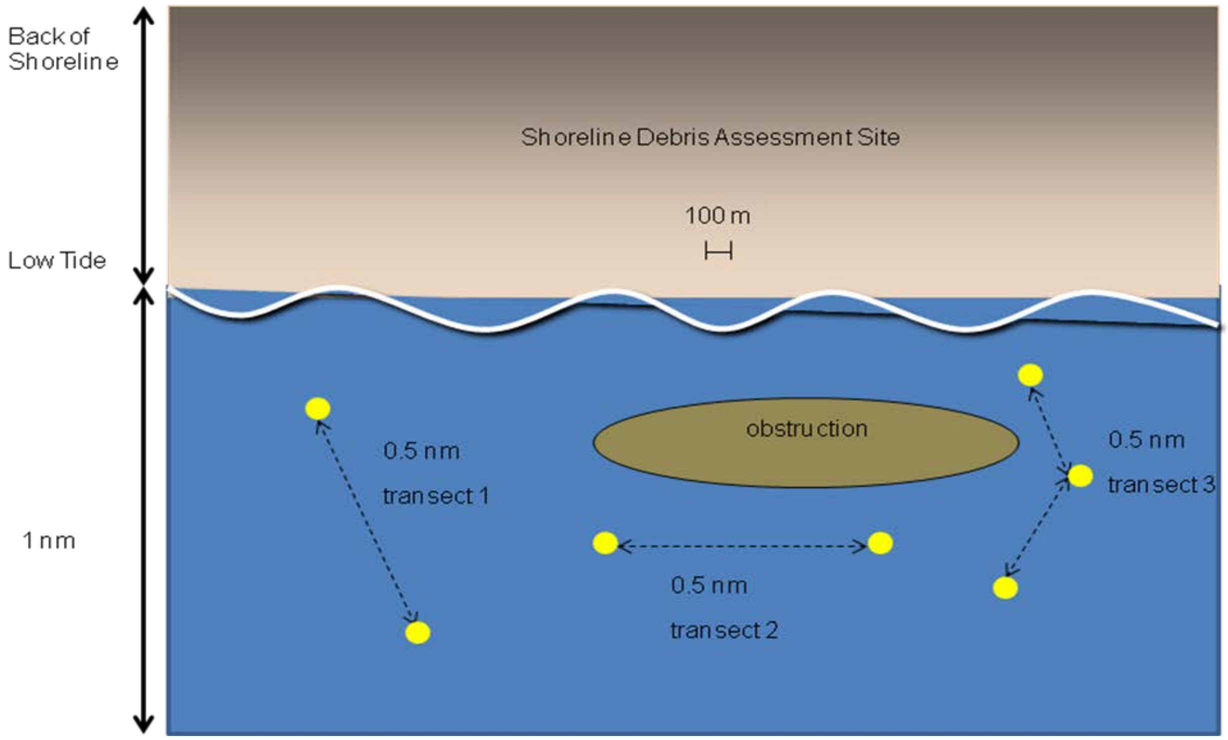

Figure 6. Pelagic sampling will occur within two nautical miles of the shoreline assessment site. Yellow circles represent points at which to note GPS coordinates. For example, if obstructions are present, it is necessary to take GPS coordinates whenever the vessel changes heading and not only at the beginning and end of each trawl transect.

All transects should follow the same methodology. A manta net, with a body composed of 0.330mm nylon mesh and measuring approximately 3m in length, is towed horizontally at the surface (Figures 7 and 8). Depending on sea state, weights are added to the bridle to ensure balanced coverage of the surface waters. Alternately, weights can be added to a tow line that connects the bridle to the winch line.

A digital or analog flowmeter is attached to the net frame and suspended in the center of the net mouth. The initial flowmeter reading is taken just prior to deployment of the net apparatus; this reading should not change before placement in the water. A swivel connects the tow rope to the manta net bridle, which is offset so that one side is slightly longer than the other. A buoy is attached to the net for safety purposes. The net is deployed from the back or the side of the vessel, with enough slack on the winch line to allow the net to smoothly skim the surface of the water and completely avoid the vessel's wake. The two side paravanes should be at or above the water's surface. This may require securing the winch line from the A-frame to a cleat on one side of the stern. An angle of approximately 20 degrees between the line of the vessel and the net is desirable for minimizing interaction with the vessel wake. The shorter side of the bridle should be closer to the vessel to assist in obtaining the correct angle. The trawl is deployed for a total in-water time of 15min at a speed of 1-2 knots. The in-water time should include any deployment and retraction time when the net is submerged in the water and the flowmeter is recording volume.

During the trawl, vessel speed and tow rope length should be adjusted to ensure the net is properly skimming the surface away from the vessel wake. While watching the net, note any large debris items that initially are funneled into the net and then escape. These should be detailed, per site, on a large debris datasheet.

At the end of the trawl, the flowmeter reading is recorded as soon as the net is retracted into the vessel. Contents of the net are gently washed, from the outside, into the cod end with seawater. The cod end is detached, and its entire contents are washed with seawater into glass sample jars for transportation to the laboratory. Large debris items, approximately >20cm, should be counted on a separate large debris datasheet for each site and then discarded appropriately. All other trawl contents are kept in glass jars for further analysis. Jars should be labeled with the site ID, transect number, and date. Obvious large natural items can be discarded, but recorded on the datasheet. Photos should be taken of the process throughout, especially the cod end contents at the end of each trawl.

In the laboratory, the sample is sieved through two screens (5mm, 0.33mm) to collect debris items. Sort sieved samples by size class into glass sample jars for counting and identification. Two size fractions (x > 5mm), and (5mm > x > 0.33mm), remain. The larger size fraction, or macro-debris, should be sorted by material category and tallied on debris datasheets. The smaller size fraction, composed of micro-debris, should be stored in seawater and frozen upon returning from the field. Further laboratory methods include a more thorough washing with salt or freshwater, sorting out obvious pieces of natural debris, drying the total sample, and tallying obvious debris on debris datasheets. Calipers should be used to measure all visible macro- and micro-debris items. Each trawl should be tallied on a separate datasheet. Analytical methods are currently in development to analyze plastic polymers in water, sediment, and sand samples.

During data analysis, volume of water filtered can be determined with equations that will vary based on the type of flowmeter used. In general, the distance in meters is calculated per transect by subtracting the initial and final readings of the flowmeter and applying a correction factor specific to the flowmeter. Distance is then multiplied by the area of the net mouth to determine a volume:

D = (flowmeter final – flowmeter initial)*(correction factor)

V = (mouth width)*(mouth height)*(distance traveled)

The density (number of debris items/m^2) for macro-debris and micro-debris items should be calculated as follows:

D = n / V

- n = # of micro-debris items observed
- V= volume of water filtered

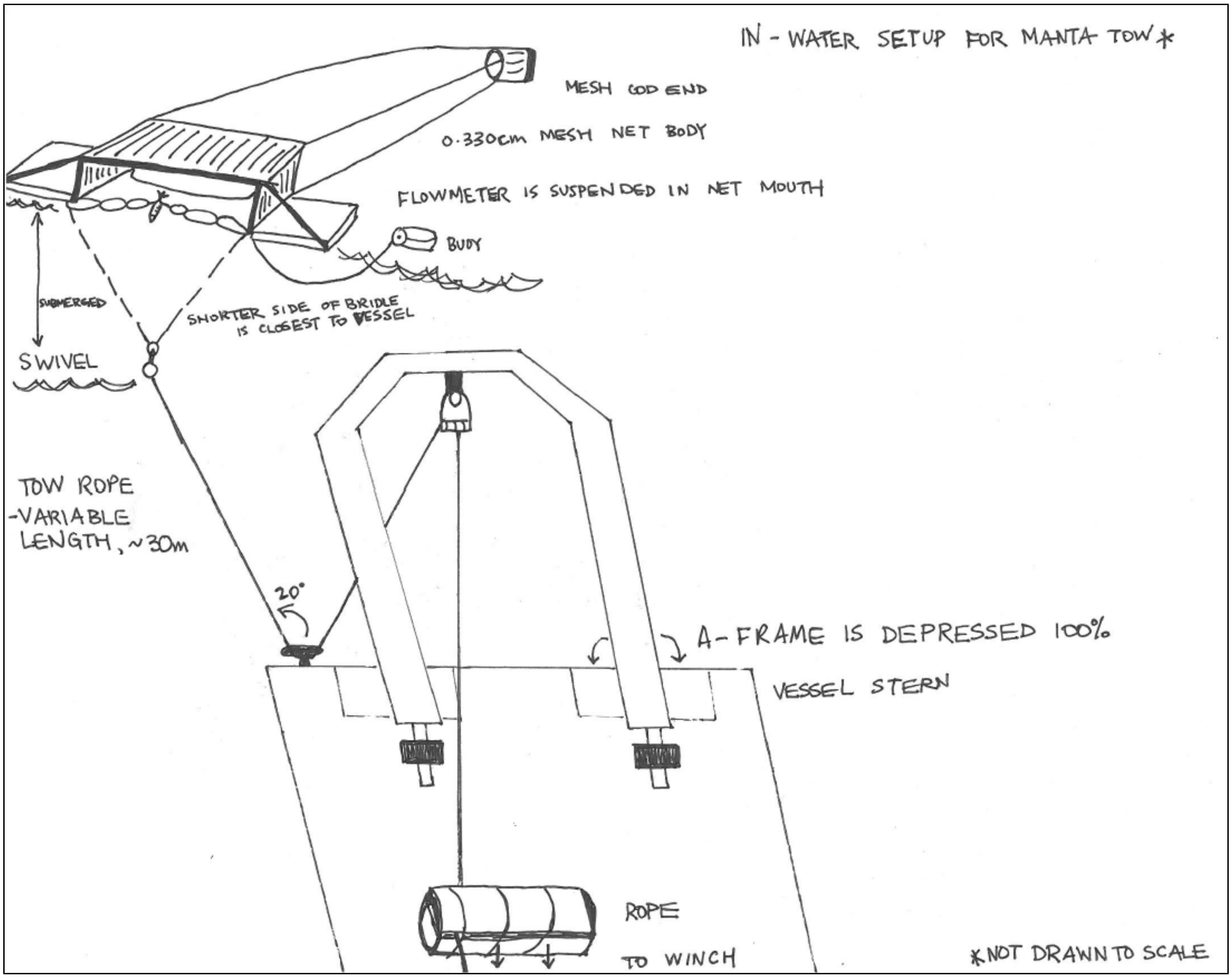

Figure 7. In-water setup for a manta tow (this drawing is not to scale). The vessel shown has an A-frame at the stern that is fully depressed, that supports a tow rope that is cleated so that the angle between the vessel and the net is approximately 20 degrees to minimize any interaction with the vessel's wake. To this end, the shorter side of the bridle should be closer to the vessel.

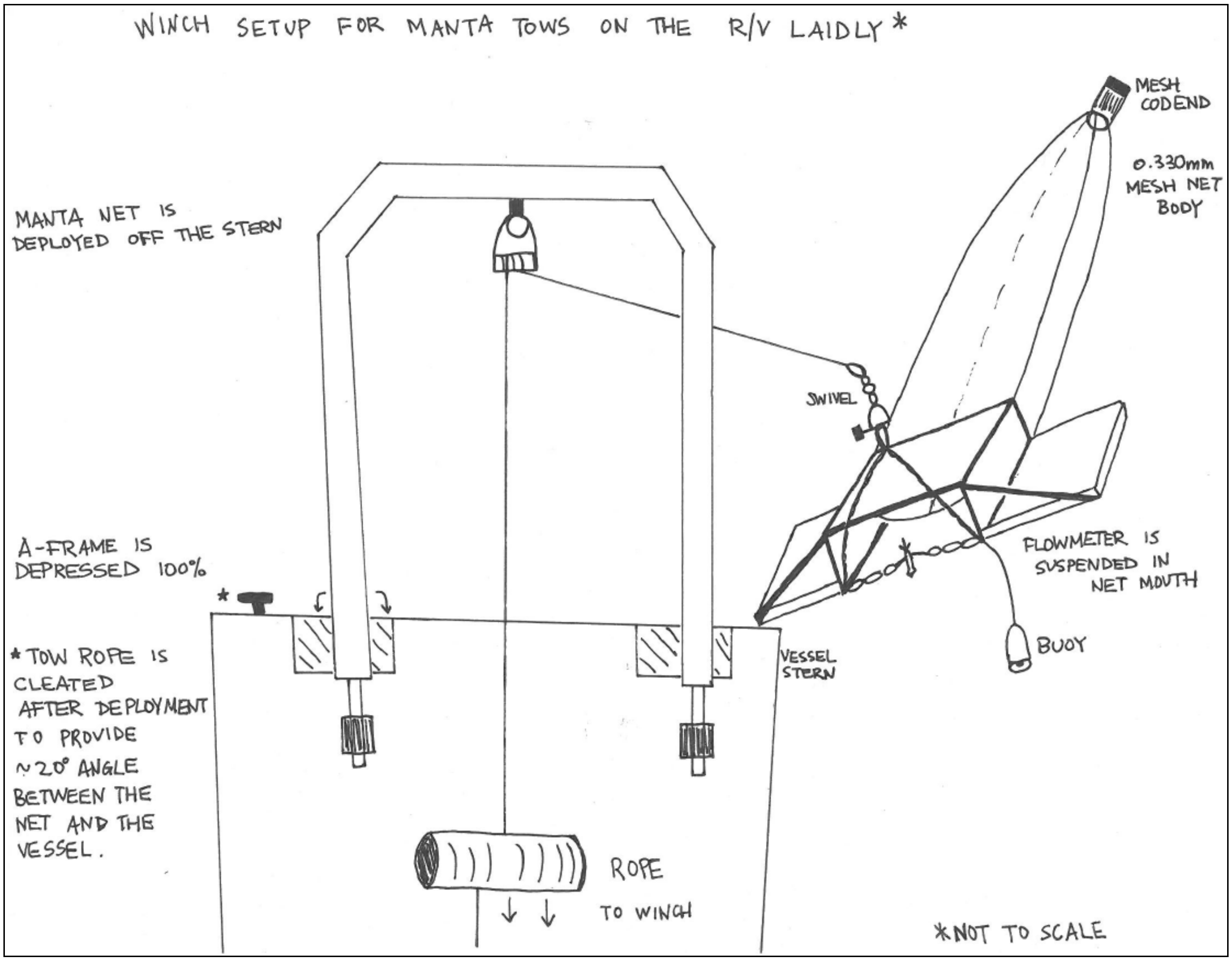

Figure 8. Winch setup for manta tows on the R/V Laidly (this drawing is not to scale). The tow rope is suspended at the A-frame, which is fully depressed. A swivel connects the tow rope to the manta net bridle. A buoy is attached to the net for safety purposes.

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