MARYLAND SYNOPTIC STREAM CHEMISTRY SURVEY: A COMPARISON OF STREAM CHEMISTRY BETWEEN ROUND 1 (1987) AND ROUND 2 (2012)

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April 2014

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ACKNOWLEDGEMENTS

This report is the brainchild of Ron Klauda and others at Maryland DNR who saw an opportunity to investigate change in the acid/base chemistry of Maryland's streams over 25 years. We are indebted to him and the hard work and dedication of the volunteers who collected data in Round 1 of the MSSCS (1987) and the MBSS field crews who collected data in Round 2 of the MSSCS (2012). We thank Keith Eshleman, Elgin Perry, Sujay Kaushal, and John Sherwell for their review and comments on the draft report.

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ABSTRACT

The acid/base status of freshwater streams can have important implications for the biological populations that inhabit them. Historically, acidic deposition (commonly called acid rain) has been one of the major sources of stream acidity in natural water bodies. With the establishment of the Acid Rain Program (ARP) under Title IV the Clean Air Act in 1990, Congress limited power plant emissions of the two types of compounds that contribute to acid rain: sulfur dioxide and nitrogen oxides. Prior to the establishment of ARP, the Maryland Department of Natural Resources (MDNR) undertook a synoptic survey in 1987 of stream chemistry to evaluate the acid status of Maryland streams. This 1987 survey found that many miles of Maryland streams were acidic or acid sensitive, especially in the Appalachian and Southern Coastal Plain regions. On the 25th anniversary of this survey, 2012, MDNR resampled 197 of the original 625 sites from the 1987 survey to determine if the acid status of these same streams had changed in the years following the Clean Air Act Title IV amendment. Sites sampled in 2012 were spread across Maryland's Appalachian Region and Southern Coastal Plain. Parameters measured during both surveys include acid neutralizing capacity (ANC), pH, conductivity, dissolved organic carbon (DOC), and dissolved inorganic carbon (DIC). Across the 2012 study area, as well as on a regional basis, streams had higher ANC and higher pH (both indicating lower acidity) during 2012 compared to 1987. DIC also increased between 1987 and 2012. Negligible changes were evident for conductivity and DOC. Streams can be categorized into four acid categories based on their ANC values: Acidic, Highly Sensitive, Sensitive, and Not Sensitive. Across the 2012 study area, the percentage of stream miles decreased for the Acidic (10.4% to 6.6%) and Highly Sensitive (15.0% to 10.2%) categories, increased for the Not Sensitive category (39% to 47.6%), and did not change for the Sensitive category between 1987 and 2012. Overall, comparison of data from Maryland's synoptic stream chemistry surveys of 1987 and 2012 showed a reduction of acid levels in the state's non-tidal streams over this 25-year period

1 INTRODUCTION

The 2011 report to Congress from the National Acid Precipitation Assessment Program (NAPAP) described the latest scientific information and analyses associated with the costs, benefits, and environmental effectiveness of the Acid Rain Program (ARP)—a bipartisan mandate under Title IV of the 1990 Clean Air Act Amendments (CAAA) (Burns et al. 2011). The goal of Title IV was to reduce sulfur dioxide and nitrogen oxide emissions from electric generating stations. The 2011 NAPAP report to Congress focused on emission reductions, summarized changes in sulfate and nitrate deposition rates and associated environmental impacts, and evaluated the ecological effects expected from future reductions in sulfur and nitrogen emissions.

Burns et al. (2011) concluded that Title IV has successfully reduced emissions from power generation since it was enacted in 1990. Concomitantly, wet sulfate deposition, a major component of acid rain, was 42% lower in 2008-2009 in the mid-Atlantic region compared to 1990 deposition rates. Wet inorganic nitrogen deposition, another major component of acid rain, has also decreased since 1990, but less than sulfate deposition because of the continuing contribution of nitrous oxides from motor vehicles. Motor vehicle and other sources of sulfur and nitrogen emissions are not covered by the ARP. These emission and deposition reductions have contributed to measurable improvements in air quality, the beginnings of recovery in many acid-sensitive lakes and streams, and improvements in human health and visibility.

Several factors may contribute to acidic surface waters including acidic deposition, acid mine drainage (AMD), agricultural runoff, and natural organic materials. Acidic deposition comes from the atmosphere in the form of precipitation and particulates, and is associated with higher concentrations of sulfate and nitrate in the precipitation. Acid mine drainage arises from the oxidation of iron and sulfur from mine spoils and abandoned mine shafts, and may cause extreme acidification in surface waters. If strongly affected by acid mine drainage, streams will have high levels of sulfate, manganese, iron, and conductivity. Agricultural runoff high in nitrogen fertilizers and other acidifying compounds provides a third source of acidification. Lastly, the natural decay of organic materials may contribute acidity in the form of organic anions, as in blackwater streams associated with bottomland wetlands. Streams with organic sources of acidity are often characterized by high concentrations of dissolved organic carbon.

To determine if levels of acid neutralizing capacity (ANC), a chemical indicator of the ability of a lake or stream to neutralize acid inputs, have improved in Maryland streams, the Department of Natural Resources (MDNR) repeated the Maryland Synoptic Stream Chemistry Survey (MSSCS) of 1987 (Knapp and Saunders 1988) on its 25th anniversary in 2012. The goal of the 2012 survey was to obtain a measure of change in the extent of acidified and acid-sensitive streams in Maryland after 25 years. Sampling for the 2012 MSSCS was limited to the most acid-sensitive regions: Appalachian Region (AP) and Southern Coastal Plain (sCP). In 1987, 139 sites were sampled in the AP and 99 in the SCP using a probability-based design. In 2012, 116 of the original sites were randomly selected and resampled within the same reach in the AP. 81 sites were resampled in the SCP (Figures 1-1 and 1-2).

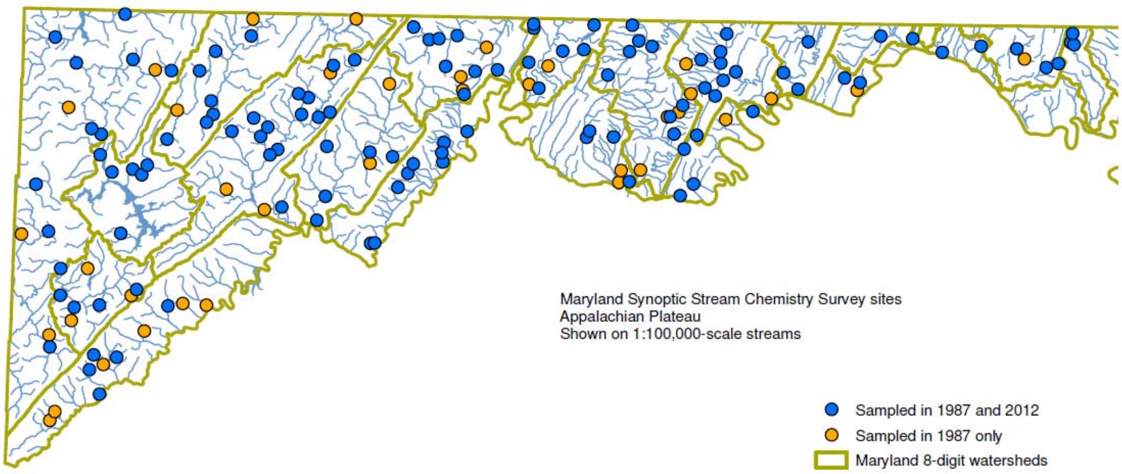


Figure 1-1. 2012 MSSCS sample sites in the Appalachian Region (1987 MSSCS sites not sampled in 2012 are shown in orange)

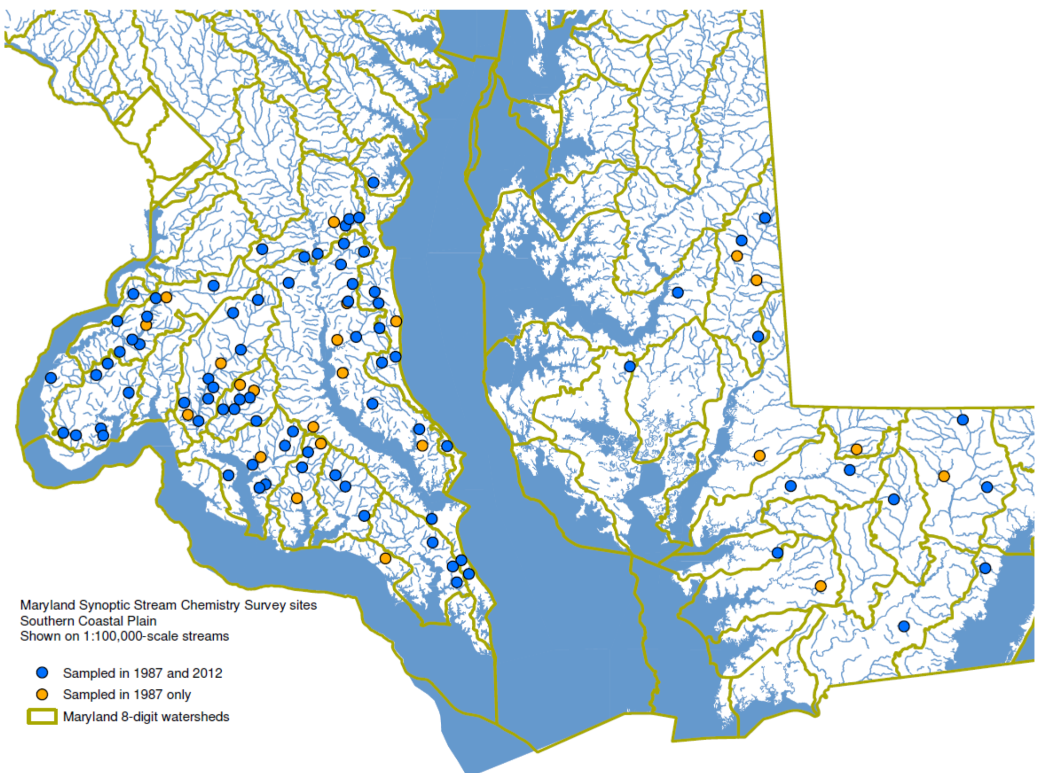


Figure 1-2. 2012 MSSCS sites in the southern Coastal Plain (1987 MSSCS sites not sampled in 2012 are shown in orange)

The MSSCS measured six water quality parameters during both surveys: Acid neutralizing capacity (ANC), pH, conductivity, dissolved organic carbon (DOC), and dissolved inorganic carbon (DIC; Table 1-1). Ranging from 0 to 14, pH is a unitless measure of the hydrogen ion concentration in a solution. A pH value of 7.0 is considered neutral. As the value of pH decreases below 7.0, the stream is considered to be more acidic while conversely, as the value of pH increases, the stream is considered to be more basic or alkaline. ANC (µeq/L) is a measure of the buffering capacity of the stream water against acidification. This measure has a wide range of possible values for which four categories have been developed (Table 1-2). Conductivity (µS/cm or microsiemens per centimeter) measures the ability of a solution to pass an electrical current. Conductivity in streams is mainly affected by the geology of the area through which the stream flows, and this value can be influenced by the concentration of dissolved inorganic anions (e.g., chloride, nitrate, phosphate) or cations (e.g., sodium, calcium, or iron) that the stream bed may confer to the stream water. DOC (mg/L) is a measure of the organic acidity in the stream and can be indicative of the chemistry in blackwater streams. Blackwater streams are naturally acidic (typically pH < 6) and slow moving, often having a gradient of less than 1%. Occurring in the Pocomoke and Nanticoke/Wicomico basins of the Coastal Plain of Maryland, blackwater streams tend to accumulate organic matter due to their slow moving nature and high rates of organic decomposition, leading to levels of DOC greater than 8 mg/L. Therefore, DOC and pH values can be interpreted together to distinguish clearwater from blackwater streams, the latter having higher acidy as a result of natural, autochthonous processes. Like DOC, measurements of dissolved inorganic carbon (DIC) and color can help identify those stream reaches where acidity may be derived from sources other than atmospheric deposition. DIC and DOC measurements are also useful as Quality Assurance and Quality Control parameters to assist in the interpretation of pH, ANC, and conductivity data. There were five parameters—chloride, nitrate-nitrogen, sulfate, total nitrogen, and total phosphorus—measured during the 2012 survey that were not measured in 1987. Elevated levels of sulfate may be indicative of acid mine drainage or atmospheric deposition. Increased levels of nitrate-nitrogen, total nitrogen, or total phosphorus could point to agricultural sources of acidity. As these variables are regularly sampled across the state by the Maryland Biological Stream Survey (MBSS), they were included in the 2012 MSSCS sampling to augment the MBSS database. Although color was sampled during both 1987 and 2012, the analytical test for color is highly subjective and dependent upon the observer conducting the test; therefore, we did not make comparisons between color results in 1987 and 2012.

Numerous factors could potentially influence our interpretation of changes in these stream chemistry variables. Land use changes between survey years and climate variables, such as temperature and rainfall, may have differed between the two surveys. The original MSSCS employed volunteers who collected water samples on weekends, so baseflow conditions were not a prerequisite of sampling; however, no samples were taken in the two regions after very large rain events. In 2012, DNR employees used detailed weather forecasts to avoid sampling after large precipitation events that might confound comparison of the two surveys. Temperature can affect water chemistry by increasing the level of acidity in the water. To reduce differences in the sampling period temperatures between 1987 and 2012, the degree days were calculated for both time periods. Based on thresholds outlined in the MBSS Sampling Manual (Stranko et al. 2014), sampling should occur before an accumulated 440 degrees for the Coastal Plain and 1050 degrees for the rest of Maryland. In 1987, this meant sampling occurred in March for the sCP and May for the AP. While sampling began in the sCP in March in 2012, calculations determined that 2012 was much warmer than 1987, so the AP was sampled in April instead of waiting until May. We compared weekly temperature and rainfall during the time period of the survey for each year. Sampling dates in 2012 were also chosen to occur during a period when rainfall was similar to patterns experienced during the 1987 survey. In 2012, sampling was limited to the range of flow conditions experienced in 1987. In 1987, precipitation occurred on two sampling dates (one sample date each in AP and sCP), with maximum rainfall measuring no more than 0.2” on the day of sampling. Two sampling dates in 1987 occurred on days following a rainfall event. One AP sample date occurred 4 days after a 0.8” rain event and one sCP sample date occurred 3 days after a 0.4” rainfall event. In order to match 2012 sampling conditions with those experienced in 1987, sampling in 2012 was avoided on (1) days when it rained more than 0.2” and (2) on days less than 72 hours after a rainfall of more than 0.5”.

Table 1-1. Water quality parameters measured in the 1987 and 2012 MSSCS

Parameter	1987	2012
Acid Neutralizing Capacity (ANC)	X	X
pH	X	X
Conductivity	X	X
Dissolved Organic Carbon (DOC)	X	X
Dissolved Inorganic Carbon (DIC)	X	X
Color	X	X
Chloride (Cl)		X
Nitrate-Nitrogen (NO3-N)		X
Sulfate (SO4)		X
Total Nitrogen (TN)		X
Total Phosphorus (TP)		X

Table 1-2. ANC categories and the range of ANC values that define them

ANC (µeq/L)	ANC Category
≤ 0	Acidic
>0 to ≤ 50	Highly Sensitive
>50 to ≤ 200	Sensitive
>200	Not Sensitive

In this report, we examined the change in each variable across the sites that were sampled in both rounds of the MSSCS (1987 vs. 2012). We considered how each stream chemistry variable changed between rounds and how the percentage of stream miles in each category of ANC changed between rounds. Each of these analyses was conducted at the study area, MSSCS region, and MSSCS subregion scales. In separate appendices, we report results for the above analyses by PSU (Appendix A), comparisons of land use between years (Appendix B), and comparisons of temperature and precipitation between years (Appendix C).

2 METHODS

Each MSSCS Round 2 (2012) site was matched with its paired Round 1 (1987) site using a 1:24,000-scale USGS topographic map. The MSSCS region, subregion, and PSU (MBSS primary sampling units which are single or combined Maryland 8-digit watersheds) for each site pair were determined in a GIS. The total stream miles for each of these strata was determined using the 1:24,000-scale map layer and assumed to be the same for Rounds 1 and 2 of MSSCS. All PSU level analyses are reported in Appendix A. The sample collection protocols used in 2012 were comparable to those used in 1987 (Knapp and Saunders 1987, Knapp et al. 1988). Laboratory analytical methods were similar for each of the parameters sampled, but there were some differences (Table 2-1)

Table 2-1. Water quality parameters measured during both the 1987 and 2012 MSSCS surveys and the laboratory methods used to analyze each parameter.

Parameter	Method	
	1987	**2012**
ANC	Titration (using modified Gran analysis) using Orion 611 pH meter	Same (although automated now)
pH	Orion Model 611 pH meter and Orion Ross Model combination 81-04 pH electrode	Same
Conductivity	Wheatstone Bridge	Wheatstone Bridge with digital meter (aka, conductivity cell)
DOC	Ultraviolet-promoted persulfate oxidation, followed by IR detection	Same technique, better instrumentation
DIC	Manual injection into instrument	Aliquot is filtered, placed in auto-sampler vial with no headspace and refrigerated immediately. Automated injection into instrument.
Color	Analyst visually compares the sample color to a series of Platinum Cobalt standards. Standards were produced in the lab	Analyst visually compares the sample color to a series of Platinum Cobalt standards. Standards were manufactured discs calibrated to the PtCo units of color at the increments recommended by the analytical method.

Land use in the catchments draining to each sample stream reach were calculated using land cover data from National Land Cover Database (NLCD) for the closest available dates, i.e., 1992 and 2006 (Fry et al. 2011). We calculated the percentage of forest, agriculture, wetland, urban, water, and barren land in each catchment and compared summary statistics (mean, median, 25th percentile, 75th percentile, minimum, and maximum) between 1992 and 2006. We also constructed scatterplots of the sites, by plotting the percentage of land use for 1987 vs. the percentage for 2012 for each of 6 land use types (urban, forest, agricultural, barren, water, and wetland) and examined whether any sites diverged from the 1:1 line to explore sites that may have had noticeable changes in land use. These comparisons found virtually no difference in land use between survey rounds and thus we did not include land use as a covariate in our analyses. Comparisons of land use are reported in Appendix (B).

Temperature and precipitation from four regional airports (Reagan National, Hagerstown, Salisbury, and BWI) were gathered for 1 March through 30 April 2012 and compared to the data reported from these locations in 1987. To approximate the precipitation patterns in 1987, DNR employees used detailed weather forecasts in 2012 to avoid sampling after large precipitation events that might confound comparison of the surveys. This minimized the precipitation differences between rounds and we therefore assumed these differences would not influence our interpretation of stream chemistry analyses. Comparisons of temperature and precipitation are reported in Appendix C).

Mid-Atlantic streams that are acidified by acid mine drainage are characterized by having low ANC values (< 200 μeq/L) as well as high concentrations of iron (30 to 35,000 μM), manganese, and sulfate (10,000 to 250,000 μeq/L), as well as high conductivity and low pH (1.6-3.4). Herlihy, et al. (2001) established a stepwise method that identifies the sources of stream acidity based on the concentration of anions, cations, and organic compounds in the sample. We used the data collected during 2012 to identify streams that were acidified by acid mine drainage and subsequently removed these sites from the analysis.

We calculated descriptive statistics (the 25^{th}, 50^{th} (median), and 75^{th} percentiles as well as the minimum and maximum value) for each of six variables collected during the MSSCS Round 1 (1987) and Round 2 (2012): ANC, pH, conductivity, DOC, and DIC. Descriptive statistics were calculated for four scales of spatial strata:

(1) the overall study area which excludes some portions of the state,
(2) two primary MSSCS regions (Appalachian Region and Southern Coastal Plain),
(3) four MSSCS subregions (Appalachian Plateau, Ridge and Valley, Eastern Southern Coastal Plain, and Western Southern Coastal Plain) (Figure 2-1), and
(4) PSUs (for a map of the 84 PSUs, visit: http://www.esm.versar.com/pprp/bibliography/MBSS_2000-2004/Coverpages_Chps1-3.pdf).

We used the two primary MSSCS regions to mirror the reporting of the first round of the MSSCS. In the 1987 MSSCS, the western Valley and Ridge province was included with the Appalachian Plateau sampling strata because of the similar nature of their geologies (MDNR 1987). Therefore, for the sake of comparing the two surveys, we also included both of these provinces together in the Appalachian Region, one of the two primary MSSCS regions in 2012. Subsequently, we split the two primary MSSCS regions into the four MSSCS subregions to explore regional differences and to reduce the variability in the primary MSSCS regions. The descriptive statistics are shown in box plots or tables for a simple comparison between Rounds 1 and 2 of the MSSCS. Raw data values are graphed as dot plots to explore the density of data across the range of variation.

A Wilcoxon Signed Rank Test was used to determine whether the change between Rounds 1 and 2 of MSSCS were statistically significant ($p \leq 0.05$). The Wilcoxon Signed Rank Test is non-parametric statistical hypothesis test that can be used to compare the means of two sets of data that have matched pairs between them. In this instance, the 1987 data and the 2012 data are two data sets in which the matched pairs consist of a site sampled in 1987 and the same site sampled in 2012. The advantage of such a paired test is that it removes the variation at the site level. Wilcoxon Signed Rank is a non-parametric analog of the parametric paired t-test (i.e., Student's t Test). A non-parametric test was chosen because the data violated the assumptions of normality and heteroscedasticity required for parametric statistics. A significant difference between the 1987 mean and the 2012 mean is assessed with the test statistic (S) and an evaluation of the associated p-value. Differences with a p-value ≤ 0.05 were considered to be statistically significant.

The percentage of stream miles in each category of ANC was calculated for 1987 and 2012 and plotted to compare between Rounds 1 and 2 of MSSCS. This was done for each of four scales of strata: the overall study area (but note that not all regions of the state were sampled), the MSSCS regions (Appalachian Region and Southern Coastal Plain), the MSSCS subregions (Appalachian Plateau without Ridge and Valley, Ridge and Valley, Eastern Southern Coastal Plain, and Western Southern Coastal Plain), and PSUs (Figure 2-1). The same ANC categories were used for both rounds of sampling: less than 0 μeq/L is Acidic, 0-50 μeq/L is Highly Sensitive, 50-200 μeq/L is Sensitive, and >200 μeq/L is Not Sensitive.

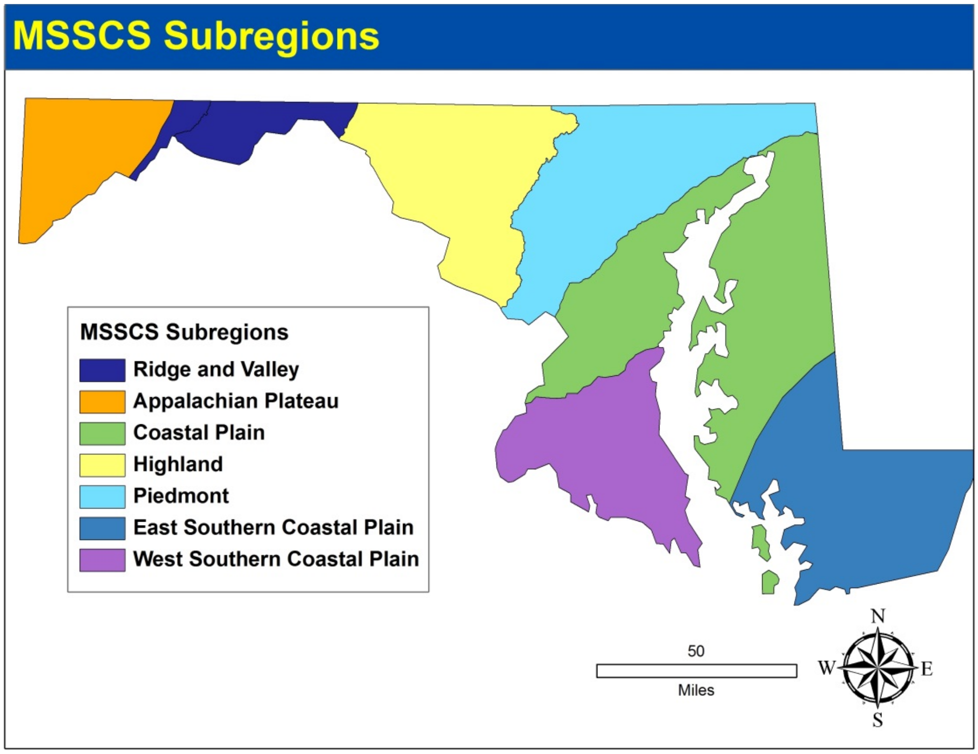


Figure 2-1. Map of the MSSCS subregions (Appalachian Region without Ridge and Valley included, Ridge and Valley, Eastern Southern Coastal Plain, and Western Southern Coastal Plain). The MSSCS regions discussed in this report are the combination of Appalachian Region (without Ridge and Valley) and Ridge and Valley into the "Appalachian Region" and combination of Eastern and Western subregions into the "Southern Coastal Plain region."

3 RESULTS

The analysis of results is straightforward. First, we compared values of each of the six variables between 1987 and 2012 at the levels of the overall study area (note that this excludes some regions of the state), MSSCS region, MSSCS subregion, and PSU. The state, region, and subregion statistics are robust, but many PSUs had few sites, so they are shown to illustrate geographic patterns in variable change. Second, we compared the percentage of stream miles in each ANC category between 1987 and 2012. Results for study area, region, and subregion are provided below and results by PSU are provided in Appendix A. Eight sites were excluded from the analysis because they were likely acidified by acid mine drainage (Table 3-1). Only one of these sites moved to a more acidic category based on ANC values in 2012. Removing these eight sites resulting in the following sample sizes: Study Area N=189; MSSCS Regions: Appalachian Region=108, Southern Coastal Plain=81; MSSCS Subregions: Appalachian Plateau=53, Ridge and Valley=55, Eastern Coastal Plain=13, and Western Coastal Plain=68.

The percentage forest, agriculture, urban, and other land uses in the catchments draining to each sample stream reach were virtually identical between 1992 and 2006 (Appendix B). For this reason, land use change over the 25 years was judged not to be a confounding factor.

Table 3-1. MSSCS sites acidified by acid mine drainage (AMD). AD=atmospheric deposition.

Site Name	MSSCS Region	MSSCS Subregion	MDE 8 Digit Name	Basin	Source of Acidity
CASS-059-P	Appalachian Region	Appalachian Plateau	Casselman River	Youghiogheny	AMD and AD
CASS-439-P	Appalachian Region	Appalachian Plateau	Casselman River	Youghiogheny	AMD
DCRL-011-P	Appalachian Region	Appalachian Plateau	Deep Creek Lake	Youghiogheny	AMD
PRLN-018-P	Appalachian Region	Ridge and Valley	Potomac River L N Branch	North Branch Potomac	AMD
PRUN-044-P	Appalachian Region	Appalachian Plateau	Potomac River U N Branch	North Branch Potomac	AMD
PRUN-054-P	Appalachian Region	Appalachian Plateau	Potomac River U N Branch	North Branch Potomac	AMD and AD
WILL-063-P	Appalachian Region	Appalachian Plateau	Wills Creek	North Branch Potomac	AMD
WILL-086-P	Appalachian Region	Appalachian Plateau	Wills Creek	North Branch Potomac	AMD

3.1 COMPARISON OF MEAN VALUES BETWEEN ROUND 1 (1987) AND ROUND 2 (2012)

3.1.1 Acid Neutralizing Capacity (ANC)

Spatial Overview for ANC

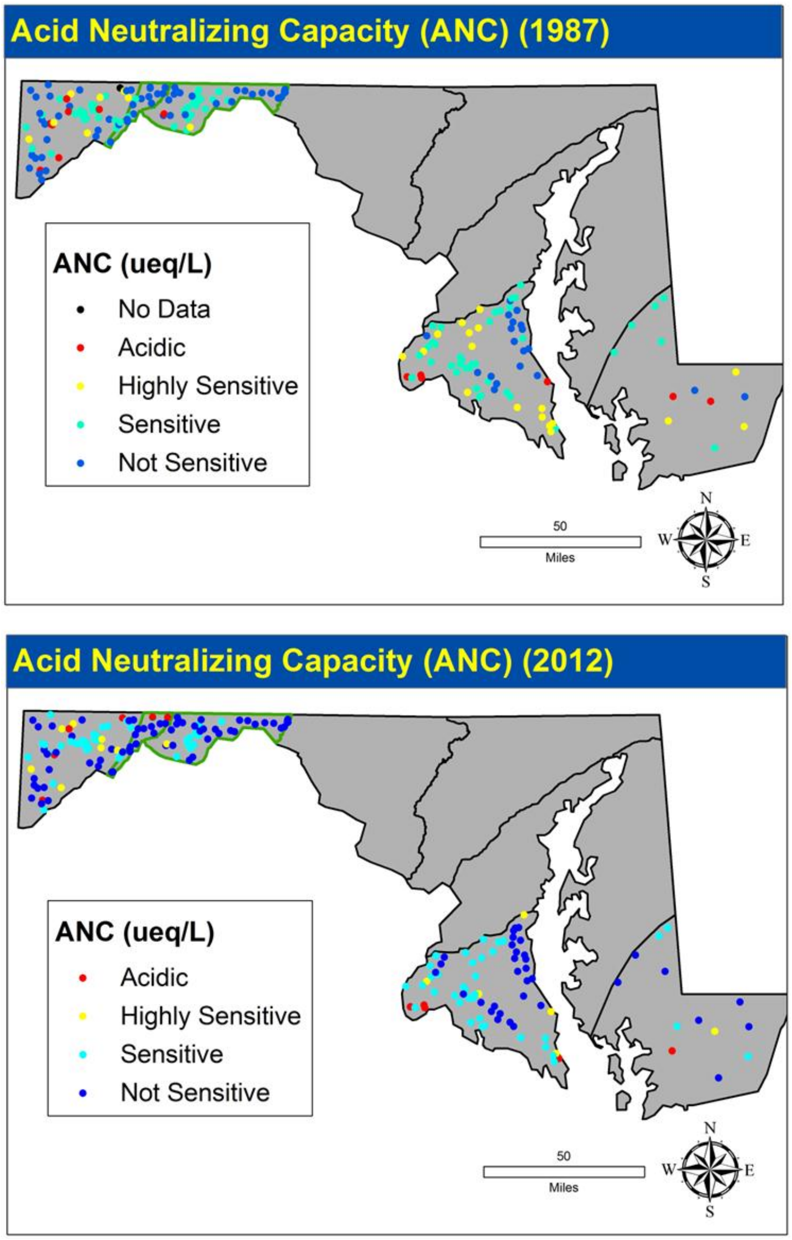


Figure 3-1. Maps showing the ANC category for each site. Top panel shows Round 1 (1987) and bottom panel shows Round2 (2012) of MSSCS. The area outlined in green contains the Ridge and Valley MSSCS subregion. See Table 1-2 for the ANC values that bound each category.

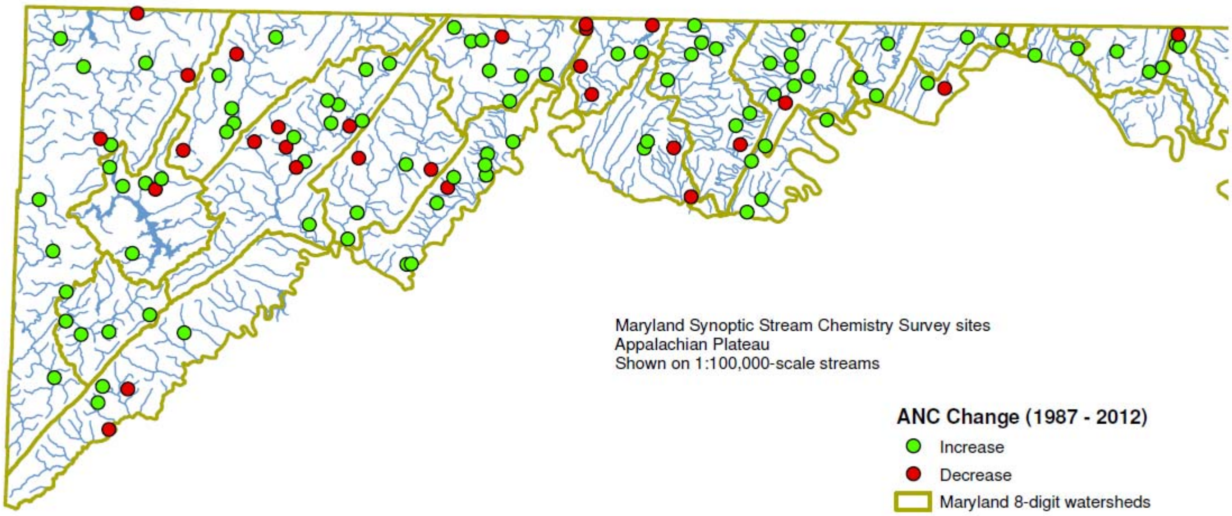


Figure 3-2. Map of the Appalachian Region showing whether site ANC increased or decreased between 1987 and 2012.

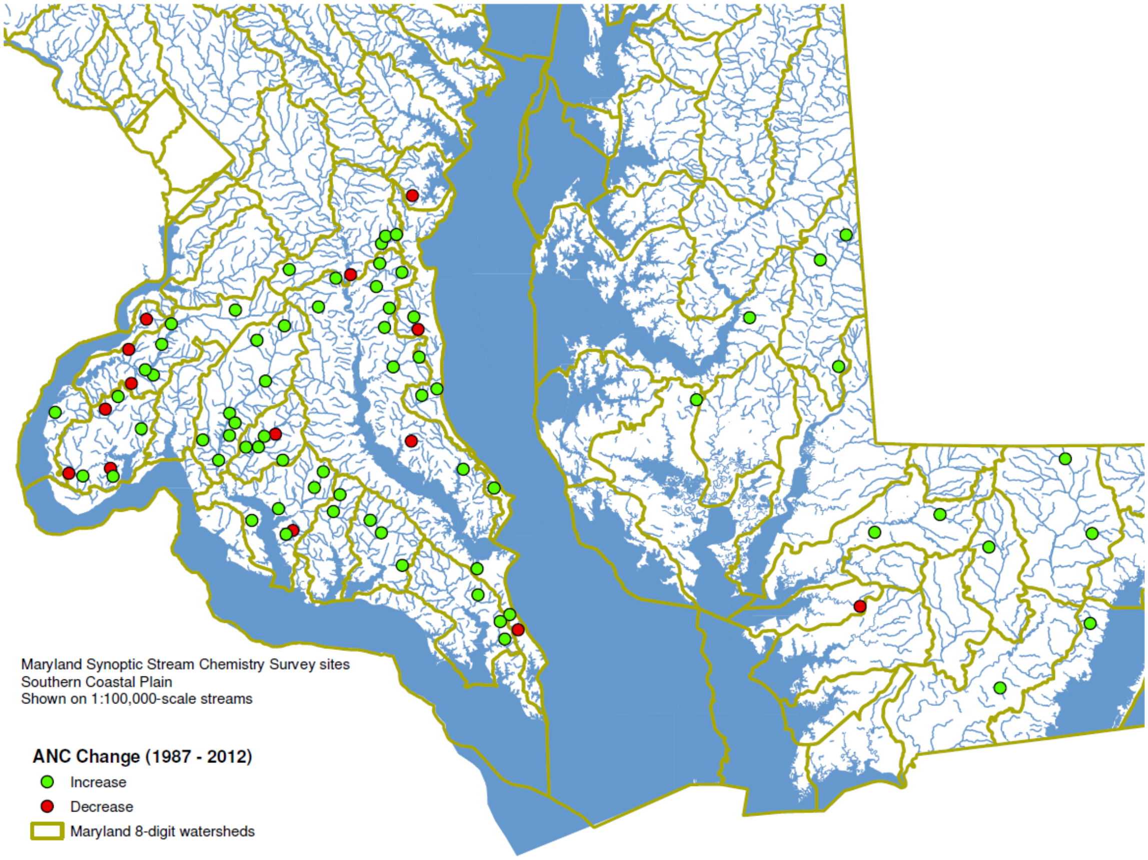
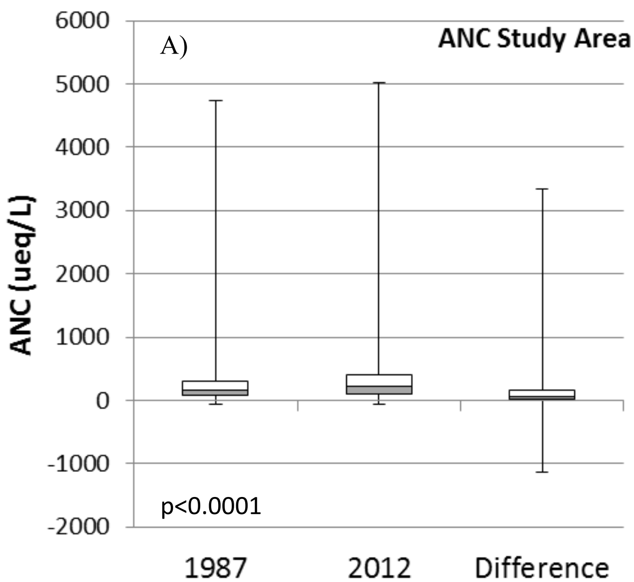


Figure 3-3. Map of the Coastal Plain showing whether site ANC increased or decreased between 1987 and 2012.

Overall Findings for ANC

ANC increased significantly between 1987 and 2012. This pattern was evident in the study area, between MSSCS regions, and among MSSCS subregions (Figures 3-1 through 3-7). Among the 35 PSUs, 32 had increases in median ANC between rounds (Appendix A, Table A-1). Examination of the box plots for overall ANC showed that there was a wide range of variation during both rounds of sampling. The 75th percentile indicates that 75% of the sites had ANC less than 292 µeq/L during 1987 and 381 µeq/L during 2012 (Figure 3-4) despite maximum values of 4,731 µeq/L and 5,024 µeq/L in each round respectively. Even with this variability, the increase in ANC was statistically significant. The extreme values of ANC in both 1987 and 2012 occurred at sites in the Ridge and Valley subregion where natural limestone deposits may be affecting stream ANC (K. Eshleman *pers. comm.*). The scatterplot of 1987 ANC vs. 2012 ANC provides another way to examine the data. There are more sites that fall above the 1:1 line (i.e., the no change line) than below it, indicating that more sites experienced an increase in ANC between rounds (Figure 3-6). All but 3 PSUs experienced an increase in median ANC between rounds (Appendix A, Table A-1).



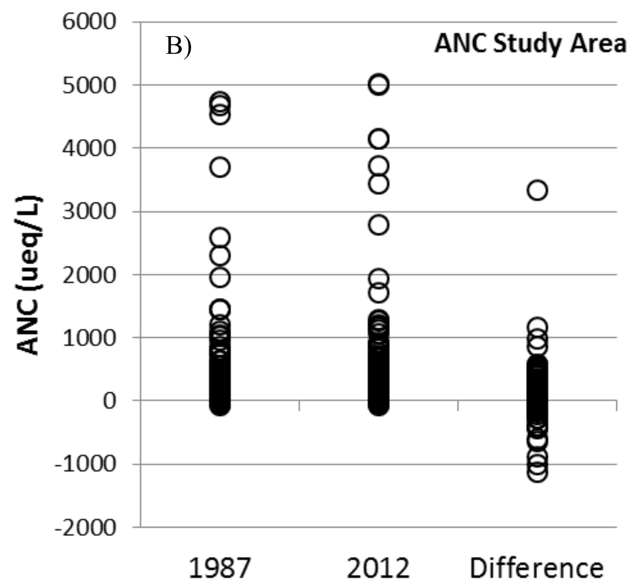


Figure 3-4. Acid neutralizing capacity (ANC) in the study area. Panel A) Box and whisker plot depicting the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Panel B) Dot plot showing all values.

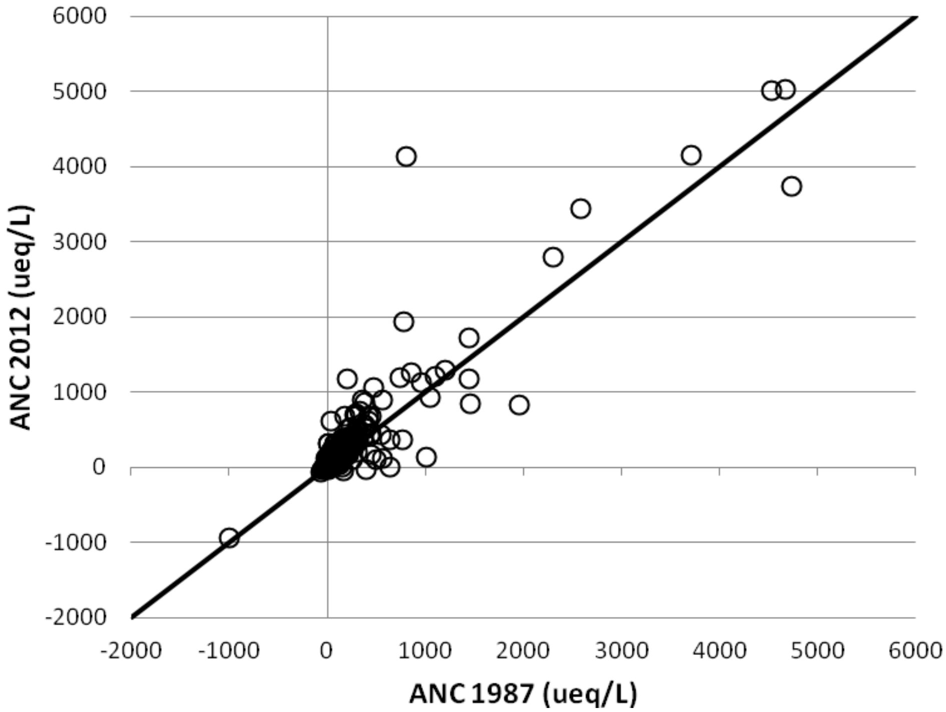


Figure 3-5. Scatterplot of acid neutralizing capacity (ANC) comparing the values at all individual sites within the study area in 1987 vs. 2012. A 1:1 line is drawn to indicate no change between years. Sites falling above this line had an increase in ANC between years and those falling below this line had a decrease in ANC between years.

MSSCS Regions for ANC

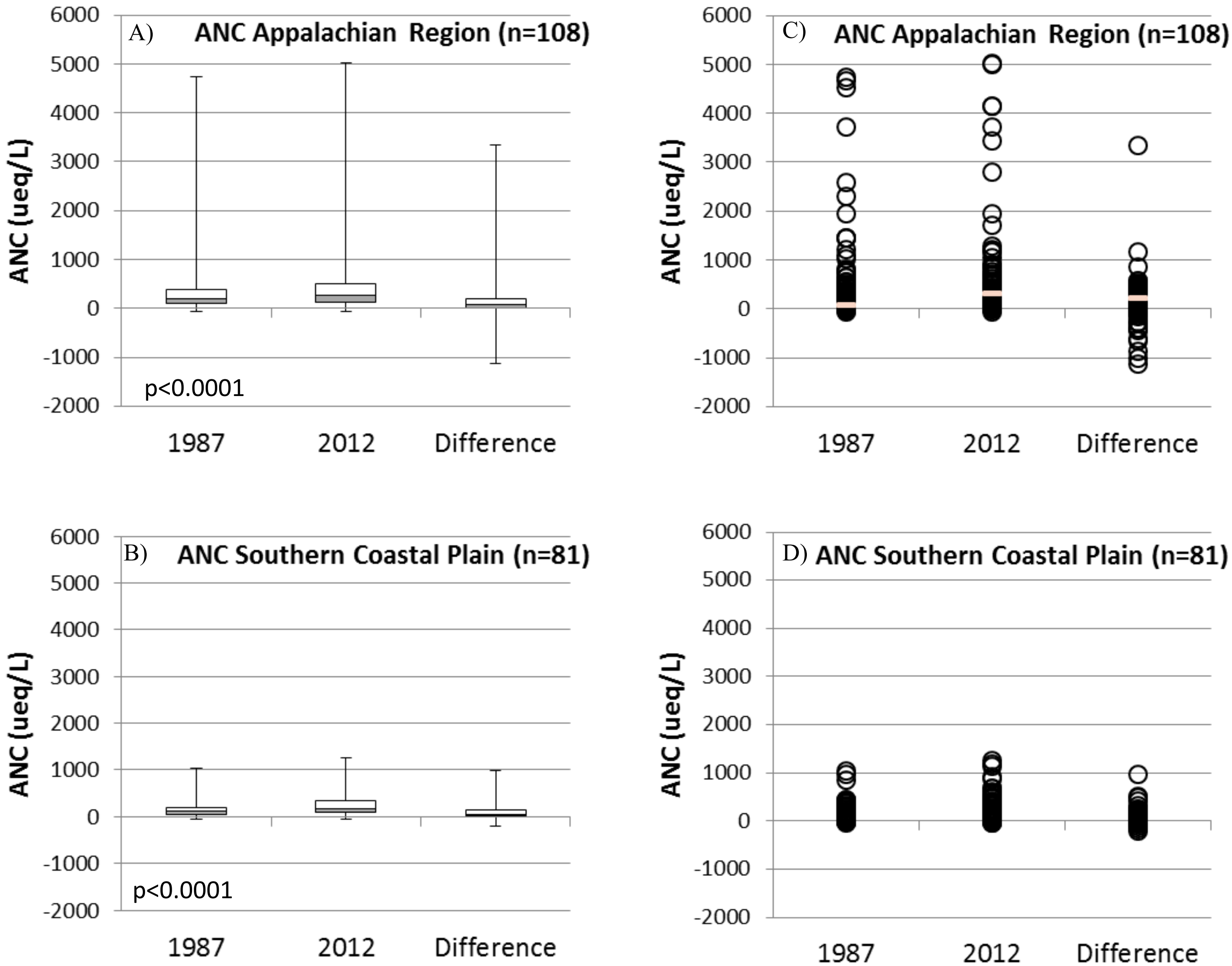


Figure 3-5. Acid neutralizing capacity (ANC) in Appalachian Region and Southern Coastal Plain. Box and whisker plots for A) Appalachian Region and B) Southern Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Region and D) Southern Coastal Plain show all values.

MSSCS Subregions for ANC

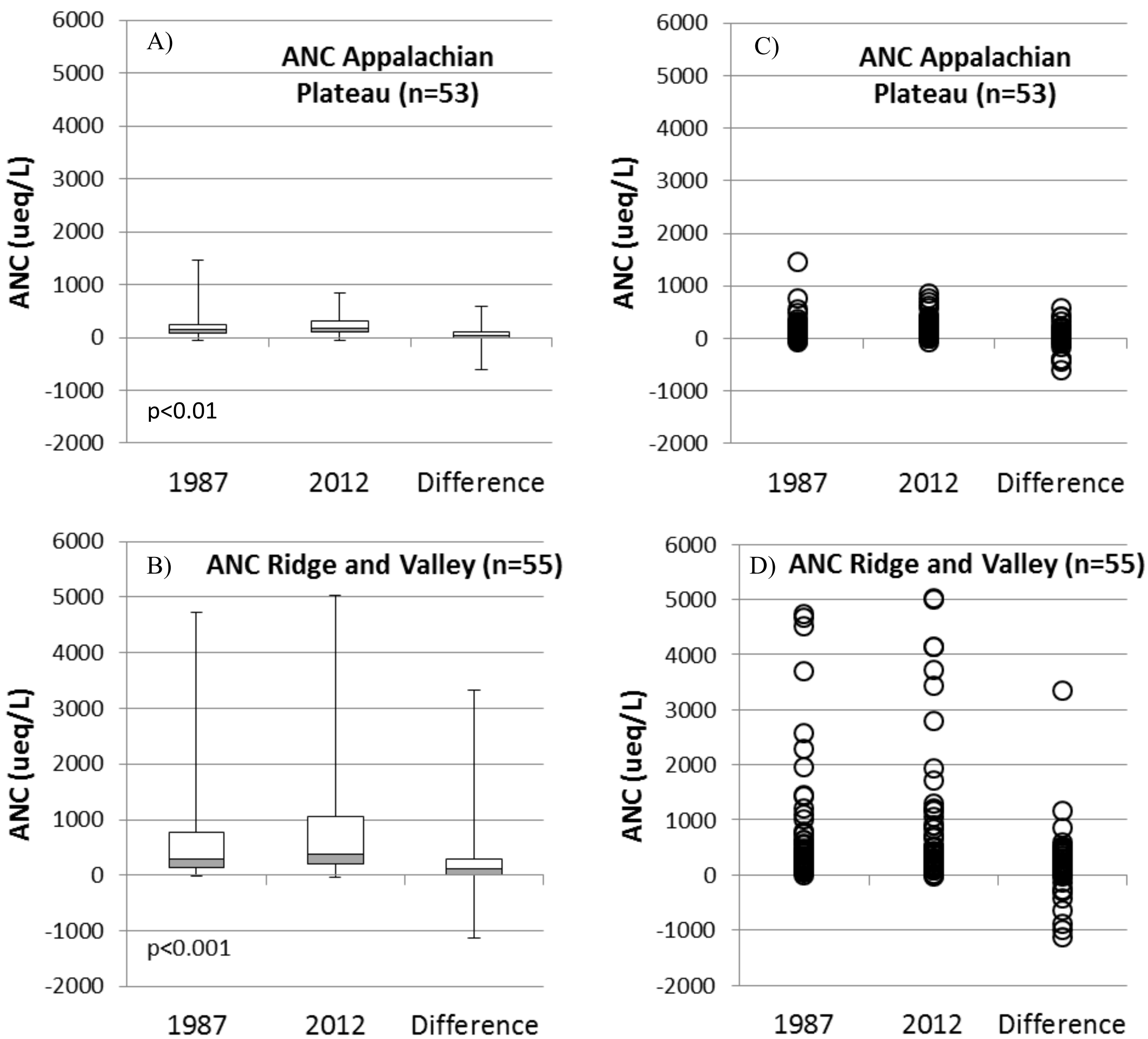


Figure 3-6. Acid Neutralizing Capacity for the MSSCS regions Appalachian Plateau and Ridge and Valley. Box and whisker plots for A) Appalachian Plateau and B) Ridge and Valley depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Plateau and D) Ridge and Valley show all values.

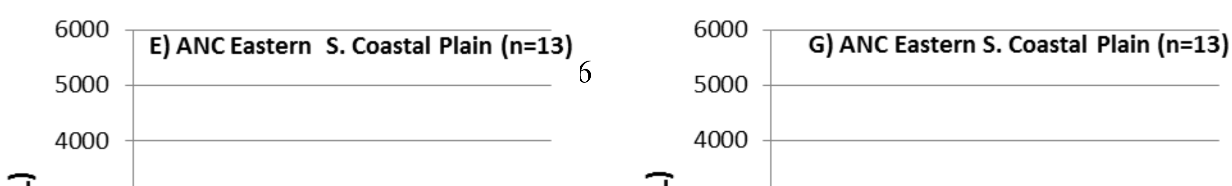


Figure 3-6 (continued). Acid Neutralizing Capacity for the MSSCS subregions Box and whisker plots for E) Eastern S. Coastal Plain and F) Western S. Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for G) Eastern S. Coastal Plain and H) Western S. Coastal Plain show all values.

3.1.2 pH

Spatial Overview for pH

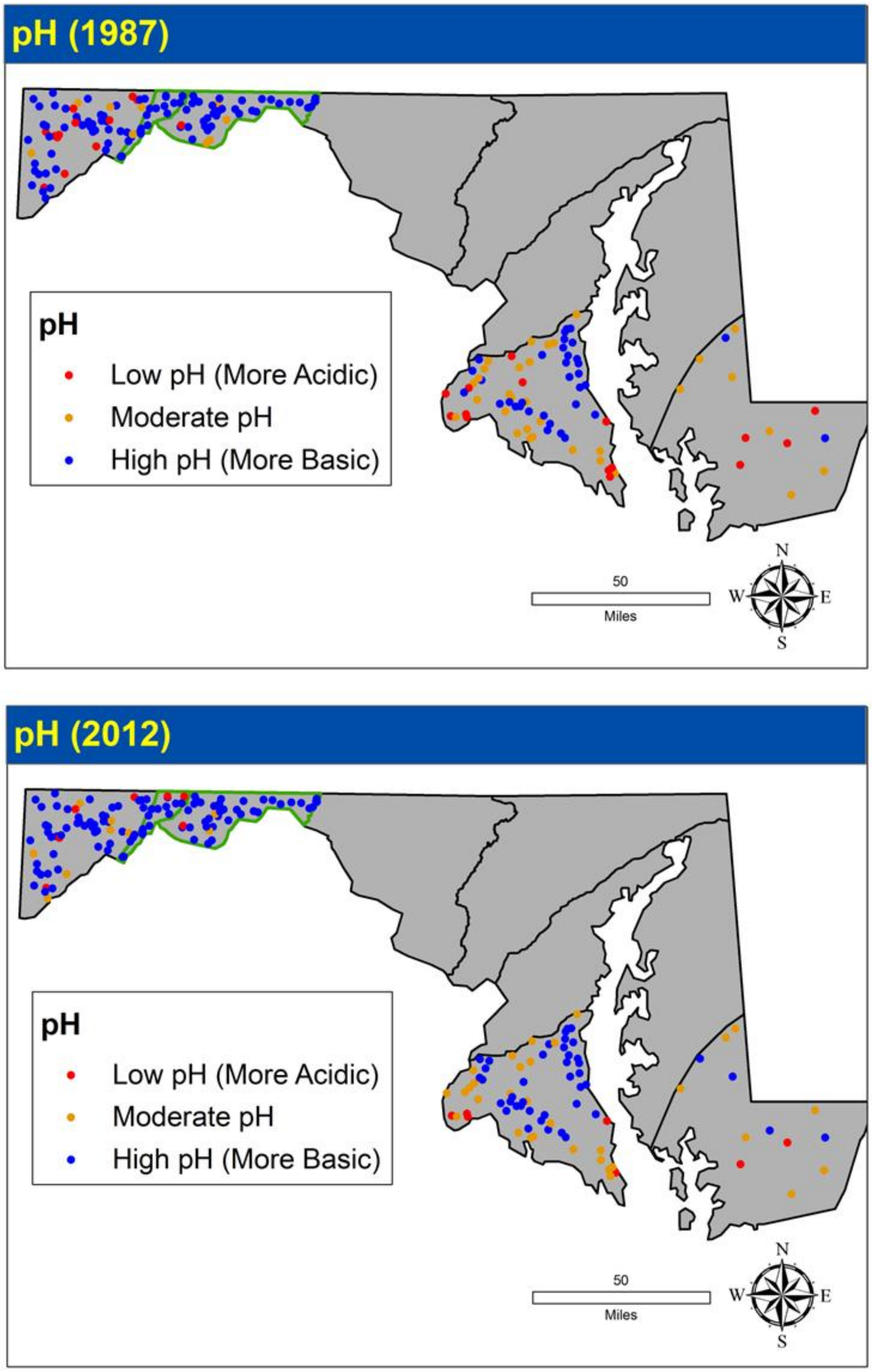


Figure 3-7. Maps showing the pH for each site. Top Panel shows Round 1 (1987) and Bottom Panel shows Round 2 (2012) of MSSCS. The region outlined in green contains the

Ridge and Valley MSSCS subregion. Low pH: 3.0-5.5, Moderate pH 5.5-6.5; high pH: > 6.5.

Overall Findings for pH

Streams were significantly less acidic in 2012 compared to 1987 as measured by pH. This pattern was evident across the study area between MSSCS regions, and among MSSCS subregions (Figures 3-8 through 3-11). Among the 34 PSUs, 29 had an increase in median pH (reduced acidity) between rounds (Appendix A, Table A-2).

Study Area for pH

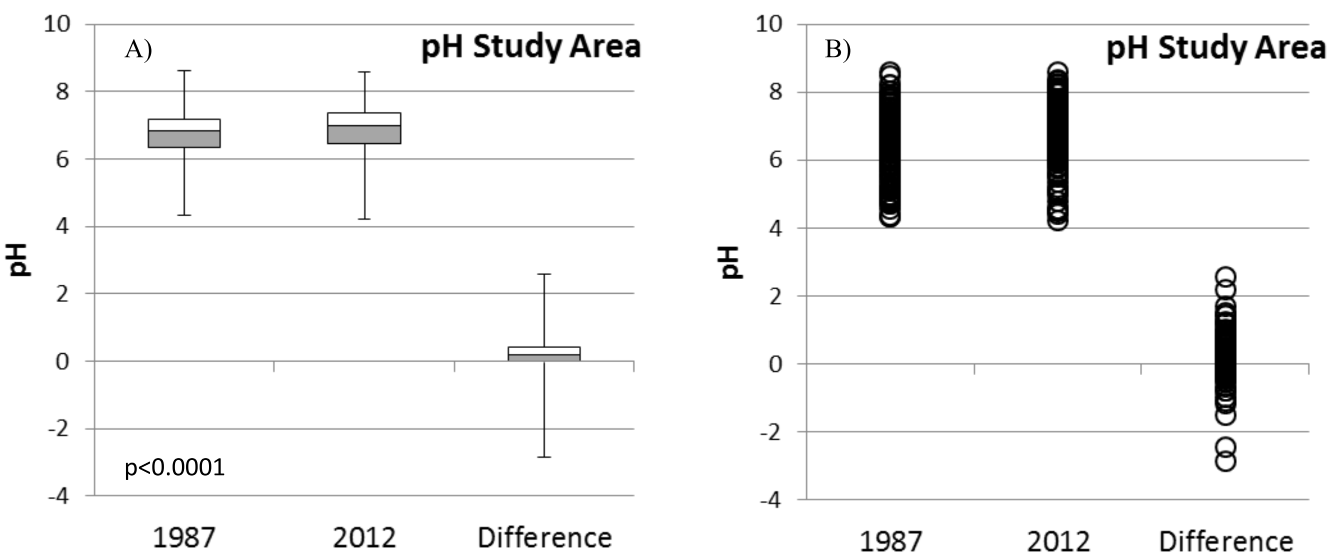


Figure 3-8. pH in the study area. Panel A) Box and whisker plot depicting the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Panel B) Dot plot showing all values.

MSSCS Regions for pH

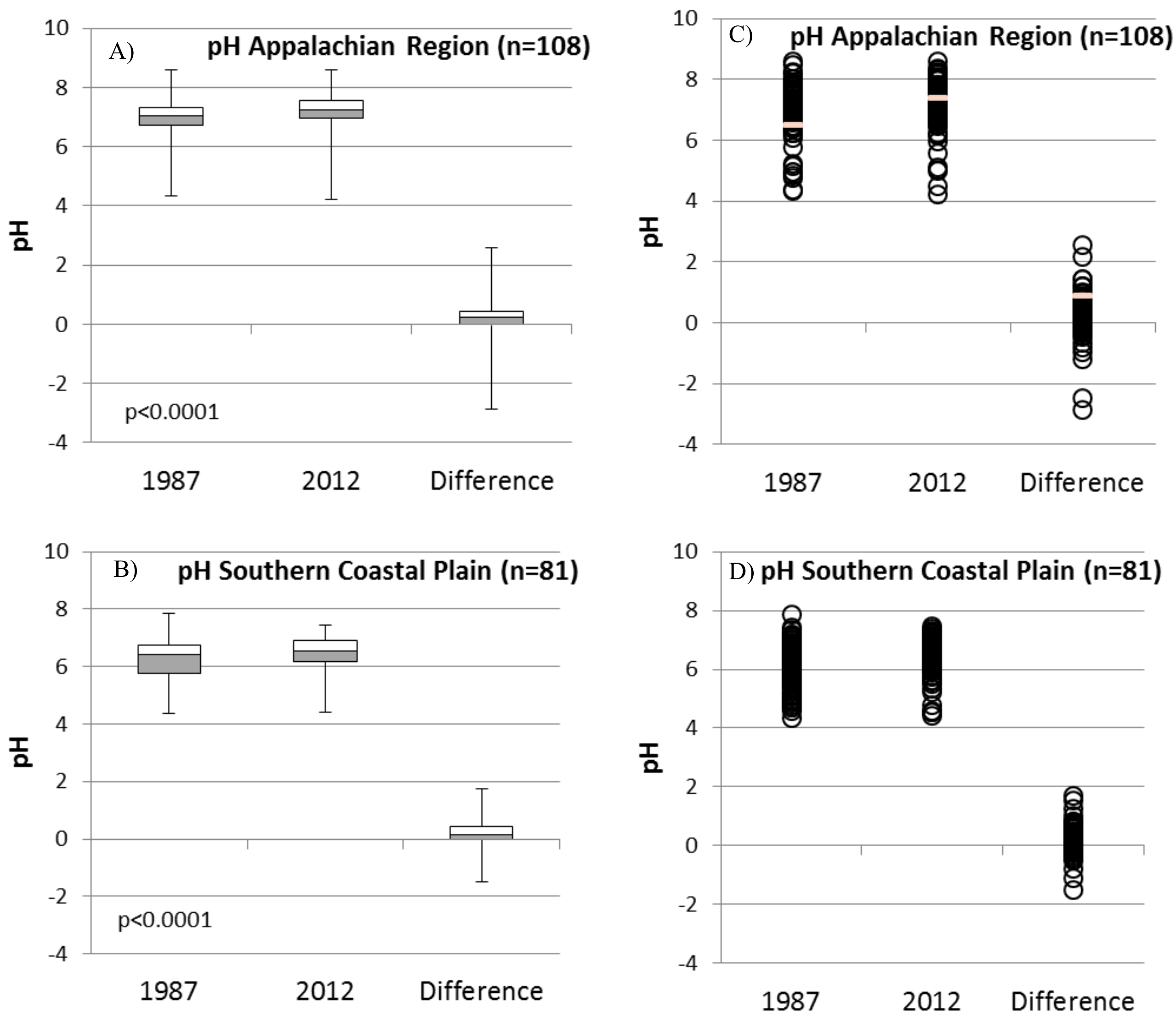


Figure 3-9. pH in MSSCS Regions. Box and whisker plots for A) Appalachian Region and B) Southern Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Region and D) Southern Coastal Plain show all values.

MSSCS Subregions for pH

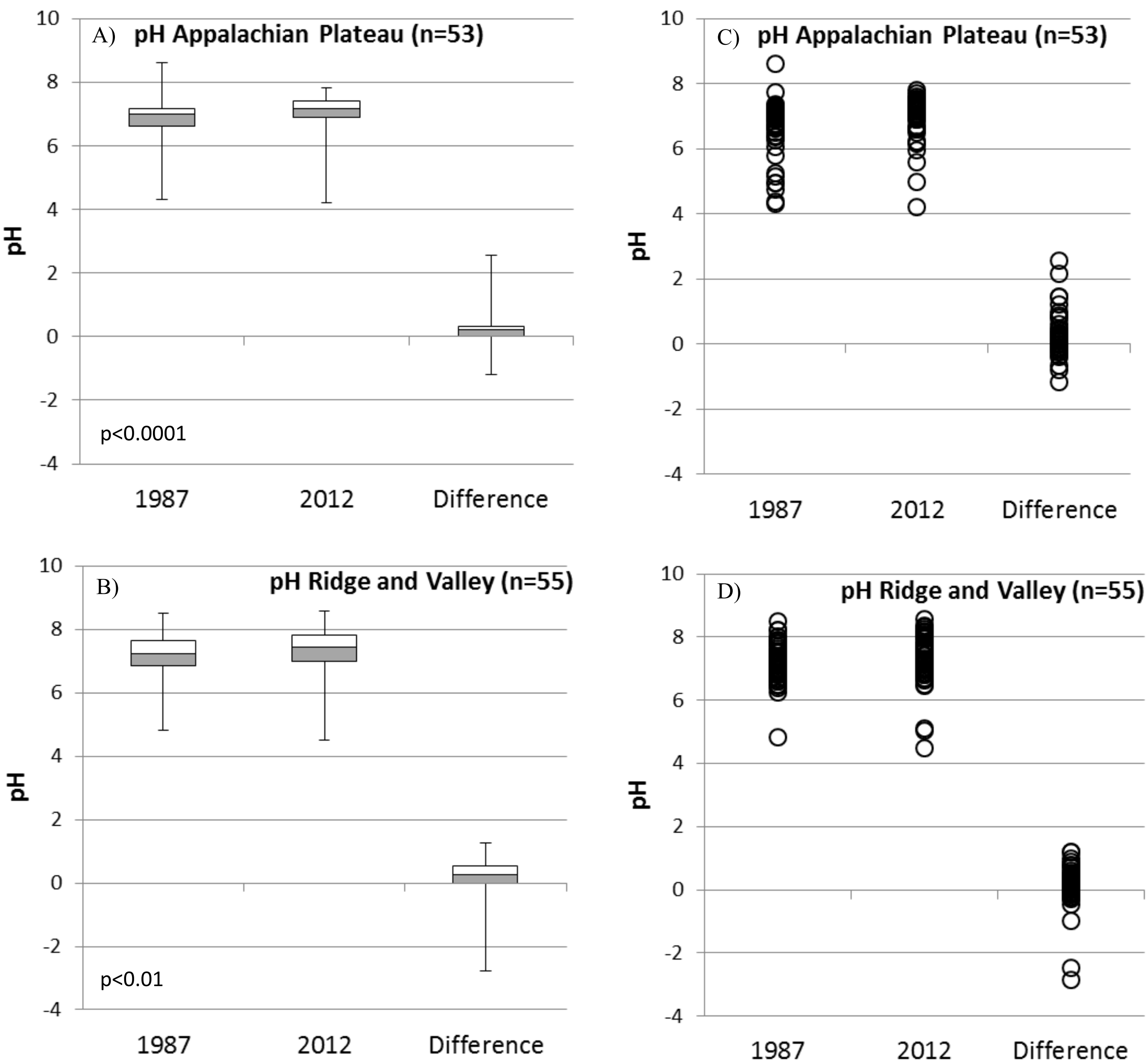


Figure 3-10. pH for the MSSCS subregions. Box and whisker plots for A) Appalachian Plateau and B) Ridge and Valley depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Plateau and D) Ridge and Valley show all values.

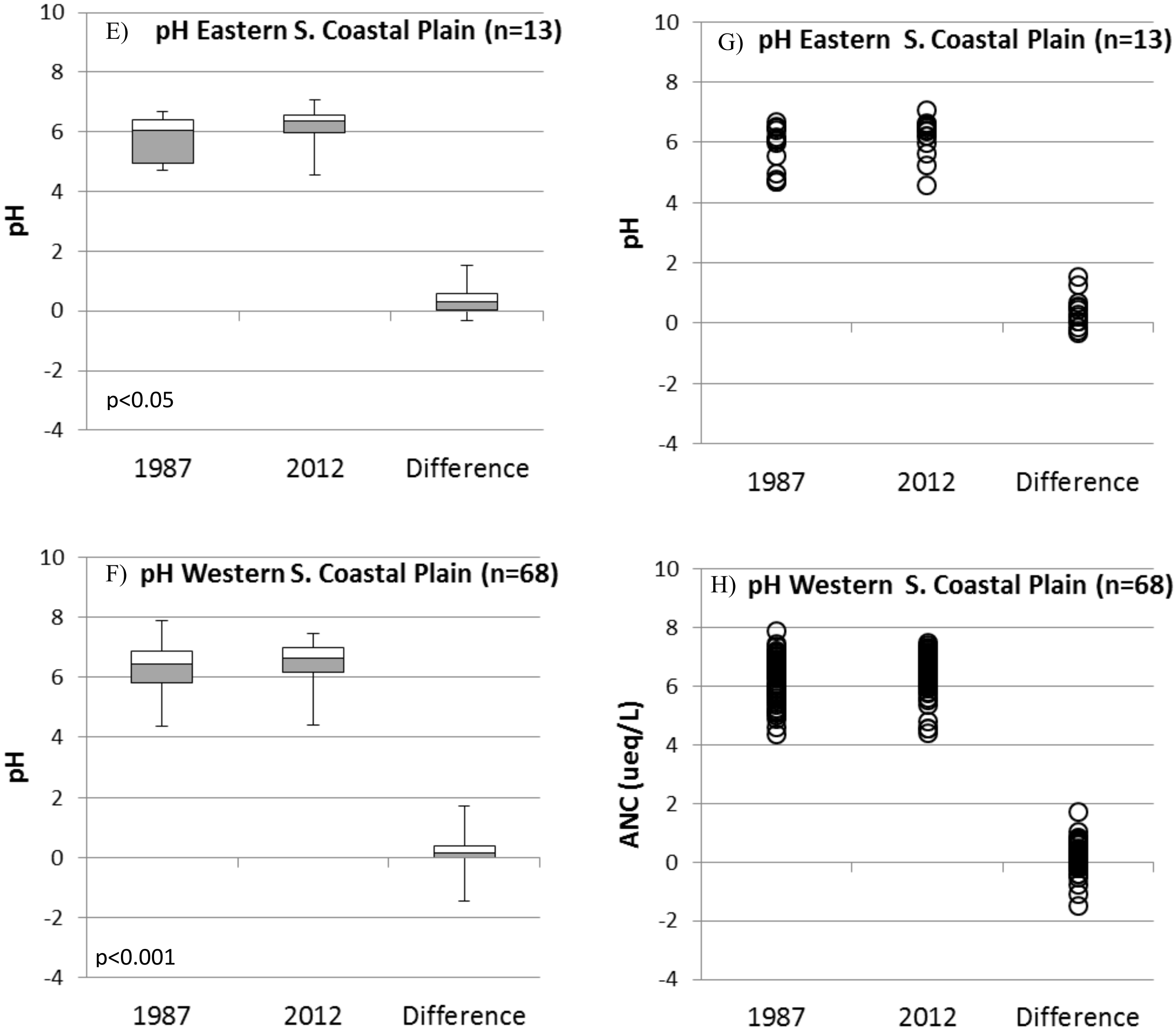


Figure 3-10 (continued). pH for the MSSCS subregions. Box and whisker plots for E) Eastern S. Coastal Plain and F) Western S. Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for G) Eastern S. Coastal Plain and H) Western S. Coastal Plain show all values.

3.1.3 Conductivity

Spatial Overview for Conductivity

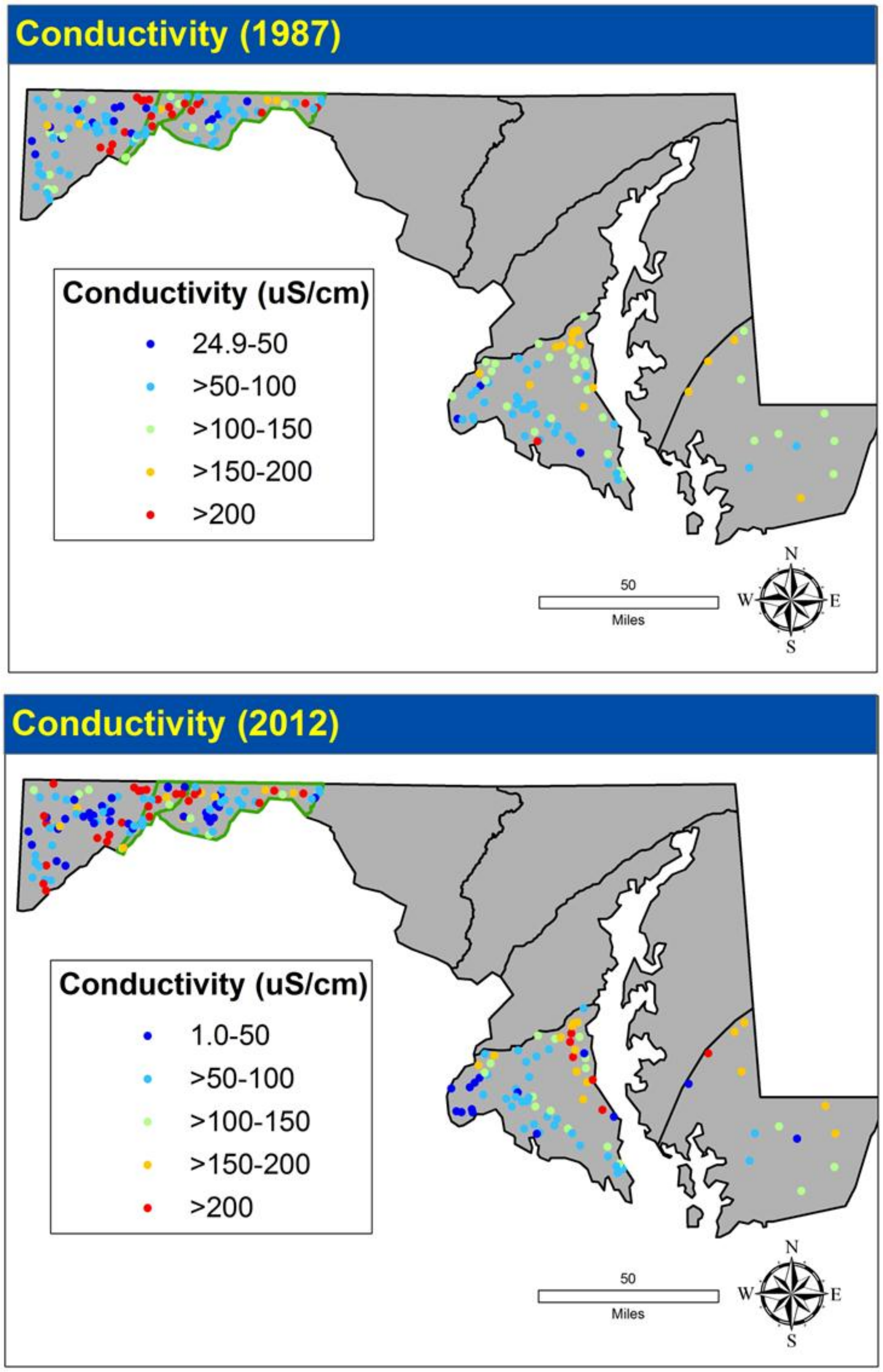


Figure 3-11. Maps showing the conductivity (µS/cm) category for each site. Top Panel shows Round 1 (1987) and Bottom Panel shows Round2 (2012) of MSSCS. The region

outlined in green contains the Ridge and Valley MSSCS subregion.

Overall Findings for Conductivity

There were no significant changes in conductivity at the overall study area level, between MSSCS regions, or among MSSCS subregions (Figures 3-11 through 3-15). Fifteen of the 34 PSUs had an increase in median conductivity between rounds while the remainder decreased (Appendix A, Table A-3).

Study Area for Conductivity

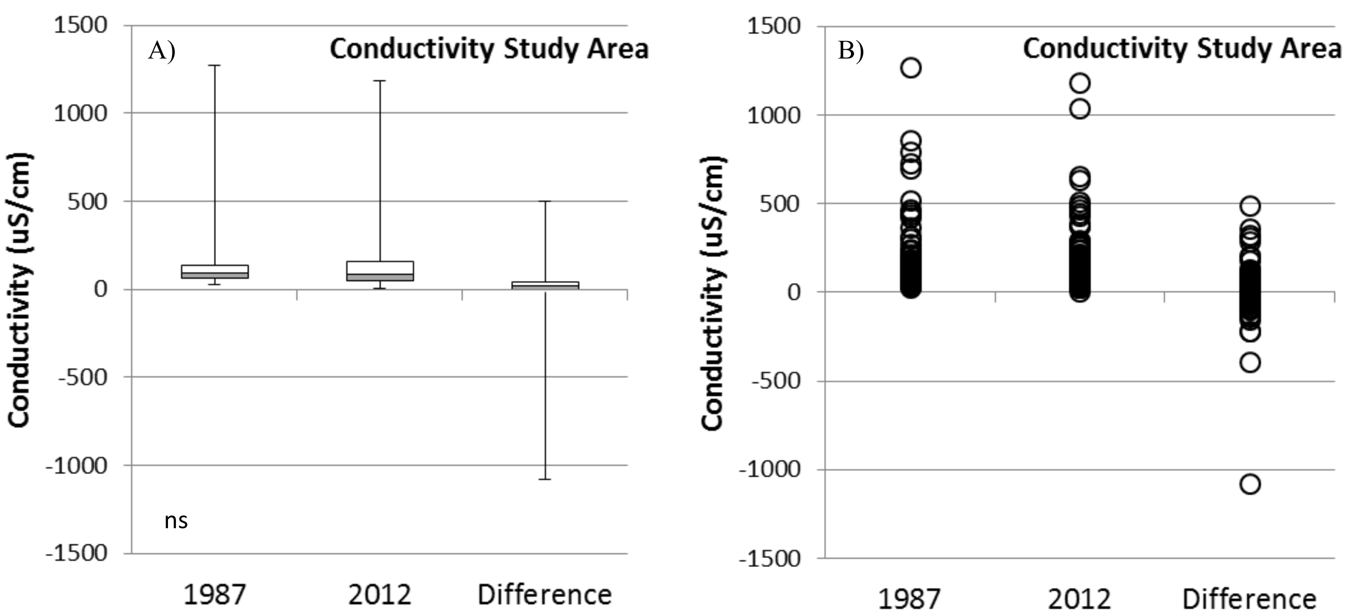


Figure 3-12. Conductivity in the study area. Panel A) Box and whisker plot depicting the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. ns indicates no significant difference from Wilcoxon Signed Rank test. Panel B) Dot plot showing all values.

MSSCS Regions for Conductivity

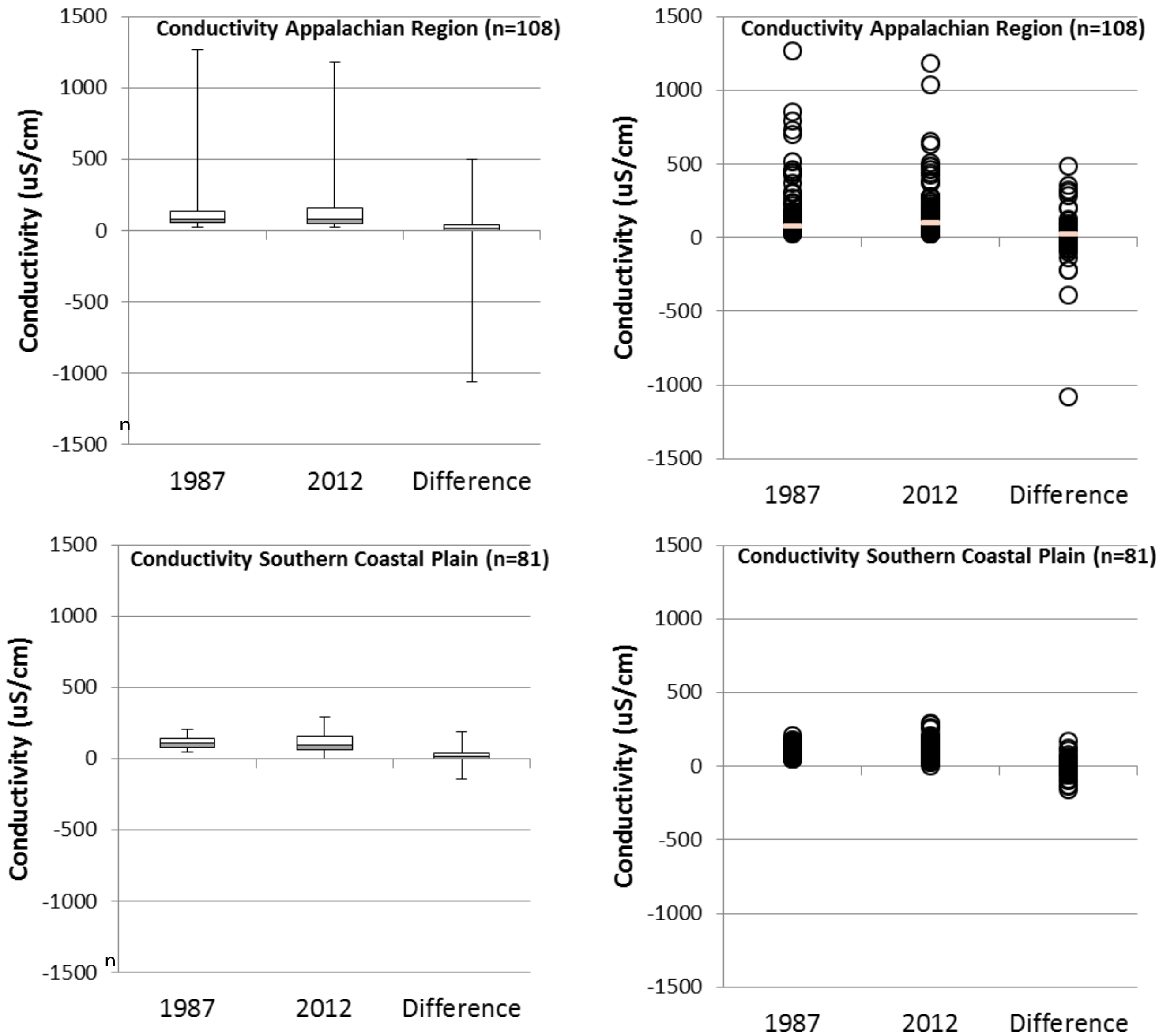


Figure 3-13. Conductivity in the MSSCS regions. Box and whisker plots for A) Appalachian Region and B) Southern Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Region and D) Southern Coastal Plain show all values.

MSSCS Subregions

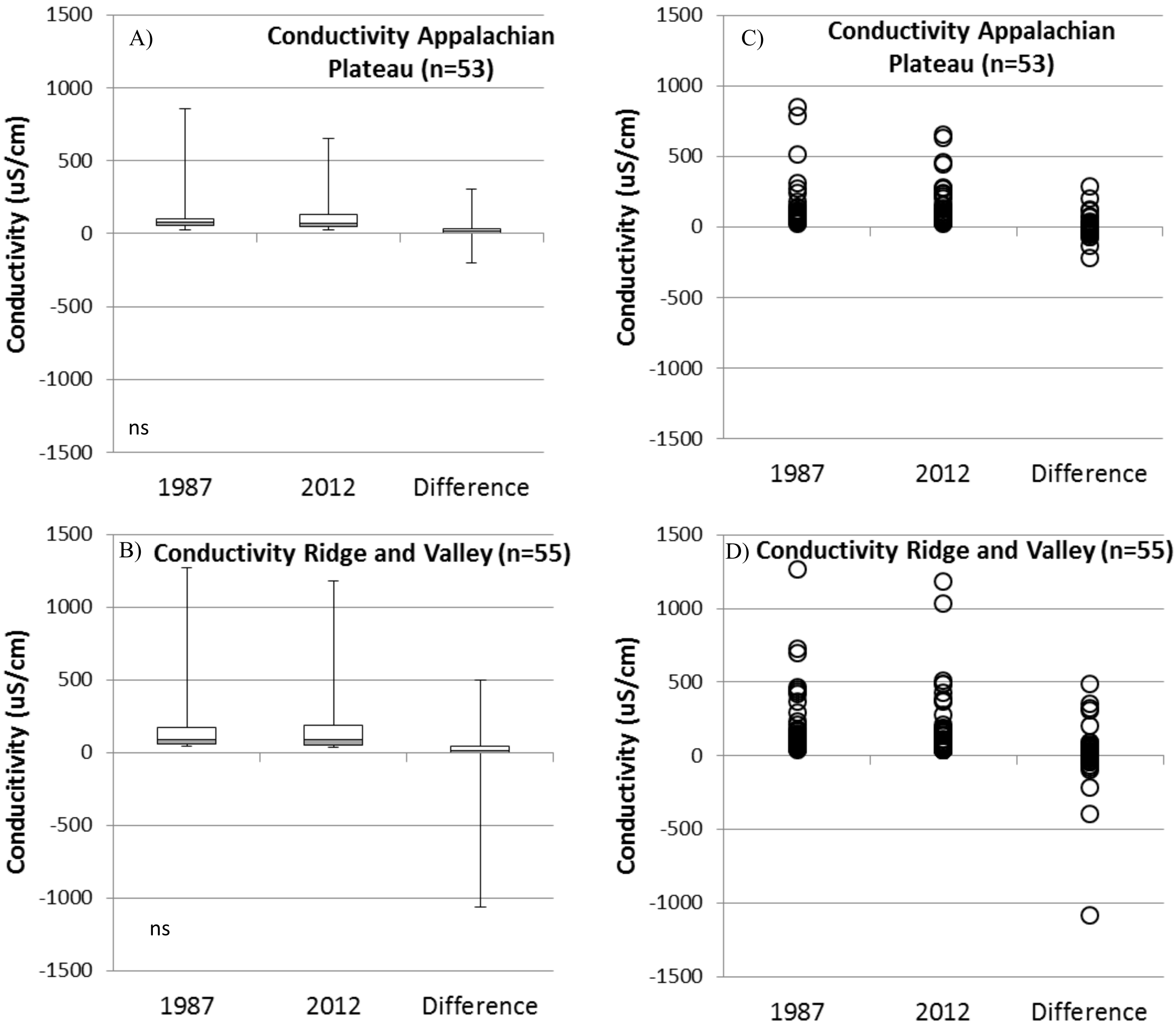


Figure 3-14. Conductivity for the MSSCS subregions. Box and whisker plots for A) Appalachian Plateau and B) Ridge and Valley depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Plateau and D) Ridge and Valley show all values.

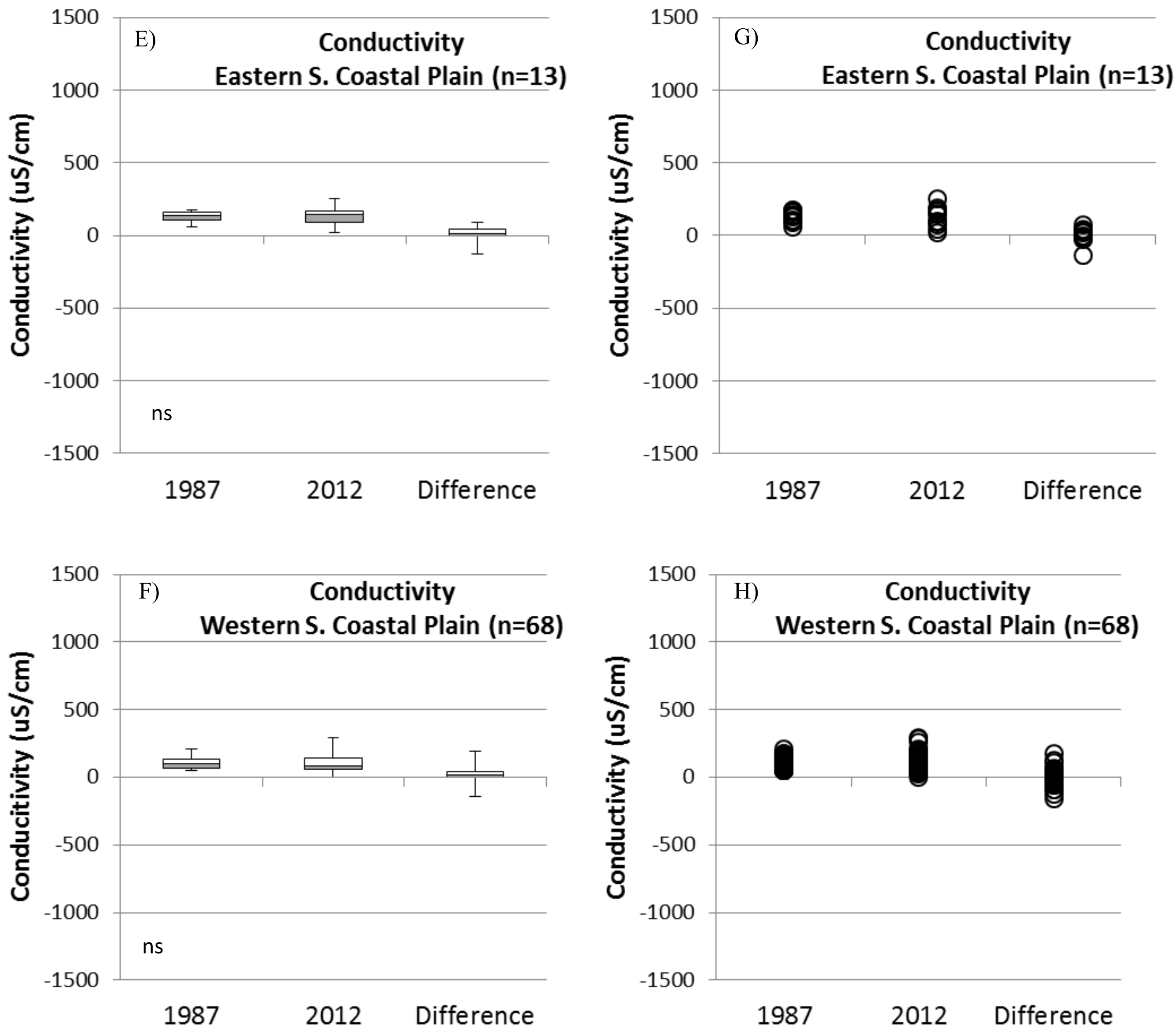
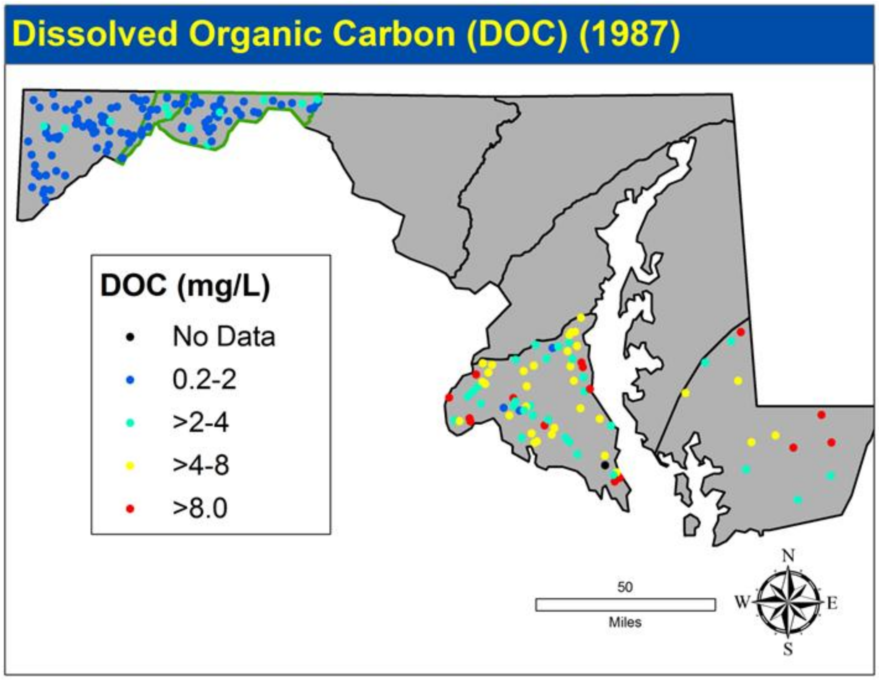


Figure 3-14 (Continued). Conductivity for the MSSCS subregions. Box and whisker plots for E) Eastern S. Coastal Plain and F) Western S. Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for G) Eastern S. Coastal Plain and H) Western S. Coastal Plain show all values.

3.1.4 Dissolved Organic Carbon (DOC)

Spatial Overview for DOC



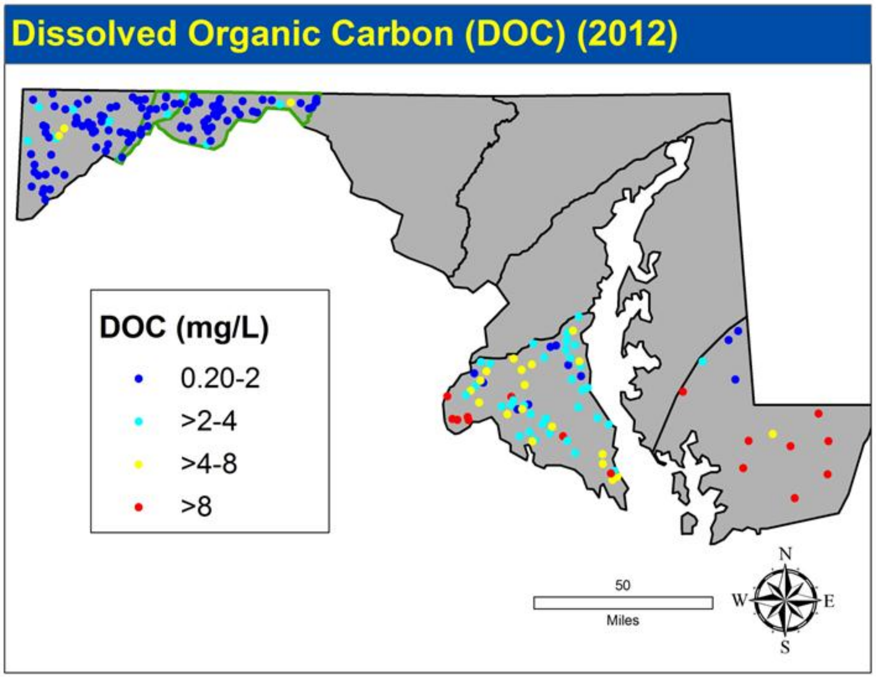


Figure 3-15. Maps showing the dissolved organic carbon (DOC) (mg/L) for each site. Top Panel shows Round 1 (1987) and Bottom Panel shows Round2 (2012) of MSSCS. The region outlined in green contains the Ridge and Valley MSSCS subregion.

Overall Findings for DOC

DOC was generally higher in the Southern Coastal Plain compared to the Appalachian Plateau. Significant changes in DOC occurred in the MSSCS region of Southern Coastal Plain and in the MSSCS subregion of Western Coastal Plain (Figures 3-16 through 3-19). No other comparisons including the overall study area were significant. Median DOC increased in 29 of the 34 PSUs (Appendix A, Table A-4).

Study Area for DOC

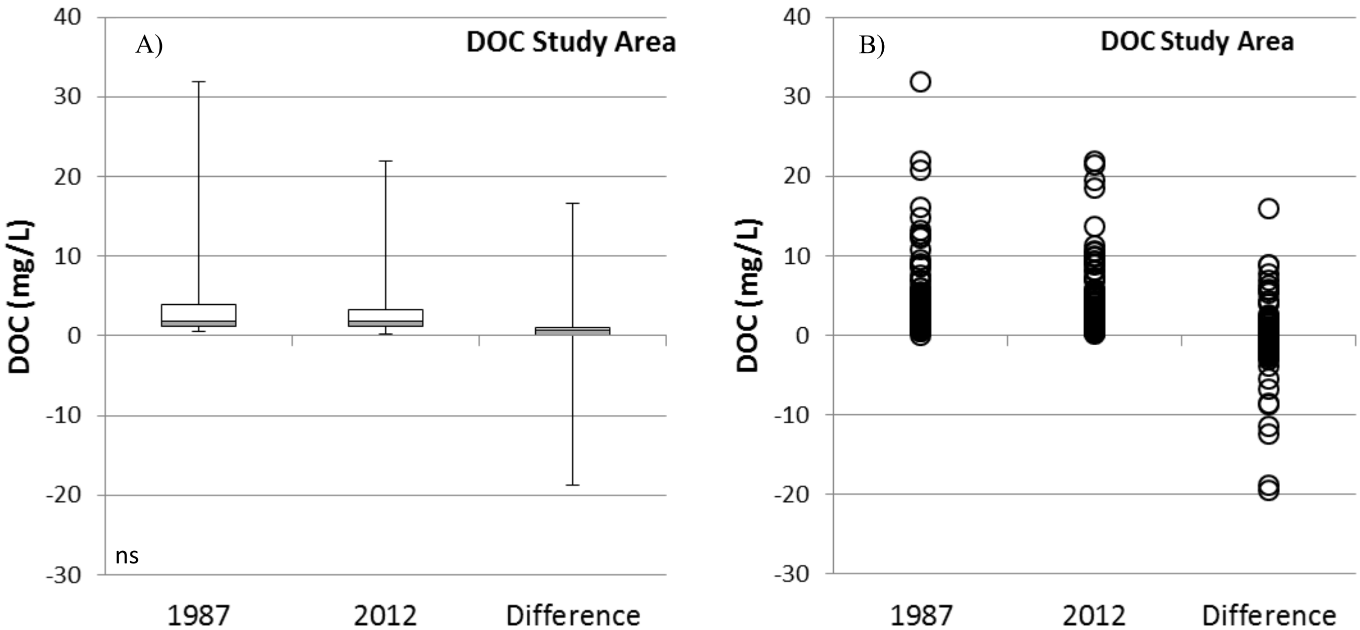


Figure 3-16. Dissolved Organic Carbon (DOC) in the study area. Panel A) Box and whisker plot depicting the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. ns indicates no significant difference from Wilcoxon Signed Rank test. Panel B) Dot plot showing all values.

MSSCS Regions for DOC

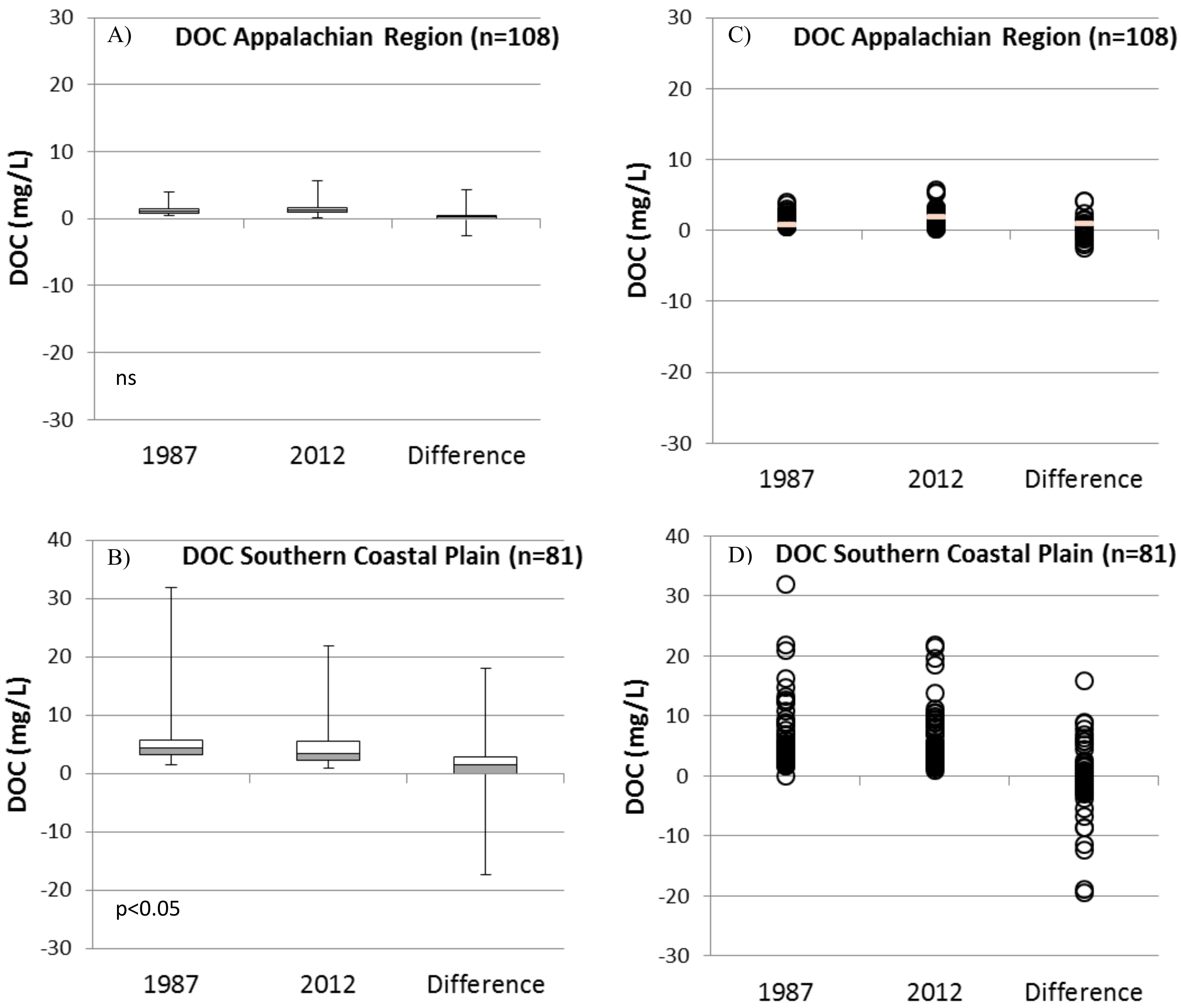


Figure 3-17. Dissolved Organic Carbon (DOC) in the MSSCS Regions. Box and whisker plots for A) Appalachian Region and B) Southern Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Region and D) Southern Coastal Plain show all values.

MSSCS Subregions for DOC

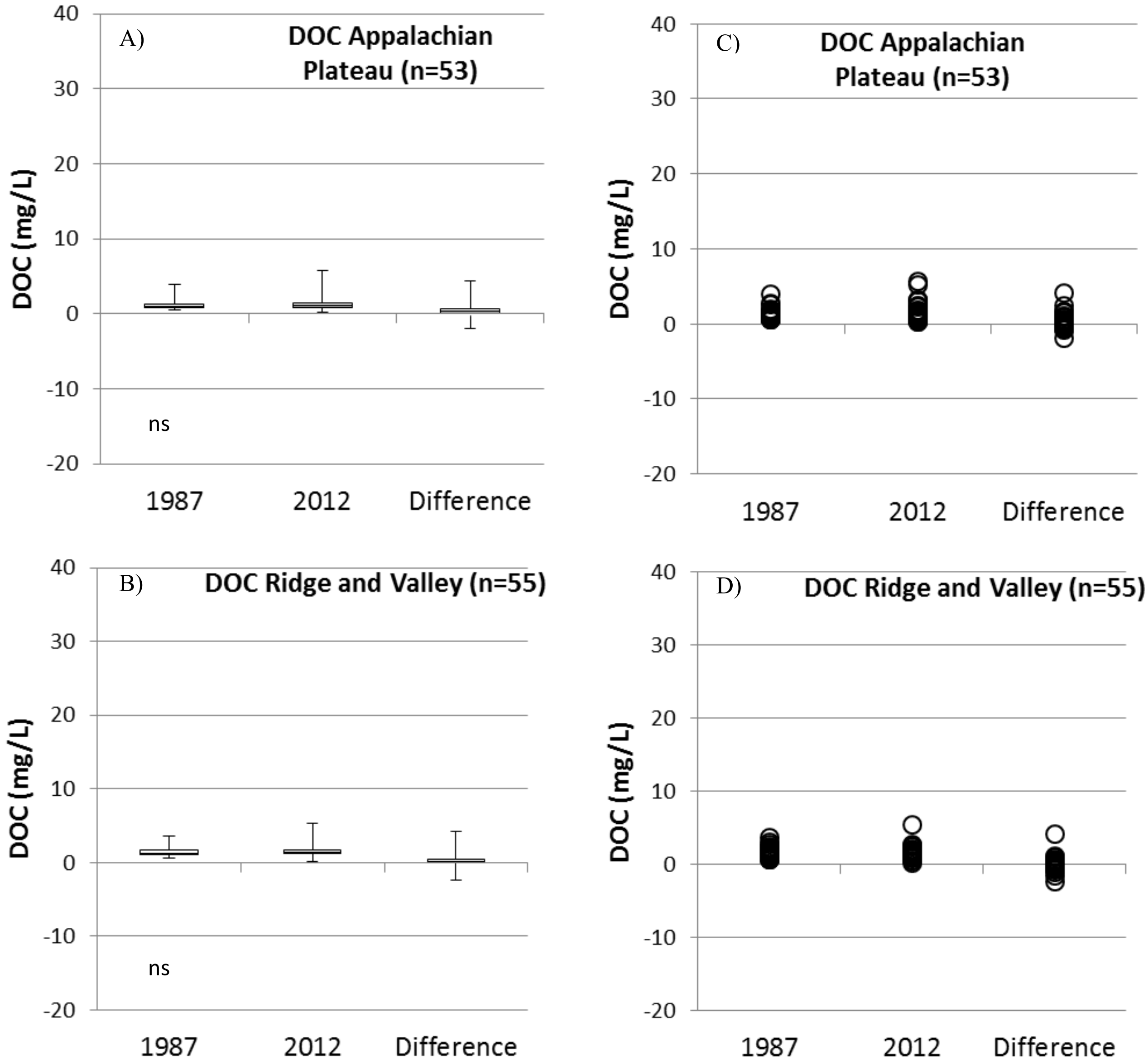


Figure 3-18. Dissolved Organic Carbon (DOC) for the MSSCS subregions. Box and whisker plots for A) Appalachian Plateau and B) Ridge and Valley depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C)

Appalachian Plateau and D) Ridge and Valley show all values.

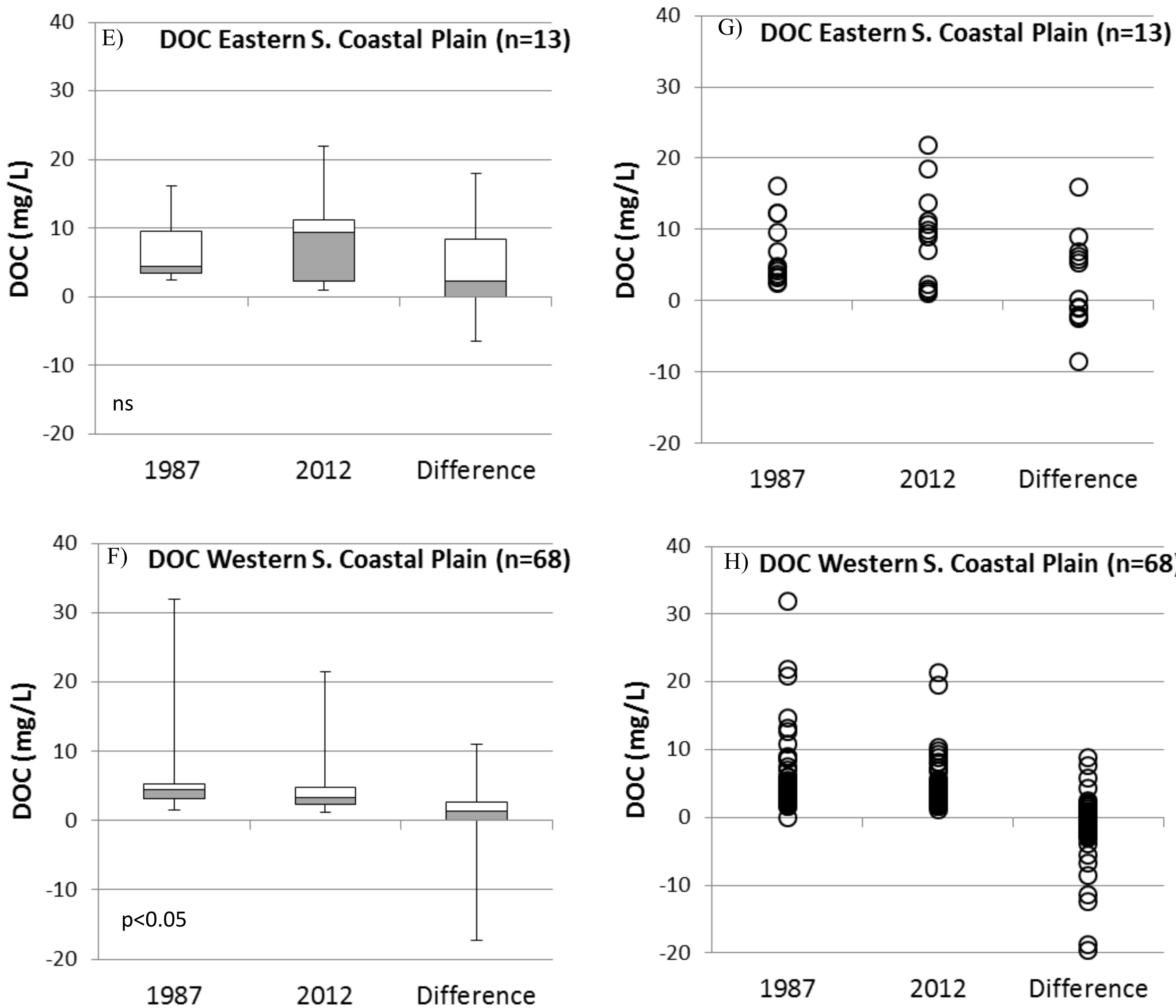
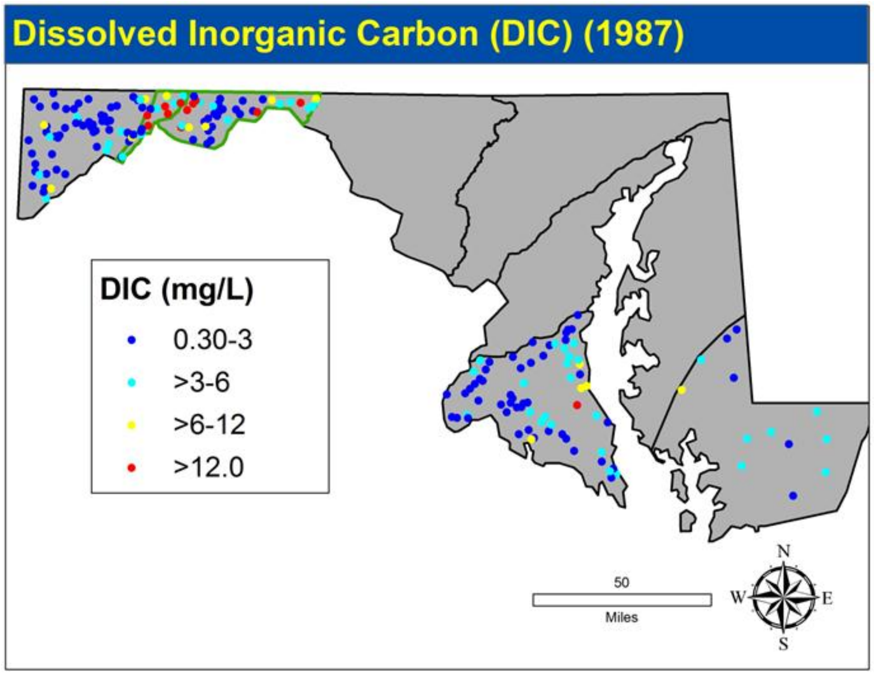


Figure 3 18 (Continued). Dissolved Organic Carbon (DOC) for the MSSCS subregions. Box and whisker plots for E) Eastern S. Coastal Plain and F) Western S. Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for G) Eastern S. Coastal Plain and H) Western S. Coastal Plain show all values.

3.1.5 Dissolved Inorganic Carbon (DIC)

Spatial Overview for DIC



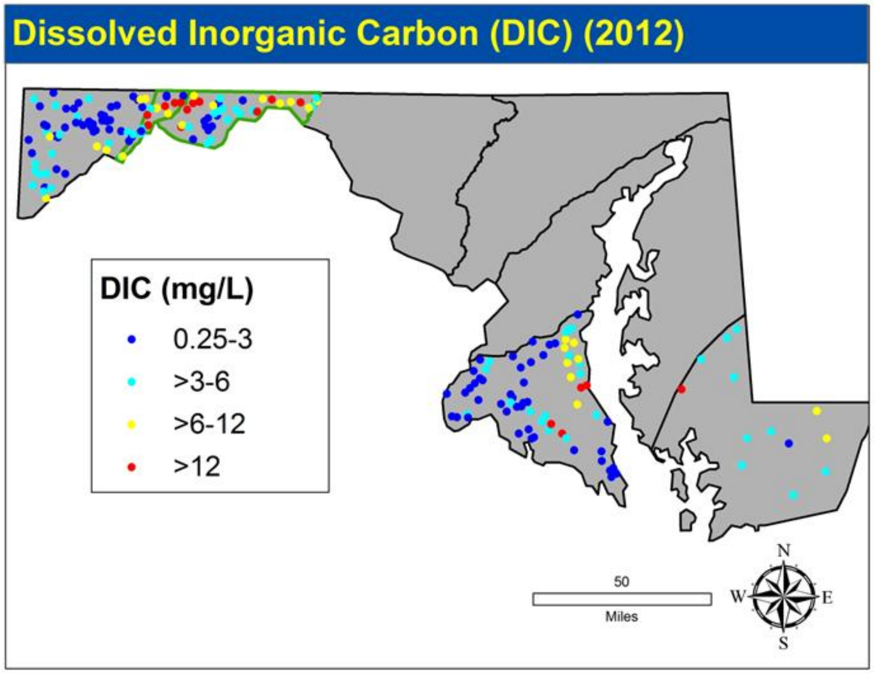


Figure 3-19. Maps showing the dissolved organic carbon (DIC) (mg/L) for each site. Top Panel shows Round 1 (1987) and Bottom Panel shows Round 2 (2012) of MSSCS. The

region outlined in green contains the Ridge and Valley MSSCS subregion.

Overall Findings for DIC

DIC increased significantly between 1987 and 2012. This pattern was evident in the study area, between MSSCS regions, and among MSSCS subregions (Figures 3-20 through 3-23). Sixteen of the 34 PSUs had increased DIC between rounds while 2 PSUs exhibited no change; DIC increased in the remaining PSUs (Appendix A Table A-5).

Study Area for DIC

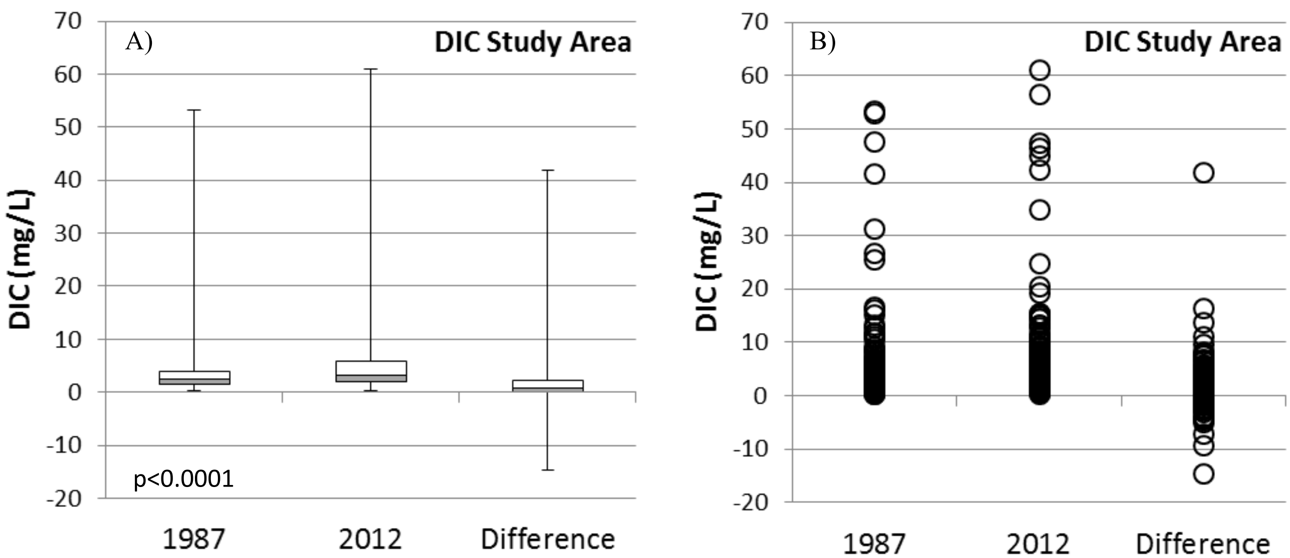


Figure 3-20. Dissolved Inorganic Carbon (DIC) in the study area. Panel A) Box and whisker plot depicting the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Panel B) Dot plot showing all values.

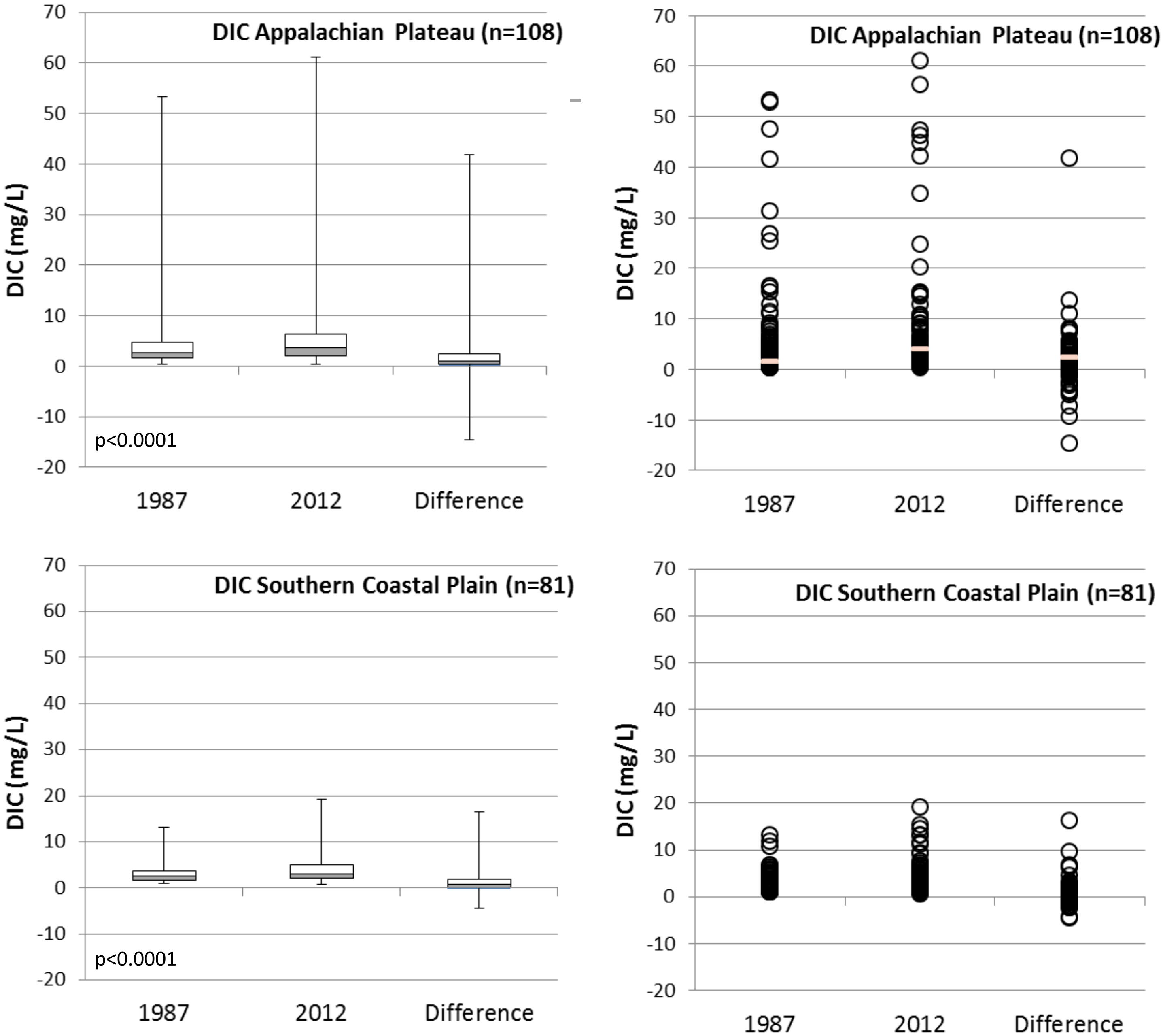


Figure 3-21. Dissolved Inorganic Carbon (DIC) in the MSSCS Regions. Box and whisker plots for A) Appalachian Region and B) Southern Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Region and D) Southern Coastal Plain show all values.

MSSCS Subregions for DIC

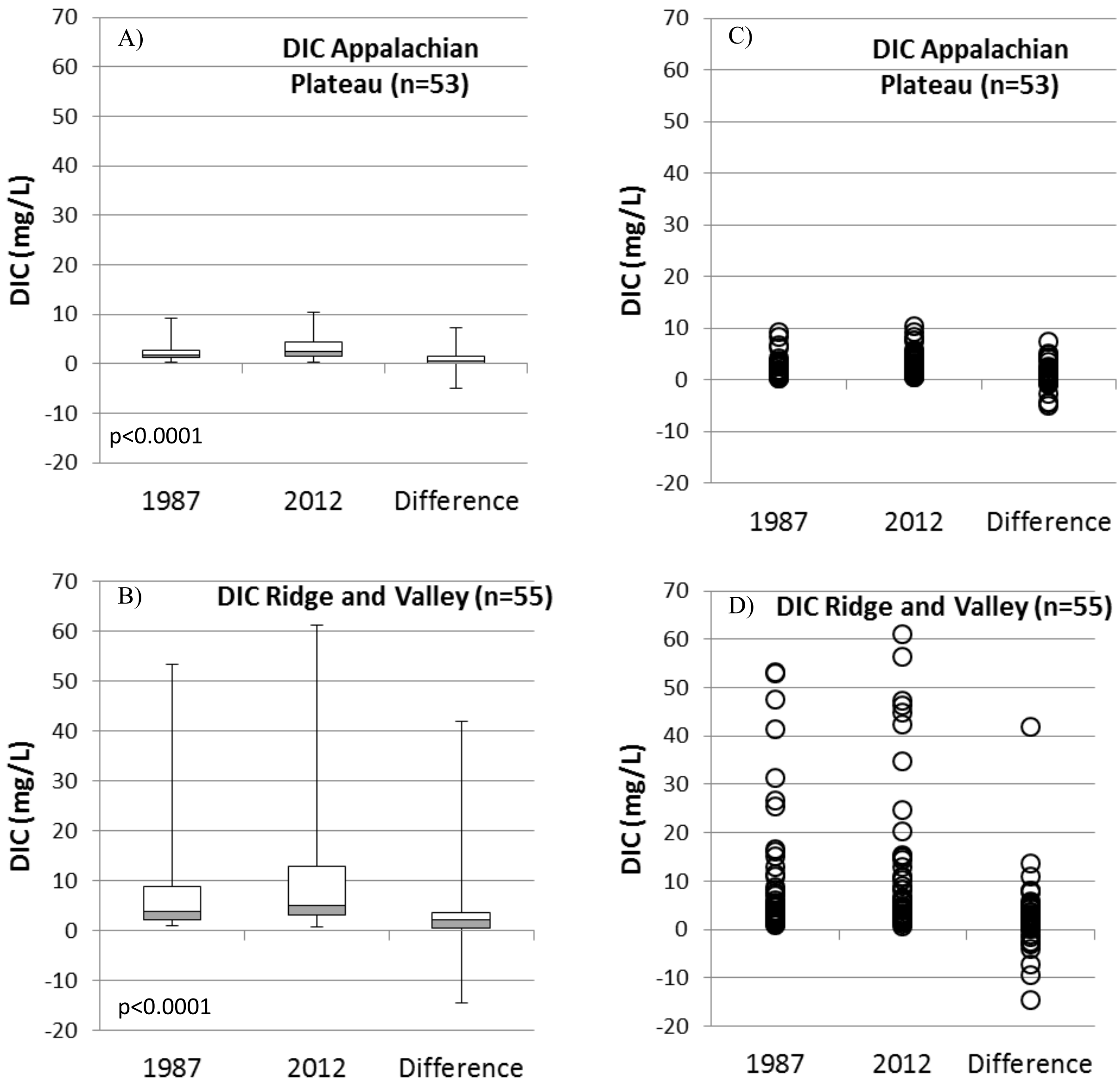
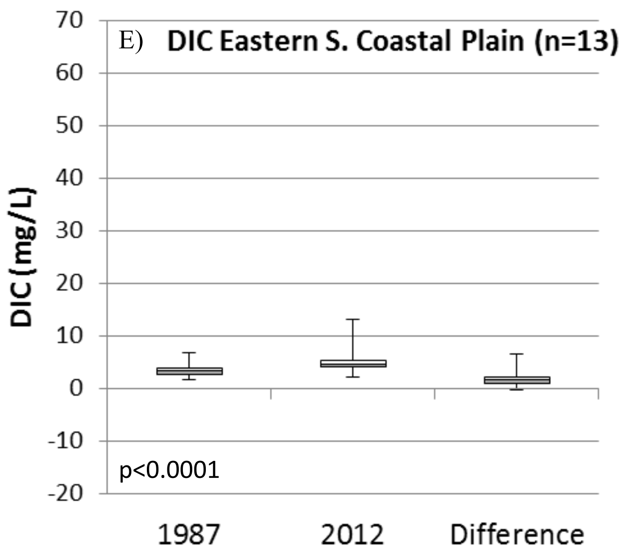
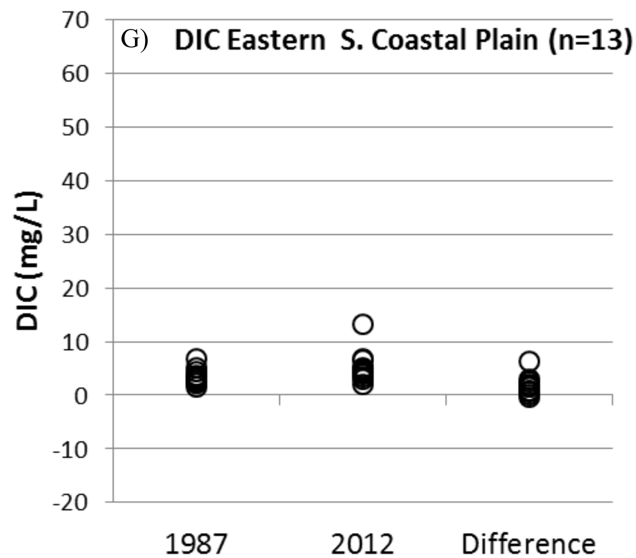
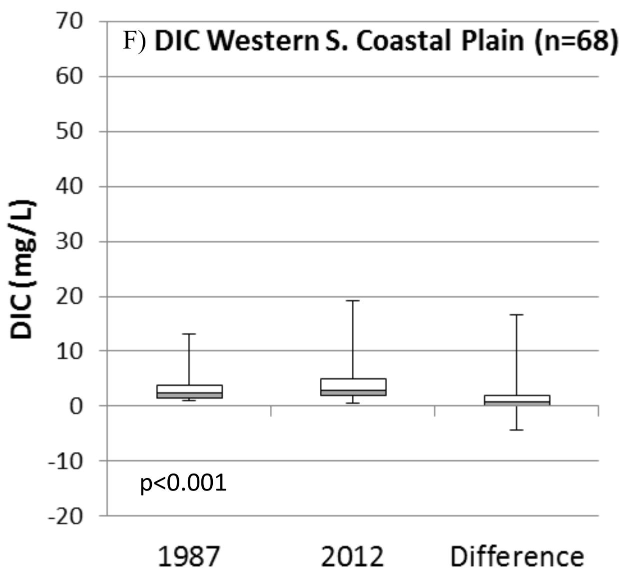


Figure 3-22. Dissolved Inorganic Carbon (DIC) for the MSSCS subregions. Box and whisker plots for A) Appalachian Plateau and B) Ridge and Valley depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test. Dot plots for C) Appalachian Plateau and D) Ridge and Valley show all values.







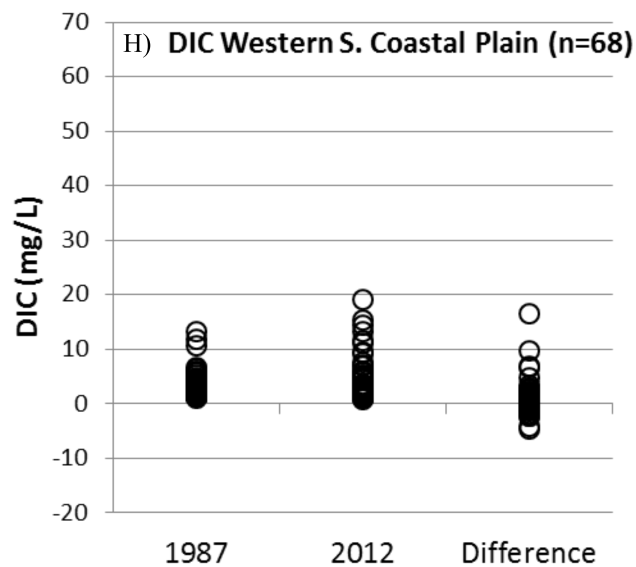


Figure 3 22 (Continued). Dissolved Inorganic Carbon (DIC) for the MSSCS subregions. Box and whisker plots for E) Eastern S. Coastal Plain and F) Western S. Coastal Plain depict the 25th, 50th (median), and 75th percentile for 1987, 2012, and the difference between years. Whiskers indicate the minimum and maximum values in the dataset. P-values indicate significance from Wilcoxon Signed Rank test.

Dot plots for G) Eastern S. Coastal Plain and H) Western S. Coastal Plain show all values.

3.2 COMPARISON OF THE % STREAM MILES IN EACH ANC CATEGORY IN ROUND 1 (1987) AND ROUND 2 (2012)

The analysis of change in ANC and other variables measured at the same sites in 1987 and 2012 clearly demonstrates a decrease in acidic characteristics over 25 years. We also took advantage of the probability-based sampling design to estimate the percentage of stream miles in ANC categories in 1987 and 2012. The change in these estimates provides a clearer picture of how the extent of the most acid sensitive streams (as indicated by ANC) declined during this time period.

3.2.1 Overall Findings for Change in %Stream Miles in ANC Categories

At the study area level, the percentage of stream miles decreased in both the acidic and highly sensitive categories of ANC whereas the percentage of stream miles in the not sensitive category increased. There was no change in the percentage of stream miles in the sensitive category (Figures 3-24, 3-25 Tables 3-1, 3-2). In the MSSCS regions, stream miles shifted to adjacent, less acidic ANC categories, i.e., from acidic to highly sensitive and from sensitive to not sensitive (Figure 3-26, Tables 3-3, 3-4). Similar patterns were evident in the MSSCS subregions. However, in Eastern Southern Coastal Plain, more stream miles shifted into the sensitive category than any other category (Figure 3-27, Tables 3-5, 3-6). The percentage change in and the number of stream miles for each ANC category per PSU are reported in the Appendix A (Appendix A, Tables A-6, A-7, and A-8) for an examination of change between rounds at a finer spatial resolution.

Table 3-2. 1987 Stream mile statistics for overall study area

Acid Category	Reach Count	Miles in Category	Total Sampled Miles Overall	% of Miles Overall
Acidic	15	18.82	181.20	10.4
Highly Sensitive	26	27.25	181.20	15.0
Sensitive	79	64.46	181.20	35.6
Not Sensitive	77	70.67	181.20	39.0

Table 3-3. 2012 Stream mile statistics for overall study area

Acid Category	Reach Count	Miles in Category	Total Sampled Miles Overall	% of Miles Overall
Acidic	11	11.96	181.20	6.6
Highly Sensitive	14	18.46	181.20	10.2
Sensitive	73	64.50	181.20	35.6
Not Sensitive	99	86.27	181.20	47.6

Study Area % in ANC Categories

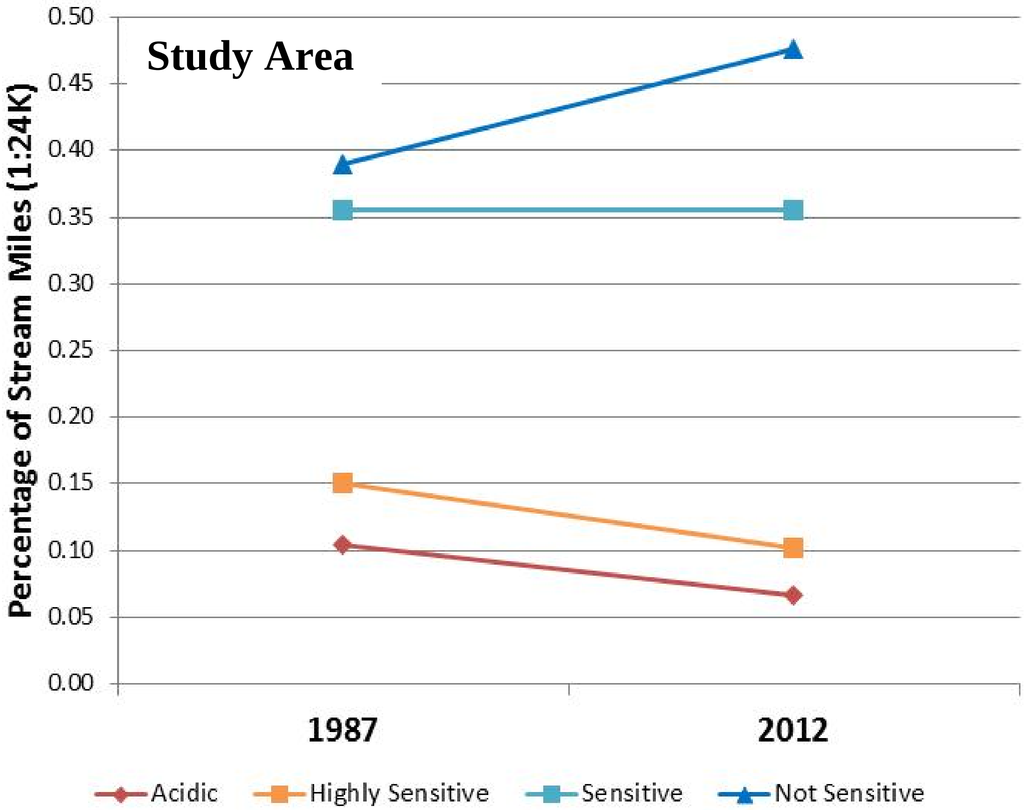


Figure 3-23. The percentage of stream miles in each of the four ANC categories for 1987 and 2012

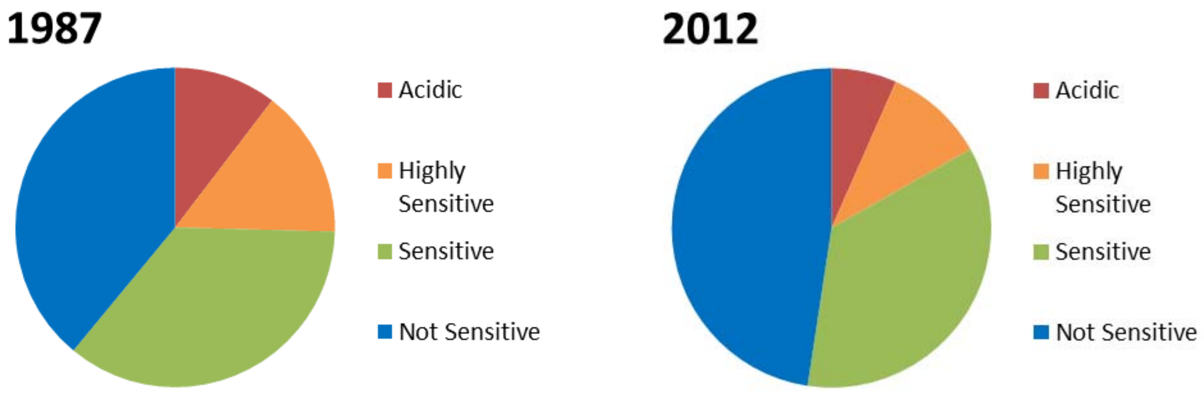


Figure 3-24. The percentage of stream miles in the overall study area in each of the four ANC categories for 1987 and 2012.

MSSCS Regions for % in ANC Categories

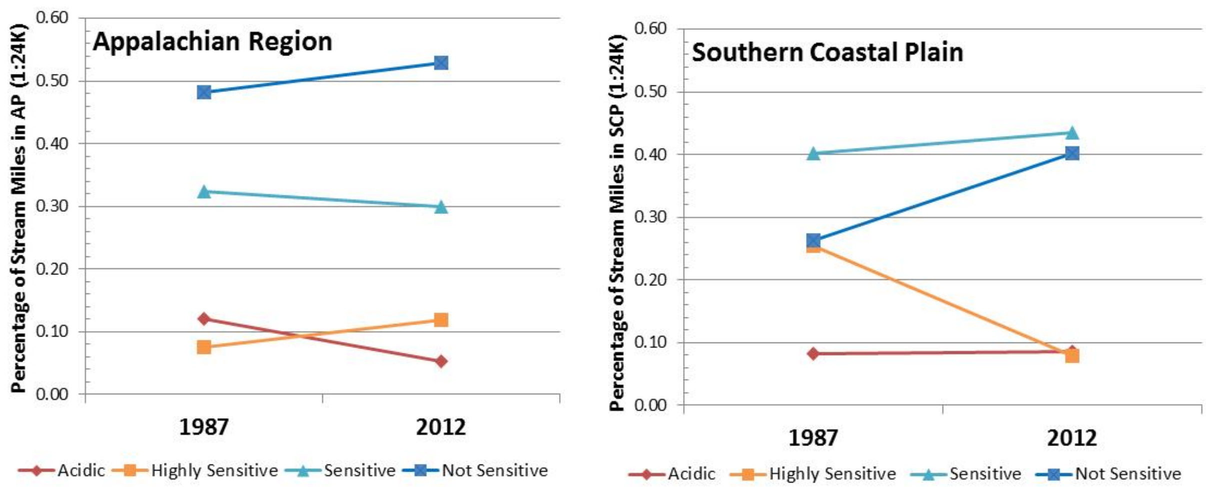


Figure 3-25. The percentage of stream miles in each of the four ANC categories for 1987 and 2012 in the MSSCS regions. A) Appalachian Region and B) Southern Coastal Plain

Table 3-4. 1987 Stream mile statistics for MSSCS regions.

Ecoregion	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in Ecoregion	% of Miles in Ecoregion
Appalachian Region	Acidic	9	12.60	105.36	12.0
Appalachian Region	Highly Sensitive	8	7.92	105.36	7.5
Appalachian Region	Sensitive	41	34.03	105.36	32.3
Appalachian Region	Not Sensitive	58	50.80	105.36	48.2
Southern Coastal Plain	Acidic	6	6.22	75.84	8.2
Southern Coastal Plain	Highly Sensitive	18	19.33	75.84	25.5
Southern Coastal Plain	Sensitive	38	30.43	75.84	40.1
Southern Coastal Plain	Not Sensitive	19	19.86	75.84	26.2

Table 3-5. 2012 Stream mile statistics for MSSCS regions.

Ecoregion	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in Ecoregion	% of Miles in Ecoregion
Appalachian Region	Acidic	6	5.53	105.36	5.2
Appalachian Region	Highly Sensitive	8	12.53	105.36	11.9
Appalachian Region	Sensitive	37	31.51	105.36	29.9
Appalachian Region	Not Sensitive	65	55.80	105.36	53.0
Southern Coastal Plain	Acidic	5	6.43	75.84	8.5
Southern Coastal Plain	Highly Sensitive	6	5.93	75.84	7.8
Southern Coastal Plain	Sensitive	36	33.00	75.84	43.5
Southern Coastal Plain	Not Sensitive	34	30.48	75.84	40.2

MSSCS Subregions for % in ANC Categories

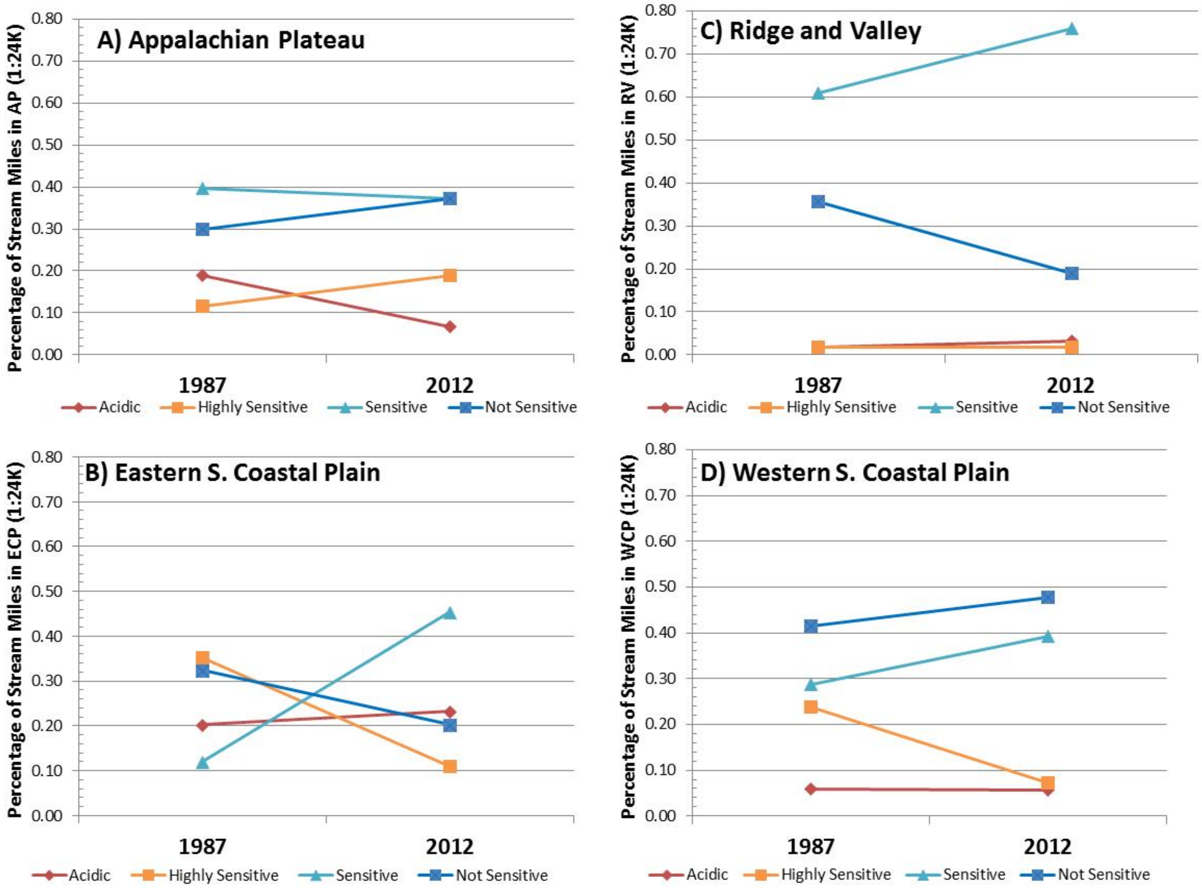


Figure 3-26. The percentage of stream miles in each of the four ANC categories for 1987 and 2012 in the MSSCS subregions: A) Appalachian Plateau, B) Eastern Southern Coastal Plain, C) Bottom Right Panel, and D) Western Southern Coastal Plain

Table 3-6. 1987 Stream mile statistics for MSSCS subregions

MSSCS Region	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in MSSCS Region	% of Miles in MSSCS Region
Appalachian Plateau	Acidic	8	11.90	62.84	19
Appalachian Plateau	Highly Sensitive	7	7.19	62.84	11
Appalachian Plateau	Sensitive	24	24.92	62.84	40
Appalachian Plateau	Not Sensitive	21	18.84	62.84	30
Ridge and Valley	Acidic	1	0.70	42.52	2
Ridge and Valley	Highly Sensitive	1	0.73	42.52	2
Ridge and Valley	Sensitive	34	25.89	42.52	61
Ridge and Valley	Not Sensitive	20	15.19	42.52	36
Eastern Coastal Plain	Acidic	2	2.41	11.81	20
Eastern Coastal Plain	Highly Sensitive	3	4.15	11.81	35
Eastern Coastal Plain	Sensitive	2	1.43	11.81	12
Eastern Coastal Plain	Not Sensitive	6	3.82	11.81	32
Western Coastal Plain	Acidic	4	3.81	64.03	6
Western Coastal Plain	Highly Sensitive	15	15.18	64.03	24
Western Coastal Plain	Sensitive	17	18.43	64.03	29
Western Coastal Plain	Not Sensitive	32	26.61	64.03	42

Table 3-7. 2012 Stream mile statistics for MSSCS subregions

MSSCS Region	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in MSSCS Region	% of Miles in MSSCS Region
Appalachian Plateau	Acidic	4	4.12	62.84	7
Appalachian Plateau	Highly Sensitive	7	11.83	62.84	19
Appalachian Plateau	Sensitive	23	23.46	62.84	37
Appalachian Plateau	Not Sensitive	26	23.43	62.84	37
Ridge and Valley	Acidic	2	1.40	42.52	3
Ridge and Valley	Highly Sensitive	1	0.70	42.52	2
Ridge and Valley	Sensitive	42	32.33	42.52	76
Ridge and Valley	Not Sensitive	11	8.08	42.52	19
Eastern Coastal Plain	Acidic	1	2.76	11.81	23
Eastern Coastal Plain	Highly Sensitive	1	1.29	11.81	11
Eastern Coastal Plain	Sensitive	7	5.36	11.81	45
Eastern Coastal Plain	Not Sensitive	4	2.40	11.81	20
Western Coastal Plain	Acidic	4	3.67	64.03	6
Western Coastal Plain	Highly Sensitive	5	4.64	64.03	7
Western Coastal Plain	Sensitive	27	25.11	64.03	39
Western Coastal Plain	Not Sensitive	32	30.60	64.03	48

4 DISCUSSION

The Maryland Synoptic Stream Chemistry Survey (MSSCS) was carried out in 1987 to better understand the extent and severity of acid effects on streams throughout Maryland. The 1987 MSSCS clearly demonstrated that significant portions of Maryland streams were acidic or acid sensitive, especially in the Appalachian and Southern Coastal Plain regions (Knapp et al. 1988). Since 1993, the annual Maryland Biological Stream Survey (MBSS) led by the Maryland Department of Natural Resources has shown that the acidic condition of these streams has degraded biological communities (Southerland et al. 2005). Concern about acidification at the national level led to the passage of the Clean Air Act Amendments (CAAA) of 1990, which curtailed power plant emissions of nitrogen and sulfur, the main drivers of ecosystem acidification in the U.S. While large scale declines in atmospheric deposition of nitrogen and sulfur oxides have occurred since the CAAA (EPA 2003), surface-water acidification remains a problem in many regions including Maryland (Greaver et al. 2012).

The work presented here found that both stream pH and ANC increased in the Appalachian Region and in the Southern Coastal Plain of Maryland during the 25 years between 1987 and 2012. This change was also significant for all of the subregions studied. These results translated to an overall 10% decline in the number of stream miles considered to be acidic or acid sensitive in Maryland since passage of the CAAA. These findings are consistent with other studies that have reported improvements in the stream chemistry in this region concomitant with a reduction in the emission of acidic compounds. Examining two sites in the Appalachian Plateau of Maryland, one study found an increase in ANC during the years 1990 to 2005 that was simultaneous with a decline in stream water sulfate (Eshleman et al. 2008). At the more acid-sensitive site in their study, ANC doubled (from 21 to 42 ueq/L). Similar responses were found in streams in the Catskill and Adirondack regions of New York (Burns et al. 2005). A decade ago, EPA analyzed long-term stream and lake monitoring data collected between 1990 and 2000 in five acid-sensitive regions of the U.S; the Northern Appalachian Plateau, the Ridge and Blue Ridge, the Adirondack Mountains, New England, and the Upper Midwest (U.S. EPA 2003). None of the sampling sites were located in Maryland; however, one of the physiographic provinces in the EPA study, Northern Appalachian Plateau, overlaps with regions studied here. EPA (2003) found that the percentage of acid stream kilometers decreased by 28% in the Northern Appalachians, concurrent with a decline in atmospheric sulfate and nitrate deposition. Little change in stream acidity in the Ridge and Blue Ridge was observed. Notably, the increase in ANC was greater for more acidic surface waters. A decline in atmospheric acid deposition and a simultaneous decline in stream acidity have been reported by others (Burns et al. 2006, Eshleman 2008), yet many factors affect stream chemistry and acid patterns at the watershed level.

Underlying stream lithology can influence how acid deposition affects stream chemistry. Researchers have demonstrated a trend of increasing alkalinity in Maryland streams (30 out of 45 Maryland streams studied) from 1978 to 2010 and have attributed this trend to chemical weathering of the underlying stream bed limestone lithology caused by acid precipitation (Kaushal et al. 2013). This pattern has similarly been reported for other systems (Likens et al. 1996, Kilham 1982). The current study found an overall decline in dissolved inorganic carbon which could include bicarbonate, a product of limestone weathering. This suggests that the increase in pH and ANC observed here could be caused by an increase in chemical weathering due to continuing acid rain as well as by the decline in acid precipitation (EPA 2003). The former point may explain why significant miles of streams in the Appalachian Region and Southern Coastal Plain regions remain acidic or acid sensitive. Future study is needed to tease apart these potential driving factors.

Topographic elevation may also play a role in stream acidity. Higher rates of alkalization were noted for watersheds at higher elevation (Kaushal et al. 2013), perhaps due to greater acid deposition combined with the thinner soils and little capacity to buffer acid effects that characterize mountainous regions (Weathers et al. 2000). The highest elevations in Maryland occur in the Appalachian Region. Of the 108 Appalachian sites in our study, 82 (76%) experienced an increase in ANC, while 67 (83%) of 81 lower elevation sites in the Coastal Plain showed increases in ANC. These similar changes between 1987 and 2012 suggest that elevation may not be distinguishing the ANC values among sites in these two regions, although additional study is required to fully understand the role of topography.

Land use history is also a potential driver of nutrient cycling and changes in stream water chemistry in forested ecosystems. Lower pH, higher sulfate, and higher conductivity are characteristic of streams draining agricultural watersheds compared to forested peatlands (Saarinen et al. 2013). Agricultural runoff high in nitrogen fertilizers and other acidifying compounds provides a source of acidification. Higher nitrate concentrations in stream water have been associated with increased forest floor nitrification in old growth forests compared to forests with a history of disturbances such as logging or burning (Goodale and Aber 20011). This pattern may be due to an excess accumulation of nitrogen relative to carbon in the soil resulting from the low rates of productivity present in old growth forests coupled with chronic nitrogen addition. In blackwater streams associated with cypress wetlands, the natural decay of organic materials acidity in the form of organic anions (Dosskey and Bertsch 1994). For the current study, comparison of land use between the years closest to the years of the two surveys (1987 and 2012) for which land use data were available (1994 and 2006) showed little change. Moreover, sites that were suspected to be affected by acid mine drainage were excluded from the analysis. The persistence of a regional scale pattern in watershed chemistry even after taking these factors into account suggests that land use history is not a major driver of the changes in acidity we observed.

Time lags in the response of stream water chemistry to the CAAA have been observed in several ecosystems. A study of five headwater stream basins in undeveloped forested areas throughout the Northeast U.S. (part of the USGS Hydrological Benchmark Network; (Cobb and Bieseker 1971, Lawrence 1987) that examined data from 1984 to 1996 for precipitation and the years 1968 to 1996 for stream chemistry, found a decrease in sulfate in precipitation and a concomitant reduction in stream water sulfate that did not translate to decreased stream acidity (Clow and Mast 1999). A similar pattern was observed in the Hubbard Brook Experimental Forest in New Hampshire over a similar time period (Driscoll et al. 1989, Likens et al. 1996). Apparent time lags between changes in precipitation chemistry and stream chemistry could result from a reduction in the leaching of base cations (e.g., Ca + MG) from the soil exchange complex. Decreased rates of base cation loss from watersheds are likely indicators of slower rates of soil acidification which could limit the rate of surface water recovery from reduction in acidic deposition seen in this study.

Conductivity is an indicator of the amounts of dissolved inorganic ions (e.g., nitrate, sulfate, magnesium, aluminum) in the stream water. This variable is directly affected by watershed geology. Streambeds made of materials that do not ionize, such as granite, contain water with lower conductivity; whereas those composed of materials such as clay that dissolve into ionic compounds have higher conductivity. Although there was little change in conductivity across the study region or in any of the subregions between 1987 and 2012, median conductivity tended to be higher in the Coastal Plain than in the Appalachian Region during both years surveyed. This finding suggests that geology rather than changes in acid deposition are driving patterns in conductivity in Maryland streams.

Nitrogen oxides can also affect watershed chemistry, and the CAAA of 1990 were aimed at curtailing the emissions of these compounds as well. Nitrogen addition to a nitrogen-limited forest is expected to act as a fertilizer and enhance production, however other responses are possible. In an investigation of the long-term surface water nitrate trends for a group of nine forested sites in the Appalachians, researchers found that nitrate-nitrogen concentrations declined from 1986 to 2005 (Eshleman et al. 2013). An ecosystem can become nitrogen saturated; i.e., the net export of nitrate brought about by the deposition of nitrogen (e.g., through acid rain, agricultural fertilization) to the watershed can occur in amounts greater than can be assimilated by its soil and vegetation (Williams et al. 1996, Aber, et al 1998). Export of excess nitrate can lead to more acidic streams, leaching of soil cations, and mobilization of aluminum. Forest clear cutting can also stimulate nitrification and lead to soil acidification and chemical weathering (Aquilina et al. 2012) While the nitrogen dynamics of forested ecosystems are complex, some evidence suggests that long-term nitrogen deposition can lead to elevated mortality rates and decreased growth rates for some tree species (Aber et al. 1995). Numerous other factors are at play in forested ecosystems including water availability, herbivory, fire history, climate change, and land use change (e.g., Mitchell et al. 1996), and should be considered in the course of biogeochemical studies. Nitrogen data were not available for both years examined in the current study, so changes in nitrogen oxides were not considered. Future analysis of statewide nitrate sampling by the MBSS in the years between 1987 and 2012 may help to elucidate these patterns.

Beyond the question of whether there has been a change in stream acidity over time is the question of how such a change affects the biological resources in Maryland streams. Numerous studies have demonstrated the detrimental effects of acidification on stream biota, including invertebrates, fish, and amphibians (Baker et al. 1996, Schindler et al. 1985, Baker and Schofield 1982, Gallagher and Baker 1990, Kahl and Scott 1994, Clark and Hall 1985). The biological response can be a reduction in vital rates, including growth, survivorship, reproduction, hatching success, and resource competition, which may scale up to population and community level effects. Increased stream acidity can cause chronic stress to the ecosystem and lead to lower body weight and smaller size that make fish less able to compete for food and habitat. Some particularly sensitive species of zooplankton and fish experience deleterious effects at pH between 5.6 and 5.9 (Baker and Christensen 1991). The young of most species are more sensitive to environmental conditions than adults and at pH 5 most fish eggs cannot hatch.

Increased stream acidity can also cause levels of aluminum in surface waters that are harmful to fish (Baker and Christensen 1991). Toxic, inorganic species of aluminum can be leached from silicate substrata when they come into contact with acidic waters. Declines in invertebrate groups such as Ephemeroptera have been associated with low pH, as have community-level indices for invertebrates such as species richness (Rosemond et al. 1992). Increases in acidity have been shown to affect the levels of mercury in fish populations, which poses a human health risk (Gilmour and Henry 1991). This mechanism is not clearly understood, but one hypothesis is that that increased sulfate concentrations may stimulate the production of methyl-mercury, which is the most bio-available form. There is also research indicating that the decline in acid rain may enhance mercury concentrations in fish (Hongve, et. al 2012). Lower acid environments lead to the release of organic carbon, which fosters the methylation of mercury.

The study presented here highlights the intrinsic value of long-term monitoring data for uncovering responses to the implementation of environmental regulations. Resampling sites in acid sensitive regions of Maryland 22 years after the passage of the CAAA showed an overall pattern of decreased acidity across the study area. Given the findings of this study, we make the following recommendations for future research. First, continued monitoring of the sites sampled in 2012, at an appropriate time interval, could provide a more robust view of long-term stream chemistry in Maryland streams. Will stream acidity continue to decline at sites where pH and ANC increased between 1987 and 2012 and can we model future trends? How will climate change influence watershed acidity? Continued long-term monitoring could begin to address such questions. An additional or alternative approach would be to use other currently existing datasets to fill in the time gaps between the two rounds of the MSSCS.

In 2000, the Maryland Department of Natural Resources conducted a study of a subset of 28 resampled sites from the MSSCS streams in the Appalachian Region that were considered to be acidic or highly acid sensitive in the 1987 Round of the MSSCS and during the MBSS sampling years of 1995-1997 (MDNR 2001). Data from the MBSS could also provide stream acid data for the years between the two sampling rounds of the MSSCS (MDNR 2013). While the MBSS has not sampled the identical sites sampled by MSSCS, coarser spatial scale patterns from the intervening years could be explored with this method. Second, local-scale patterns that are evident in the existing dataset could be explored. For example, there are some sites in the western shore region of Maryland that maintained low pH and ANC from 1987 to 2012. Additional scrutiny of site-specific factors at these locations and whether such factors are chronic or episodic would be of interest to local watershed managers. Third, data from the MBSS could be explored to examine biological responses to changes in watershed chemistry. The MBSS has collected benthic, fish, mussel, and amphibian data across the state since 1993. An integration of this biological and stream chemistry data would be a valuable step toward identifying sites for restoration.

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APPENDIX A
TABLES OF ANC, pH, CONDUCTIVITY, DOC, DIC AND STREAM MILES BY ANC CATEGORIES BY PSU

Table A-1. The median, 25th, and 75th percentile for ANC per PSU during round 1 (1987) and round 2 (2012) of the MSSCS. Green indicates an increase and blue indicates a decrease in the median between rounds. The units for ANC are µeq/L.

		1987	1987	1987	2012	2012	2012	
PSUNAME	**n**	**Median**	**25th Percentile**	**75th Percentile**	**Median**	**25th Percentile**	**75th Percentile**	**Change in the Median between 1987 and 2012**
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	1	42.8	42.8	42.8	154.7	154.7	154.7	111.9
Breton/St. Clements Bays	5	199.6	169.9	286.2	369.8	226.4	379.9	170.2
Casselman River	5	211.2	35.2	217.7	161.8	25.6	273.0	-49.4
Dividing Creek/Nassawango Creek	1	-8.4	-8.4	-8.4	22.5	22.5	22.5	30.9
Evitts Creek	7	799.2	444.5	1951.0	823.5	-3.2	4137.6	24.3
Fifteen Mile Creek	9	149.4	78.6	161.5	251.4	120.0	298.9	102.0
Fishing Bay/Transquaking River	1	166.6	166.6	166.6	223.0	223.0	223.0	56.4
Georges Creek	5	286.8	156.4	299.5	366.4	38.8	410.5	79.6
Gilbert Swamp	5	112.0	82.2	152.4	145.6	128.3	194.8	33.6
Honga River/Little Choptank/Lower Choptank	1	146.5	146.5	146.5	375.6	375.6	375.6	229.1
Little Conococheague/Licking Creek	6	544.8	391.4	741.6	593.9	362.6	1194.6	49.1
Little Youghiogheny/Deep Creek Lake	9	216.6	136.6	248.9	302.4	279.3	343.0	85.8
Lower Pocomoke River	1	111.8	111.8	111.8	255.1	255.1	255.1	143.3
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	3	8.9	-1.1	203.8	130.7	-24.5	310.1	121.8
Marshyhope Creek	3	85.3	69.3	127.9	181.7	152.8	242.7	96.4
Mattawoman Creek	7	73.0	47.8	106.8	156.5	93.5	230.9	83.5
Nanjemoy Creek	7	5.3	-15.8	107.6	29.5	-25.4	97.7	24.2
Patuxent River (Middle)	5	170.8	98.7	179.6	217.5	127.3	331.9	46.7
Patuxent River lower	13	245.1	87.6	387.5	453.0	138.4	605.7	207.9
Potomac Lower Tidal/Potomac Middle Tidal	2	96.5	6.5	186.4	110.6	58.7	162.5	14.2
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	4	333.6	262.8	566.4	703.6	504.4	1418.1	370.0
Potomac River (Lower North Branch)	12	248.1	106.4	554.9	259.8	167.2	579.4	11.7
Potomac River AL Co/Sideling Hill Creek	9	147.9	78.3	183.4	262.0	239.9	304.7	114.1
Potomac River Upper North Branch	3	209.4	-10.7	762.8	359.9	24.5	401.5	150.5

Table A-1. (Continued)

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Savage River	14	101.4	71.5	125.8	128.7	78.4	160.7	27.3
South River/West River	1	78.3	78.3	78.3	24.5	24.5	24.5	-53.8
St. Mary's River	3	30.5	6.9	42.2	72.3	63.8	116.4	41.8
Town Creek	8	743.3	176.5	3148.2	793.9	160.2	3793.5	50.6
Upper Pocomoke River	2	153.9	9.5	298.3	406.1	324.3	487.9	252.2
West Chesapeake Bay	6	430.2	120.3	852.7	546.6	242.4	1133.4	116.5
Wicomico River	6	132.5	75.6	171.1	149.5	137.4	269.4	17.0
Wills Creek	6	419.6	170.9	1439.8	771.9	236.0	899.3	352.3
Youghiogheny River	11	203.0	85.8	243.3	189.8	104.4	246.7	-13.2
Zekiah Swamp	8	61.2	30.5	108.1	132.0	107.7	164.5	70.8

Table A-2. The median, 25th, and 75th percentile for pH per PSU during round 1 (1987) and round 2 (2012) of the MSSCS. Green indicates an increase and blue indicates a decrease in the median between rounds. pH is unitless.

		1987	1987	1987	2012	2012	2012	
PSUNAME	**n**	**Median**	**25th Percentile**	**75th Percentile**	**Median**	**25th Percentile**	**75th Percentile**	**Change in the Median between 1987 and 2012**
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	1	5.5	5.5	5.5	6.2	6.2	6.2	0.7
Breton/St. Clements Bays	5	6.8	6.6	7.0	6.6	6.0	6.8	-0.1
Casselman River	5	7.1	6.3	7.2	7.0	6.2	7.3	-0.1
Dividing Creek/Nassawango Creek	1	4.8	4.8	4.8	5.2	5.2	5.2	0.4
Evitts Creek	7	7.6	7.2	7.9	7.4	5.1	8.0	-0.2
Fifteen Mile Creek	9	7.0	6.7	7.2	7.4	6.8	7.6	0.5
Fishing Bay/Transquaking River	1	6.0	6.0	6.0	5.6	5.6	5.6	-0.3
Georges Creek	5	7.1	6.9	7.2	7.5	6.5	7.5	0.3
Gilbert Swamp	5	6.7	6.7	6.9	6.7	6.7	6.8	0.0
Honga River/Little Choptank/Lower Choptank	1	6.5	6.5	6.5	7.1	7.1	7.1	0.6
Little Conococheague/Licking Creek	6	7.4	7.4	7.5	7.7	7.2	7.8	0.3
Little Youghiogheny/Deep Creek Lake	9	6.9	5.2	7.0	7.2	7.0	7.4	0.2
Lower Pocomoke River	1	6.0	6.0	6.0	6.4	6.4	6.4	0.3
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	3	4.7	4.7	6.4	6.0	4.6	6.6	1.3
Marshyhope Creek	3	6.2	6.1	6.7	6.4	6.2	6.6	0.2
Mattawoman Creek	7	6.3	6.3	6.6	6.8	6.2	7.0	0.5
Nanjemoy Creek	7	5.1	4.6	6.4	5.5	4.6	6.3	0.4
Patuxent River (Middle)	5	6.6	6.0	6.7	6.8	6.5	6.9	0.2
Patuxent River lower	13	6.9	6.4	7.1	7.1	6.6	7.2	0.2
Potomac Lower Tidal/Potomac Middle Tidal	2	6.0	5.1	6.9	6.3	5.8	6.9	0.3
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	4	7.1	7.0	7.3	7.8	7.6	8.2	0.7
Potomac River (Lower North Branch)	12	7.0	6.7	7.5	7.2	7.1	7.6	0.2
Potomac River AL Co/Sideling Hill Creek	9	6.7	6.5	6.8	7.0	6.8	7.2	0.3
Potomac River Upper North Branch	3	7.3	5.0	7.3	7.4	6.2	7.5	0.2

Table A-2. (Continued)

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Savage River	14	7.0	6.6	7.1	7.1	7.0	7.2	0.1
South River/West River	1	6.0	6.0	6.0	5.8	5.8	5.8	-0.2
St. Mary's River	3	5.4	5.2	5.9	6.1	6.0	6.2	0.6
Town Creek	8	7.7	7.1	8.0	7.7	6.9	8.2	-0.1
Upper Pocomoke River	2	5.7	5.0	6.5	6.5	6.5	6.6	0.8
West Chesapeake Bay	6	6.9	6.5	7.2	7.1	6.8	7.3	0.1
Wicomico River	6	6.4	5.8	6.5	6.5	6.4	6.8	0.1
Wills Creek	6	7.4	7.1	8.0	7.7	7.3	8.0	0.3
Youghiogheny River	11	6.9	6.6	7.2	7.3	6.7	7.4	0.4
Zekiah Swamp	8	6.2	5.8	6.5	6.5	6.4	6.8	0.3

Table A-3. The median, 25th, and 75th percentile for conductivity per PSU during round 1 (1987) and round 2 (2012) of the MSSCS. Green indicates an increase and blue indicates a decrease in the median between rounds. The units for conductivity are µS/cm.

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	1	103	103	103	101	101	101	-2
Breton/St. Clements Bays	5	78	78	82	80	67	94	2
Casselman River	5	81	65	84	119	47	128	38
Dividing Creek/Nassawango Creek	1	62	62	62	40	40	40	-22
Evitts Creek	7	117	93	698	148	43	426	31
Fifteen Mile Creek	9	62	56	70	57	42	87	-5
Fishing Bay/Transquaking River	1	162	162	162	22	22	22	-140
Georges Creek	5	239	80	273	200	31	244	-39
Gilbert Swamp	5	82	63	99	92	86	114	11
Honga River/Little Choptank/Lower Choptank	1	176	176	176	252	252	252	76
Little Conococheague/Licking Creek	6	98	61	233	83	50	135	-15
Little Youghiogheny/Deep Creek Lake	9	82	70	138	79	72	153	-4
Lower Pocomoke River	1	175	175	175	146	146	146	-29
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	3	100	86	103	91	74	101	-10
Marshyhope Creek	3	143	134	167	175	169	191	32
Mattawoman Creek	7	120	65	134	109	79	165	-12
Nanjemoy Creek	7	64	57	66	37	33	47	-27
Patuxent River (Middle)	5	151	150	165	168	156	173	17
Patuxent River lower	13	136	128	154	161	139	210	25
Potomac Lower Tidal/Potomac Middle Tidal	2	123	110	136	62	41	83	-61
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	4	145	118	166	183	156	350	38
Potomac River (Lower North Branch)	12	92	64	123	74	54	149	-19
Potomac River AL Co/Sideling Hill Creek	9	64	57	67	67	55	90	3
Potomac River Upper North Branch	3	76	52	113	71	33	274	-5

Table A-3. (Continued)								
		1987	1987	1987	2012	2012	2012	
PSUNAME	**n**	**Median**	**25th Percentile**	**75th Percentile**	**Median**	**25th Percentile**	**75th Percentile**	**Change in the Median between 1987 and 2012**
Savage River	14	57	49	61	48	41	54	-9
South River/West River	1	133	133	133	76	76	76	-57
St. Mary's River	3	60	51	63	58	54	60	-2
Town Creek	8	117	58	360	135	49	429	18
Upper Pocomoke River	2	131	129	134	163	155	171	31
West Chesapeake Bay	6	125	98	145	139	43	164	13
Wicomico River	6	94	68	110	69	58	73	-25
Wills Creek	6	241	80	514	324	67	441	83
Youghiogheny River	11	77	45	93	86	44	104	10
Zekiah Swamp	8	82	76	101	74	61	79	-8

Table A-4. The median, 25th, and 75th percentile for dissolved organic carbon (DOC) per PSU during round 1 (1987) and round 2 (2012) of the MSSCS. Green indicates an increase and blue indicates a decrease in the median between rounds. The units for DOC are mg/L.

		1987	**1987**	**1987**	**2012**	**2012**	**2012**	
PSUNAME	**n**	**Median**	**25th Percentile**	**75th Percentile**	**Median**	**25th Percentile**	**75th Percentile**	**Change in the Median between 1987 and 2012**
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	1	2.4	2.4	2.4	9.4	9.4	9.4	6.9
Breton/St. Clements Bays	5	3.9	3.2	4.6	2.9	2.3	5.1	-1.0
Casselman River	5	1.3	0.8	1.4	1.6	1.2	2.2	0.2
Dividing Creek/Nassawango Creek	1	12.4	12.4	12.4	11.2	11.2	11.2	-1.1
Evitts Creek	7	1.7	1.4	2.3	1.7	0.8	2.5	0.0
Fifteen Mile Creek	9	1.1	1.1	1.2	1.3	1.3	1.4	0.2
Fishing Bay/Transquaking River	1	4.8	4.8	4.8	13.8	13.8	13.8	8.9
Georges Creek	5	0.7	0.7	0.7	0.4	0.3	0.4	-0.3
Gilbert Swamp	5	3.4	2.3	3.6	2.1	1.8	2.5	-1.2
Honga River/Little Choptank/Lower Choptank	1	3.2	3.2	3.2	2.3	2.3	2.3	-1.0
Little Conococheague/Licking Creek	6	2.0	1.4	2.2	1.4	1.3	1.6	-0.6
Little Youghiogheny/Deep Creek Lake	9	1.5	1.3	1.6	1.2	0.8	1.5	-0.3
Lower Pocomoke River	1	3.8	3.8	3.8	9.0	9.0	9.0	5.3
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	3	4.4	2.6	6.8	10.7	7.1	18.4	6.3
Marshyhope Creek	3	4.2	3.4	9.5	1.4	0.9	1.7	-2.8
Mattawoman Creek	7	4.7	3.7	5.1	3.1	2.0	5.3	-1.6
Nanjemoy Creek	7	3.7	3.6	12.7	8.1	4.2	19.5	4.4
Patuxent River (Middle)	5	4.7	2.9	5.2	3.4	2.1	3.8	-1.4
Patuxent River lower	13	4.6	2.6	5.1	2.6	2.2	3.3	-2.0
Potomac Lower Tidal/Potomac Middle Tidal	2	6.6	4.6	8.7	6.3	2.3	10.4	-0.3
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	4	1.5	1.3	1.9	2.0	1.6	3.9	0.5
Potomac River (Lower North Branch)	12	1.2	1.2	1.7	1.6	1.2	1.7	0.3
Potomac River AL Co/Sideling Hill Creek	9	1.3	1.1	1.6	1.5	1.4	1.7	0.2
Potomac River Upper North Branch	3	0.9	0.8	1.9	1.1	1.0	1.1	0.2

Table A-4. (Continued)

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Savage River	14	0.8	0.7	1.1	1.0	0.9	1.2	0.2
South River/West River	1	4.2	4.2	4.2	3.3	3.3	3.3	-0.9
St. Mary's River	3	5.6	2.4	8.8	7.0	4.4	8.2	1.4
Town Creek	8	1.2	1.0	1.3	1.3	1.0	1.6	0.1
Upper Pocomoke River	2	14.2	12.2	16.2	15.9	9.9	21.9	1.7
West Chesapeake Bay	6	5.9	3.2	10.8	2.7	2.1	3.6	-3.2
Wicomico River	6	4.5	3.0	5.9	3.4	2.9	3.9	-1.1
Wills Creek	6	0.8	0.6	1.0	0.9	0.6	1.1	0.0
Youghiogheny River	11	0.9	0.8	1.2	1.1	0.8	1.9	0.2
Zekiah Swamp	8	5.0	2.9	6.8	4.7	2.8	6.2	-0.2

Table A-5. The median, 25th, and 75th percentile for dissolved inorganic carbon (DIC) per PSU during round 1 (1987) and round 2 (2012) of the MSSCS. Green indicates an increase and blue indicates a decrease in the median between rounds. The units for DIC are mg/L.

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	1	3.4	3.4	3.4	3.0	3.0	3.0	-0.4
Breton/St. Clements Bays	5	2.8	2.5	3.0	5.3	3.4	13.2	2.5
Casselman River	5	2.5	0.7	2.6	2.2	0.7	3.7	-0.3
Dividing Creek/Nassawango Creek	1	1.6	1.6	1.6	2.1	2.1	2.1	0.5
Evitts Creek	7	8.3	5.4	25.4	10.8	1.1	47.3	2.5
Fifteen Mile Creek	9	1.9	1.4	2.0	3.2	1.9	3.8	1.3
Fishing Bay/Transquaking River	1	6.8	6.8	6.8	13.2	13.2	13.2	6.4
Georges Creek	5	3.3	1.9	3.5	4.7	1.1	5.3	1.3
Gilbert Swamp	5	1.8	1.3	1.9	2.2	1.8	2.8	0.4
Honga River/Little Choptank/Lower Choptank	1	3.3	3.3	3.3	4.9	4.9	4.9	1.6
Little Conococheague/Licking Creek	6	6.4	3.5	8.7	7.3	4.8	14.5	0.9
Little Youghiogheny/Deep Creek Lake	9	2.7	1.8	3.0	4.5	3.9	5.5	1.8
Lower Pocomoke River	1	2.8	2.8	2.8	4.5	4.5	4.5	1.7
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	3	3.3	3.1	4.4	4.0	3.5	5.2	0.7
Marshyhope Creek	3	2.3	2.2	2.7	4.6	4.2	4.8	2.3
Mattawoman Creek	7	1.7	1.2	1.9	2.9	2.5	3.1	1.2
Nanjemoy Creek	7	2.0	1.5	2.4	2.1	1.6	2.9	0.1
Patuxent River (Middle)	5	2.9	2.6	3.0	3.4	2.6	4.9	0.5
Patuxent River lower	13	4.3	2.8	5.8	6.0	3.0	7.7	1.7
Potomac Lower Tidal/Potomac Middle Tidal	2	2.3	1.5	3.1	2.3	2.0	2.7	0.0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	4	4.1	3.3	7.8	8.3	6.3	17.4	4.2
Potomac River (Lower North Branch)	12	3.7	2.4	6.8	5.0	2.9	7.5	1.3
Potomac River AL Co/Sideling Hill Creek	9	2.4	1.4	2.6	4.2	3.2	4.6	1.8
Potomac River Upper North Branch	3	2.5	0.5	9.2	4.7	0.8	5.1	2.2

Table A-5. (Continued)

PSUNAME	n	1987 Median	1987 25th Percentile	1987 75th Percentile	2012 Median	2012 25th Percentile	2012 75th Percentile	Change in the Median between 1987 and 2012
Savage River	14	1.4	1.0	1.6	1.8	1.2	2.1	0.3
South River/West River	1	2.4	2.4	2.4	1.4	1.4	1.4	-1.0
St. Mary's River	3	2.2	1.6	3.3	1.3	1.0	2.1	-1.0
Town Creek	8	8.2	2.3	36.4	9.7	2.4	44.4	1.5
Upper Pocomoke River	2	4.4	3.8	5.1	6.6	6.6	6.7	2.2
West Chesapeake Bay	6	6.1	2.4	10.7	7.5	3.7	14.5	1.4
Wicomico River	6	3.1	2.3	4.6	2.8	2.4	4.5	-0.4
Wills Creek	6	4.6	2.2	8.3	9.4	3.2	10.9	4.8
Youghiogheny River	11	1.9	1.2	2.8	2.5	1.9	3.2	0.7
Zekiah Swamp	8	1.7	1.4	2.3	2.3	2.0	2.7	0.6

Table A-6. The change in the percentage of stream miles between round 1 (1987) and round 2 (2012) of the MSSCS by PSU. Green indicates an increase between rounds and blue indicates a decrease between rounds.

PSU	Acid Category	% of Stream Miles in PSU 1968	% of Stream Miles in PSU 2012	Change in % Stream Miles 1987-2012
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Acidic	0%	0%	0%
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Highly Sensitive	100%	0%	-100%
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Sensitive	0%	100%	100%
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Not Sensitive	0%	0%	0%
Breton/St. Clements Bays	Acidic	0%	0%	0%
Breton/St. Clements Bays	Highly Sensitive	10%	0%	-10%
Breton/St. Clements Bays	Sensitive	41%	10%	-32%
Breton/St. Clements Bays	Not Sensitive	49%	90%	41%
Casselman River	Acidic	32%	16%	-16%
Casselman River	Highly Sensitive	22%	22%	0%
Casselman River	Sensitive	13%	43%	30%
Casselman River	Not Sensitive	34%	20%	-14%
Dividing Creek/Nassawango Creek	Acidic	100%	0%	-100%
Dividing Creek/Nassawango Creek	Highly Sensitive	0%	100%	100%
Dividing Creek/Nassawango Creek	Sensitive	0%	0%	0%
Dividing Creek/Nassawango Creek	Not Sensitive	0%	0%	0%
Evitts Creek	Acidic	0%	35%	35%
Evitts Creek	Highly Sensitive	0%	0%	0%
Evitts Creek	Sensitive	0%	14%	14%
Evitts Creek	Not Sensitive	100%	51%	-49%
Fifteen Mile Creek	Acidic	0%	0%	0%
Fifteen Mile Creek	Highly Sensitive	0%	0%	0%
Fifteen Mile Creek	Sensitive	85%	47%	-38%
Fifteen Mile Creek	Not Sensitive	15%	53%	38%
Fishing Bay/Transquaking River	Acidic	0%	0%	0%
Fishing Bay/Transquaking River	Highly Sensitive	0%	0%	0%
Fishing Bay/Transquaking River	Sensitive	100%	0%	-100%
Fishing Bay/Transquaking River	Not Sensitive	0%	100%	100%
Georges Creek	Acidic	0%	0%	0%
Georges Creek	Highly Sensitive	0%	39%	39%
Georges Creek	Sensitive	39%	0%	-39%
Georges Creek	Not Sensitive	61%	61%	0%

Table A-6. (Continued)

PSU	Acid Category	% of Stream Miles in PSU 1968	% of Stream Miles in PSU 2012	Change in % Stream Miles 1987-2012
Gilbert Swamp	Acidic	0%	0%	0%
Gilbert Swamp	Highly Sensitive	0%	36%	36%
Gilbert Swamp	Sensitive	88%	52%	-36%
Gilbert Swamp	Not Sensitive	12%	12%	0%
Honga River/Little Choptank/Lower Choptank	Acidic	0%	0%	0%
Honga River/Little Choptank/Lower Choptank	Highly Sensitive	0%	0%	0%
Honga River/Little Choptank/Lower Choptank	Sensitive	100%	0%	-100%
Honga River/Little Choptank/Lower Choptank	Not Sensitive	0%	100%	100%
Little Conococheague/Licking Creek	Acidic	0%	0%	0%
Little Conococheague/Licking Creek	Highly Sensitive	0%	0%	0%
Little Conococheague/Licking Creek	Sensitive	0%	0%	0%
Little Conococheague/Licking Creek	Not Sensitive	100%	100%	0%
Little Youghiogheny/Deep Creek Lake	Acidic	24%	11%	-13%
Little Youghiogheny/Deep Creek Lake	Highly Sensitive	2%	0%	-2%
Little Youghiogheny/Deep Creek Lake	Sensitive	8%	21%	13%
Little Youghiogheny/Deep Creek Lake	Not Sensitive	66%	68%	2%
Lower Pocomoke River	Acidic	0%	0%	0%
Lower Pocomoke River	Highly Sensitive	0%	0%	0%
Lower Pocomoke River	Sensitive	100%	0%	-100%
Lower Pocomoke River	Not Sensitive	0%	100%	100%
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Acidic	26%	65%	39%
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Highly Sensitive	65%	0%	-65%
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Sensitive	0%	26%	26%
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Not Sensitive	8%	8%	0%
Marshyhope Creek	Acidic	0%	0%	0%
Marshyhope Creek	Highly Sensitive	0%	0%	0%
Marshyhope Creek	Sensitive	100%	54%	-46%
Marshyhope Creek	Not Sensitive	0%	46%	46%
Mattawoman Creek	Acidic	0%	0%	0%
Mattawoman Creek	Highly Sensitive	25%	0%	-25%
Mattawoman Creek	Sensitive	43%	78%	36%
Mattawoman Creek	Not Sensitive	32%	22%	-10%
Nanjemoy Creek	Acidic	46%	46%	0%
Nanjemoy Creek	Highly Sensitive	22%	22%	0%

Table A-6. (Continued)

PSU	Acid Category	% of Stream Miles in PSU 1968	% of Stream Miles in PSU 2012	Change in % Stream Miles 1987-2012
Nanjemoy Creek	Sensitive	32%	32%	0%
Nanjemoy Creek	Not Sensitive	0%	0%	0%
Patuxent River (Middle)	Acidic	0%	0%	0%
Patuxent River (Middle)	Highly Sensitive	15%	0%	-15%
Patuxent River (Middle)	Sensitive	77%	31%	-46%
Patuxent River (Middle)	Not Sensitive	9%	69%	60%
Patuxent River lower	Acidic	0%	4%	4%
Patuxent River lower	Highly Sensitive	12%	4%	-8%
Patuxent River lower	Sensitive	36%	33%	-4%
Patuxent River lower	Not Sensitive	52%	59%	8%
Potomac Lower Tidal/Potomac Middle Tidal	Acidic	0%	0%	0%
Potomac Lower Tidal/Potomac Middle Tidal	Highly Sensitive	65%	0%	-65%
Potomac Lower Tidal/Potomac Middle Tidal	Sensitive	35%	100%	65%
Potomac Lower Tidal/Potomac Middle Tidal	Not Sensitive	0%	0%	0%
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Acidic	0%	0%	0%
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Highly Sensitive	0%	0%	0%
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Sensitive	0%	0%	0%
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Not Sensitive	100%	100%	0%
Potomac River (Lower North Branch)	Acidic	5%	0%	-5%
Potomac River (Lower North Branch)	Highly Sensitive	0%	5%	5%
Potomac River (Lower North Branch)	Sensitive	40%	22%	-18%
Potomac River (Lower North Branch)	Not Sensitive	55%	73%	18%
Potomac River AL Co/Sideling Hill Creek	Acidic	0%	0%	0%
Potomac River AL Co/Sideling Hill Creek	Highly Sensitive	13%	0%	-13%
Potomac River AL Co/Sideling Hill Creek	Sensitive	76%	23%	-54%
Potomac River AL Co/Sideling Hill Creek	Not Sensitive	11%	77%	66%
Potomac River Upper North Branch	Acidic	48%	15%	-33%
Potomac River Upper North Branch	Highly Sensitive	0%	33%	33%
Potomac River Upper North Branch	Sensitive	0%	15%	15%
Potomac River Upper North Branch	Not Sensitive	52%	36%	-15%
Savage River	Acidic	24%	0%	-24%
Savage River	Highly Sensitive	20%	24%	4%
Savage River	Sensitive	56%	61%	5%
Savage River	Not Sensitive	0%	15%	15%

Table A-6. (Continued)

PSU	Acid Category	% of Stream Miles in PSU 1968	% of Stream Miles in PSU 2012	Change in % Stream Miles 1987-2012
South River/West River	Acidic	0%	0%	0%
South River/West River	Highly Sensitive	0%	100%	100%
South River/West River	Sensitive	100%	0%	-100%
South River/West River	Not Sensitive	0%	0%	0%
St. Mary's River	Acidic	0%	0%	0%
St. Mary's River	Highly Sensitive	100%	0%	-100%
St. Mary's River	Sensitive	0%	100%	100%
St. Mary's River	Not Sensitive	0%	0%	0%
Town Creek	Acidic	0%	0%	0%
Town Creek	Highly Sensitive	0%	0%	0%
Town Creek	Sensitive	23%	34%	11%
Town Creek	Not Sensitive	77%	66%	-11%
Upper Pocomoke River	Acidic	0%	0%	0%
Upper Pocomoke River	Highly Sensitive	46%	0%	-46%
Upper Pocomoke River	Sensitive	0%	0%	0%
Upper Pocomoke River	Not Sensitive	54%	100%	46%
West Chesapeake Bay	Acidic	11%	0%	-11%
West Chesapeake Bay	Highly Sensitive	0%	11%	11%
West Chesapeake Bay	Sensitive	16%	0%	-16%
West Chesapeake Bay	Not Sensitive	73%	89%	16%
Wicomico River	Acidic	0%	0%	0%
Wicomico River	Highly Sensitive	26%	0%	-26%
Wicomico River	Sensitive	33%	58%	25%
Wicomico River	Not Sensitive	40%	42%	1%
Wills Creek	Acidic	13%	13%	0%
Wills Creek	Highly Sensitive	20%	0%	-20%
Wills Creek	Sensitive	15%	20%	5%
Wills Creek	Not Sensitive	53%	68%	15%
Youghiogheny River	Acidic	0%	0%	0%
Youghiogheny River	Highly Sensitive	7%	14%	8%
Youghiogheny River	Sensitive	37%	39%	3%
Youghiogheny River	Not Sensitive	57%	46%	-11%
Zekiah Swamp	Acidic	0%	0%	0%
Zekiah Swamp	Highly Sensitive	55%	0%	-55%

Table A-6. (Continued)

PSU	Acid Category	% of Stream Miles in PSU 1968	% of Stream Miles in PSU 2012	Change in % Stream Miles 1987-2012
Zekiah Swamp	Sensitive	45%	88%	42%
Zekiah Swamp	Not Sensitive	0%	12%	12%

Table A-7. Round 1 (1987) Stream mile statistics for PSUs					
PSU	**Acid Category**	**Reach Count**	**Miles in Category**	**Total Sampled Miles in PSU**	**% of Miles in PSU**
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Acidic	0	0.00	0.00	0
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Highly Sensitive	1	0.48	0.48	100
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Sensitive	0	0.00	0.00	0
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Not Sensitive	0	0.00	0.00	0
Breton/St. Clements Bays	Acidic	0	0.00	0.00	0
Breton/St. Clements Bays	Highly Sensitive	3	0.36	3.73	10
Breton/St. Clements Bays	Sensitive	2	1.55	3.73	41
Breton/St. Clements Bays	Not Sensitive	2	1.82	3.73	49
Casselman River	Acidic	4	3.14	9.93	32
Casselman River	Highly Sensitive	1	2.16	9.93	22
Casselman River	Sensitive	1	1.27	9.93	13
Casselman River	Not Sensitive	3	3.36	9.93	34
Dividing Creek/Nassawango Creek	Acidic	1	1.29	1.29	100
Dividing Creek/Nassawango Creek	Highly Sensitive	0	0.00	0.00	0
Dividing Creek/Nassawango Creek	Sensitive	0	0.00	0.00	0
Dividing Creek/Nassawango Creek	Not Sensitive	0	0.00	0.00	0
Evitts Creek	Acidic	0	0.00	0.00	0
Evitts Creek	Highly Sensitive	0	0.00	0.00	0
Evitts Creek	Sensitive	0	0.00	0.00	0
Evitts Creek	Not Sensitive	1	3.97	3.97	100
Fifteen Mile Creek	Acidic	0	0.00	0.00	0
Fifteen Mile Creek	Highly Sensitive	0	0.00	0.00	0
Fifteen Mile Creek	Sensitive	8	4.79	5.63	85
Fifteen Mile Creek	Not Sensitive	2	0.84	5.63	15
Fishing Bay/Transquaking River	Acidic	0	0.00	0.00	0
Fishing Bay/Transquaking River	Highly Sensitive	0	0.00	0.00	0
Fishing Bay/Transquaking River	Sensitive	1	0.19	0.19	100
Fishing Bay/Transquaking River	Not Sensitive	0	0.00	0.00	0
Georges Creek	Acidic	0	0.00	0.00	0
Georges Creek	Highly Sensitive	0	0.00	0.00	0
Georges Creek	Sensitive	2	2.60	6.59	39
Georges Creek	Not Sensitive	2	3.99	6.59	61
Gilbert Swamp	Acidic	0	0.00	0.00	0
Gilbert Swamp	Highly Sensitive	0	0.00	0.00	0
Gilbert Swamp	Sensitive	4	3.10	3.52	88

Table A-7. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
Gilbert Swamp	Not Sensitive	2	0.42	3.52	12
Honga River/Little Choptank/Lower Choptank	Acidic	0	0.00	0.00	0
Honga River/Little Choptank/Lower Choptank	Highly Sensitive	0	0.00	0.00	0
Honga River/Little Choptank/Lower Choptank	Sensitive	1	0.88	0.88	100
Honga River/Little Choptank/Lower Choptank	Not Sensitive	0	0.00	0.00	0
Little Conococheague/Licking Creek	Acidic	0	0.00	0.00	0
Little Conococheague/Licking Creek	Highly Sensitive	0	0.00	0.00	0
Little Conococheague/Licking Creek	Sensitive	0	0.00	0.00	0
Little Conococheague/Licking Creek	Not Sensitive	1	3.92	3.92	100
Little Youghiogheny/Deep Creek Lake	Acidic	4	2.04	8.38	24
Little Youghiogheny/Deep Creek Lake	Highly Sensitive	1	0.18	8.38	2
Little Youghiogheny/Deep Creek Lake	Sensitive	1	0.66	8.38	8
Little Youghiogheny/Deep Creek Lake	Not Sensitive	6	5.50	8.38	66
Lower Pocomoke River	Acidic	0	0.00	0.00	0
Lower Pocomoke River	Highly Sensitive	0	0.00	0.00	0
Lower Pocomoke River	Sensitive	1	1.26	1.26	100
Lower Pocomoke River	Not Sensitive	0	0.00	0.00	0
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Acidic	3	1.12	4.24	26
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Highly Sensitive	1	2.76	4.24	65
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Sensitive	0	0.00	0.00	0
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Not Sensitive	1	0.35	4.24	8
Marshyhope Creek	Acidic	0	0.00	0.00	0
Marshyhope Creek	Highly Sensitive	0	0.00	0.00	0
Marshyhope Creek	Sensitive	1	1.49	1.49	100
Marshyhope Creek	Not Sensitive	0	0.00	0.00	0
Mattawoman Creek	Acidic	0	0.00	0.00	0
Mattawoman Creek	Highly Sensitive	3	2.51	9.88	25
Mattawoman Creek	Sensitive	4	4.23	9.88	43
Mattawoman Creek	Not Sensitive	1	3.14	9.88	32
Nanjemoy Creek	Acidic	3	3.15	6.91	46
Nanjemoy Creek	Highly Sensitive	1	1.54	6.91	22
Nanjemoy Creek	Sensitive	3	2.22	6.91	32
Nanjemoy Creek	Not Sensitive	0	0.00	0.00	0
Patuxent River (Middle)	Acidic	0	0.00	0.00	0
Patuxent River (Middle)	Highly Sensitive	3	0.82	5.59	15

Table A-7. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
Patuxent River (Middle)	Sensitive	3	4.28	5.59	77
Patuxent River (Middle)	Not Sensitive	1	0.49	5.59	9
Patuxent River lower	Acidic	0	0.00	0.00	0
Patuxent River lower	Highly Sensitive	3	1.53	12.61	12
Patuxent River lower	Sensitive	4	4.58	12.61	36
Patuxent River lower	Not Sensitive	7	6.50	12.61	52
Potomac Lower Tidal/Potomac Middle Tidal	Acidic	0	0.00	0.00	0
Potomac Lower Tidal/Potomac Middle Tidal	Highly Sensitive	2	1.80	2.77	65
Potomac Lower Tidal/Potomac Middle Tidal	Sensitive	1	0.97	2.77	.35
Potomac Lower Tidal/Potomac Middle Tidal	Not Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Acidic	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Highly Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Not Sensitive	1	2.01	2.01	100
Potomac River (Lower North Branch)	Acidic	3	0.70	13.30	5
Potomac River (Lower North Branch)	Highly Sensitive	0	0.00	0.00	0
Potomac River (Lower North Branch)	Sensitive	5	5.26	13.30	40
Potomac River (Lower North Branch)	Not Sensitive	7	7.34	13.30	55
Potomac River AL Co/Sideling Hill Creek	Acidic	0	0.00	0.00	0
Potomac River AL Co/Sideling Hill Creek	Highly Sensitive	3	0.73	5.74	13
Potomac River AL Co/Sideling Hill Creek	Sensitive	6	4.37	5.74	76
Potomac River AL Co/Sideling Hill Creek	Not Sensitive	2	0.64	5.74	11
Potomac River Upper North Branch	Acidic	2	2.70	5.62	48
Potomac River Upper North Branch	Highly Sensitive	0	0.00	0.00	0
Potomac River Upper North Branch	Sensitive	0	0.00	0.00	0
Potomac River Upper North Branch	Not Sensitive	3	2.92	5.62	52
Savage River	Acidic	3	3.25	13.59	24
Savage River	Highly Sensitive	2	2.74	13.59	20
Savage River	Sensitive	11	7.60	13.59	56
Savage River	Not Sensitive	0	0.00	0.00	0
South River/West River	Acidic	0	0.00	0.00	0
South River/West River	Highly Sensitive	0	0.00	0.00	0
South River/West River	Sensitive	1	0.67	0.67	100
South River/West River	Not Sensitive	0	0.00	0.00	0
St. Mary's River	Acidic	0	0.00	0.00	0

Table A-7. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
St. Mary's River	Highly Sensitive	1	2.31	2.31	100
St. Mary's River	Sensitive	0	0.00	0.00	0
St. Mary's River	Not Sensitive	0	0.00	0.00	0
Town Creek	Acidic	0	0.00	0.00	0
Town Creek	Highly Sensitive	0	0.00	0.00	0
Town Creek	Sensitive	2	1.55	6.79	23
Town Creek	Not Sensitive	2	5.24	6.79	77
Upper Pocomoke River	Acidic	0	0.00	0.00	0
Upper Pocomoke River	Highly Sensitive	2	0.91	1.99	46
Upper Pocomoke River	Sensitive	0	0.00	0.00	0
Upper Pocomoke River	Not Sensitive	1	1.08	1.99	54
West Chesapeake Bay	Acidic	3	0.66	6.14	11
West Chesapeake Bay	Highly Sensitive	0	0.00	0.00	0
West Chesapeake Bay	Sensitive	1	1.00	6.14	16
West Chesapeake Bay	Not Sensitive	4	4.48	6.14	73
Wicomico River	Acidic	0	0.00	0.00	0
Wicomico River	Highly Sensitive	3	1.04	3.92	26
Wicomico River	Sensitive	4	1.30	3.92	33
Wicomico River	Not Sensitive	1	1.58	3.92	40
Wills Creek	Acidic	4	0.77	6.19	13
Wills Creek	Highly Sensitive	2	1.21	6.19	20
Wills Creek	Sensitive	1	0.91	6.19	15
Wills Creek	Not Sensitive	4	3.29	6.19	53
Youghiogheny River	Acidic	0	0.00	0.00	0
Youghiogheny River	Highly Sensitive	3	0.90	13.71	7
Youghiogheny River	Sensitive	4	5.02	13.71	37
Youghiogheny River	Not Sensitive	6	7.79	13.71	57
Zekiah Swamp	Acidic	0	0.00	0.00	0
Zekiah Swamp	Highly Sensitive	2	3.28	5.98	55
Zekiah Swamp	Sensitive	5	2.70	5.98	45
Zekiah Swamp	Not Sensitive	0	0.00	0.00	0

Table A-8. Round 2 (2012) Stream mile statistics for PSUs

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Acidic	0	0.00	0.00	0
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Highly Sensitive	0	0.00	0.00	0
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Sensitive	1	0.48	0.48	100
Assawoman/Isle of Wight/Sinepuxent/Newport/Chincoteague Bays	Not Sensitive	0	0.00	0.00	0
Breton/St. Clements Bays	Acidic	0	0.00	0.00	0
Breton/St. Clements Bays	Highly Sensitive	0	0.00	0.00	0
Breton/St. Clements Bays	Sensitive	1	0.36	3.73	10
Breton/St. Clements Bays	Not Sensitive	2	3.36	3.73	90
Casselman River	Acidic	4	1.55	9.93	16
Casselman River	Highly Sensitive	1	2.16	9.93	22
Casselman River	Sensitive	3	4.23	9.93	43
Casselman River	Not Sensitive	2	1.99	9.93	20
Dividing Creek/Nassawango Creek	Acidic	0	0.00	0.00	0
Dividing Creek/Nassawango Creek	Highly Sensitive	1	1.29	1.29	100
Dividing Creek/Nassawango Creek	Sensitive	0	0.00	0.00	0
Dividing Creek/Nassawango Creek	Not Sensitive	0	0.00	0.00	0
Evitts Creek	Acidic	3	1.40	3.97	35
Evitts Creek	Highly Sensitive	0	0.00	0.00	0
Evitts Creek	Sensitive	1	0.55	3.97	14
Evitts Creek	Not Sensitive	4	2.02	3.97	51
Fifteen Mile Creek	Acidic	0	0.00	0.00	0
Fifteen Mile Creek	Highly Sensitive	0	0.00	0.00	0
Fifteen Mile Creek	Sensitive	4	2.65	5.63	47
Fifteen Mile Creek	Not Sensitive	2	2.98	5.63	53
Fishing Bay/Transquaking River	Acidic	0	0.00	0.00	0
Fishing Bay/Transquaking River	Highly Sensitive	0	0.00	0.00	0
Fishing Bay/Transquaking River	Sensitive	0	0.00	0.00	0
Fishing Bay/Transquaking River	Not Sensitive	1	0.19	0.19	100
Georges Creek	Acidic	0	0.00	0.00	0
Georges Creek	Highly Sensitive	2	2.60	6.59	39
Georges Creek	Sensitive	0	0.00	0.00	0
Georges Creek	Not Sensitive	3	3.99	6.59	61
Gilbert Swamp	Acidic	0	0.00	0.00	0
Gilbert Swamp	Highly Sensitive	3	1.28	3.52	36
Gilbert Swamp	Sensitive	3	1.82	3.52	52

Table A-8. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
Gilbert Swamp	Not Sensitive	1	0.42	3.52	12
Honga River/Little Choptank/Lower Choptank	Acidic	0	0.00	0.00	0
Honga River/Little Choptank/Lower Choptank	Highly Sensitive	0	0.00	0.00	0
Honga River/Little Choptank/Lower Choptank	Sensitive	0	0.00	0.00	0
Honga River/Little Choptank/Lower Choptank	Not Sensitive	1	0.88	0.88	100
Little Conococheague/Licking Creek	Acidic	0	0.00	0.00	0
Little Conococheague/Licking Creek	Highly Sensitive	0	0.00	0.00	0
Little Conococheague/Licking Creek	Sensitive	0	0.00	0.00	0
Little Conococheague/Licking Creek	Not Sensitive	1	3.92	3.92	100
Little Youghiogheny/Deep Creek Lake	Acidic	3	0.94	8.38	11
Little Youghiogheny/Deep Creek Lake	Highly Sensitive	0	0.00	0.00	0
Little Youghiogheny/Deep Creek Lake	Sensitive	2	1.76	8.38	21
Little Youghiogheny/Deep Creek Lake	Not Sensitive	7	5.68	8.38	68
Lower Pocomoke River	Acidic	0	0.00	0.00	0
Lower Pocomoke River	Highly Sensitive	0	0.00	0.00	0
Lower Pocomoke River	Sensitive	0	0.00	0.00	0
Lower Pocomoke River	Not Sensitive	1	1.26	1.26	100
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Acidic	3	2.76	4.24	65
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Highly Sensitive	0	0.00	0.00	0
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Sensitive	1	1.12	4.24	26
Lower Wicomico/Monie Bay/Wicomico Creek/Wicomico River Head	Not Sensitive	1	0.35	4.24	8
Marshyhope Creek	Acidic	0	0.00	0.00	0
Marshyhope Creek	Highly Sensitive	0	0.00	0.00	0
Marshyhope Creek	Sensitive	2	0.80	1.49	54
Marshyhope Creek	Not Sensitive	2	0.69	1.49	46
Mattawoman Creek	Acidic	0	0.00	0.00	0
Mattawoman Creek	Highly Sensitive	0	0.00	0.00	0
Mattawoman Creek	Sensitive	4	7.75	9.88	78
Mattawoman Creek	Not Sensitive	2	2.13	9.88	22
Nanjemoy Creek	Acidic	3	3.15	6.91	46
Nanjemoy Creek	Highly Sensitive	1	1.54	6.91	22
Nanjemoy Creek	Sensitive	3	2.22	6.91	32
Nanjemoy Creek	Not Sensitive	0	0.00	0.00	0
Patuxent River (Middle)	Acidic	0	0.00	0.00	0
Patuxent River (Middle)	Highly Sensitive	0	0.00	0.00	0

Table A-8. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
Patuxent River (Middle)	Sensitive	2	1.74	5.59	31
Patuxent River (Middle)	Not Sensitive	2	3.85	5.59	69
Patuxent River lower	Acidic	4	0.52	12.61	4
Patuxent River lower	Highly Sensitive	1	0.49	12.61	4
Patuxent River lower	Sensitive	3	4.12	12.61	33
Patuxent River lower	Not Sensitive	8	7.48	12.61	59
Potomac Lower Tidal/Potomac Middle Tidal	Acidic	0	0.00	0.00	0
Potomac Lower Tidal/Potomac Middle Tidal	Highly Sensitive	0	0.00	0.00	0
Potomac Lower Tidal/Potomac Middle Tidal	Sensitive	1	2.77	2.77	100
Potomac Lower Tidal/Potomac Middle Tidal	Not Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Acidic	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Highly Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Sensitive	0	0.00	0.00	0
Potomac R WA Co/Marsh Run/Tonoloway/Little Tonoloway	Not Sensitive	1	2.01	2.01	100
Potomac River (Lower North Branch)	Acidic	0	0.00	0.00	0
Potomac River (Lower North Branch)	Highly Sensitive	3	0.70	13.30	5
Potomac River (Lower North Branch)	Sensitive	3	2.86	13.30	22
Potomac River (Lower North Branch)	Not Sensitive	9	9.73	13.30	73
Potomac River AL Co/Sideling Hill Creek	Acidic	0	0.00	0.00	0
Potomac River AL Co/Sideling Hill Creek	Highly Sensitive	0	0.00	0.00	0
Potomac River AL Co/Sideling Hill Creek	Sensitive	2	1.30	5.74	23
Potomac River AL Co/Sideling Hill Creek	Not Sensitive	2	4.44	5.74	77
Potomac River Upper North Branch	Acidic	4	0.87	5.62	15
Potomac River Upper North Branch	Highly Sensitive	1	1.84	5.62	33
Potomac River Upper North Branch	Sensitive	1	0.87	5.62	15
Potomac River Upper North Branch	Not Sensitive	2	2.05	5.62	36
Savage River	Acidic	0	0.00	0.00	0
Savage River	Highly Sensitive	3	3.25	13.59	24
Savage River	Sensitive	12	8.35	13.59	61
Savage River	Not Sensitive	1	2.00	13.59	15
South River/West River	Acidic	0	0.00	0.00	0
South River/West River	Highly Sensitive	1	0.67	0.67	100
South River/West River	Sensitive	0	0.00	0.00	0
South River/West River	Not Sensitive	0	0.00	0.00	0
St. Mary's River	Acidic	0	0.00	0.00	0

Table A-8. (Continued)

PSU	Acid Category	Reach Count	Miles in Category	Total Sampled Miles in PSU	% of Miles in PSU
St. Mary's River	Highly Sensitive	0	0.00	0.00	0
St. Mary's River	Sensitive	1	2.31	2.31	100
St. Mary's River	Not Sensitive	0	0.00	0.00	0
Town Creek	Acidic	0	0.00	0.00	0
Town Creek	Highly Sensitive	0	0.00	0.00	0
Town Creek	Sensitive	3	2.33	6.79	34
Town Creek	Not Sensitive	2	4.46	6.79	66
Upper Pocomoke River	Acidic	0	0.00	0.00	0
Upper Pocomoke River	Highly Sensitive	0	0.00	0.00	0
Upper Pocomoke River	Sensitive	0	0.00	0.00	0
Upper Pocomoke River	Not Sensitive	1	1.99	1.99	100
West Chesapeake Bay	Acidic	0	0.00	0.00	0
West Chesapeake Bay	Highly Sensitive	2	0.66	6.14	11
West Chesapeake Bay	Sensitive	0	0.00	0.00	0
West Chesapeake Bay	Not Sensitive	5	5.49	6.14	89
Wicomico River	Acidic	0	0.00	0.00	0
Wicomico River	Highly Sensitive	0	0.00	0.00	0
Wicomico River	Sensitive	4	2.29	3.92	58
Wicomico River	Not Sensitive	2	1.63	3.92	42
Wills Creek	Acidic	3	0.77	6.19	13
Wills Creek	Highly Sensitive	0	0.00	0.00	0
Wills Creek	Sensitive	2	1.21	6.19	20
Wills Creek	Not Sensitive	5	4.20	6.19	68
Youghiogheny River	Acidic	0	0.00	0.00	0
Youghiogheny River	Highly Sensitive	3	1.98	13.71	14
Youghiogheny River	Sensitive	4	5.41	13.71	39
Youghiogheny River	Not Sensitive	5	6.32	13.71	46
Zekiah Swamp	Acidic	0	0.00	0.00	0
Zekiah Swamp	Highly Sensitive	0	0.00	0.00	0
Zekiah Swamp	Sensitive	7	5.24	5.98	88
Zekiah Swamp	Not Sensitive	2	0.74	5.98	12

APPENDIX B
LAND USE CHANGE

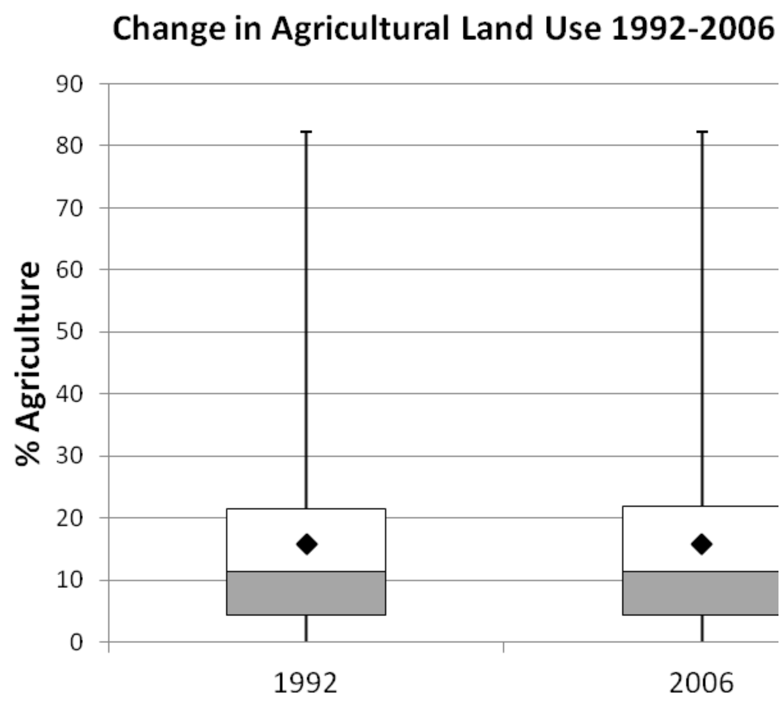

Figure B-1. The percentage of agricultural land use in 1992 and 2006

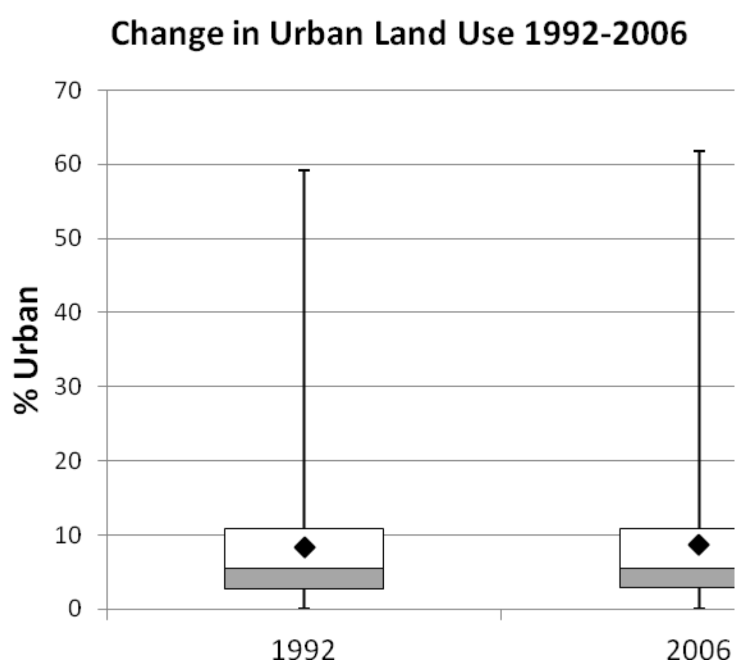

Figure B-2. The percentage of urban land use in 1992 and 2006

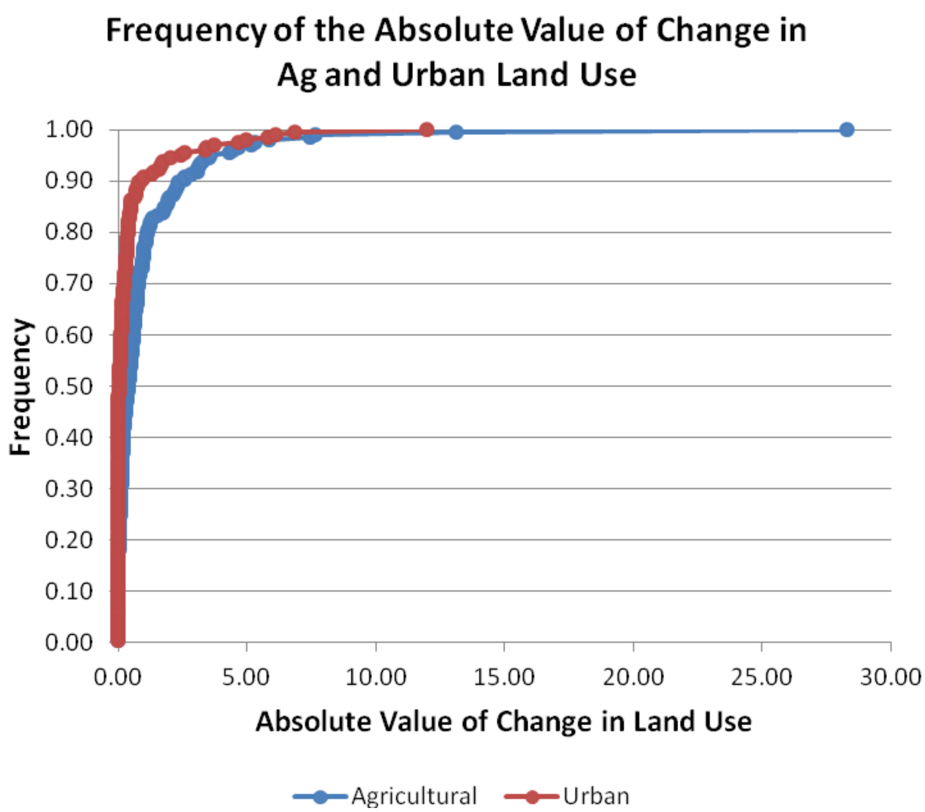

Figure B-3. The frequency of change in agricultural and urban land use between 1992 and 2006 across the 197 sites that were sampled during both years of MSSCS

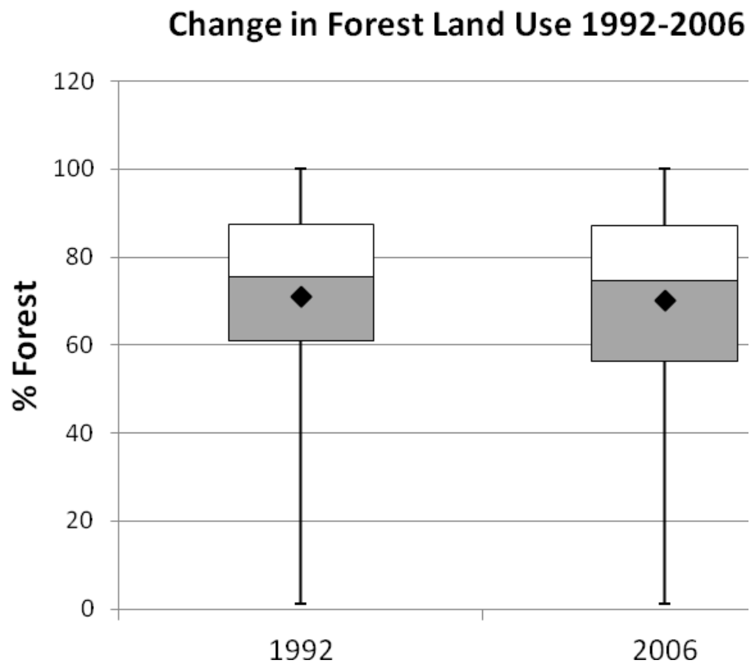

Figure B-4. The percentage of forested land use in 1992 and 2006

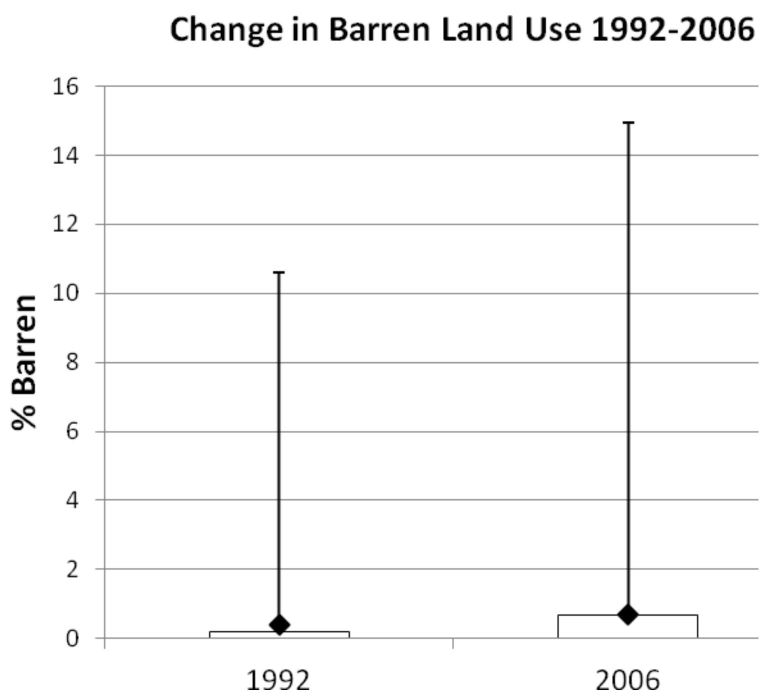

Figure B-5. The percentage of barren land use in 1992 and 2006

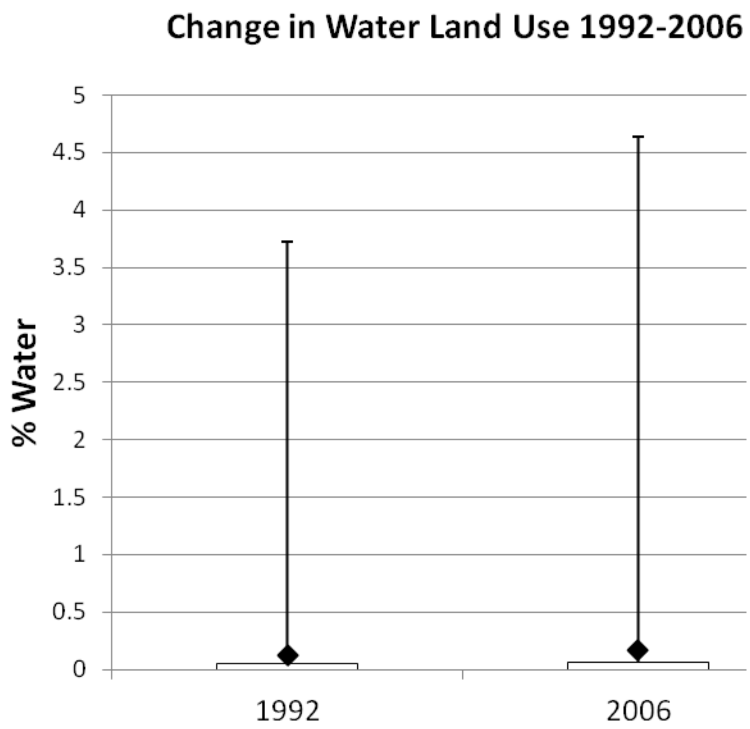

Figure B-6. The percentage of water land use in 1992 and 2006.

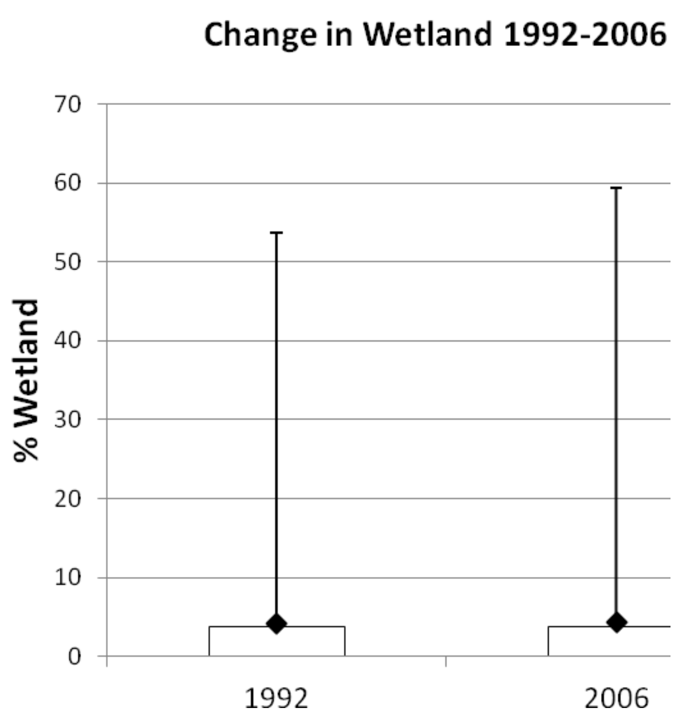

Figure B-7. The percentage of water land use in 1992 and 2006.

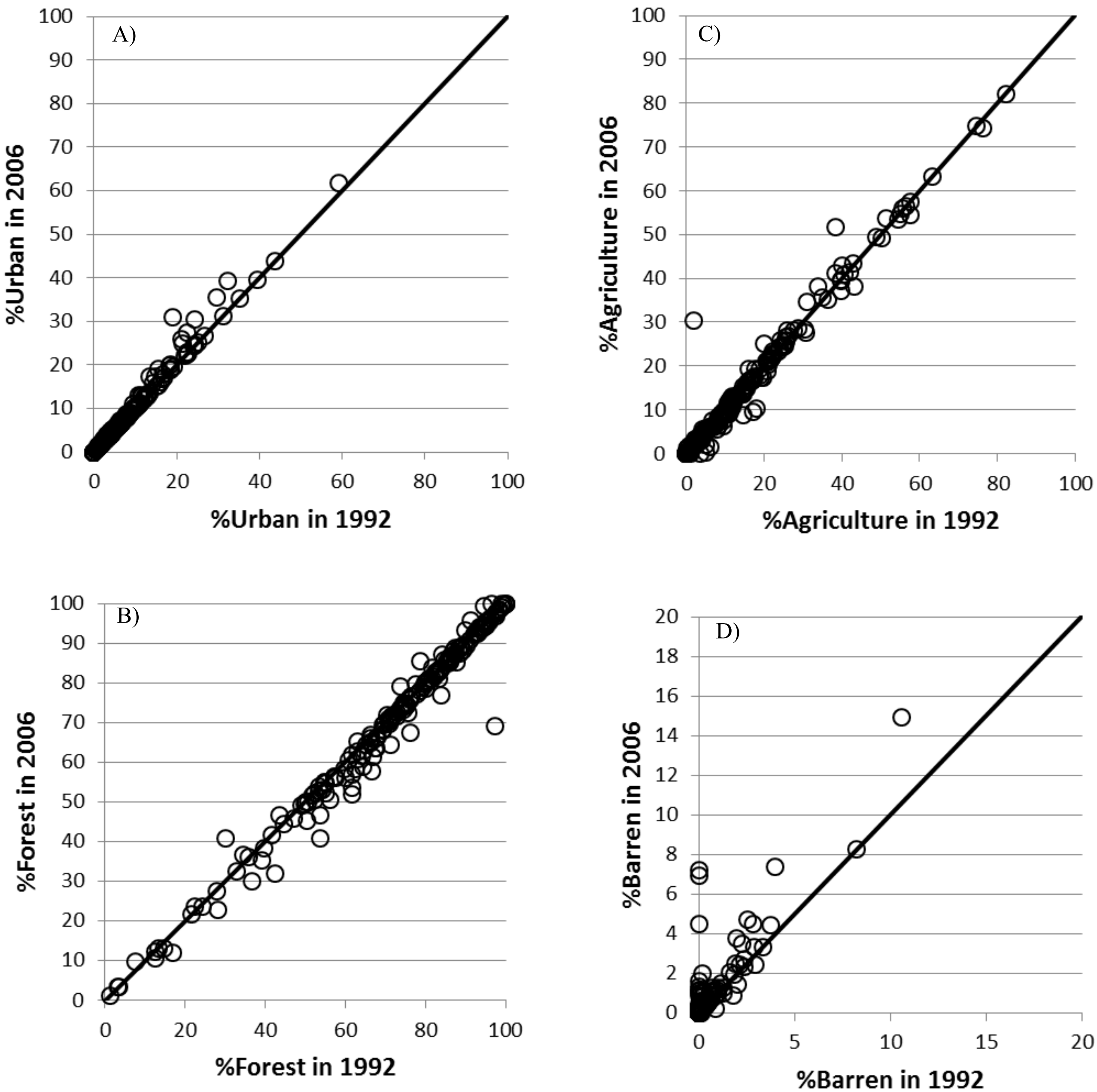

Figure B-8. Scatterplots of land use comparing the percentage of each land use type in 1992 and 2006. A) Urban, B) Forest, C) Agriculture, D) Barren, E) Water, and F) Wetland. A 1:1 line is drawn on each figure to indicate no change. Points falling above this line showed an increase in the land use type between years and points falling below the line showed a decrease in the land use type between years.

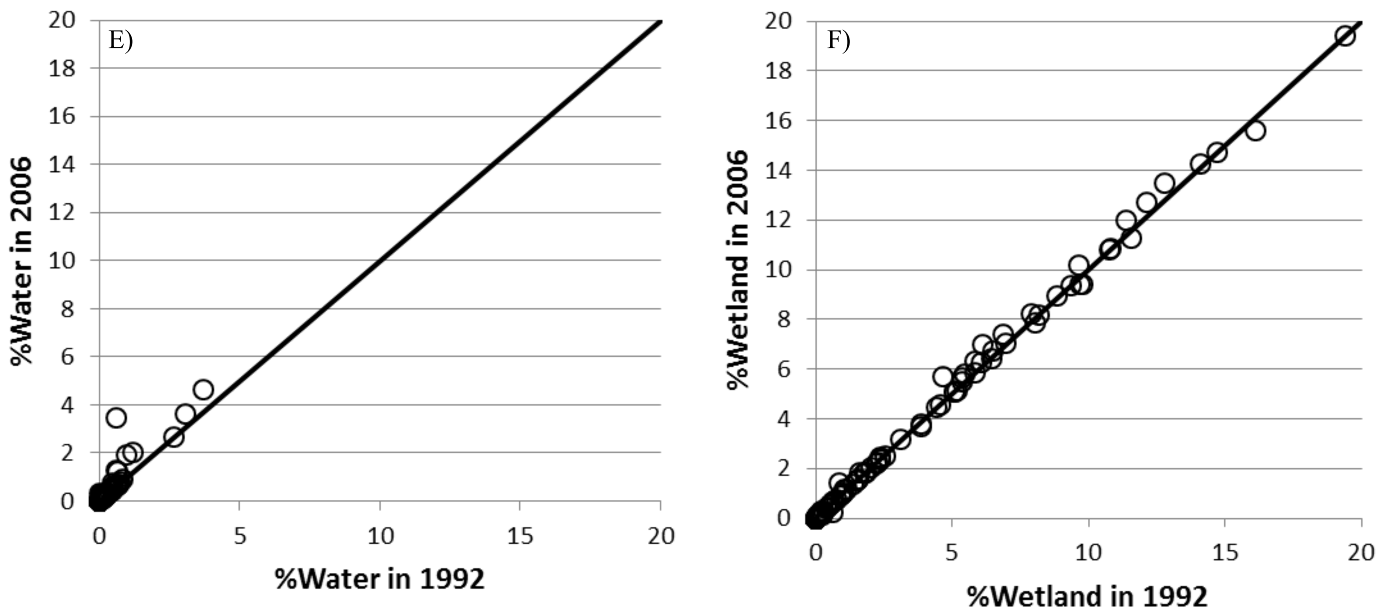

Figure B-8 (continued).

APPENDIX C:
TEMPERATURE AND PRECIPITATION AT 4 REGIONAL AIRPORTS

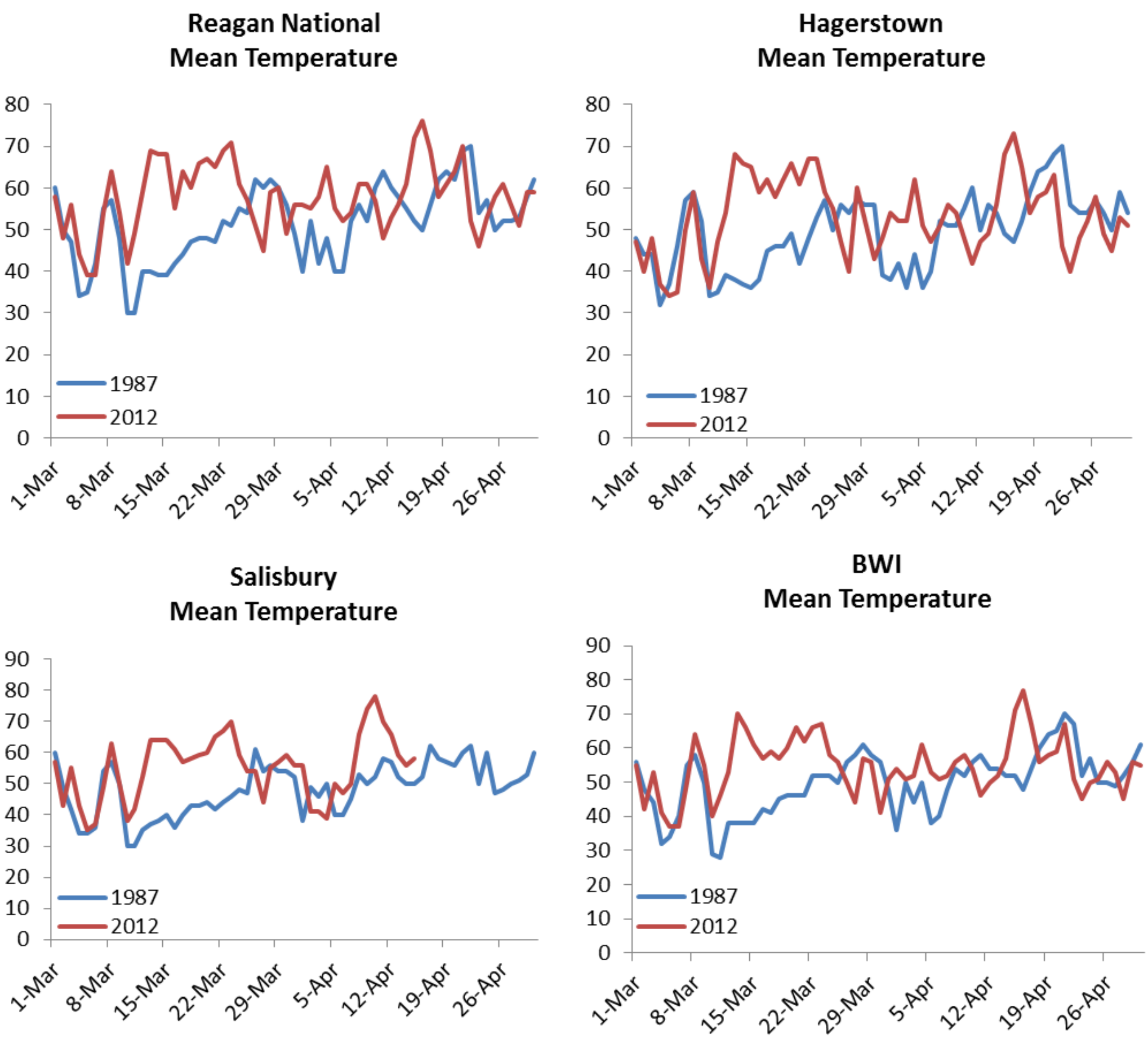

Figure C-1. Mean Temperature (degrees F) within the MSSCS sampling extent. Upper Left Panel: Reagan National Airport. Upper Right Panel: Hagerstown Airport. Lower Left Panel: Salisbury Airport. Lower Right Panel: Baltimore-Washington International Airport.

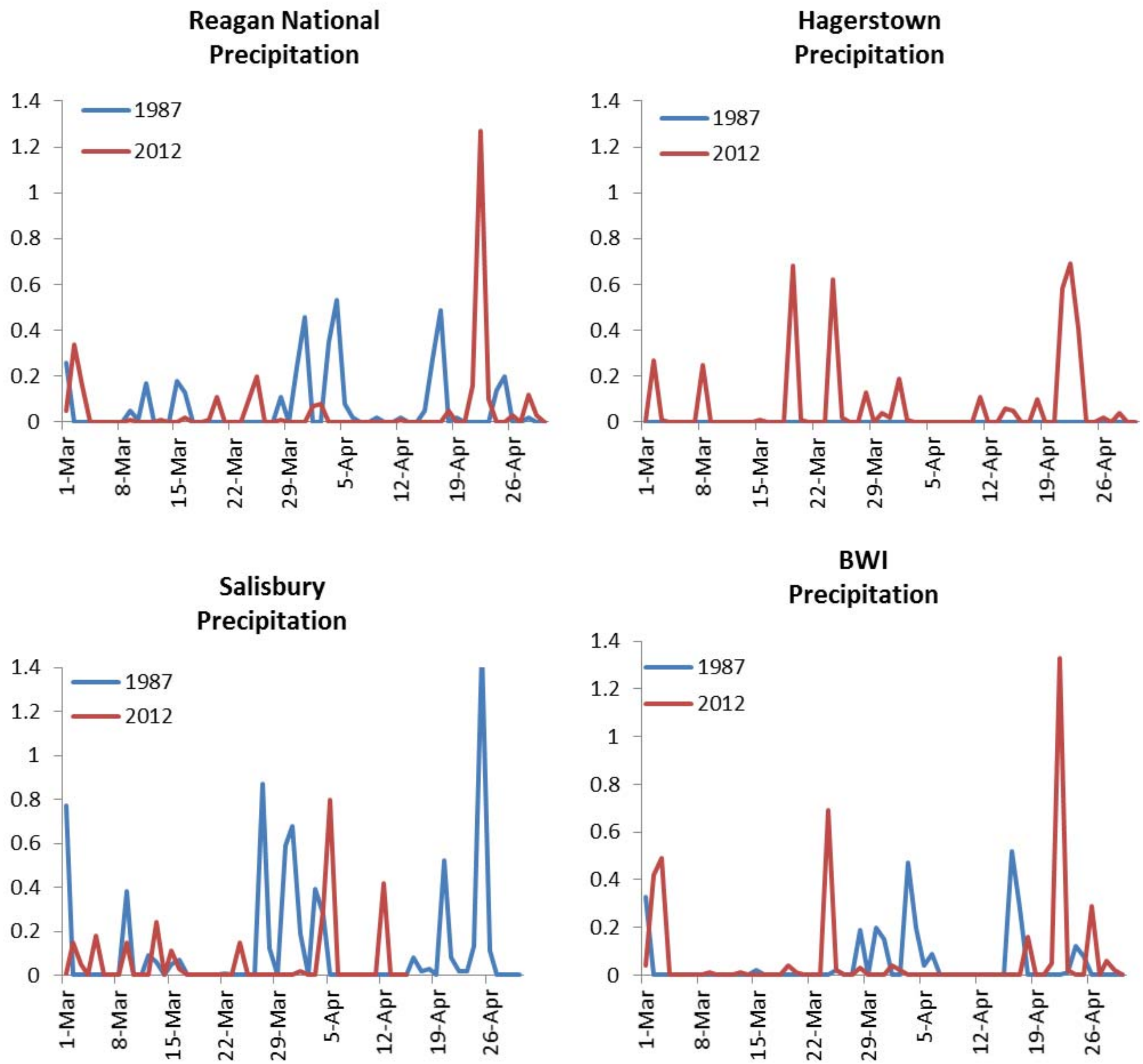

Figure C-2. Precipitation (inches) within the MSSCS sampling extent. Upper Left Panel: Reagan National Airport. Upper Right Panel: Hagerstown Airport. Lower Left Panel: Salisbury Airport. Lower Right Panel: Baltimore-Washington International Airport.