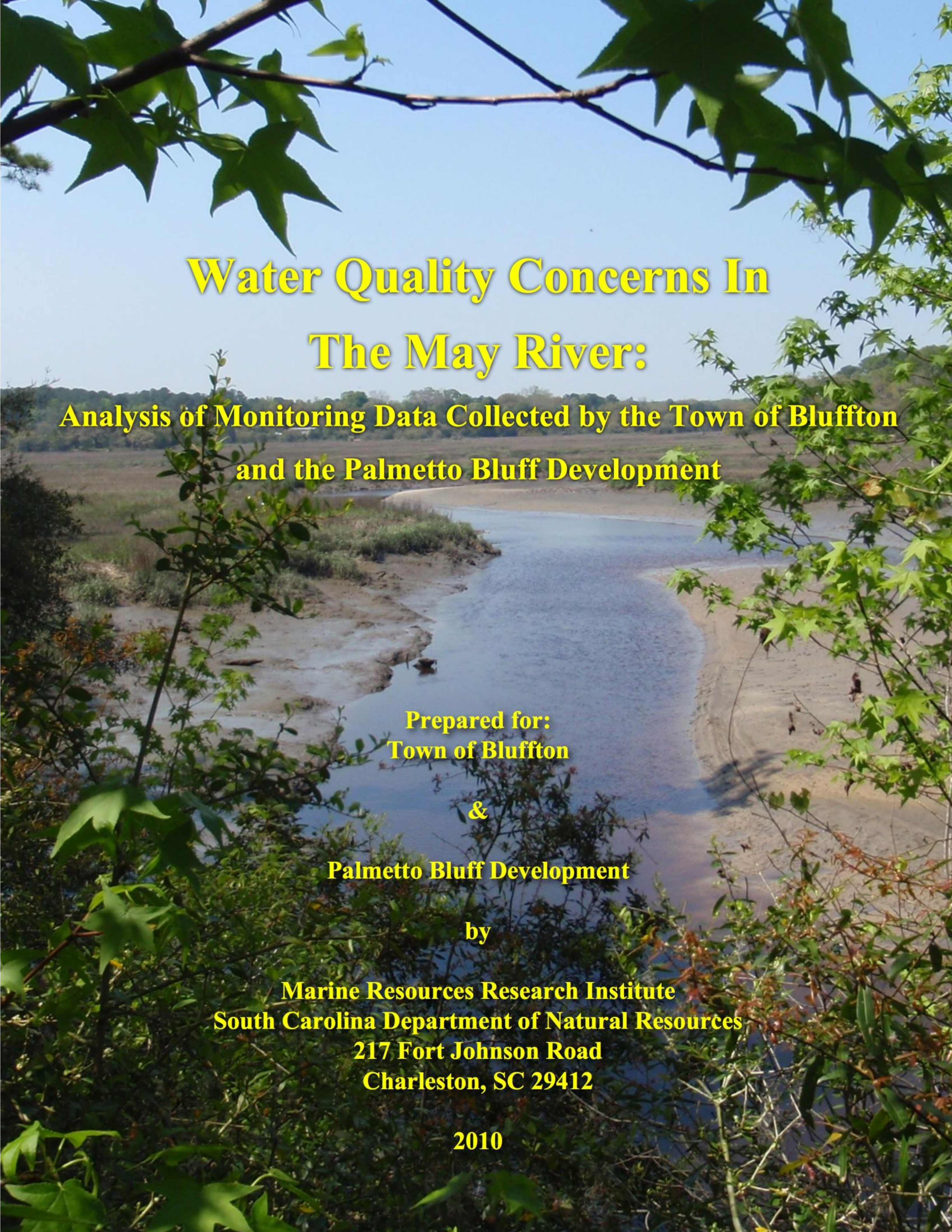

Water Quality Concerns In The May River:

Analysis of Monitoring Data Collected by the Town of Bluffton and the Palmetto Bluff Development

Prepared for:
Town of Bluffton

&

Palmetto Bluff Development

by

Marine Resources Research Institute
South Carolina Department of Natural Resources
217 Fort Johnson Road
Charleston, SC 29412

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Water Quality Concerns in the May River:
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Prepared by:

Derk C. Bergquist,
Robert F. Van Dolah,
Jordan Felber
Charles Keppler

Marine Resources Research Institute
South Carolina Department of Natural Resources
217 Ft. Johnson Road
Charleston, SC 29412

Prepared for:

Town of Bluffton
PO Box 386
Bluffton, SC 29910

and

Palmetto Bluff Development
15 Village Park Square
Bluffton, SC 29910

Palmetto
Bluff
Development

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EXECUTIVE SUMMARY

The May River provides an important recreational, cultural, and economic resource for the citizens of Beaufort County and especially the residents of Bluffton. Based in part on findings and recommendations provided from a baseline assessment of environmental and biological conditions in the May River (Van Dolah *et al.* 2004b), the Town of Bluffton and the Palmetto Bluff Development each initiated monitoring programs in their respective watersheds and the main stem of the river to obtain additional water quality information. More recently, these local communities established a May River Technical Advisory Committee (TAC) to evaluate the information obtained to date, assist in the identification of development-related impacts, and provide recommendations for alleviating or reversing these impacts.

While the existing data collected from the various monitoring efforts provide a rich database to evaluate water quality concerns, the TAC recommended that these and data available from other sources (e.g. SCDHEC, SCDNR) be thoroughly analyzed using statistical approaches to guide future community efforts. This study addresses three core issues:

I. Are significant changes in water quality occurring in the May River?
II. Are developed drainages acting as significant sources of pollutants to the May River system?
III. What monitoring efforts will be most valuable and feasible to continue into the future?

Data sets used to address these issues included sampling in both the main stem of the river and sampling runoff from various upland locations. The main stem sampling included near-continuous basic water quality data (temperature, salinity, dissolved oxygen, pH) obtained for approximately one year at three sites, other data obtained at four sites for several water quality parameters (nutrients, total organic carbon and dissolved solids, total suspended solids, biochemical oxygen demand, bacteria, and four metals), volunteer monitoring data for basic water quality data, bacterial data from 8 SCDHEC monitoring stations sampled monthly for bacterial concentrations, and one SCDHEC ambient monitoring stations station sampled monthly for a broad suite of water quality measures. Data from the upland runoff included rain event samples of several water quality parameters (nutrients, bacteria, total suspended solids) from six drainages on the northern shoreline of the May River, and both wet and dry water quality samples (bacteria, nutrients, turbidity, pH, DO, salinity) from 14 drainages at Palmetto Bluff representing both undeveloped and developed watersheds. Eight stations were sampled along a gradient from the upland drainage of the Palmetto Bluff golf course and through a tidal creek draining that golf course, and at two sites located along the shoreline upriver and downriver from the mouth of that creek. Some of these data sets were compared with data obtained by the SCDNR's South Carolina Estuarine and Coastal Assessment Program (SCECAP), SCDNR Land Use database, and National Land Cover database. Other data sets were evaluated for their utility in addressing the above issues, but were not analyzed further since they did not lend appreciably better insight to those issues.

Considerable effort was spent evaluating and interpreting the quality of the above data sets and organizing all data into Excel spreadsheets using standardized formats. Details of the specific data sets and statistical approaches for analyzing those data sets are provided in the methods section of the report.

Question I. Are significant changes in water quality occurring in the May River?

Salinity does not appear to be decreasing (becoming more fresh) in any part of the May River, in fact, salinity has been increasing suggesting a decrease in total freshwater inflow to the system. Salinity increased in the May River as a whole and at every station regardless of the origin of the data, and these increases were significant at several station in the middle (19-18) and lower (19-01 and 19-12) sections of the May River. All of the stations represented by the SCDHEC Shellfish data set possessed similar annual average salinities regardless of location within the river and showed a similar pattern of variability between 1994 and 2008. The stations represented by the Main Stem data set did not clearly reflect salinities in the SCDHEC data set and indicated a gradient of increasing salinity from the most upstream station (M4) to the most downstream station (M1).

Year-to-year salinity variation observed in the May River was closely related to precipitation patterns documented within the southwestern portion of the South Carolina. An overall pattern of decreasing rainfall coincided with the overall increase in salinity during the period examined here. Similarly, the period of highest salinities at the SCDHEC stations between 1999 and 2002 happened over a period of declining rainfall between 1998 and 2001. When corrected for background rainfall levels, salinity still changed significantly through time, but these changes were not significantly different among the different stations. At six of the seven SCDHEC Shellfish stations, salinity increased through time (although not significantly) even after correcting for the effects of total annual precipitation. This may reflect an actual decrease in upland runoff into the May River due to construction of stormwater ponds in some areas. However, it may also reflect limitations in the data sets used in the analysis including regional rather than water-specific rainfall data and sampling of salinity once per month. More focused and intensive data sets would be required to directly link changes in land use and stormwater ponds to changes in runoff and river salinity

Much of the concern related to water quality in the May River centers around fecal coliform bacteria concentrations, several data sets were carefully evaluated to address this issue. Elevated fecal coliform bacteria concentrations affect the ability to harvest shellfish in the May River as well as suitability for primary contact recreation. One of the best data sets available to address this issue was the SCDHEC shellfish database. Analysis of those data indicate that, as a whole, the May River has been experiencing an increase in fecal coliform bacteria concentrations since the mid to late 1990's. Bacteria concentrations showed significant inter-annual variability at some stations, but did not vary significantly or systematically among calendar months at any of the stations. The SCDHEC station (19-19) located farthest upriver increased significantly over time with a geometric mean fecal coliform levels of 30.3 colonies/100ml in 2008, which was much higher than in preceding years. Additionally, the incidence of fecal coliform levels above 43 colonies/100ml increased during the 2004-2008 time period. These levels exceed allowable levels for shellfish harvesting.

The higher and more rapidly increasing fecal coliform levels in the upper portion of the May River, as compared to the lower portions, likely reflect a combination of water body size and flushing rate, as well as development trends in the different May River watersheds. The upper and middle sections of the May River experience less flushing and more freshwater input relative to the size of the river than the lower portion, which also has higher salinity water. Fecal coliform bacteria levels were significantly and inversely related to salinity at almost every station. Rapid development in the upper section of the river is also likely to be playing a role in the changing conditions in the middle section of the river. Similar trends of increased bacteria concentrations in the upper portions of the May River were observed in the baseline study, and have been documented in other studies of estuarine watersheds.

Relative to similarly sized effluent-free water bodies in Beaufort County, most of the May River does not appear to be degraded with respect to fecal coliform bacteria. However, the degradation of the upper portion of the May River may extend into other sections of the river if recent trends continue and efforts are not made to eliminate or reduce the sources of these bacteria.

Rates of freshwater inflow likely play an important role in the water quality on the May River. Fecal coliform bacteria levels were significantly and inversely related to salinity at almost every station. These relationships were strongest in the stations located farther upstream in the May River as compared to those located farther downstream. This could reflect the greater influence of freshwater drainages on the narrower, shallower and lower-salinity upstream portions and the greater influence of higher-salinity seawater on the more downstream portions of the May River.

Instream fecal coliform levels are closely but not entirely related to rainfall patterns in the southern portion of the state. Discrete increases in fecal coliform levels were sometimes quite consistent among stations suggesting a common driving cause. The influence of rainfall was also clearly reflected in the low fecal coliform levels recorded at all DHEC Shellfish stations from 1999 through 2001, a period when rainfall levels were at their lowest in the southern portion of South Carolina. Increases in fecal coliform levels in recent years occurred during a period of decreasing rainfall and increasing salinities. This suggests either that there has been an increase the sources of fecal coliforms (wildlife, domestic animals, etc.) rather than an increase in total runoff volume or that runoff has become more episodic.

The main stem data set collected by Palmetto Bluff documented no significant temporal trends in fecal coliform levels, but generally confirmed the broader spatial patterns documented by the SCDHEC shellfish data set. The station located farthest upstream (M4) had the highest average fecal coliform levels and these levels decreased farther downstream.

Elevated nutrient concentrations represent another threat to water quality in the May River. Existing monitoring activities conducted in the main stem of the estuary did not detect significant changes in nutrients, as measured by total nitrogen and total phosphorus. The concentrations of both nutrients were highest in August sampling events, and lowest in March sampling events reflecting a consistent seasonal fluctuation in nutrient inputs to the river. Nutrient levels were higher in the upper portions compared to the lower portions of the river, mirroring the spatial patterns documented for fecal coliform bacteria. The upper portion of the river is very close to various upland sources of nutrients (both natural and anthropogenic) and is immediately downstream of a large impoundment. Nutrient loading to this portion of the river is likely exacerbated by a low dilution capacity and long residence time.

No consistent and significant changes in dissolved oxygen, pH and total suspended solids were detected in the May River. These water quality measures also showed a clear spatial gradient with evidence of increasing degradation closer to the headwaters of the May River.

Question II: Are developed drainages acting as significant sources of pollutants to the May River system.

Although the original desire of the TAC was to determine whether stormwaer runoff was affecting water quality in the May River, the existing data sources do not allow this question to be addressed due to a lack of comparable data both in the drainages and in the May River itself. To properly address this question, additional field and modeling studies, including measures of flow would be necessary. The data do allow the comparison of level of contaminants that are entering the May River from both developed and undeveloped drainages at Palmetto Bluff, including the golf course, and from drainages entering the river from the Bluffton (north) side of the river.

Analysis of the Palmetto Bluff developed (Phase I) drainages showed little evidence of having degraded water quality when compared to the undeveloped (Phase II) drainages. Fecal coliform concentrations were highest in drainages from undeveloped subwatersheds and lowest in the impoundment/ pond drainages, but these differences were not statistically significant. Turbidity, total nitrogen (TN), and total phosphorus (TP) were all significantly higher in the impoundment/pond drainages than in either the developed or undeveloped drainages. Rain events resulted in significantly higher concentrations of fecal coliform bacteria from all drainages, particularly in the undeveloped subwatersheds where terrestrial wildlife deposits represent the most likely source. Turbidity, TN and TP concentrations were also higher during rain events, but the differences were not statistically significant. The largest increases in these parameters occurred at the stations associated with the impoundment at the headwaters of the May River. During the monitoring period analyzed for this report, the developed Palmetto Bluff subwatersheds did not show evidence of being a major source of fecal coliform pollution through stormwater runoff. This may be due to a combination of low-density and young age of the developments at Palmetto Bluff, the displacement of wildlife into undeveloped areas, and/or adequate containment and control of stormwater runoff.

The Palmetto Bluff golf course drainage showed a clear gradient of water quality in the tidal creek that links the golf course to the May River, but the golf course drainage is not likely to be the sole source of those pollutants. This is based on concentrations that sometimes were higher in the creek than in the upland cistern of the golf course. However, stormwater runoff results in higher fecal coliform bacteria levels, phosphorus concentrations and turbidity in the water bodies adjacent to the golf course that, in some cases, exceeded levels typical of undeveloped drainages in the area.

Runoff from rain events in the drainages on the Bluffton side of the May River had significantly elevated fecal coliform levels, nutrient concentrations and turbidities when compared to the developed and undeveloped drainages at Palmetto Bluff. Fecal coliform levels were particularly high in the most upstream drainages. Phosphorus concentrations in Stoney Creek, Rose Dhu, and Verdier Cover were 15-20 times greater than the undeveloped Palmetto Bluff drainages, and ten times greater than the threshold for “poor” phosphorus conditions used by the SCECAP program for estuarine watersheds. The high fecal coliform levels, phosphorus concentrations, and turbidities in the Bluffton drainages may reflect a combination of land cover/land use and flushing rates in the different watersheds.

Question III: What monitoring efforts will be most valuable and feasible to continue into the future?

Collectively, the data sets assembled by the Town of Bluffton and Palmetto Bluff Development, combined with the data collected by SCDHEC and SCDNR, provide a robust level of information about the condition of the May River. Our review of these data provide an opportunity to compare the information obtained through each of these efforts and make recommendations for modifying and streamlining future sampling efforts.

Main Stem Monitoring Efforts:

Monitoring within the main stem of the May River, and not just in creeks and drainages, should be continued. Sampling the main part of the river is critical because it is 1) the location of the primary resources of concern, and 2) the water body upon which state management decisions are based. Monitoring of headwater creeks and drainages provides a useful early warning system for changes occurring within local subwatersheds, but unusually high values observed for water quality parameters may not result in high levels of those parameters farther downstream in a creek or in the main stem of the river. We recommend that main stem monitoring be continued and expanded to complement existing state monitoring data and to link water quality in headwater creeks to that in the May River more directly. We also recommend relocating them to better represent the length of the river and for better integration with the existing SCDHEC station.

Data sondes recording continuous water quality data in the main stem of the river have provided a detailed measure of physical and environmental variability over a one year period. However, this type of data collection is very expensive to conduct, the data set collected is too short to evaluate temporal trends, and management decisions are difficult to make since the data are not consistent with SCDHEC methodology. If such an effort is continued (see later recommendations), subsets of the continuous water quality data provide an accurate estimate of monthly averages and monthly variability within the data set as a whole. The middle five days of each month appear to provide the best relationship to total month averages. The value of continued collection of these data for future management decisions is not clear. If this effort is continued, these goals should be more clearly stated. If it is determined that additional continuous data are not needed in the future, we recommend re-allocating effort and funds to implementation of a monitoring program that includes other water quality parameters that are of direct concern and is consistent with SCDHEC methodology.

The volunteer monitoring network collected data that were consistent with other data sources, but, if continued, we recommend that the network be utilized to assist with a more coordinated sampling effort and focus on water quality parameters of greatest concern. Such sampling would require others to process the samples in one or more qualified laboratories.

Upland drainage Monitoring Efforts:

The Phase I and II drainage data collected by the Palmetto Bluff Development provided useful information on inputs to the May River from both developed and undeveloped subwatersheds. Continuing this type of monitoring would be useful, but the effort could be reduced and streamlined, and methodological issues associated with the past sampling effort should be improved. These issues include ensuring that sampling events are timed to be comparable between (or at least within) a drainage type, detection and reporting limits (both low and high) are standardized and suitable for the monitoring needs, and in-field measurements are accurately and correctly obtained. We recommend some restructuring of the existing stations to streamline and improve data collection efforts, if continued.

The Palmetto Bluff golf course data provided good information on levels of fecal coliform and nutrients in the golf course cistern and adjacent Palmetto Bluff creek that leads to the May River. Based on the findings, we do not recommend continued sampling of this system, with the exception of maintaining a station in the headwaters and near the mouth of the creek as part of an improved overall monitoring effort of the subwatershed drainages flowing into the May River.

The Bluffton rain event data provided useful information on potential inputs to the May River from the Town of Bluffton, but several limitations need to be addressed in future efforts. While the headwater creek sampling provides useful sentinel data for potential changes in pollutant levels, their link to management decisions must be better established. Sampling at the confluence of the same drainages with the May River (i.e. mouth of the creeks) concurrently with the headwaters would also be useful to understand potential loading of contaminants from these creeks. We provide several modest changes in the existing monitoring effort to improve the value of an overall monitoring program. We also provide several alternative methods for obtaining these data, ranging from employing a private contracting firm (likely the most expensive option), working with one or more cooperating state agencies to collect and/or process samples (intermediate expense option), utilizing volunteers in a more coordinated manner with samples processed at qualified laboratories (the least expensive option), or a combination of the above.

Summary of Recommendations:

As part of a longer-term monitoring strategy for the May River, we recommend a more coordinated effort that builds on existing programs and includes monitoring in the main stem of the May River and in targeted creek systems in a coordinated effort between the Town of Bluffton and the Palmetto Bluff Development. Specific recommendations include:

- Discontinue the existing continuous data sonde program and collect this type of data only as needed for specific targeted studies,
- Continue to collect data routinely at main stem river stations, but reposition those stations,
- Monitor the most critical parameters (fecal coliform bacteria, TN,TP, turbidity) and basic water quality measures in the headwaters/drainages of developed subwatersheds in both Palmetto Bluff and Bluffton (specific recommended locations provided in the report),
- Monitor drainages from at least three undeveloped drainages on Palmetto Bluff,
- Discontinue monitoring at most Palmetto Bluff Golf Course stations,
- Sample headwater and creek mouths routinely as well as following rain events,
- Improve quality assurance/quality control and consistency of sample and data collection among Bluffton, Palmetto Bluff and state monitoring programs,
- Structure future monitoring efforts or research around clear and focused questions.

BACKGROUND

The May River represents an important recreational, cultural and economic resource for residents and visitors (Town of Bluffton, 2008). Due to its exceptional water quality and importance to local communities, the river was designated as having Outstanding Resource Water (SCDHEC 2001) by the South Carolina Department of Health and Environmental Control. The May River continues to support a significant recreational shellfish fishery due to its extensive oyster beds and good water quality, but rapid population growth and development threaten this status.

The coastal counties of South Carolina have grown 35% since 1990 and are expected to grow another 30% by 2025 (SC Budget and Control Board, 2005). Beaufort County saw its population grow by 14% between 2000 and 2005 (SC Budget and Control Board, 2005). This growth is accompanied by the expansion of infrastructure and the urbanization of previously undeveloped areas resulting in increased impervious cover (roadways, parking lots, roofs, etc.) and stormwater runoff. For coastal water bodies, increasing development in surrounding watersheds often results in degraded water and sediment quality and increased restrictions on primary contact recreation and fisheries consumption advisories (Sanger *et al.*, 1999a, b; Lerberg *et al*., 2000, Van Dolah *et al*., 2008).

Recognizing the potential impact of recent increased development within the May River watershed, surrounding communities have taken an interest in protecting this valuable natural resource. In 2002, the Town of Bluffton secured funding to initiate a study of environmental conditions within the May River (Van Dolah *et al.*, 2004). The goal of that project was to provide a largely pre-development baseline against which future assessments of condition could be compared. The Town of Bluffton followed this up by initiating a monitoring program and developing the "May River Waterbody Management Plan" in consultation with DHEC-OCRM in 2008 (Town of Bluffton, 2008). As part of the plan to develop the Palmetto Bluff area on the south bank of the May River, the Palmetto Bluff Development initiated a monitoring program. Local communities also joined forces and established a May River Technical Advisory Committee (TAC) consisting of specialists from numerous academic, government, and non-profit organizations, as well as private citizens. The purpose of this committee was to assist in the identification of development-related impacts to the May River and solutions for alleviating and/or reversing these impacts.

The monitoring programs conducted by the Town of Bluffton and the Palmetto Bluff Development have provided a rich database of recent water quality information. Portions of these data have been described in detailed reports prepared for the Town of Bluffton (BP Barber, 2007, 2008). In 2008, the May River TAC recommended these data and other available data for this drainage system be statistically analyzed and synthesized to assist in guiding future community efforts. The current study was initiated to address three core issues through a detailed analysis of these data:

I. Are significant changes in water quality occurring in the May River?
II. Are developed drainages acting as significant sources of pollutants to the May River system?
III. What monitoring efforts will be most valuable and feasible to continue into the future?

METHODS

Data sets:

A large number of data sets were available to examine water quality issues in the May River and its tributaries including those generated by the Town of Bluffton and Palmetto Bluff Development as well as numerous state sources (Table 1; Figure 1a,b). The parameters, sampling locations within the river system, and monitoring time frame and frequency varied amongst data sets.

The Town of Bluffton provided two primary data sets: "Continuous Data Sondes" and "Rain Event" (Table 1). The study design and sampling protocols are described in detail by BP Barber (2008) and therefore are described only briefly here. The continuous sonde data set was collected by deploying YSI 6600 or 6920 continuous monitoring sondes at three locations within the May River: in the upper zone near the confluence of Rose Dhu Creek with the May River (S-RD), in the middle zone in Verdier Cove near Thomas Heyward Street (S-VC), and in the lower section near the Alljoy boat landing (S-AJ) (Figure 1a,b). The data records from S-RD and S-AJ included temperature, conductivity and salinity, dissolved oxygen, pH, turbidity and chlorophyll-a recorded continuously at 15 minute intervals between mid-April 2007 and late June/mid-July 2008. The data record at S-VC was similar to the other two, but it lacked chlorophyll-a.

Table 1. Primary data sets available for analysis of patterns and trends in May River water quality.

Data Source	**Data Set**	**Parameters of Interest**
Town of Bluffton	Continuous Sonde	Temperature, salinity, pH, dissolved oxygen, turbidity, chlorophyll-a
	Rain Event	Nitrogen, phosphorous, total suspended solids, turbidity, fecal coliform, *Escherichia coli*
	Volunteer Network	Temperature, salinity, water clarity, dissolved oxygen
Palmetto Bluff	Main Stem	Salinity, turbidity, nitrogen, phosphorous, fecal coliform
	Phase Drainages	Salinity, turbidity, nitrogen, phosphorous, fecal coliform
	Golf Course	Salinity, turbidity, nitrogen, phosphorous, fecal coliform
SCDHEC	Ambient	
	Shellfish	Fecal coliform
SCDNR	May River Baseline Study	Temperature, salinity, turbidity, dissolved oxygen, fecal coliform, nitrogen, phosphorous, chlorophyll-a
	South Carolina Estuarine and Coastal Assessment Program (SCECAP)	Temperature, salinity, turbidity, dissolved oxygen, fecal coliform, nitrogen, phosphorous, chlorophyll-a

Figure 1a. Locations of all stations sampled within the May River system and analyzed here.

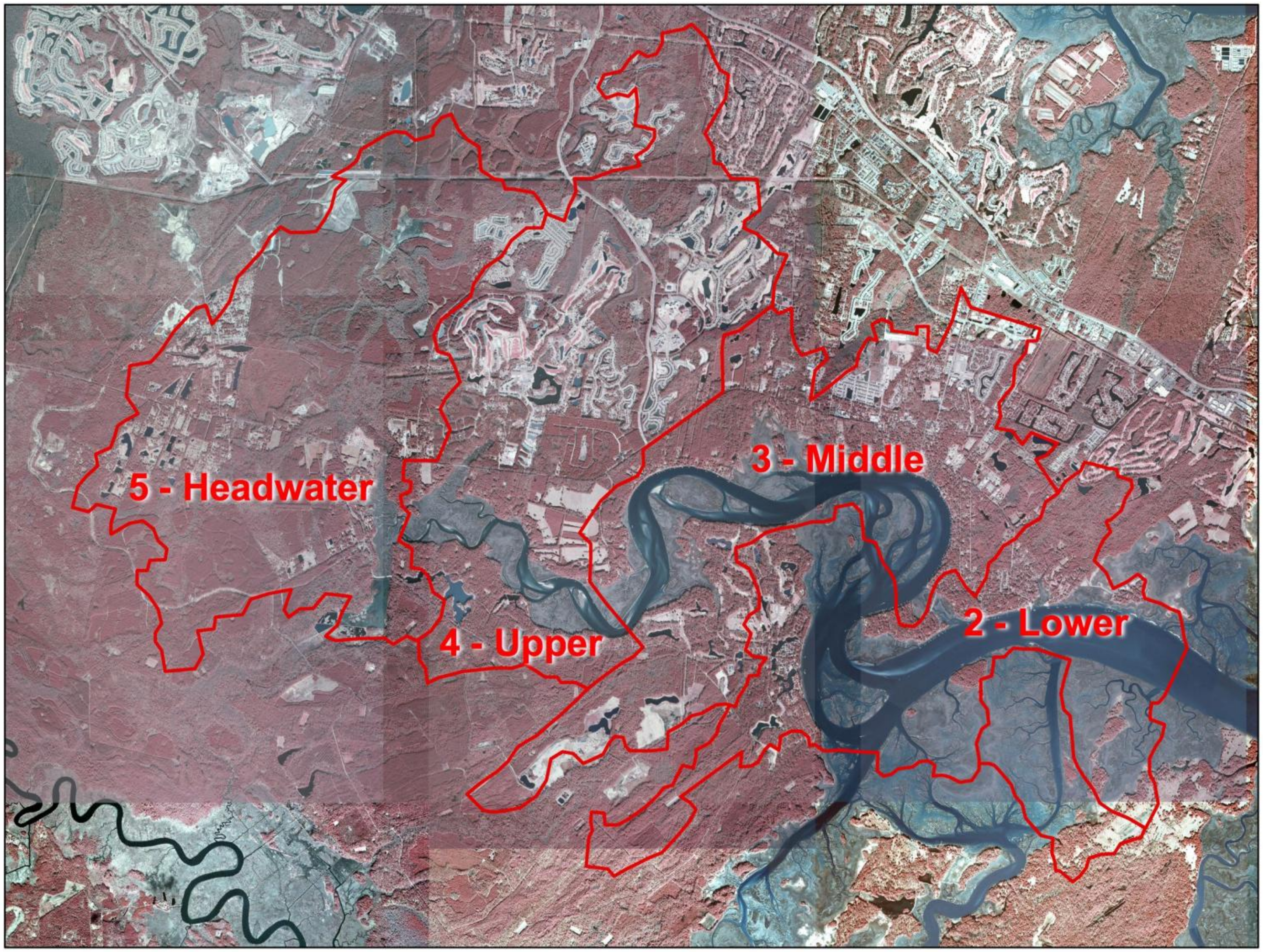


Figure 1b. Boundaries of the subwatershed drainages identified in the May River Waterbody Management Plan and used here to designate the "headwater", "upper", "middle" and "lower" sections of the May River.

The Rain Event data set was collected by sampling six stormwater drainages (Bluffton Village (R-BV), Verdier Cove at Thomas Heyward Street (R-VC), Rose Dhu Creek (R-RD), Stoney Creek (R-SC), Huger Cove (R-HC) and Guerrard Cove (R-GC)) that enter the May River system from a variety of land uses (Figure 1), however, only two data points were available for Huger Cove and Guerrard Cove, so these were not included in the analyses. Grab sampling occurred within 72 hours of eleven rainfall events (defined as total rainfall of at least 0.1 inches), and samples were processed for turbidity, total suspended solids (TSS), nitrate/nitrite (NO_x), total Kjeldahl nitrogen (TKN), ammonia (NH_4), total nitrogen (TN), total phosphorous (TP), total coliform bacteria, fecal coliform bacteria, and *E. coli*.

The Volunteer Network data set involved volunteers collecting basic water quality at four accessible points in the May River system: Stoney Creek (V-SC), Rose Dhu (V-RD), Osprey Point (V-OP) and Crystal Beach (V-CB) (Figure 1a). Temperature, salinity, dissolved oxygen and water clarity were recorded on a weekly to biweekly basis at each site.

The Palmetto Bluff Development produced a database of physical and chemical water quality parameters that were separated into three data sets: "Main Stem", "Phase Drainages", and "Golf Course" (Table 1). The Main Stem data set involved the collection of "grab" water samples by boat at four locations within the May River system (M1 through M4; Figure 1). Samples were collected four times each year (March, June, August, October) between March 19, 2002 and June 10, 2008 and were processed for total organic carbon (TOC), total dissolved solids (TDS), TSS, five-day biochemical oxygen demand (BOD_5), TKN, NO_x, TN, TP, dissolved phosphorus (DP), fecal coliform bacteria, and four metals (cadmium, copper, lead and zinc). Temperature, salinity and dissolved oxygen were also determined.

The Phase Drainages data set involved the collection of grab water samples from up to14 natural (II-1 through II-6) and man-made (I-1 through I-6) drainages in the May River system (Figure 1a) between May 10, 2002 and August 18, 2008. These data were collected and processed by different contractors, with the first collecting only following rainfall events between May 10, 2002 and February 7, 2007, and the second contractor collecting approximately bimonthly and after rain events from May 23, 2007 to August 18, 2008. The data from the first contractor have been summarized in Appendix A-4 but were excluded from the analysis because data collection was often either not paired through time between the two phases (Phase I – developed and Phase II-undeveloped) and/or several sampling events occurred many days after a presumed rain event. The data from the second contractor were collected more rigorously and systematically, and, in our estimation, was of higher quality than that of the first contractor. The Phase Drainages data set included pH, turbidity, salinity, dissolved oxygen, TN, TP, and fecal coliform bacteria. The Golf Course data set included grab water samples from eight stations associated with a tidal creek that drains the May River Golf Course at Palmetto Bluff and flows into the May River as well as two stations located within the May River below and above the confluence of this creek with the May River. The samples were collected biweekly and following rain events primarily between August 27, 2007 and August 18, 2008. Due to lab error, most of the useable data were limited to the time period after December 26, 2007. For both the Phase Drainages and the Golf Course data sets, if a rain event preceded a quarterly sampling event, only a single collection was performed.

Two additional data sets collected routinely by the South Carolina Department of Health and Environmental Control were also analyzed: "SCDHEC Ambient" and "SCDHEC Shellfish". The

SCDHEC Ambient data set is part of the Ambient Water Quality Monitoring Network that monitors physical and chemical water quality parameters on a monthly basis statewide. This source included data on depth, dissolved oxygen, pH, salinity, temperature, turbidity, NH_4, TKN, NO_x, TN, TP and fecal coliform bacteria between January 2001 and December 2006. Although the May River hosts only a single station from this network (MD-173 near Alljoy), this data set represents one of the more long-term data records available for this water body (Figure 1a).

The SCDHEC Shellfish data set is part of the SCDHEC shellfish monitoring program that monitors water quality associated with state shellfish grounds. This data set included monthly data on fecal coliform bacteria and salinity for eight locations within the May River system (19-01 through 19-25; Figure 1a). Only data from January 1994 to December 2008 were included in our analyses as this time period was most consistently sampled among the different stations. Although largely limited to salinity and fecal coliform bacteria, the SCDHEC Shellfish data set is the longest and most consistently collected data set available for addressing temporal trends in May River water quality.

Several additional data sets were used for comparisons when appropriate: the May River Baseline Study (Van Dolah *et al.*, 2004b), the South Carolina Estuarine and Coastal Assessment Program (SCECAP) (Van Dolah *et al*., 2002, 2004a, 2006), the SCDNR Land Use Database (Van Dolah *et al.*, 2008), and the National Land Cover Database (NLCD; http://www.epa.gov/mrlc/). One objective of the current analysis was to compare the monitoring data collected by the Town of Bluffton and the Palmetto Bluff Development to data collected during the May River Baseline Study. Unfortunately there was little overlap in stations locations, sampling methodology, and parameters between these efforts (Appendix C), so few comparisons were possible. The most robust comparison would be between Baseline Study Continuous Water Quality/Quantity (data held by USGS) and the Bluffton Continuous Sonde data set, specifically for specific conductivity and dissolved oxygen. It is important to note that even these comparisons would be limited due to existing natural inter-annual variability.

Data Analysis:

The data sets were obtained from their respective sources as Excel spreadsheets and either divided into data subsets or combined with other data sets to address the three core questions. The analyses performed were specific to both the data set and the question being addressed. The analytical procedures employed are described for each question below.

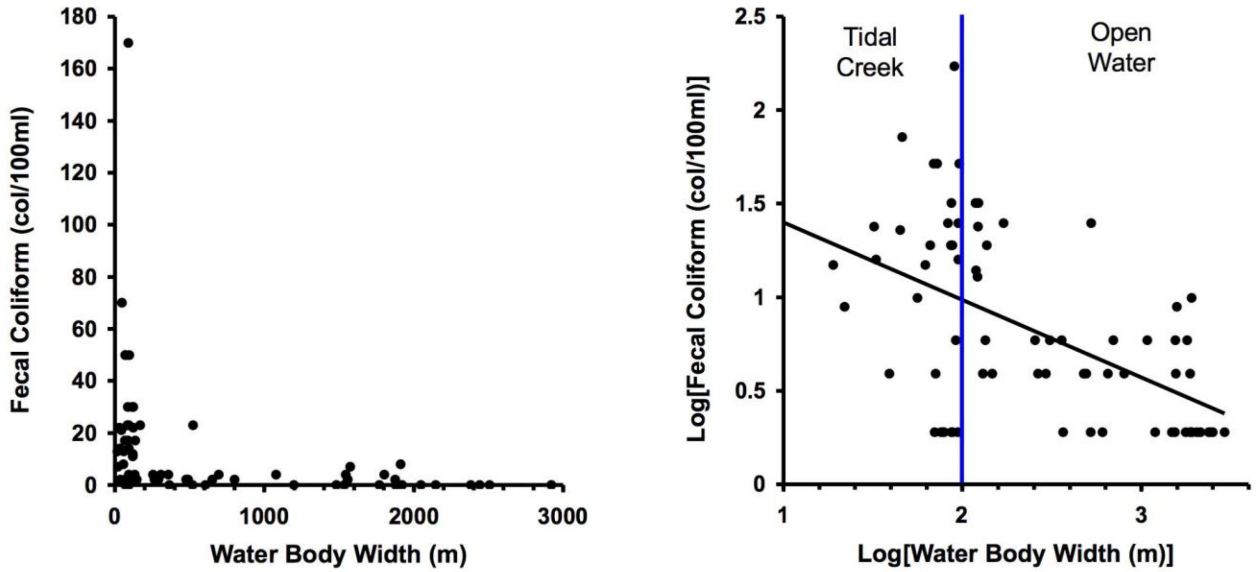
Question I: Are significant changes in water quality occurring in the May River?

Three data sets provided the best opportunity to examine recent changes in May River water quality: SCDHEC Shellfish, SCDHEC Ambient, and Main Stem. For the SCDHEC data sets, eight stations in the SCDHEC Shellfish Monitoring Network (19-19, 19-24, 19-16, 19-18, 19-25, 19-01, 19-17A, 19-12) and one SCDHEC Ambient Water Quality Station (MD-173) were analyzed. Fecal coliform and salinity data were available at monthly intervals from 1994 to 2008 for most of the DHEC Shellfish stations and from 2001 to 2006 for the SCDHEC Ambient station (sampling continues at these stations, but more recent data were not available). Fecal coliform data were $\log_{10}(x+1)$ transformed to improve normality and analyzed for each individual station using an analysis of covariance (ANCOVA) with salinity (as a proxy for rainfall) as a covariate and year and month as factors. Yearly least square mean values for fecal coliform bacteria were generated from this analysis in order to remove variation due to salinity and season. These yearly least-square means were then regressed against year as a continuous predictor in order to examine trends at each station. In order to examine whether fecal coliform bacteria levels in different drainage areas within the May River watershed were changing differently, the shellfish monitoring stations were then divided into two groups dependent on where they occurred within two recently delineated drainage areas as defined by the May River Waterbody Management Plan (2008). These drainage areas represented the middle section (including stations 19-24, 19-16, 19-18) and lower section (including stations 19-25, 19-01, 19-12) of the May River (Figure 1b). The yearly least-square means of fecal coliform bacteria concentrations for each station were combined and analyzed using a nested ANCOVA with section (middle vs. lower) as a main factor, year as covariate, and station as a nested term within section. Salinity measured at the SCDHEC Shellfish stations was analyzed similarly.

Additionally, the SCDHEC ambient data set included salinity, dissolved oxygen, pH, turbidity, TN, and TP. These data were analyzed in a similar manner to the fecal coliform data, except that salinity was not a covariate in the initial ANCOVA. Each water quality measure was transformed prior to analysis as needed.

The Main Stem data set was analyzed in a manner similar to the SCDHEC Shellfish data set. For fecal coliform data, an ANCOVA with salinity as a covariate and Year and Season was used to determine whether significant differences among years and seasons could be detected on the parameters at each station after correction for salinity. Season represented the four sampling periods each year: March, June, August, and October. All other data (nutrients, turbidity, etc.) were analyzed similarly except that salinity was not included in the model (analysis of variance: ANOVA). Yearly least square mean values for each parameter were generated from the ANCOVA/ANOVAs above in order to account for variability due to sampling season and salinity (fecal coliform only). These data were then regressed against year in order to examine yearly trends at each station. Salinity was analyzed similarly.

To estimate a natural background level for each parameter (fecal coliform bacteria, TN, TP, dissolved oxygen, pH, TSS and turbidity), data collected by the South Carolina Estuarine and Coastal Assessment Program from undeveloped, presumably effluent-free areas in Beaufort County were plotted against water body width (bank-to-bank distance) at the collection location. Stations in the "effluent-free" group had to have less than 10% of upland area as development within one kilometer (with development being the sum of the open, low-density, medium-density and high-density development categories in the National Land Cover Database). Additionally, only stations that were not in close proximity to potential urban or industrial sources of pollution when examined visually on aerial photography were considered. The relationship between each parameter and water body width for this "effluent-free" data set was then used to estimate a background level at each sample location within the May River (Figure 2). Although substantial variability remains unexplained in these relationships (see fecal coliform graph in Figure 2), this was determined to provide a more reasonable estimate of typical background levels for this study than dividing habitat into categories (such as the SCECAP designations of tidal creek and open water habitat based on whether creek width was less than or greater than 100 m).



Data Source	Station	Width of May River (m)	Estimated Background Level						
			Fecal Coliform	TN	TP	DO	pH	TSS	Turbidity
SCDHEC	19-19	84	8.8	0.66	0.097	3.96	7.20	41.1	18.4
SCDHEC	19-24	166	6.0	0.61	0.090	4.12	7.26	35.1	15.9
SCDHEC	19-16	273	4.5	0.58	0.085	4.24	7.30	31.3	14.2
SCDHEC	19-18	102	7.9	0.64	0.095	4.01	7.22	39.3	17.7
SCDHEC	19-25	223	5.1	0.59	0.087	4.19	7.28	32.8	14.9
SCDHEC	19-01	443	3.3	0.55	0.080	4.36	7.33	28.0	12.8
SCDHEC	19-12	136	6.8	0.62	0.092	4.08	7.24	36.8	16.6
SCDHEC	19-17A	130	6.9	0.63	0.092	4.07	7.24	37.2	16.8
SCDHEC	MD-173	722	2.3	0.52	0.076	4.47	7.37	24.9	11.5
Palmetto Bluff	M1	285	4.4	0.58	0.085	4.25	7.30	31.0	14.1
Palmetto Bluff	M2	197	5.5	0.60	0.088	4.16	7.27	33.7	15.3
Palmetto Bluff	M3	71	9.6	0.67	0.098	3.92	7.19	42.7	19.1
Palmetto Bluff	M4	21	17.4	0.75	0.110	3.64	7.10	56.1	24.7

Figure 2. Relationship between fecal coliform levels and water body width at effluent free stations in Beaufort County sampled by SCECAP. The equation for the line shown in the second graph ($\log_{10}$(fecal coliform + 1.9) = 1.872 – 0.4372$\log_{10}$(width + 1)) was used to estimate background fecal coliform levels for the SCDHEC Shellfish and Main Stem (Table 4elow figures). The blue line shows the boundary (100 m) between tidal creek and open water habitats as defined by SCECAP. The same process was used to estimate background levels for the other key parameters. These other parameters were not measured at the SCDHEC Shellfish stations, but estimates are shown for future reference.*

Question II: Are developed drainages acting as significant sources of pollutants to the May River system?

Many of the longer-term impacts of development on aquatic ecosystems occur as a result of stormwater run-off carrying pollutants from the land into adjacent water bodies. Three data sets provided the best opportunity to examine the potential influence of stormwater runoff on the May River: Bluffton Rain Event and Palmetto Bluff Phase Drainages and Golf Course data sets.

The Palmetto Bluff Phase Drainages data set includes sampling stations in both "developed" (parts of Phase I) and "undeveloped" (Phase II and parts of Phase I) areas, thus these stations can be compared to determine whether there is evidence that development of Phase I has resulted in elevated levels of non-point source pollutants. Some Phase I stations were closely associated with ponds or impounded wetlands rather than with residential/commercial development; these stations were separated into a third category referred to as "impoundments". These data sets also included sampling during dry (less than 0.5 inches of rainfall during previous 72 hours) and wet (greater than or equal to 0.5 inches of rainfall during previous 72 hours) periods. This full data set began in May 2002 under a first contractor, and in February 2007, that work was assumed by a new contractor and continued through August 2008. The first contractor sampled after eleven major rain events (>1 inch rainfall), but sampling was not well paired between developed, impoundment and undeveloped drainages. For example, in some cases only Phase I drainages were sampled, leaving no Phase II drainages with which to compare. In other cases, one Phase was sampled and several days later the other Phase was sampled. Under the second contractor, data collection was more consistent and included routine sampling during "dry" periods in addition to sampling after rain events (defined by this contractor as >0.5 inches of rainfall in a 72 hour period). Because the two data sets were not comparable (different definitions of rain event) and the first data set was judged as less robust, only the data collected by the second contractor were analyzed here.

The analysis of the Phase Drainages data set was limited to four parameters: fecal coliform levels, total nitrogen, total phosphorus, and turbidity. Two parameters that were measured were excluded from the analysis: dissolved oxygen and pH. pH was measured sporadically and <30% of the samples had associated pH values. Dissolved oxygen data were reported inconsistently (apparently fluctuating between measurements of concentration in mg/l and % saturation) and included several extremely anomalous data points (for example, values of 170). It was concluded that these two parameters did not constitute robust and dependable data sets. The four remaining parameters were analyzed using a nested 2-way ANOVA with "rainfall" (wet event vs. dry event) and "drainage type" (developed vs. impoundment vs. undeveloped) as factors and "station" as a nested factor within drainage type.

Palmetto Bluff's Golf Course data set included a spatial series of samples starting in a dry, rock-lined culvert (station 12) and adjacent collection cistern (station 3) of the Palmetto Bluff Golf Course, through its headwater drainage into Palmetto Bluff Creek (station 1), along a short downstream gradient in the creek (stations 2 and 8), and to stations located upstream (station 10) and downstream (station 9) within the May River (Figure 3). This data set included sampling during dry (< 0.5 inches of rainfall during previous 72 hours) and wet ($\geq$ 0.5 inches of rainfall during previous 72 hours) periods between February 8, 2007 and August 18, 2008 (Figure 3). As with the Phase Drainages data set, the analysis of the Golf Course data set was limited to four parameters: fecal coliform levels, total nitrogen, total phosphorus, and turbidity. To examine broad spatial differences and differences among wet and dry sampling events, these parameters were analyzed using a two-way ANOVA with "station" and "rainfall" (wet event vs. dry event) as factors. To more specifically analyze spatial gradients within this system a series of paired t-tests were performed during wet events and during dry events. First, measurements taken in the headwater drainage (station 1) were compared to measurements taken in the cistern (station 3). Second, values at each of the creek stations (1, 2 and 8) were compared to values in the May River (average of stations 9 and 10).

Bluffton's Rain Event data set includes samples collected between July 8, 2005 and February 18, 2008 from headwater drainages in the vicinity of the Town of Bluffton: Bluffton Village, Verdier Cove, Rose Dhu Creek and Stoney Creek. Two additional sites along the May River (Huger Cove and Guerrard Cove) were sampled starting in July 25, 2007, but at the time of analysis, these only included two sampling dates so the data were not included here. All collections were made following rain events that exceeded 0.1 inches in 72 hours. The average for each measure was calculated for each drainage prior to analysis. These were statistically compared to wet event data collected by Palmetto Bluff for their Phase Drainages data set using one-way ANOVA with "data set" (Rain Event vs. developed vs. impoundment vs. undeveloped) as a factor. Specific pairwise comparisons between the Bluffton Rain Event data set and each of the Palmetto Bluff Phase Drainages data sets (developed, impoundment, undeveloped) were performed using standard t-tests.

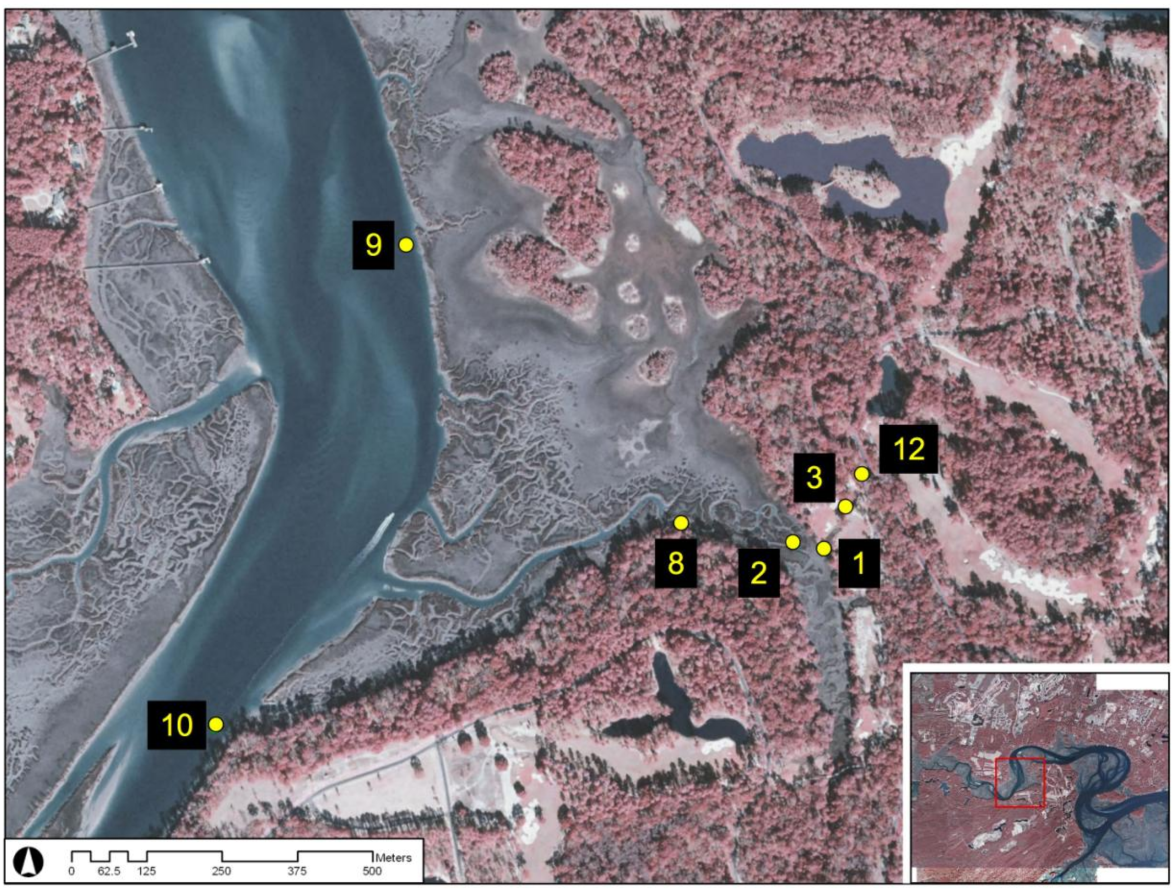


Figure 3. Locations of stations in the Golf Course data set.

Question III: What monitoring efforts will be most valuable and feasible to continue into the future?

Eight different monitoring efforts are currently ongoing in the main stem and headwaters of the May River: Town of Bluffton's Rain Event, Continuous Data Sondes and Volunteer Network, the Palmetto Bluff Development's Main Stem, Phase Drainages and Golf Course, and SCDHEC Ambient and Shellfish. Based on the analyses for Questions I and II and several additional analyses (see below), recommendations were derived to continue, expand, reduce or eliminate particular monitoring activities. Those monitoring efforts we recommend continuing or expanding were those that 1) produced the most unique and useful data, 2) presented the greatest potential to address the primary issues of concern, and/or 3) related most clearly to regulatory standards. Those monitoring efforts we recommend reducing or eliminating were those that 1) produced data redundant with a higher-quality or more established data set, 2) resulted in data with limited utility in terms of the primary concerns for May River stakeholders, and/or 3) successfully addressed their intended purpose.

The Town of Bluffton's Continuous Data Sondes and Volunteer Network data sets were not analyzed as part of the first two questions, however, their utility to addressing issues of concern in the May River were examined. Both data sets represented short-term records, thus they were not appropriate to examine long-term trends in the May River (Question 1). These data sets also did not represent the most relevant locations (headwaters) or the widest range of parameters (fecal coliform and nutrients) to examine inputs to the May River (Question 2). Additionally, patterns in the Continuous Datasonde data set were thoroughly described elsewhere (BP Barber, 2008). This does not mean that the data were not valid or useful, only that a full analysis within the goals of this report would not have provided informative conclusions. In order to determine whether the effort and cost of maintaining the continuous data sondes can be reduced, the data sonde records were divided into three data subsets (first five days of each month, middle five days of each months, and every other week) and the average, minimum and maximum values for those subsets were compared to the full data set. Comparison of average values between the data subsets and the full data sets allowed the examination of whether data subsets capture the broader monthly and seasonal patterns in water quality parameters. Comparison of minimum and maximum values allow the examination of whether data subsets provide accurate estimation of water quality variability seen in the full data set. Graphs of the Volunteer Monitoring Network were first examined for unusual observations. The reliability of the data was examined by comparing trends in water quality parameters at the Rose Dhu Creek station to the same parameters recorded by the continuous datasonde at the mouth of Rose Dhu Creek for a similar time period.

RESULTS AND DISCUSSION

Question I: Are significant changes in water quality occurring in the May River?

Salinity:

Salinity does not appear to be decreasing (becoming more fresh) in any part of the May River, in fact, salinity has been increasing suggesting a decrease in total freshwater inflow to the system. Salinity varied significantly between years at all stations except Main Stem M1-M3, and did not show a significant systematic variation among months (Table 2; Appendix B-1). Salinity increased in the May River as a whole and at every station regardless of the origin of the data, and these increases were significant at several stations in the middle (19-18) and lower (19-01 and 19-12) sections of the May River (Table 4; Appendix B-2 and B-3). All of the stations represented by the SCDHEC Shellfish data set possessed similar annual average salinities regardless of location within the river and showed a similar pattern of variability between 1994 and 2008 (Figure 4). The stations represented by the Main Stem data set did not clearly reflect salinities in the SCDHEC data set and indicated a gradient of increasing salinity from the most upstream station (M4) to the most downstream station (M1) (Figure 4). These differences between the SCDHEC and Main Stem data sets are not surprising because the SCDHEC data set was collected monthly throughout the year while the Main Stem data set was collected four times during the wet season (March to October).

Table 4. Results of regression analysis of year least-square means from ANCOVA against year in SCDHEC shellfish and ambient and main stem data sets. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Station	p-value	R^2	Slope
19-19	0.158	8.1	+
19-24	0.550	0.0	+
19-16	*0.050*	*20.7*	+
19-18	***0.022***	***29.4***	**+**
19-25	0.279	2.7	+
19-01	***0.024***	***28.4***	**+**
19-12	***0.017***	***31.9***	**+**
MD-173	0.570	0.0	+
M1	*0.083*	*37.9*	+
M2	*0.053*	*47.3*	+
M3	0.128	27.8	+
M4	0.191	17.7	+

Table 2. Results of ANCOVA salinity data in SCDHEC shellfish and ambient and main stem data sets. For simplicity, only p-values are shown here; full results are shown in Appendix B.1. P-values in bolded italics indicate significance at 0.01; p-values in italics indicate marginal significance at 0.05.

Source	19-19	19-24	19-16	19-18	19-25	19-01
Year	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
Month	0.523	0.194	0.193	0.290	0.241	0.336
Source	**19-12**	**MD-173**	**M1**	**M2**	**M3**	**M4**
Year	***<0.001***	***0.006***	0.429	0.241	0.111	*0.024*
Month	0.092	0.588	0.539	0.416	0.686	0.370

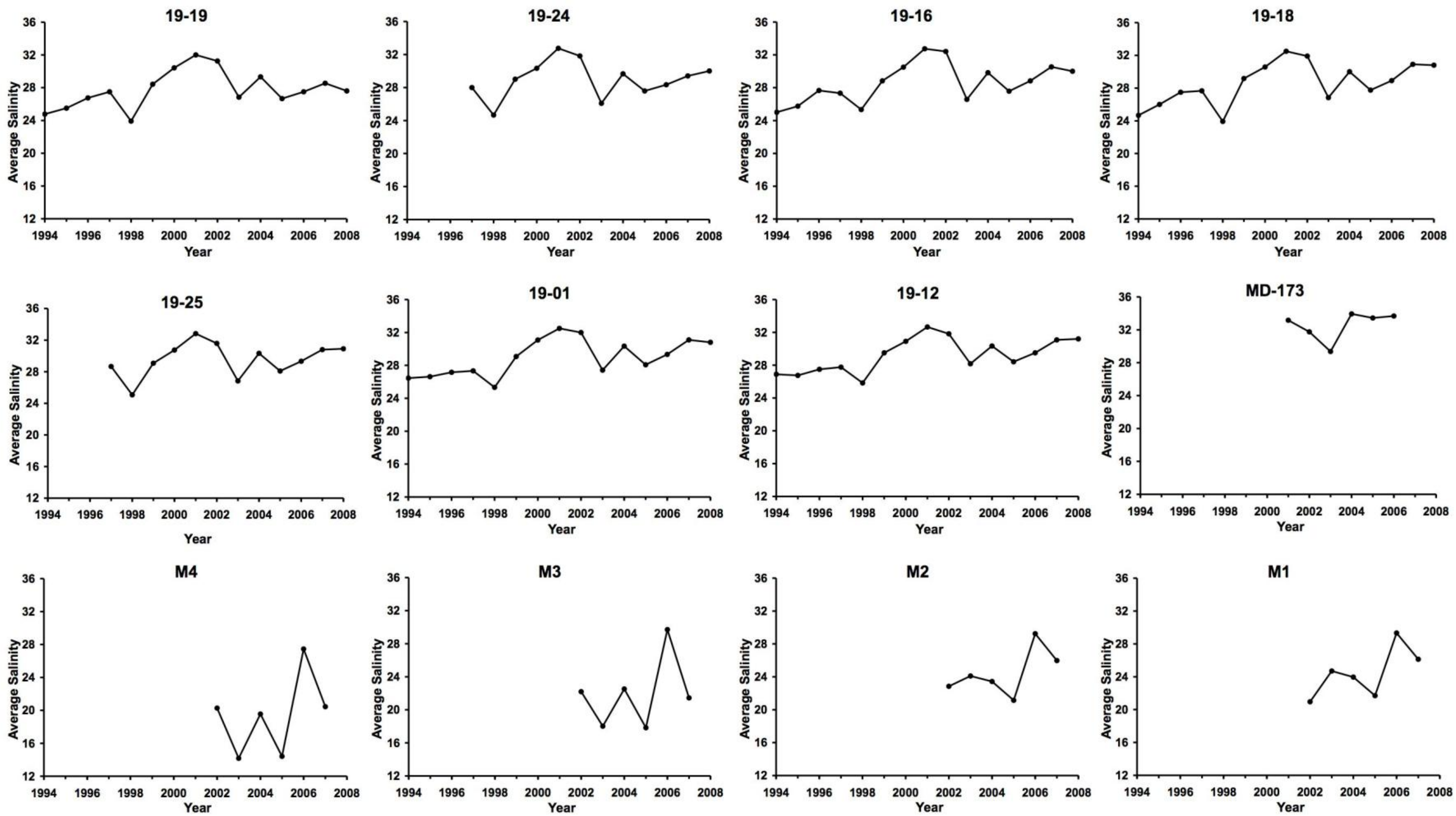


Figure 4. Annual average salinity (ppt) at SCDHEC Shellfish and Ambient stations and at the Main Stem stations.

Year-to-year salinity variation observed in the May River was closely related to precipitation patterns documented within the southwestern portion of the South Carolina. Monthly total precipitation data was mined from NOAA's National Climate Data Center using the U.S. National/State/Divisional Data set for the period 1/1/1994 to 12/31/2008 and summed to obtain total annual precipitation for the "Southern division" of South Carolina. Even at this coarse scale of resolution, the influence of rainfall patterns on average salinity within the May River is apparent (Figure 5). An overall pattern of decreasing rainfall coincided with the overall increase in salinity during this period. Similarly, the period of highest salinities at the SCDHEC stations between 1999 and 2002 happened over a period of declining rainfall between 1998 and 2001. Conceptually, inter-annual differences in precipitation could be masking the effects of stormwater-related changes in salinity. For example, during a period of decreasing annual rainfall, a location with significant stormwater inputs may not increase in salinity as fast as a location without those inputs. Using multiple regression, this was determined to not be a likely scenario in the May River. When corrected for background rainfall levels, salinity still changed significantly through time, but these changes were not significantly different among the different stations (Appendix B-4). In fact, at six of the seven SCDHEC Shellfish stations, salinity increased through time (although not significantly) even after correcting for the effects of total annual precipitation. This may reflect a decrease in total upland runoff into the May River due to altered hydrology from the construction of stormwater ponds.

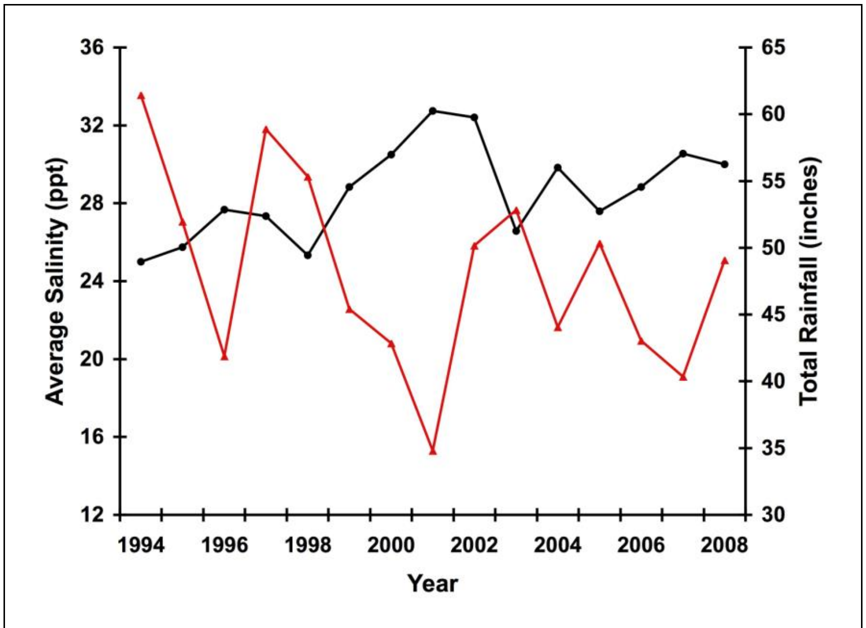


Figure 5. Total annual precipitation (red line) in the "Southern division" of South Carolina from NOAA's National Climate Data Center. Data from the SCDHEC Shellfish station 19-16 (approximate middle of river length) is shown for reference.

It is important to note that the data sets used in this analysis have limitations that affect the interpretation of the analyses. First, the analysis utilized regional rainfall data that do not accurately reflect actual rainfall in specific watersheds. Second, the salinity data were collected once a month at the SCDHEC shellfish stations, and once during each of four months at the Main Stem stations. While these data very closely reflect average salinity measured continuously over longer periods of time (Table 3), they would not necessarily be capable of capturing salinity conditions shortly after major rain events or thoroughly describing short-term salinity

Table 3. Comparison of average salinity between nearby Continuous Sonde and SCDHEC Shellfish stations between May 2007 and May 2008. RD = Rose Dhu, VC = Verdier Cove, AJ = Alljoy.

Comparison	Continuous Average	SCDHEC Shellfish Average
S-RD vs. 19-19	26.5	27.7
S-VC vs. 19-16	30.1	30.2
S-AJ vs. 19-12	31.8	31.3

variability. B.P. Barber's (2008) analysis of rainfall and near-continuous salinity data showed strong short-term changes in salinity following major rainfall events (2+") at Rose Dhu and Verdier Cove and very little change in salinity at Alljoy. This highlights both the watershed-specific pattern of salinity response to rainfall as well as the very strong and short-term nature of many rain events in the area, especially near the headwater of the river. In fact, when salinity data are compared between nearby SCDHEC Shellfish and Continuous Sonde data sets, these limitations become even more apparent. For example, at the confluence of Rose Dhu Creek with the May River, the Continuous Sonde dataset detected numerous low salinity events between May 2007 and May 2008, but the SCDHEC Shellfish data set (from station 19-19) detected relatively minor decreases in salinity for only a subset of the events (Figure 6). Although less-intensive sampling (such as done for the SCDHEC Shellfish and Main Stem stations) provide useful information on long-term changes in average conditions, they can not address all of the potential mechanisms linking land use changes to water quality. Well-focused and intensive data sets would be required to directly link changes in land use and stormwater pond systems to runoff and salinity changes in the May River.

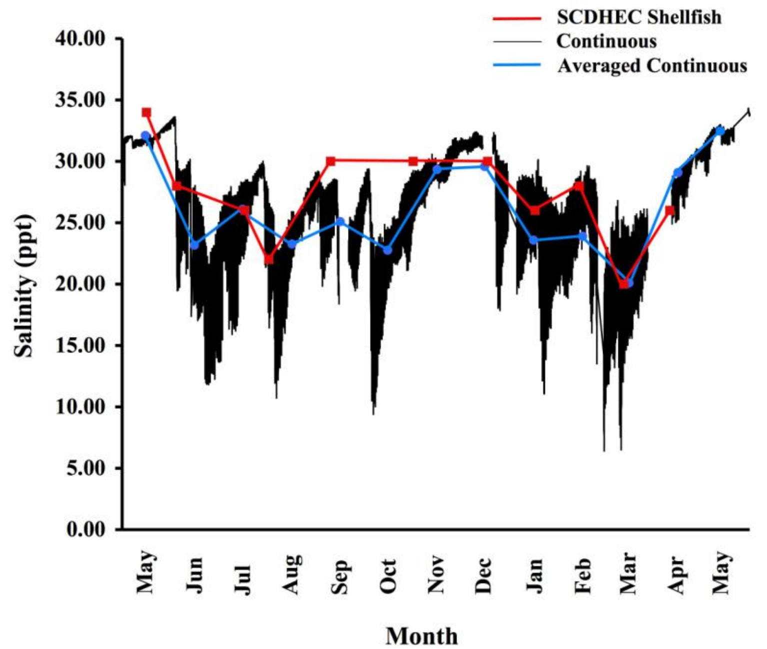


Figure 6. Salinity measured by the SCDHEC Shellfish station 19-19 data set compared to the Dose Dhu Continuous Sonde data. Monthly averages of the Continuous Sonde data set are also shown.

Fecal Coliform Bacteria:

Analysis of the SCDHEC Shellfish data suggest that, as a whole, the May River has been experiencing an increase in fecal coliform bacteria concentrations since the mid to late 1990's. In the SCDHEC shellfish and ambient station data sets, fecal coliform bacteria levels showed significant inter-annual variability at some stations, but did not vary significantly or systematically among calendar months (intra-annually) at any of the stations (Table 5; Appendix B-5). Fecal coliform bacteria levels increased significantly through time at station 19-18 and increased marginally through time at station 19-24 when the variability due to salinity and sampling month were removed (Table 6). Results for the remaining stations were statistically not significant, but positive trends (increasing fecal coliform levels through time) dominated. Although fecal coliform levels did not increase in a significant linear manner since 1994 at station 19-19 (the most upriver shellfish monitoring station), a trend of recent increases in fecal coliform levels is apparent at this location. In 2008, the geometric mean fecal coliform level at this station was 30.3 colonies/100 ml, a level that was much higher than in the preceding years (Figure 7; Appendix A-1). Additionally, the incidence of fecal coliform levels above 43 colonies/100 ml have increased during the 2004-2008 time period (Figure 8). When all of

Table 5. Results of ANCOVA for fecal coliform bacteria data in SCDHEC shellfish and ambient and main stem data sets. For simplicity, only p-values are shown here; full results are shown in Appendix B.1. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Source	19-19	19-24	19-16	19-18	19-25	19-01
Year	***<0.001***	*0.073*	0.127	***0.015***	0.848	0.111
Month	0.636	0.975	0.147	0.580	0.985	0.470
Salinity	***<0.001***	***0.001***	***<0.001***	***<0.001***	*0.077*	*0.055*
Source	**19-12**	**MD-173**	**M1**	**M2**	**M3**	**M4**
Year	0.473	***0.007***	0.346	0.932	0.301	0.698
Month	0.616	*0.076*	0.534	0.156	0.554	0.554
Salinity	***0.017***	***0.039***	0.822	0.322	0.443	0.901

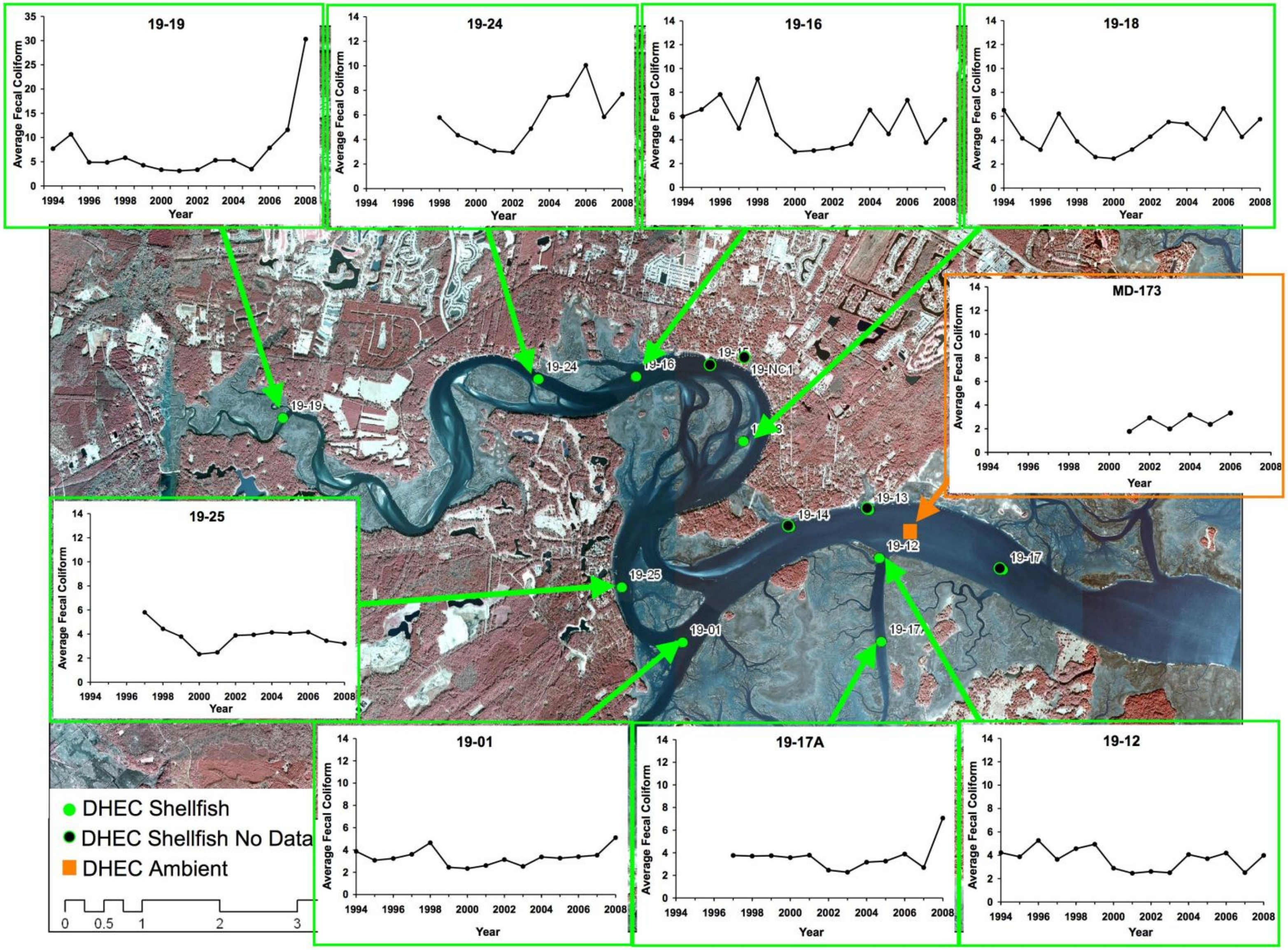
the stations within the middle and lower sections of the May River were analyzed together, fecal coliform bacteria levels were increasing through time (Appendix B-6).

Table 6. Results of regression analysis of year least-square means from ANCOVA against year in SCDHEC shellfish and ambient and main stem data sets.

Station	p-value	R^2	Slope
19-19	0.143	9.3	+
19-24	*0.077*	*20.8*	+
19-16	0.519	0.0	+
19-18	**0.029**	**26.3**	**+**
19-25	0.806	0.0	-
19-01	0.184	6.5	+
19-12	0.744	0.0	-
MD-173	0.531	0.0	+
M1	0.507	0.0	-
M2	0.346	1.4	-
M3	0.762	0.0	-
M4	0.661	0.0	-

The higher and more rapidly increasing fecal coliform levels in the upper portions of the May River as compared to the lower portions likely reflect a combination of water body size and flushing rate as well as development trends in the different May River subwatersheds. Analyses of the SCDHEC shellfish data set suggest several interesting patterns in fecal coliform levels among the various sections of the May River and with salinity and rainfall. When comparing the middle and lower sections, fecal coliform levels were somewhat higher (although not significantly) in the middle section and increasing marginally faster in the middle section of the May River ("Section" and "Section X Year" interaction in Appendix B-6). Other studies have documented inverse relationships between fecal coliform levels and water body size and have suggested that this pattern may result from increased flushing, greater distance from potential sources, increased dilution capacity, and increased mortality due to higher salinity in the farther downstream segments of a river (Anderson *et al.* 1979; Mallin *et al.* 1999; Felber 2007). The patterns observed may also reflect differences and/or changes in developed land use/land cover within the subwatersheds emptying into the May River. Watersheds with medium to high-density urban/suburban development tend to produce more high-volume and flashy runoff than undeveloped watersheds, resulting in the rapid concentration and transport of pollutants into surrounding water bodies (Mallin *et al.* 2000; Van Dolah *et al.* 2008; DiDonato *et al.* 2009). The middle (3) and lower (2) subwatersheds were the most heavily developed along the May River in both 1999 and 2006, with the portion of each subwatershed north of the river being much more developed than that south of the river (Table 7; Figure 1b). The middle subwatershed was more heavily developed in 1999, but the lower subwatershed was more developed in 2006. Development in the lower and upper subwatersheds also increased the most between 1999 and 2006 (especially north of the river). The somewhat higher fecal coliform levels detected in the middle section of the May River may be a result of a combination of factors including its size and flushing rate as well as its subwatershed being more heavily developed for a longer period of time. By comparison, the lower section is larger and presumably more well-flushed and lies in a

Figure 7. Average annual fecal coliform levels (geometric means by calendar year) for eight SCDHEC shellfish stations and one SCDHEC ambient station.



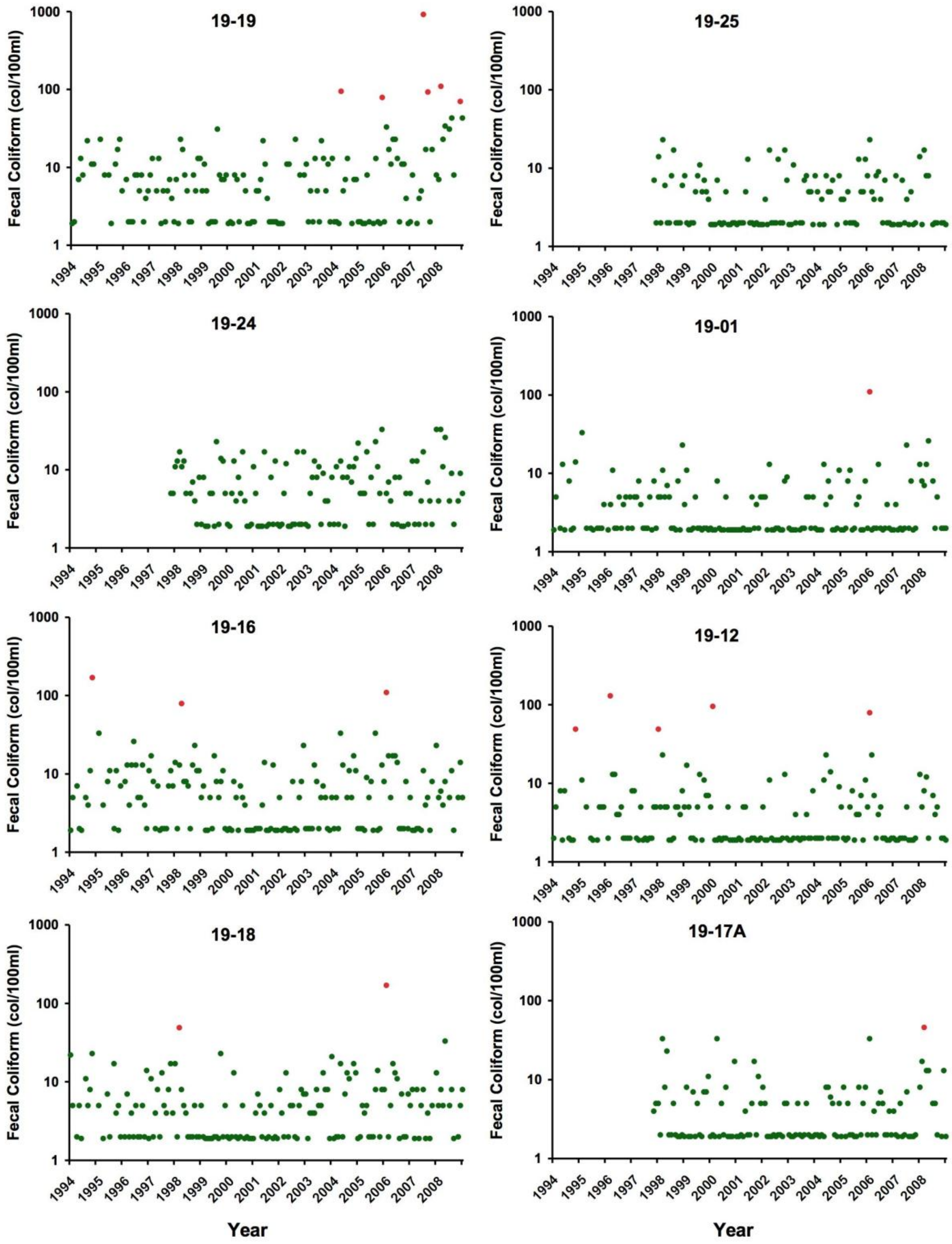


Figure 8. Fecal coliform bacteria levels at the SCDHEC shellfish stations. Values exceeding 43 colonies/100 ml shown in red.

subwatershed that has been more recently developed. The greater increases in fecal coliform concentrations in the middle section as compared to the lower section may reflect similar interactions between the river's physical characteristics and changes in upland land use/cover. Rapid development of the upper subwatershed (increases in impervious cover from 22% to 33% on the north side and 5% to 12% on the south side) also are likely to be playing a role in the changing conditions on the middle section of the May River. In fact, the only shellfish station located in the upper section of the May River (19-19), has shown a major increase in average fecal coliform levels in recent years (Figure 7). This station is located near the confluence of Rose Dhu Creek with the May River. The subwatershed drained by Rose Dhu Creek developed rapidly in recent years and has become the focus of additional studies being performed by the Town of Bluffton.

Table 7. Impervious cover (% of total upland) from manual dot counts during 1999 and 2006 in each drainage area both north and south of the May River (Figure 1b). Change in impervious cover between 1999 and 2006 is also calculated.

Drainage Area	1999	2006	Change
2 (Lower)			
North	22.2	33.3	+11.1
South	4.7	11.9	+7.2
3 (Middle)			
North	34.2	30.9	-3.3
South	1.7	5.4	+3.7
4 (Upper)			
North	7.5	19.7	+12.2
South	3.1	7.1	+4.0
5 (Headwater)	3.8	6.4	+2.6

Relative to similarly-sized effluent-free water bodies in Beaufort County, most of the May River does not appear to be degraded with respect to fecal coliform levels. Most parts of the May River system generally have similar or lower average fecal coliform levels than were observed during the summer months (June through August) in effluent-free water bodies of similar width sampled by SCECAP in Beaufort County (Figure 2; Figure 9). This may partially reflect the relatively shorter length and lower sinuosity of the May River relative to many of the other tidal creeks and rivers in Beaufort County, resulting in greater flushing especially in the lower section of the May River, which exchanges directly with the Calibogue Sound. The upper section and upper portions of the middle section of the May River have historically had average summer fecal coliform levels that are lower than typical effluent-free waters of Beaufort County (Figure 9). Fecal coliform levels at several SCDHEC shellfish stations in these more upper portions of the May occasionally exceeded the effluent-free average, and the only station in the upper section (19-19) substantially exceeded the average in both 2007 and 2008 (Figure 9). This same general pattern of greater fecal coliform levels in the upper section and upper portions of the middle section (particularly near shellfish station 19-19) was also detected in the Baseline Study (Van Dolah *et al*., 2004). Since summer fecal coliform levels in most portions of the May River are lower than has been observed in effluent-free water bodies of Beaufort County, most of the May River does not appear to be impaired with respect to fecal coliform levels. The upper portion of the May River, however, shows signs of degradation and this may extend into other sections of the river if recent trends continue.

Rates of freshwater inflow likely play an important role in the water quality on the May River. Fecal coliform bacteria levels were significantly and inversely related to salinity at almost every station (Table 5; Appendix B-5). Several studies have noted strong inverse correlations between fecal coliform bacterial levels and salinity (Mallin *et al*., 1999, 2000; Solic and Krstulovic, 1992; Carlucci and Pramer, 1959; Anderson *et al*., 1979). It has been suggested that the bactericidal effect of salinity is caused by specific ion toxicity or osmotic effect (Carlucci and Pramer, 1959). Solic and Krstulovic (1992) further suggested that salinity is an important factor influencing fecal coliform survival,

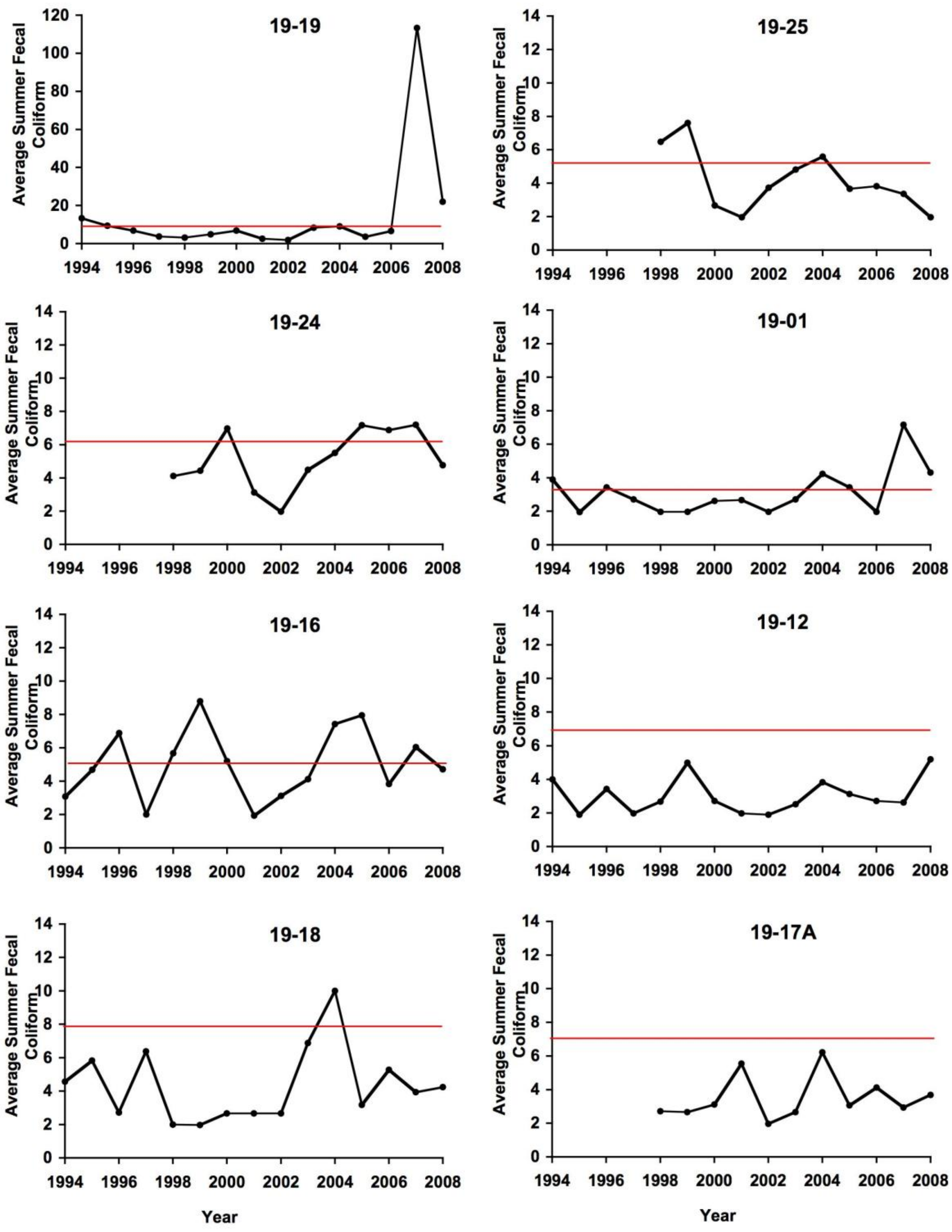


Figure 9. Average fecal coliform levels at the SCDHEC Shellfish monitoring stations during the summer (June-August) when SCECAP sampling has traditionally been performed. The red line shows the predicted fecal coliform level at each station based on the width of the river at that station and the relationship between fecal coliform levels and water body width in effluent-free waters sampled by SCECAP between 1999 and 2006 in Beaufort County.

especially in areas with regular fluctuations in salinity, such as estuarine systems. These relationships were strongest in the stations located farther upstream in the May River as compared to those located farther downstream. This could reflect the greater influence of freshwater drainages on the narrower, shallower and lower-salinity upstream portions and the greater influence of higher-salinity seawater on the more downstream portions of the May River.

Instream fecal coliform levels are closely but not entirely related to rainfall patterns in the southern portion of the state. Discrete increases in fecal coliform levels were sometimes quite consistent among stations suggesting a common driving cause. One such increase was observed on 1/24/06 and was noted to be present at all of the stations. Further analysis revealed that 0.28 inches of precipitation had fallen the day before sampling and an additional 0.14 inches fell on the day of sample collection (Beaufort MCAS). The influence of rainfall is also clearly reflected in the low fecal coliform levels recorded at all DHEC Shellfish stations from 1999 through 2001 (Figure 7), a period when rainfall levels were at their lowest in the southern portion of South Carolina (Figure 5). This is not particularly surprising as numerous studies have documented a strong positive correlation between elevated fecal coliform concentrations and rainfall (Lipp *et al*., 2001; Mallin *et al*., 2001; Siewicki *et al*., 2007), but it emphasizes the importance of upland runoff on water quality in the May River. It is interesting to note, however, that increases in fecal coliform levels in recent years (for example, at stations 19-19, 19-24 and 19-18) occurred during a period of decreasing rainfall and increasing salinities. This suggests either that there has been an increase the sources of fecal coliforms (wildlife, domestic animals, etc.) rather than an increase in total runoff volume or that runoff has become more episodic. In the latter situation, stormwater control systems may be reducing the intermittent flushing of tidal creek headwaters and adjacent wetlands where fecal coliforms accumulate. Consequently, the accumulated fecal coliform bacteria may be flushed less regularly and only during rain events large enough to exceed the capacity of the stormwater systems. This could result in a lower number of higher-concentration pulses of fecal coliforms into the May River.

The Main Stem data set documented no significant temporal trends in fecal coliform levels, but generally confirmed the broader spatial patterns documented by the SCDHEC Shellfish data set. In the Main Stem data set, no significant relationships were found between fecal coliform levels and salinity, sampling season or year (Table 5; Appendix B-5), and no significant temporal patterns were found after correcting for salinity and sampling season (Table 6). Although not significant, the relationships between fecal coliform levels and year were negative at all four stations (Table 6). Similarly, when all four stations were combined into a single analysis, no significant changes over time were detected in the main stem data set as a whole (Appendix B-7). Spatially, the station locatedfarthest upstream (M4) had the highest average fecal coliform levels and these levels decreased farther downstream towards M1 (Figure 10), but the differences were not significant. Also, like the SCDHEC shellfish stations, fecal coliform levels as measured for the Main Stem stations rarely exceeded the average for effluent-free waters of the same size based on SCECAP (Appendix A-2).

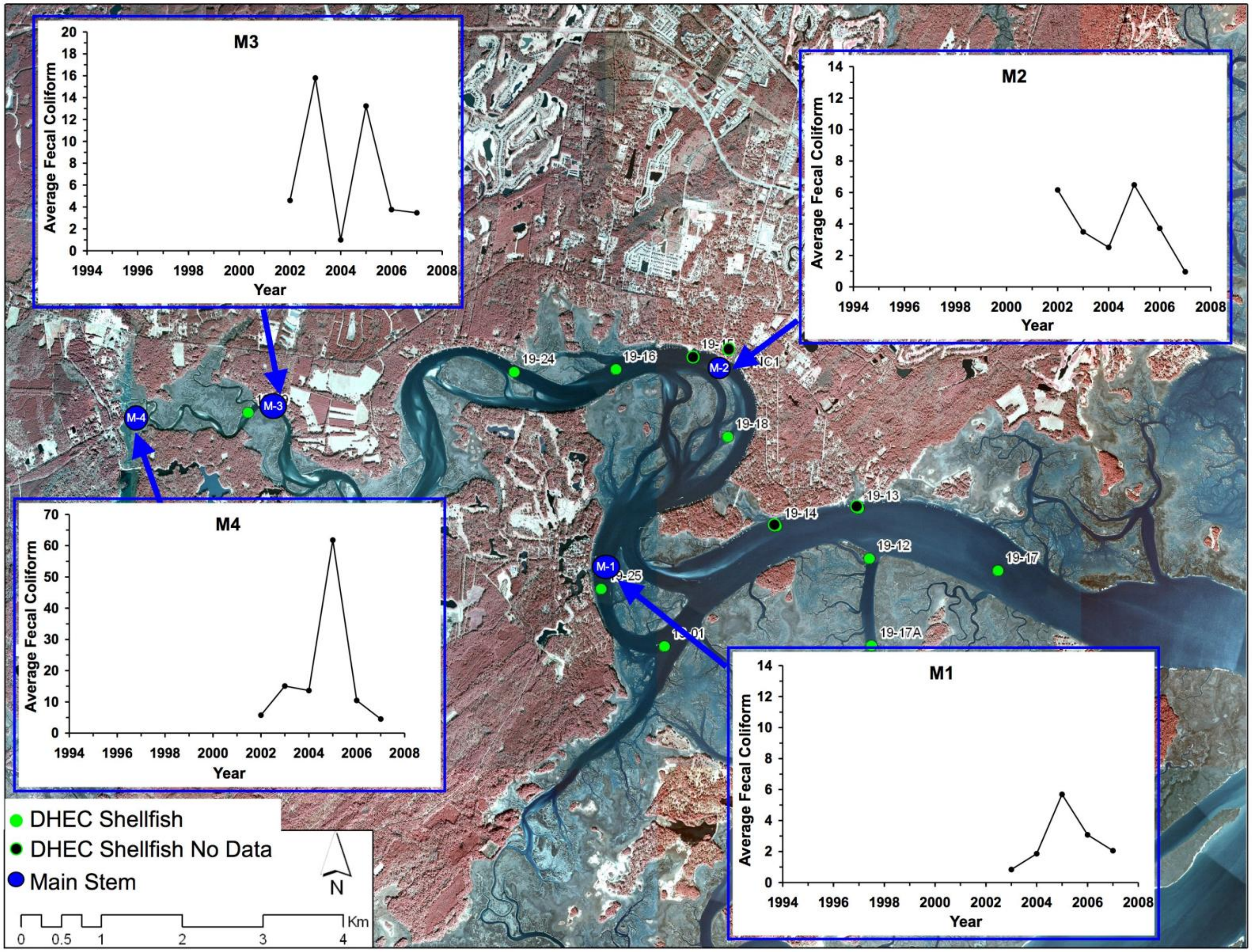


Figure 10. Average annual fecal coliform levels (geometric means by calendar year) for the four Main Stem stations

Nutrients:

Existing monitoring activities did not detect significant changes in nutrients, as measured by total nitrogen and total phosphorus, in the May River. Overall, nutrient levels measured at the Main Stem stations and the SCDHEC Ambient station were characterized by some significant intra-annual (month-to-month) and few significant inter-annual differences (Table 8; Appendix B-8; Figure 11). Inter-annual differences were most consistently detected at the SCDHEC Ambient station and not detected at the Main Stem stations. No significant yearly trend was detected in total nitrogen (TN) or total phosphorus (TP) at any of the Main Stem stations or the SCDHEC Ambient station (Table 9). This lack of a significant trend was confirmed when the Main Stem stations were analyzed together (Appendix B-9), although TN tended to decrease and TP tended to increase over the study period. The concentrations of both nutrients were highest during the August sampling event, lowest during the March sampling event, and intermediate in both June and October, reflecting a consistent seasonal fluctuation in nutrient inputs to the river. This pattern probably results from a combination of factors including seasonal differences in rainfall and peak primary productivity during the summer months.

Table 8. Results of ANCOVA for nutrient data in SCDHEC Ambient and Main Stem data sets. For simplicity, only p-values are shown here; full results are shown in Appendix B-4. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Source	MD-173	M1	M2	M3	M4
Total Nitrogen					
Year	***<0.001***	0.378	0.747	0.982	0.408
Month	***0.004***	***0.009***	0.624	0.154	0.593
Total Phosphorus					
Year	*0.058*	0.618	0.890	0.921	0.603
Month	***<0.001***	***0.006***	0.175	0.139	***0.017***

Table 9. Results of regression analysis of year least-square means from ANCOVA against year in SCDHEC Ambient and Main Stem data sets.

	Total Nitrogen			*Total Phosphorus*		
Station	**p-value**	**R^2**	**Slope**	**p-value**	**R^2**	**Slope**
MD-173	0.226	17.3	+	0.451	0.0	+
M1	0.451	0.0	-	0.886	0.0	-
M2	0.887	0.0	-	0.621	0.0	-
M3	*0.084*	37.7	-	0.287	6.6	+
M4	0.836	0.0	-	0.412	0.0	+

Nutrient levels were higher in the upper portions than in the lower portions of the May River, mirroring the spatial patterns documented for fecal coliform levels. The Main Stem station located in the most upper portion of the May River (M4) had the highest average TN and TP, whereas stations located farther downstream had the lowest concentrations of these nutrient s (Figure 9). These between-station differences were significant for both TN and TP. Main Stem station M4 in particular had significantly elevated nutrient levels. This upper portion of the river is in close proximity to various upland sources of nutrients (both natural and anthropogenic) and is immediately downstream of a large impoundment. Nutrient loading to this portion of the river is likely exacerbated by a low dilution capacity and long residence time.

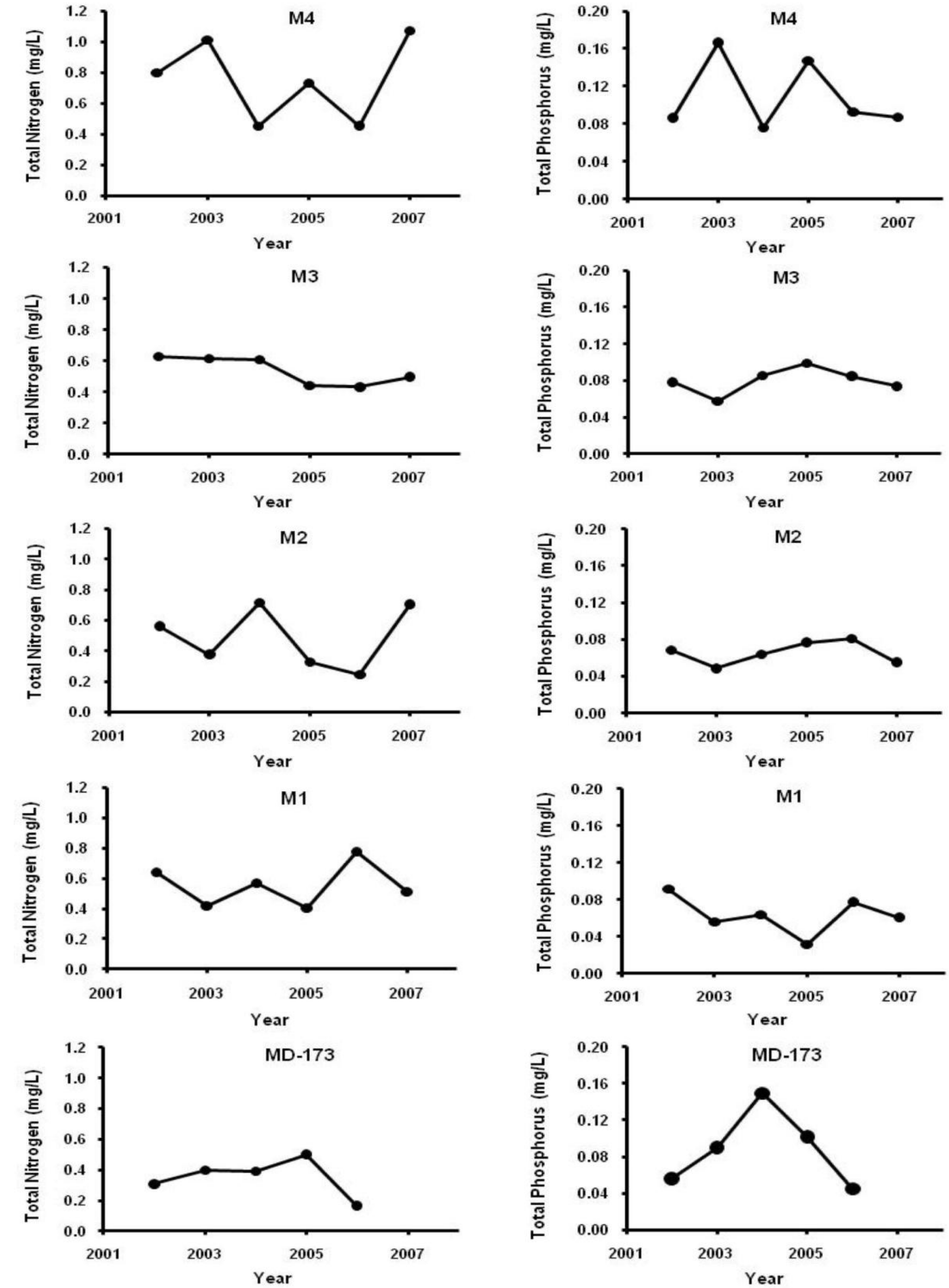


Figure 11. Average annual total nitrogen and total phosphorus concentrations for the Main Stem (M1-M4) and the SCDHEC Ambient (MD-173) stations located in the May River

Other Measures of Water Quality:

No consistent and significant changes in dissolved oxygen, pH and total suspended solids (TSS)/turbidity were detected in the May River. At most Main Stem stations, dissolved oxygen and TSS/turbidity showed significant monthly variability but little significant inter-annual variability, and pH showed little evidence of varying by month, year or salinity (Table 10; Appendix B-10). The SCDHEC Ambient station (MD-173) showed significant variability by month and year for dissolved oxygen and significant variability by month for pH and turbidity. Significant intra- and inter-annual differences were most commonly detected in monitoring stations located farthest from the May River headwaters. Once corrected for monthly variability, none of these variables increased or decreased significantly over the monitoring time period (Table 11). When all four Main Stem stations were combined into a single analysis, TSS decreased significantly over time, but dissolved oxygen and pH were not changing significantly (Appendix B-11).

Table 10. Results of ANCOVA for other water quality measures in the SCDHEC Ambient and Main Stem data sets. For simplicity, only p-values are shown here; full results are shown in Appendix B-6. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Source	MD-173	M1	M2	M3	M4
Dissolved Oxygen					
Year	***0.004***	***0.021***	0.261	0.611	0.369
Month	***<0.001***	***<0.001***	***0.001***	***<0.001***	***0.001***
pH					
Year	0.388	0.471	0.761	0.485	*0.066*
Month	***0.009***	0.278	*0.074*	*0.050*	0.123
Salinity	0.656	0.290	0.927	0.910	0.194
TSS/Turbidity					
Year	0.119	0.433	0.298	0.105	0.290
Month	***<0.001***	***0.042***	***0.016***	***<0.001***	0.141

As with the fecal coliform and nutrient data, the other water quality measures showed a clear spatial gradient with evidence of increasing degradation closer to the headwaters of the May River. The Main Stem station located farthest upstream (M4) had the lowest average dissolved oxygen, highest TSS, and lowest pH levels with dissolved oxygen and pH increasing and TSS decreasing farther downstream towards M1 and M2 (Figure 12). The between-station differences were significant for pH and TSS but not for dissolved oxygen (Appendix B-11). As with the other parameters discussed previously, this likely reflects closer proximity of upper portions of the river to sources of terrestrial input and human activity as well as less dilution capacity and longer residence times of the narrower and more sinuous headwater area.

Table 11. Results of regression analysis of year least-square means from ANCOVA against year in SCDHEC Ambient and Main Stem data sets.

	Dissolved Oxygen			*pH*			*TSS/Turbidity*		
Station	**p-value**	**R^2**	**Slope**	**p-value**	**R^2**	**Slope**	**p-value**	**R^2**	**Slope**
MD-173	0.930	0.0	-	0.268	11.5	-	0.325	4.9	-
M1	0.294	5.8	+	0.518	0.0	-	0.812	0.0	-
M2	0.362	0.1	+	0.694	0.0	+	0.190	17.8	-
M3	0.857	0.0	-	0.900	0.0	+	0.168	21.0	-
M4	0.775	0.0	+	0.346	1.3	+	0.196	17.0	-

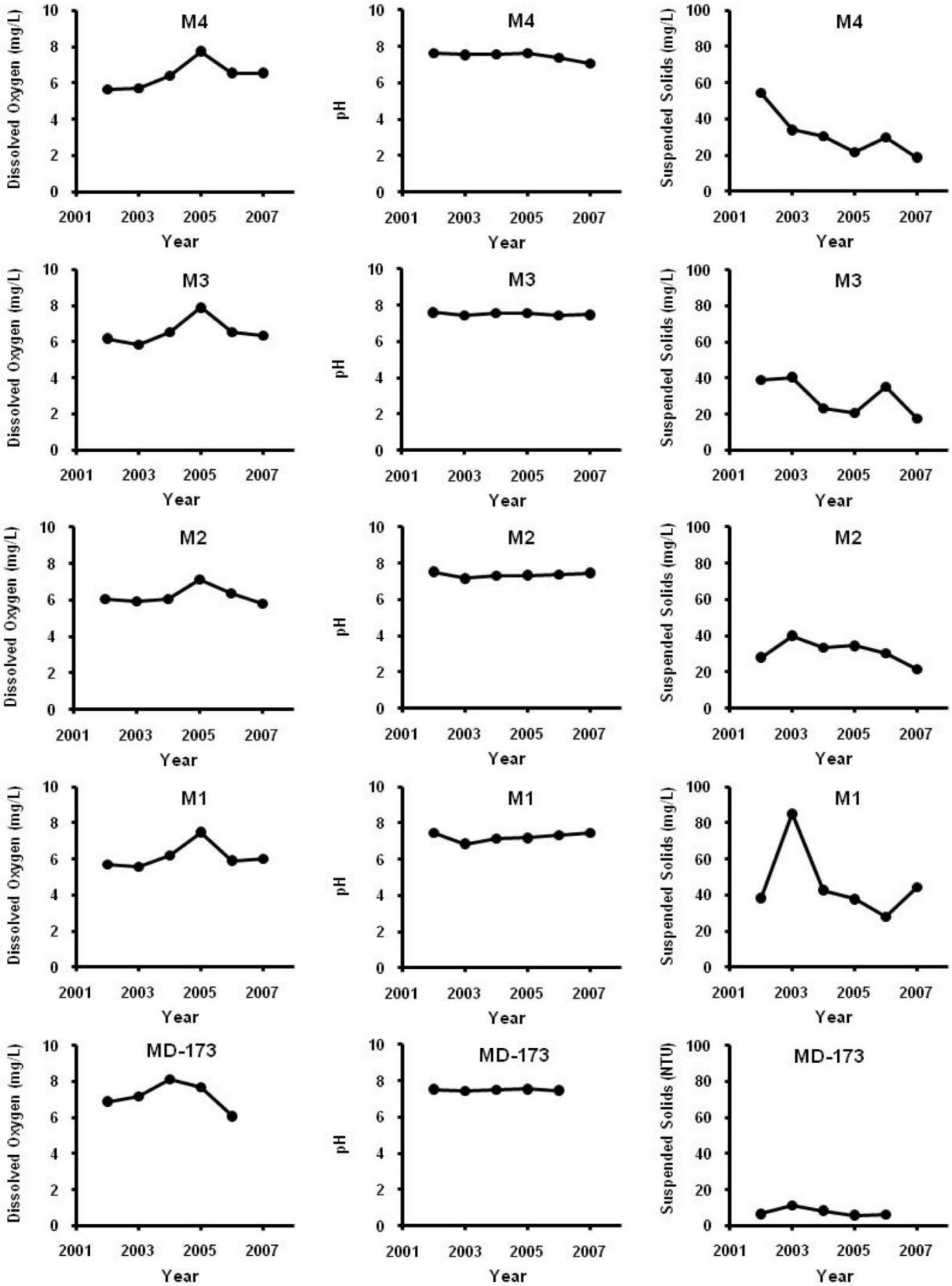


Figure 12. Average annual dissolved oxygen, pH and turbidity/TSS values for the Main Stem (M1-M4) and the SCDHEC Ambient (MD-173) stations located in the May River.

Question II: Are developed drainages acting as significant sources of pollutants to the May River system?

Stormwater runoff is a major source of pollution transport into freshwater and coastal aquatic systems. Coastal water bodies with heavily developed watersheds often have elevated levels of pathogens, nutrients and contaminants (Comeleo *et al*., 1996; Kelsey *et al.*, 2004; King *et al*., 2007; Van Dolah *et al*., 2008; DiDonato *et al*., 2009). Improper management of stormwater runoff from developed/urbanized watersheds can result in impairment of water resources (Evans *et al*., 1996; Campos and Cachola, 2007) and pose a serious public health risk (Gaffield *et al*., 2003).

The original intent of the following series of analyses was to determine whether stormwater runoff was affecting water quality in the May River. Unfortunately, the existing data sources do not allow this question to be addressed due to a lack of comparable data both in the drainages and in the May River itself. In order to properly address this question, additional field and modeling studies would be necessary. The data structure does allow the comparison of developed and undeveloped drainages in order to determine whether developed drainages are more likely to contribute pollutants (fecal coliform bacteria, nutrients and turbidity) to the May River than undeveloped drainages. This comparison is made largely possible by the collection of data by the Palmetto Bluff Development within the undeveloped Palmetto Bluff Phase II drainages. The data from a series of undeveloped sub-watersheds is compared to similar data from developed or partially-developed Palmetto Bluff subwatersheds (Phase I), to the drainage and creek associated with the Palmetto Bluff Golf Course, and to the drainages from Bluffton that comprise the Rain Event data set.

Palmetto Bluff Phase I Versus Phase II Drainages:

Developed drainages in the Palmetto Bluff area showed little evidence of having degraded water quality when compared to undeveloped drainages. Fecal coliform levels were highest in drainages from undeveloped subwatersheds and lowest in impoundment/pond drainages, but these differences were not significant overall (Table 12; Figure 13; Appendix B-12). Significant variability among stations of a type was also detected and is most noticeable in the relatively high levels of fecal coliform bacteria at developed drainage I-2, impoundment drainage I-4 and undeveloped drainages II-1 and II-2; levels at I-2 and I-4 were similar to levels in the undeveloped drainages, particularly during wet events (Figure 13). Turbidity, total nitrogen (TN) and total phosphorus (TP) were all significantly higher in impoundment/pond drainages as compared to developed or undeveloped drainages, while only TP was significantly higher in developed drainages as compared to undeveloped drainages. The elevated nutrient levels in the impoundment drainages probably represent organic matter released from these highly productive wetland systems. Unfortunately, the nutrient data for these systems did not differentiate between organic and inorganic fractions, so this cannot be confirmed.

Rain events resulted in greater outputs of fecal coliform bacteria from drainages, particularly in the undeveloped subwatersheds where terrestrial wildlife deposits represent the most likely source. Following rain (wet) events, fecal coliform bacteria levels in drainages were significantly higher than during routine bimonthly sampling (dry) events (Table 12; Figure 13; Appendix B-12). Fecal coliform levels increased the most in drainages from undeveloped subwatersheds following a rain event. Turbidity, TN and TP measured in drainages were all higher during wet events, but not significantly

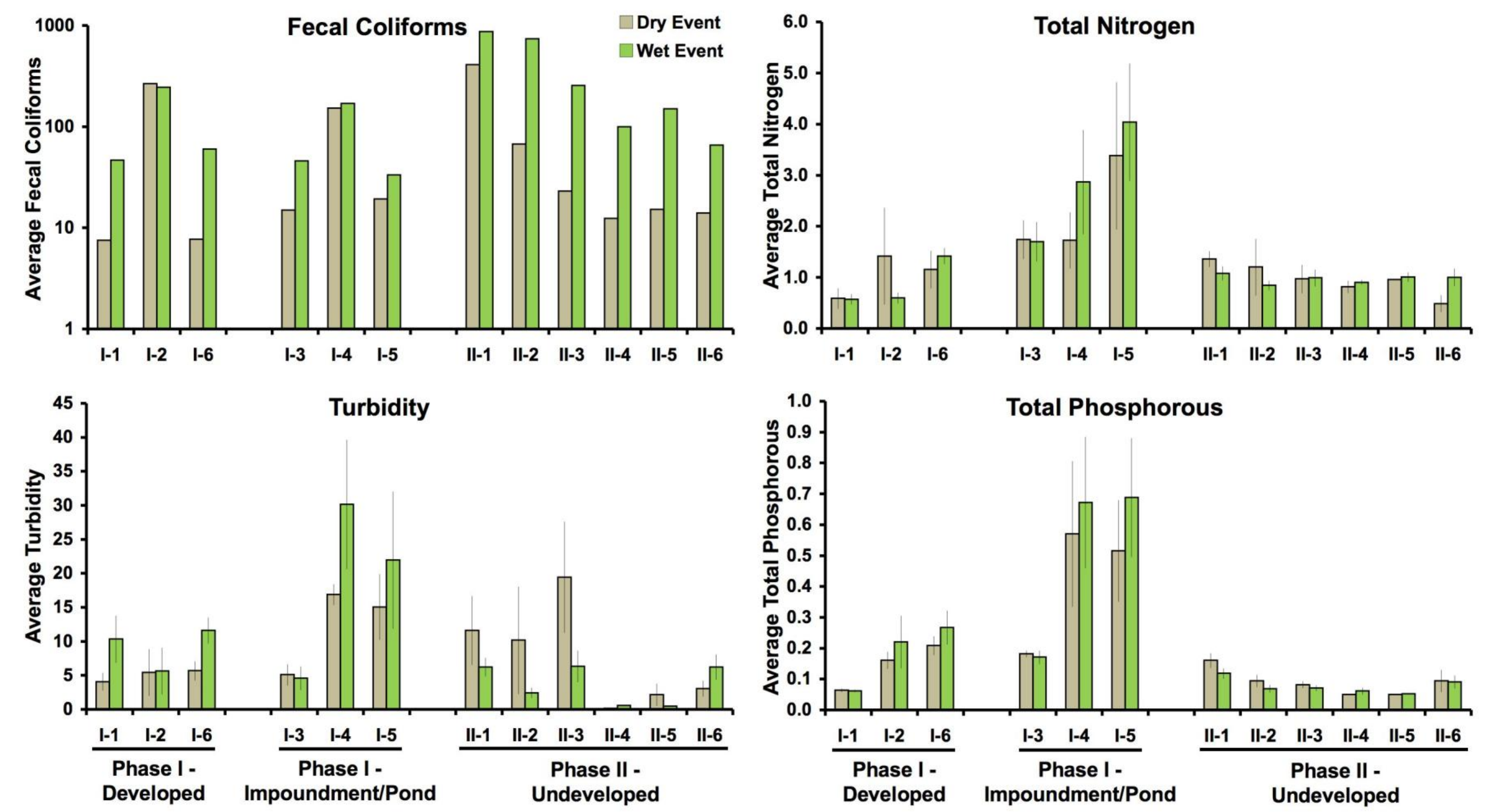


Figure 13. Average fecal coliform levels, total nitrogen, total phosphorus and turbidity during routine bimonthly ("dry") and rain event ("wet") sampling in the drainages associated with impounded wetland and developed areas in Palmetto Bluff Phase I and in the largely undeveloped Phase II.

higher, than during dry events. The largest increases in these parameters following rain events occurred in the stations associated with the impoundment at the May River headwater. Elevated fecal coliform levels are commonly observed following rain events (Lipp *et al*., 2001; Mallin *et al*., 2001; Siewicki *et al*., 2007), but the extent of the increase depends upon where deposition occurs. The very large increase in fecal coliform bacteria being discharged from the undeveloped subwatersheds during rain events may reflect mobilization of accumulated bacteria from wetland sediments or flushing of terrestrially-deposited bacteria through the wetlands and into the drainages by increased freshwater inflow. The absence of an increase in turbidity concomitant with the rain events, suggests that mobilization from wetland sediments is unlikely and that terrestrial deposits are the most likely source of fecal pollution in these systems.

Table 12. Results of nested two-way ANOVA comparing fecal coliform levels, total nitrogen, total phosphorus and turbidity among subwatershed types (Phase I developed, Phase I impoundment/pond, Phase II undeveloped) events (wet vs. dry) and stations within a subwatershed type. Full ANOVA output shown in Appendix B-8.

	p-value
Fecal Coliform	
Type	0.623
Event	***<0.001***
Station(Type)	***<0.001***
Total Nitrogen	
Type	***<0.001***
Event	0.332
Station(Type)	0.166
Total Phosphorus	
Type	***<0.001***
Event	0.326
Station(Type)	***<0.001***
Turbidity	
Type	***<0.001***
Event	0.954
Station(Type)	***<0.001***

During the monitoring period analyzed here, the developed Palmetto Bluff subwatersheds did not show evidence of being a major source of fecal coliform pollution through stormwater runoff. The positive relationship between estuarine fecal coliform levels and the amount of development/impervious cover present in a watershed has been well-documented (Mallin *et al*., 2001; Kelsey *et al*., 2004; Van Dolah *et al*., 2008; DiDonato *et al*., 2009). Common sources of fecal coliform bacteria in coastal watersheds include mammals and birds, failing septic systems, and pets. The relatively recent development occurring on Palmetto Bluff is tied to a municipal sewer system thus reducing the likelihood of human fecal pollution. Development in this area has also been low-density and has incorporated modern landscape design characteristics such as significant vegetated buffers between open areas and water bodies, characteristics likely to reduce the concentration of pet wastes and transport of that waste into ponds and creeks. Much of the fecal coliform bacteria found in coastal ponds and tidal creeks are thought to be of wildlife origin (Scarlatos, 2001; Siewicki *et al*., 2007). The undeveloped subwatersheds monitored here often contained large areas of unimpounded freshwater and brackish swamp as well as mixed forest cover, habitats that are likely to support significant wildlife populations. The fragmentation of habitat in the developed parts of Palmetto Bluff has likely displaced much of the wildlife from that area, and perhaps partially concentrated that wildlife in the undeveloped subwatersheds. During storm events, excess water inflow to the unimpounded swamp may have mobilized fecal coliform bacteria that had accumulated in these areas. Interestingly, the largest increases in fecal coliform discharges in the developed subwatersheds were associated with the overflows of two large ponds (stations I-1 and I-6; Figure 13). Generally, the development of Palmetto Bluff does not appear to have increased fecal coliform runoff to the May River at this time, perhaps due to a combination of low-density and the young age of development, the displacement of wildlife into undeveloped areas and/or containing and controlling stormwater runoff.

<u>Palmetto Bluff Golf Course Drainage:</u>

A clear gradient of water quality was detected in the tidal creek linking the Palmetto Bluff Golf Course to the May River, but this golf course drainage is not likely to be the sole source of those pollutants. All four parameters analyzed varied significantly among the stations sampled associated with the golf course (Table 13; Appendix B-13). During routine monitoring (“dry” events), fecal coliform levels, phosphorus concentrations and turbidity were significantly elevated in the headwaters of Palmetto Bluff Creek (station 1) relative to both the cistern of the Palmetto Bluff Golf Course (stations 3) and the May River (stations 9 and 10) (Table 14; Figure 14), but nitrogen was not. These same parameters were also significantly or marginally elevated in the body of Palmetto Bluff Creek (stations 2 and 8) relative to the May River. The freshwater cistern located in the golf course (station 3) had higher fecal coliform levels than measured in the May River but lower fecal coliform levels than the creek headwaters, indicating that the cistern (and parts of the golf course it drains) is not the sole source of fecal coliform to the creek system. Furthermore, when compared to a nearby station sampled in the Baseline Study (Van Dolah et al., 2004), TN and TP remained similar and turbidity and fecal coliform levels were substantially lower than those detected in this creek during 2002/2003.

Table 13. Results of two-way ANOVA comparing Fecal coliform levels, total nitrogen, total phosphorus and turbidity among events (wet vs. dry) and stations. Full ANOVA output shown in Appendix B-9.

	p-value
Fecal Coliform	
Event	***<0.001***
Station	***<0.001***
Total Nitrogen	
Event	0.284
Station	***0.001***
Total Phosphorus	
Event	***<0.001***
Station	***<0.001***
Turbidity	
Event	***<0.001***
Station	***<0.001***

Stormwater runoff results in higher fecal coliform bacteria levels, phosphorus concentrations and turbidity in water bodies in and adjacent to the Palmetto Bluff Golf Course that, in some cases, substantially exceed levels typical of undeveloped drainages in the area. Following rain events, fecal coliform levels, turbidity and phosphorus concentrations became elevated above levels detected during routine (“dry”) sampling both in the golf course cistern and in the adjacent water of the creek (Table 13; Figure 14), but nitrogen was not. Total phosphorus and turbidity increased in the cistern and adjacent tidal creek to levels well above those observed in drainages from the undeveloped Phase II area of Palmetto Bluff (Figure 14). As discussed above, non-point source pollutants are commonly observed to increase in water bodies following rain events (Lipp *et al.*, 2001; Mallin *et al.*, 2001; Gaffield *et al.*, 2003; Siewicki *et al.*,

Table 14. Results of individual paired t-tests comparing individual stations of interest along the golf-course to river transect.

	Headwater (1)		**Creek (2)**		**Creek (8)**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Fecal Coliform						
Cistern (3)	***0.012***	0.380	--	--	--	--
River (9/10)	***<0.001***	***0.013***	***<0.001***	***0.007***	***<0.001***	*0.063*
Total Nitrogen						
Cistern (3)	0.420	*0.071*	--	--	--	--
River (9/10)	0.655	0.266	0.100	0.952	0.281	0.325
Total Phosphorus						
Cistern (3)	***<0.001***	0.223	--	--	--	--
River (9/10)	***<0.001***	***0.007***	*0.096*	***0.042***	***0.027***	***0.044***
Turbidity						
Cistern (3)	***<0.001***	***0.014***	--	--	--	--
River (9/10)	***<0.001***	***0.010***	***0.001***	***0.005***	*0.070*	***0.008***

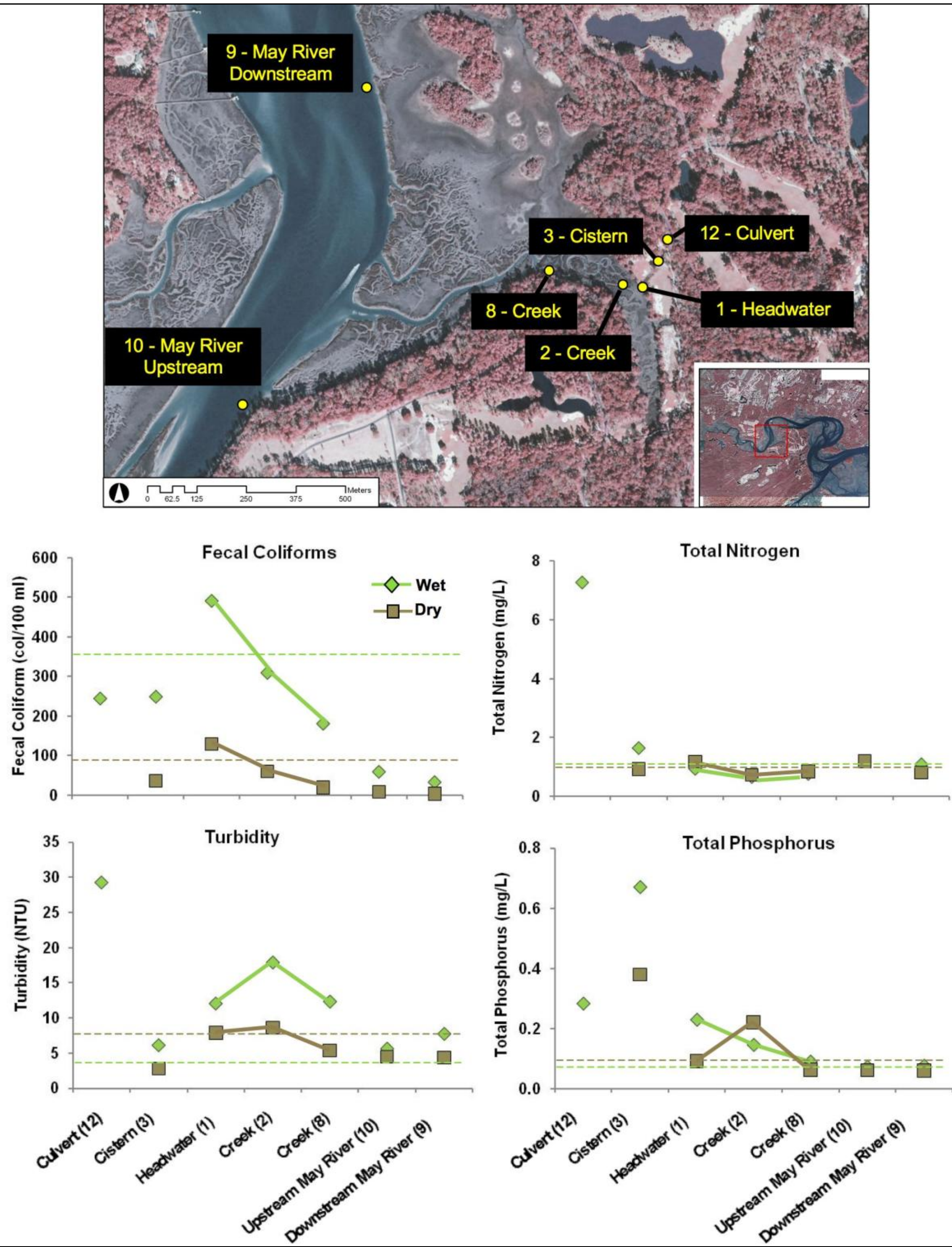


Figure 14. Average fecal coliform levels, total nitrogen, total phosphorus and turbidity during routine bimonthly ("dry") and rain event ("wet") sampling in the Palmetto Bluff Golf Course culvert (12) and cistern (3), Palmetto Bluff Creek headwaters (1), Palmetto Bluff Creek (2 and 8) and upstream (10) and downstream (9) of the confluence of Palmetto Bluff Creek with the May River. For reference, horizontal dashed lines show averages for Palmetto Bluff Phase II undeveloped drainages during dry (brown) and wet (green) events.

2007). Although high, fecal coliform levels were generally within the range typical of other Palmetto Bluff drainages, particularly in undeveloped areas. Because golf courses include a patchwork of forest fragments, they often support populations of various wildlife species (Green and Marshall, 1987; Tanner and Gange, 2005), the likely source of fecal coliform bacteria in this system. Significantly elevated turbidities in the creek itself also suggest that some resuspension of sediment-bound fecal coliform bacteria may have occurred during rain events and, to a much lesser extent, even during dry events. Nitrogen and phosphorus are commonly applied jointly as part of a turfgrass management routine, but of these two nutrients, only phosphorus was elevated above typical background levels and increased following rain events. King *et al*. (2007) found a similar pattern in a study of a municipal golf course in Texas. They suggested that because turfgrass utilizes nitrogen very efficiently, substantial runoff of this nutrient would not be expected, except during colder periods when grasses may be dormant. Further, they indicate that phosphorus is often applied well in excess of turfgrass requirements. This residual phosphorus is readily mobilized during rain events resulting in significant runoff of this nutrient into adjoining water bodies (Sims *et al*., 1998; Stamm *et al*., 1998; King *et al*., 2007). Whether the phosphorus in this system is in an organic or inorganic form can not be determined from available data, but the unusually high values in both the cistern and the creek itself strongly suggest the golf course is a source of phosphorus to this system. More careful management of the phosphorus content in applied fertilizer could help to alleviate this problem.

Bluffton Drainages Versus Palmetto Bluff Drainages:

During wet/rain events the drainages associated with Bluffton had significantly elevated fecal coliform levels, nutrient concentrations and turbidities when compared to the developed and undeveloped drainages associated with Palmetto Bluff. Of the four data sets collected for headwater drainages, the drainages associated with the Town of Bluffton typically had the highest levels for the parameters measured. Fecal coliform levels were significantly higher in the Bluffton drainages than in any of the drainages types (developed, impoundment/pond or undeveloped) sampled in Palmetto Bluff (Table 15; Figure 15; Appendix B-14). Fecal coliform levels were particularly high in the most upstream drainages, Stoney Creek and Rose Dhu (Figure 16), reflecting the general pattern of increasing fecal coliform levels upstream within the May River itself (see Question 1). Total nitrogen in the Bluffton drainages was significantly higher than in the Palmetto Bluff developed drainages,

Table 15. Results of analyses examining differences in water quality measures among the Bluffton Rain Event and the Phase Drainages (Phase I-Developed, Phase I-Impoundment, Phase II-Undeveloped) data sets. Upper portion of table shows results of nested ANOVA comparing the four data sets; lower portion of table shows results of t-test comparisons between the Bluffton Rain Event data set and each of the three Phase Drainages data sets. For simplicity, only p-values are shown here; full results are shown in Appendix B-10. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Source	**Fecal Coliform**	**Total Nitrogen**	**Total Phosphorus**	**Turbidity**
Data set	***< 0.001***	***< 0.001***	***< 0.001***	***< 0.001***
Station (Data set)	***< 0.001***	***< 0.001***	***< 0.001***	***< 0.001***
Bluffton Rain Event vs.	**Fecal Coliform**	**Total Nitrogen**	**Total Phosphorus**	**Turbidity**
Phase I-Developed	***0.001***	***0.024***	***0.005***	***0.001***
Phase I-Impoundment	***< 0.001***	***< 0.001***	0.557	0.342
Phase II-Undeveloped	***< 0.001***	0.227	***< 0.001***	***< 0.001***

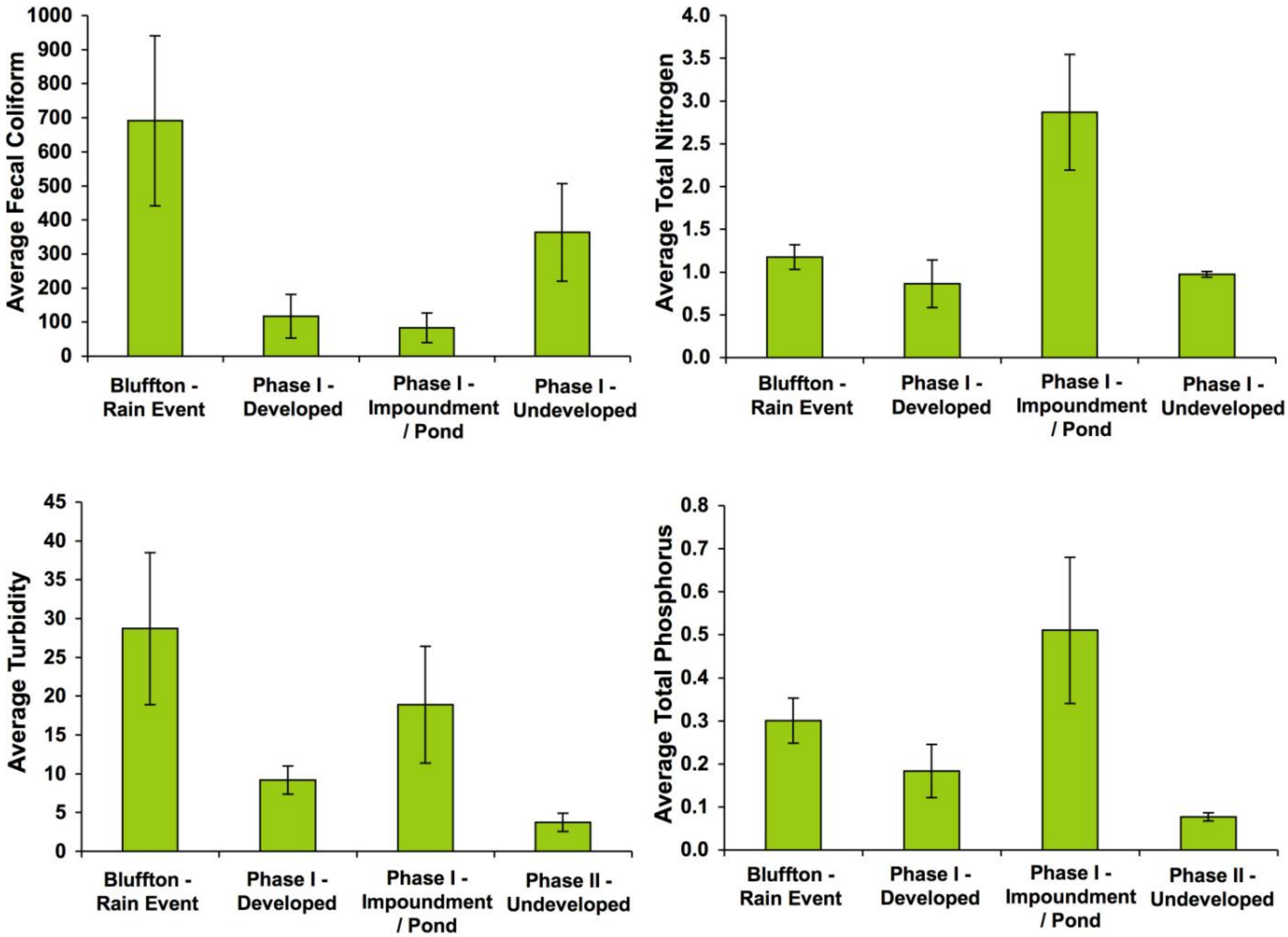


Figure 15. Comparison of average (+/-SE) fecal coliform, turbidity, total nitrogen and total phosphorus levels in the Bluffton Rain Event data set and subsets of the Palmetto Bluff Phase Drainages dataset. Averages shown here are averages of the individual station averages shown in Figure 16.

lower than impoundment drainages and similar to undeveloped drainages, while total phosphorus was significantly higher than in the Palmetto Bluff developed and undeveloped drainages and similar to impoundment drainages (Table 15; Figure 15). Phosphorus concentrations in Stoney Creek, Rose Dhu and Verdier Cove were 2-3 times greater than the undeveloped Palmetto Bluff drainages (Figure 16) and much greater than the threshold for "poor" condition used by the South Carolina Estuarine and Coastal Assessment Program (Bergquist *et al*. 2009).

The high fecal coliform levels, phosphorus concentrations and turbidities in drainages associated with Bluffton may reflect a combination of land cover/land use and flushing rate in the different drainage watersheds. The Bluffton drainages generally are associated with more heavily developed portions of subwatersheds than are the Palmetto Bluff drainages (Table 7). Rose Dhu drains a subwatershed area north of the May River that is 20% impervious, and Bluffton Village and Verdier Cove drain a subwatershed area that is 31% impervious. By comparison, the greatest impervious cover level for a subwatershed associated with Palmetto Bluff south of the river is 12%. Holland *et al.*

(2004) proposed that watershed impervious cover levels greater than 10-20% often result in impaired physical and chemical environmental conditions while impervious cover levels greater than 20-30% result in impaired biological resources. The Rose Dhu, Verdier Cove and Bluffton Village drainages exceed at least one of these criteria and should be monitored carefully to determine the best course of action for reversing or preventing further degradation. Stoney Creek, located in a heavily forested subwatershed at the May River headwaters, generally defies this pattern. Part of the pattern seen among these drainages may also be related to hydrology. Those drainages located farthest up the May River had the highest fecal coliform and phosphorus levels perhaps reflecting that these systems are less tidally flushed than those farther down the river. Stoney Creek had the highest fecal coliform levels of all the drainages sampled, and its heavily forested subwatershed suggests these levels come from a wildlife source and are intensified by a long and sinuous creek system that does not flush well. A caveat should be noted here: comparisons between data from the Bluffton and Palmetto Bluff drainages should be interpreted carefully. These two data sets were collected by different contractors, thus some of the differences detected here could reflect differences in the methodologies employed by contractors (discussed further in Question 3).

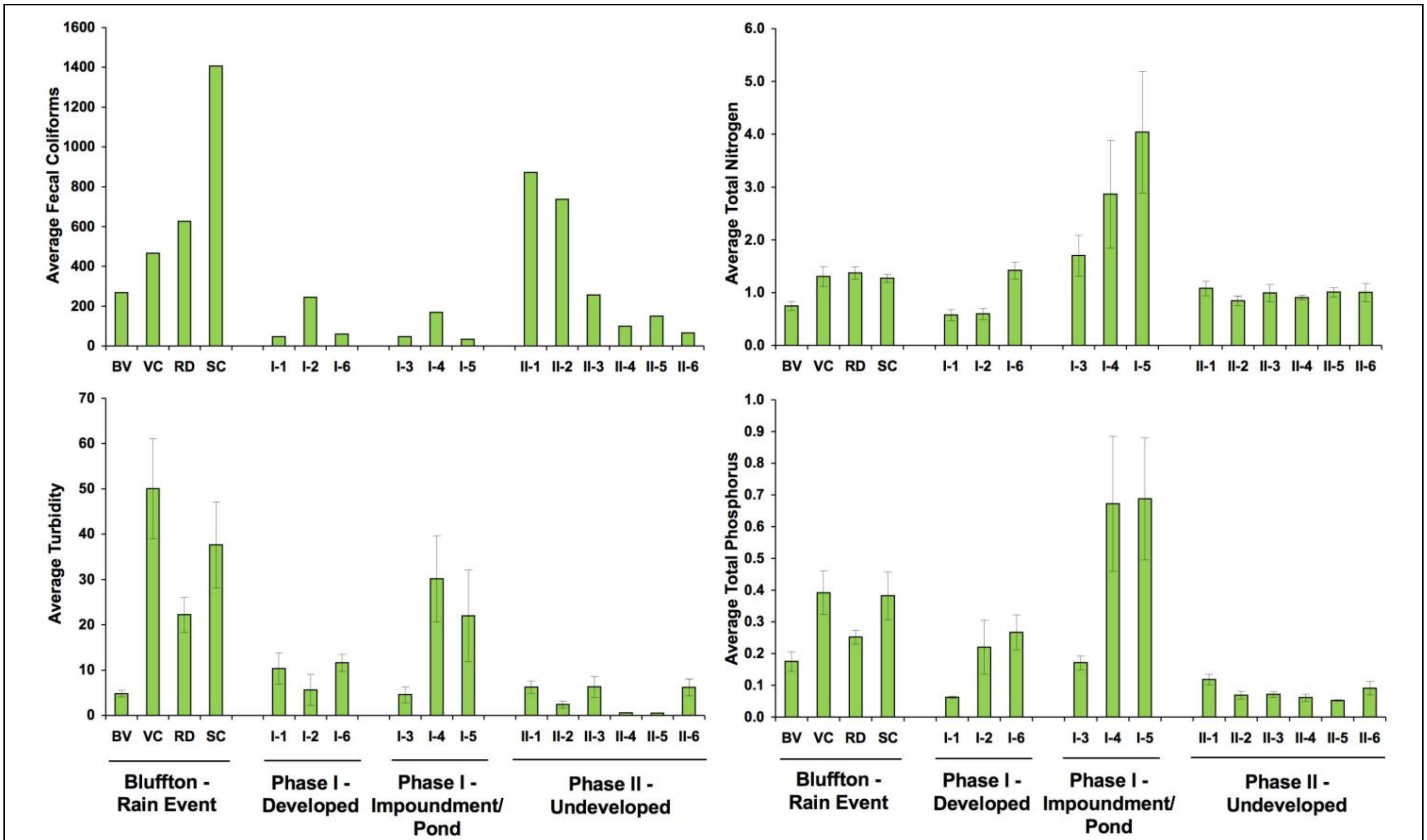


Figure 16. Average (+/-SE) fecal coliform levels, total nitrogen, total phosphorus and turbidity during rain events in individual drainages associated with Bluffton Village (BV), Verdier Cove (VC), Rose Dhu (RD), and Stoney Creek (SC) on the north side of the May River. For reference, the data are plotted alongside the Phase Drainages data collected around Palmetto Bluff.

Question III: What monitoring efforts will be most valuable and feasible to continue into the future.

Collectively the data sets assembled by the Town of Bluffton and the Palmetto Bluff Development, combined with the data collected by SCDHEC and SCDNR, provide a robust level of information about the condition of the May River. The numerous May River data sets enabled a series of informative analyses addressing questions about short- and long-term trends in water quality and about potential effluent sources of bacterial and nutrient pollution to the May River system. Our review and analysis of these data sets also provide an opportunity to compare the information obtained through each of the efforts and make recommendations on modifying and streamlining sampling efforts to maximize the utility of future data collection efforts.

Monitoring Within the Main Stem of the May River:

Monitoring within the main stem of the May River, and not just in creeks and drainages, should be continued. Monitoring within the May River main stem is critical because it is 1) the location of the primary resources of concern, and 2) the water body upon which state management decisions (shellfish and recreation closures, ORW designations, etc.) are based. Monitoring of headwater creeks (drainages) provides a useful early warning system for changes occurring within local subwatersheds, especially in the headwater areas, but as shown with the Golf Course data set, unusually high values for a parameter at the headwaters may not translate to high levels farther down the creek or in the main stem of the May River. We recommend that main stem monitoring be continued and expanded to complement existing state monitoring data and to link water quality in headwater creeks to that in the May River more directly (details below).

Continuous Water Quality Data Sondes:

Data sondes recording continuous water quality data have provided a detailed measure of physical environmental variability over a one year period in the May River. Substantial effort and cost have been dedicated to obtaining basic water quality data in the main stem of the May River using water quality data sondes. These data sondes have provided near-continuous measures of temperature, salinity, pH, dissolved oxygen, turbidity and chlorophyll *a* at three locations for the majority of one full year. The continuous nature of the data is particularly useful in several respects. First, it allows the detection of short-lived and erratic changes in water quality that may not be detected with non-continuous data collection techniques. For example, short periods of hypoxia to near-anoxia were detected by the data sonde deployed at the mouth of Rose Dhu Creek. These events occurred coincident with low tide during spring and summer and lasted only one to two hours (Figure 17). Single measurements at specific times may not have documented this pattern. Second, these data will likely prove valuable for specific modeling efforts involving freshwater inflow and tidal flushing and for describing intra-annual variability in these water quality parameters. Because overall trends and patterns in these data have been fully detailed elsewhere (BP Barber, 2008), they will not be expanded upon further here. The data set is currently too short to begin examining temporal trends in the May River and, because it is not collected consistent with SCDHEC methodology, it cannot be used to determine contravention of state water quality standards.

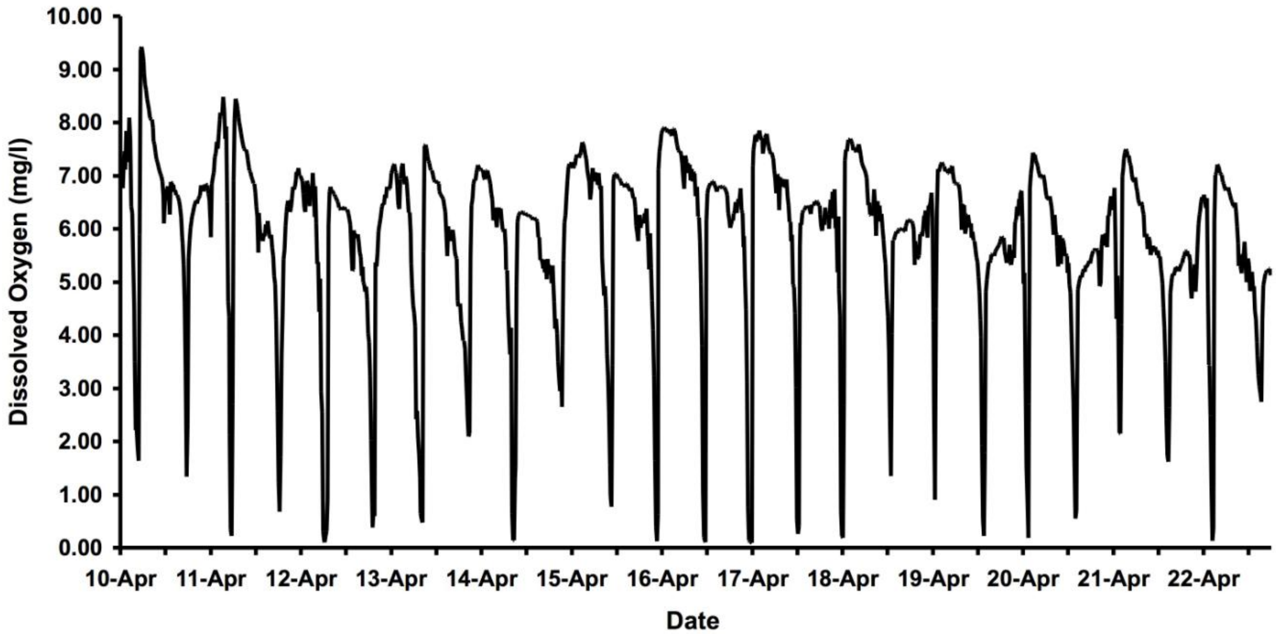


Figure 17. Dissolved oxygen levels recorded by a continuous data sonde deployed at the mouth of Rose Dhu Creek over two weeks in April 2008.

Subsets of the continuous water quality data provide an accurate estimate of monthly averages and of monthly variability in the data set as a whole. Maintenance of continuous water quality data sondes is time-consuming and expensive, especially in heavily biofouling estuarine and coastal environments. These costs could be significantly reduced if shorter, discontinuous sonde deployments are capable of describing the overall trends and variability in the May River system. In order to examine this possibility, the data sonde records were divided into three data subsets (first five days of each month, middle five days of each months, and every other week) and the average, minimum and maximum values for those subsets were compared to the full data set. The data subsets very closely reflected the monthly average trend in the full data set (Figures 17 and 18; Appendix A-7). The data subsets also captured much of the variability in the full data set, with the subsets having very similar minimum and maximum values on a month-to-month basis (Figure 18; Appendix A-7). The "First 5 Days" data subset tended to be least reflective of conditions during each month (Figure 19), while the other two subsets described the full data set similarly. Because the middle 5 days ("11-15 Days") would require less time and funding to acquire than "Every Other Week", a single deployment of five days at mid-month is recommended as the best data subset option.

Analyses of subsets of the continuous data show that this effort could be streamlined IF there is a desire and need to continue collecting data on these parameters in this manner. The continuous data sondes provided information on intra-annual patterns and short-term variability in basic water quality parameters as well as parameters of concern in specific locations (such as dissolved oxygen at the mouth of Rose Dhu Creek). While actions may be taken to address some of the water quality concerns detected by these sondes, the value of continued collection of these data for future management decisions is not clear. Because of the high cost of collecting and handling this kind of data, the goals

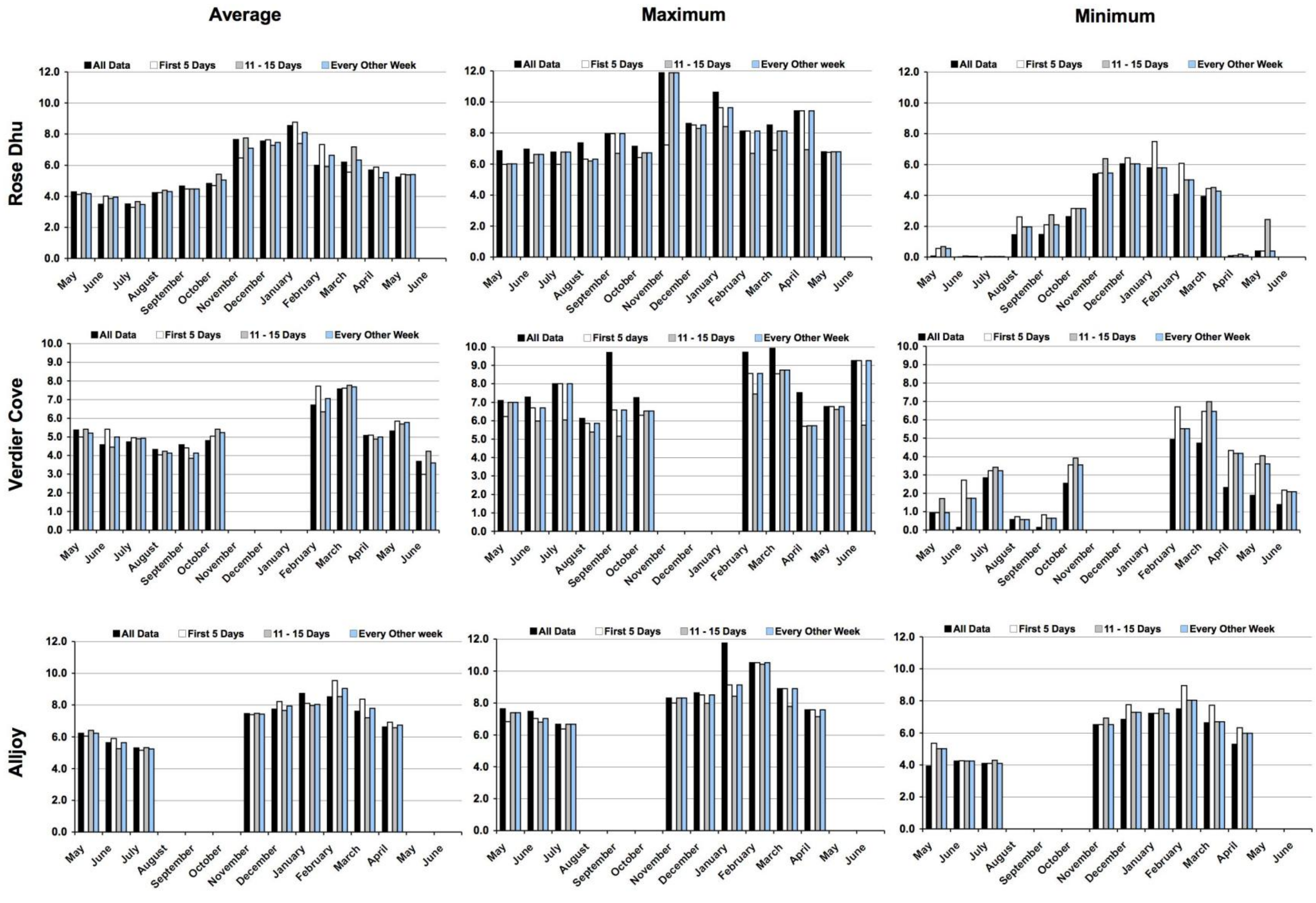


Figure 18. Monthly average, maximum and minimum dissolved oxygen concentrations (mg/l) determined from the continuous data sonde full data set and three data subsets: the first five days of each month ("First 5 Days"), the middle five days of each month ("11-15 Days"), and the first and third week of each month (Every Other Week) for Rose Dhu, Verdier Cove and Alljoy.

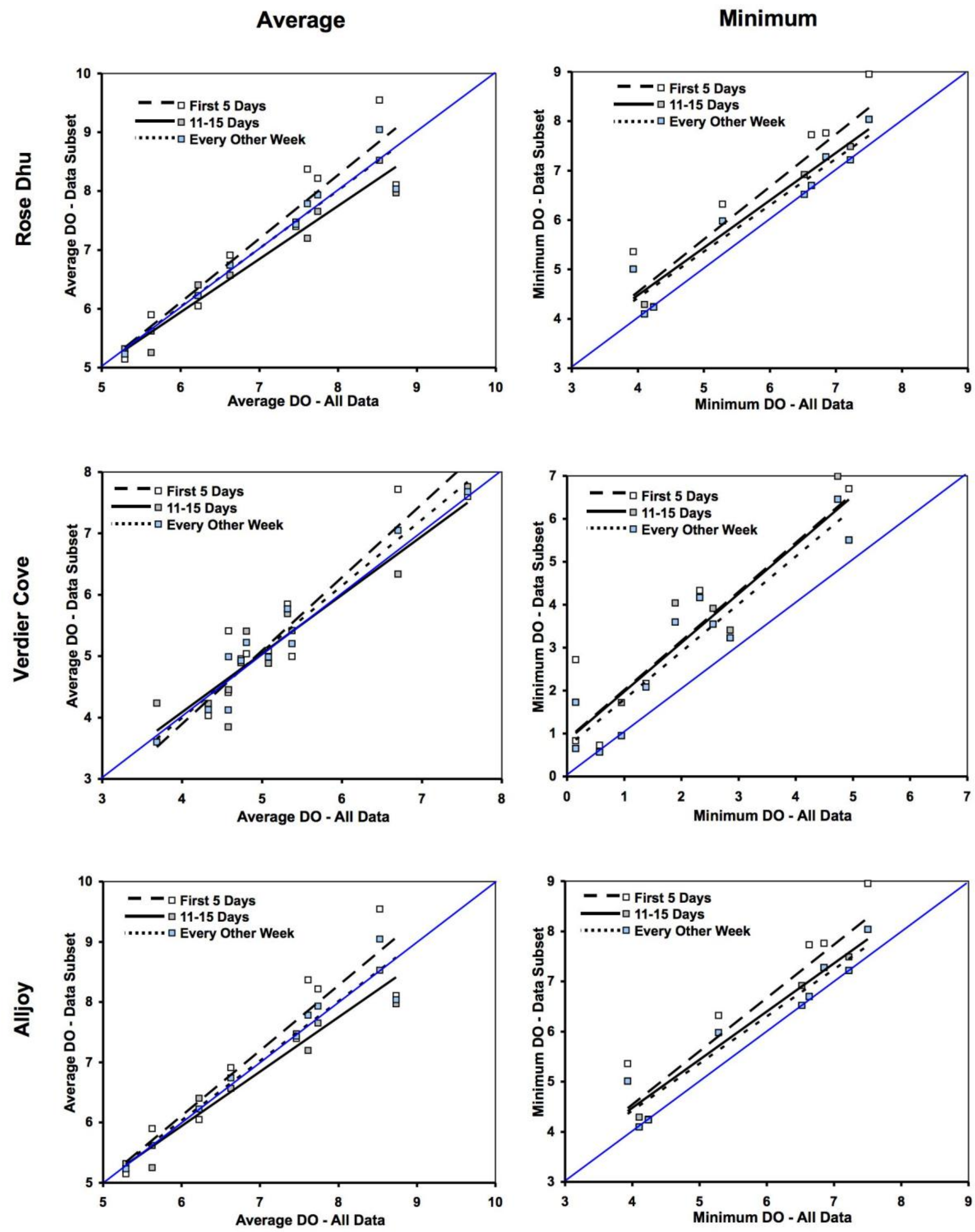


Figure 19. Relationships between monthly average and minimum dissolved oxygen concentration in each of three data subsets (the first five days of each month ("First 5 Days"), the middle five days of each month ("11-15 Days"), and the first and third week of each month (Every Other Week)) and the full data set at Rose Dhu, Verdier Cove, and Alljoy.

of continuing this effort must be explicitly stated and well focused. If it is determined that some form of continuous data would be valuable to the managers and stakeholders of the May River, we recommend consideration of several alternative strategies for reducing effort and cost:

- Reduce the number of monitoring sites and/or relocate the sites consistent with the specific question/issue that the data would address.
- Reduce deployment times to a 5-day period during the middle of each month.

If it is determined that additional continuous water quality data is not needed going forward, we recommend discontinuing collection of continuous water quality data and re-allocating effort and funds to implementation of a monitoring program (discussed in more detail below) that:

- Includes other water quality parameters that are of direct concern (fecal coliform bacteria, nutrients, turbidity, etc.)
- Is consistent with SCDHEC methodology

Main Stem:

The Palmetto Bluff Development's "Main Stem" data set should be continued and expanded. The Palmetto Bluff Development's Main Stem data set provided data on fecal coliform levels, total nitrogen, total phosphorus, dissolved oxygen, pH and turbidity within the upper, middle and lower sections of the May River's main stem. For all of these parameters except fecal coliform levels, the Main Stem data set was the only source of data in the middle and upper sections and the upper portion of the lower section of the May River. The SCDHEC shellfish monitoring program ("Shellfish" data set) provided the best and most spatially extensive data on fecal coliform levels in the lower and middle sections of the May River, but it lacked data in the upper section and did not provide data on any other parameters. The SCDHEC Ambient station included data on a wide range of water quality parameters, but only at a single location in the lower portion of the lower section of the May River. Restructuring of monitoring activities within the May River main stem should capitalize on existing state data by monitoring locations and/or parameters not included in those existing monitoring programs. We recommend the following changes:

- Repositioning the Main Stem stations to better represent the length of the May River: move M1 upstream approximately 600m and rename M-5, move M2 upstream adjacent to the oyster canning plant and rename M6, move M3 downstream to a location intermediate between Rose Dhu and Palmetto Bluff creeks and rename M-8 add a new station mid-way between M6 and M8, and discontinue M4 as a true "Main Stem" station if headwater and creek sampling recommended later is adopted. Station renaming is necessary to prevent future users from assuming the data were collected continuously in a single location.
- Focusing sampling on four core measures of water quality, fecal coliform levels, total nitrogen, total phosphorus, and turbidity, and point measurement of basic water quality parameters (temperature, salinity, dissolved oxygen, pH).
- Adopt a sampling schedule, field collection methodology and sample processing procedures consistent with those used by SCDHEC.

Volunteer Monitoring Network:

The Volunteer Monitoring Network succeeded in collecting good data sets for four creek systems, assembling a group of reliable and willing volunteers and piloting potential methodology. The Volunteer Monitoring Network collected basic water quality data (various permutations of temperature, salinity, dissolved oxygen and water clarity) approximately weekly from four locations. When two conservative measures (salinity and temperature) collected by the Volunteer network were compared to similar data collected over the same time frame by a continuous data sonde deployed in the same creek system (Rose Dhu), it proved very consistent and showed the same basic underlying temporal trend (Figure 20). The volunteers represent a valuable resource that should be encouraged to continue, but their efforts should be focused on collecting data that will be of greater value in the decision-making process.

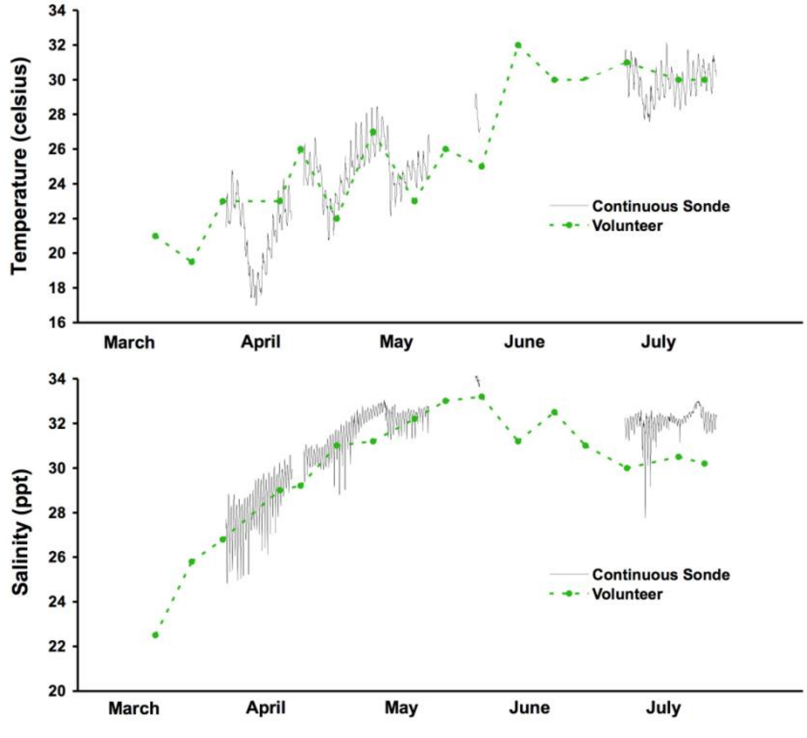


Figure 20. Values for temperature and salinity compared between data collected by the Volunteer Monitoring network and by a continuous data sonde in Rose Dhu Creek between March and July 2008.

If a desire exists to continue the Volunteer Monitoring Network, their efforts should be re-directed to assist with other water quality monitoring programs where appropriate. Instead of only collecting basic water quality data, volunteers also could assist with the collection of samples for determination of fecal coliform levels, nutrient concentrations, and turbidity. As with many other volunteer-driven programs, volunteers could each collect a modest number of samples and deliver those samples to a centralized location or to qualified lab for processing. This approach could prove advantageous in several ways. First it is likely to improve volunteer morale and buy-in by involving them in monitoring efforts with relevance to the management of the May River. Second, sample timing could be improved as numerous volunteers could be simultaneously sampling multiple locations reducing the chances of different areas being sampled at different tidal stages, times of day, etc. Third, it is likely to reduce per-site monitoring cost by utilizing volunteers for field collections. For this to be successful, however, volunteers would need to be carefully trained in proper collection and handling techniques, consistent in their approach and timing, and able to access all necessary sampling locations. Further, this effort would likely require a semi-dedicated staff person to coordinate these activities and review the data at frequent intervals to ensure that the monitoring goals are being met.

<u>Monitoring of Upland Drainages in the May River:</u>

Phase Drainages:

The Phase I data provided useful information on potential inputs to the May River from developed (or developing) areas of Palmetto Bluff and should be continued under a somewhat modified design. The Phase I data set allowed the comparison of runoff from upland and impoundment /pond-dominated subwatersheds under the current level and age of development. Continuing to sample these areas would allow the Palmetto Bluff Development to determine whether the water quality in drainage runoff changes as development and the age of the developed areas increases. As with the analyses performed here, this would also allow the comparison of runoff from the very different kinds of development occurring on the two sides of the May River. Sampling of these drainages should be continued following the relocation of some stations to improve comparability across data sets (discussed below).

The Phase II data currently provides the best available information on the "natural" levels of inputs from undeveloped subwatersheds of the May River and should be continued in the short-term at a reduced number of stations. The Palmetto Bluff Development practiced good foresight in collecting the Phase II drainage data set. All of the other data sets available for subwatershed headwaters/drainages along the May River were associated with some form of a human altered landscape, whether developed or impounded. The Phase II drainage data set provided the most natural background water quality levels with which to compare these other drainages, and therefore represents a valuable source of information. Currently, six drainages are sampled as part of this data set, but this could be modified to streamline effort and reduce cost. In the short-term, the number of stations could be reduced to three, but in the long-term (assuming monitoring continues), as development proceeds in Phase II, new "natural" or undeveloped drainages may need to be established (discussed below).

Although very useful in its current form, the Phase Drainages data set had several methodological problems that should be remedied immediately. Several problems became apparent when examining the Phase Drainages data set. First, Phase I and Phase II data were collected on different days. While this likely represents a limitation on sample holding and/or processing time, it introduces additional daily variability into the data set, and reduces the chances of detecting patterns in the data. This is particularly problematic when sampling following rain events, because one day makes a substantial difference in the runoff hydrograph and associated material inputs from a watershed. Second, sample processing and data reporting should be improved and more consistent. Upper and lower detection limits for various measures were not clear and inconsistent amongst samples. Other times, lab processing procedures appeared to have changed, as was the case with a sudden increase in dissolved inorganic phosphorus following the hiring of a new lab manager by the contract lab. For some parameters, the data were incorrectly recorded or determined. Dissolved oxygen appeared to be recorded in two different units of measurement, concentration (mg/l) and percent air saturation (%), even on the same day. pH values were sometimes missing even though salinity was measured, and pH varied unrealistically between values of 3.8 and 9.6. These issues should be corrected in future monitoring efforts.

The Phase Drainages sampling program would benefit from reducing and restructuring sampling stations and improving sample and data collection and processing. The Phase Drainages data set represented a valuable resource and we specifically recommend the following changes to improve its efficacy:

- Reduce the number of Phase II stations to three (II-2, II-4, and II-6). If monitoring continues as Phase II is developed, identify and begin sampling new "undeveloped" drainages.
- Relocate station I-5, associated with the large impoundment at the May River headwaters, to a different currently unmonitored pond drainage within Palmetto Bluff. Station I-4 provides the best comparable drainage information for that impoundment, making I-5 redundant at best.
- Collect samples/data from stations to be compared on one day under similar conditions. If this is not possible, the stations sampled on a given day should represent the full range of stations by "type" (i.e., developed or undeveloped).
- Improve the quality assurance/quality control of data received from contractors, including review of data for anomalous values, consistency of methodology and standardization of detection limits.

Palmetto Bluff Golf Course:

The Palmetto Bluff Development study provided good information on levels of fecal coliform and nutrients in the golf course cistern and adjacent Palmetto Bluff Creek that leads to the May River. Analysis of the Golf Course data set showed that concentrations of most pollutants were near or below levels found in the undeveloped Palmetto Bluff drainages. Pollutant levels were also near or well below levels measured in the developed Palmetto Bluff and Bluffton drainages, suggesting that effort may be better spent monitoring elsewhere. We see no reason to continue this study, but the headwaters and mouth of Palmetto Bluff Creek should be monitored for parameters of concern (fecal coliform bacteria, TN, TP, and turbidity) as part of a broader monitoring program (see recommendation below).

Bluffton Rain Event Data:

The Bluffton Rain Event data set provided useful information on potential inputs to the May River from the Town of Bluffton but several limitations need to be addressed in future efforts. The Bluffton Rain Event data set provided values for several important water quality parameters in creek headwaters on the north side of the May River. As a stand-alone data set, however, it was difficult to put into context for two reasons: 1) there was no means to confirm that the values were typical or atypical of other headwaters in the May River system and 2) no data were available to determine whether elevated levels of a pollutant in the creek headwaters translated to impacts within the larger water bodies of the May River. The first issue was partially addressed here by comparing the Bluffton data to similar data collected by the Palmetto Bluff Development on the south side of the river. When those data sets were compared, drainages associated with the Town of Bluffton were found to have significantly elevated levels of most pollutants relative to drainages sampled at Palmetto Bluff. Unfortunately, this comparison is tenuous because the data sets were collected and processed by different contractors with potentially different methodologies. The second issue could not be addressed here, because no data were available near the confluence of these small drainages with the May River.

The analysis of the Golf Course data set illustrates that although pollutant levels are high in a headwater system, those levels do not necessarily result in higher levels within the same creek farther downstream or in May River. This is an important point since management/regulatory decisions are made based on water quality within the main stem of the May River rather than in headwater creeks. The headwater creeks still provide a useful sentinel for potential changes in pollutant inputs, but their link to management decisions must be better established. The most straightforward means for accomplishing this is to also monitor the confluence of the same drainages with the May River.

The Bluffton Rain Event sampling program should be continued and modestly modified and expanded as part of a broader and coordinated monitoring program. The Bluffton Rain Event data set represents the best source of information on the potential inputs of pollutants to the May River system. In order to address the limitations outlined above, we recommend the following:

- Continue monitoring the headwaters of Stoney Creek, Rose Dhu, Verdier Cove, and Heyward Cove at Bluffton Village for critical parameters (fecal coliform bacteria, TN, TP, turbidity) and basic water quality parameters.
- Sample at the mouth of Stoney Creek, Rose Dhu, Palmetto Bluff Creek, Verdier Cove, and Heyward Cove for critical parameters (fecal coliform bacteria, TN, TP, turbidity) and basic water quality parameters.
- Coordinate with the Palmetto Bluff Development to obtain the same data at the headwaters and mouth of Palmetto Bluff Creek.
- Coordinate with the Palmetto Bluff Development to obtain the same data for undeveloped drainages or establish sampling at undeveloped drainages independent of Palmetto Bluff.
- Collect associated headwater and creek mouth samples concurrently, only on ebbing tides and preferably within 3 hours of low tide.
- Sample creek mouths routinely (ideally monthly) in order to develop baseline input data from the individual creeks to the May River and to detect changes in these inputs through time. Sample those headwaters with water present during dry events (such as Palmetto Bluff Creek) at the same frequency and time as creek month samples.
- Sample headwaters and creek mouths following rain events in order to determine changes in pollutant levels entering the May during rain events, the relationships between headwater and creek mouth pollutant levels, and the amount of rainfall needed to produce elevated pollutant levels entering the river.
- Ensure collection and processing are performed by the same lab/contractor/agency if possible. Regardless of whether one or multiple labs are used, ensure that methodology and detection limits are consistent with SCDHEC protocols.

The recommended changes are significant, but could be accomplished using one or a combination of three approaches:

1) Hire a consultant to collect and process samples.

2) Fund a state agency or academic research laboratory to collect samples and either process those samples or deliver them to a qualified lab for processing.

3) Utilize volunteers to collect samples and deliver the samples to a qualified lab for processing. This approach would require the volunteers be carefully trained in proper collection and handling techniques, be consistent in their approach and timing, and be able to get to all necessary sampling locations.

Summary of Recommendations:

As part of a longer-term monitoring strategy for the May River we recommend a more coordinated effort that builds on existing programs and includes monitoring in the main stem of the May River and in targeted creek headwater systems. The Town of Bluffton and the Palmetto Bluff Development developed independent monitoring/research programs that proved most valuable when analyzed together and in conjunction with existing state water quality monitoring programs. The value of future monitoring efforts and the breadth of issues addressed could be greatly improved through better coordination amongst these entities. We recommend the following components or changes useful for a coordinated monitoring effort within the May River system:

- Discontinue the existing continuous data sonde program and collect this type of data only as needed as part of targeted studies at specific locations. If the desire remains to collect basic water quality data (temperature, salinity, pH, dissolved oxygen) for the May River in general, it should be collected consistent with SCDHEC methodology (e.g. currently point measurements once a month).
- Reposition the Main Stem stations to better represent the length of the May River: move M1 upstream approximately 600m and rename M5, move M2 upstream and adjacent to the oyster canning plant and rename M6, move M3 downstream to a location intermediate between Rose Dhu and Palmetto Bluff creeks and rename M8. Add a station, M7, approximately mid-way between M6 and M8. Discontinue the existing M4 as a true "Main Stem" station.
- Monitor critical parameters (fecal coliform bacteria, TN, TP, turbidity) and basic water quality parameters in the headwaters/drainages of developed subwatersheds in both Palmetto Bluff and Bluffton: Stoney Creek, Rose Dhu, Verdier Cove, Heyward Cove at Bluffton Village, Palmetto Bluff Creek (stations 1), and Palmetto Bluff Phase I stations 1, 2, and 6. Monitor the same parameters in drainages from three impoundment/pond systems, including Phase I stations 3 and 4 and one additional pond system (to be determined).
- Monitor drainages from at least three undeveloped drainages. In the short-term, this could be accomplished by continuing monitoring at three of the six Palmetto Bluff Phase II drainages (stations 2, 4, and 6 for a spatially representative subset facing a reduced development pressure). In the longer-term, a new set of undeveloped drainages may need to be chosen as development proceeds in Phase II.
- Monitor critical parameters (fecal coliform bacteria, TN, TP, turbidity) and basic water quality parameters at the mouth of Stoney Creek (could be accomplished by relocation of existing Main Stem station M4), Rose Dhu, Palmetto Bluff Creek, Verdier Cove, and Heyward Cove.
- Discontinue monitoring of most Palmetto Bluff Golf Course stations with the exception of station 1 at the creek headwater and add a station at the mouth of the creek.
- Sampling of Main Stem stations M5-M8 should be performed monthly and concurrently with SCDHEC shellfish sampling in order to improve the comparability of these data sets.
- Sampling of headwater and associated creek mouth stations should be performed following rain events with careful attention paid to collecting samples o ebbing tides and from the two habitats close in time to ensure comparability.
- Creek mouths and headwaters (when appropriate) should also be sampled on a routine basis (preferably monthly).

Figure 21 summarizes changes in existing monitoring programs and recommended sample locations.

Figure 21. Summary of recommended changes to the monitoring station array in the May River. Outline of station symbol indicates recommended status: white outline—continue, black outline—delete, pink outline—add/new.

Improve quality assurance/quality control and consistency of sample and data collection and processing among Bluffton, Palmetto Bluff and state monitoring programs. Both quality assurance/quality control and methodological consistency introduced significant uncertainty into the analyses performed here. Quality assurance/quality control issues were apparent in practically all datasets and included inconsistent detection limits, incorrectly recorded data, and missing or unrealistic data. Inconsistency or unknown consistency was also a problem. This included changing contractors/laboratories, different contractors/laboratories used for different data sets, and changing methodologies through time.

- Request quality assurance/quality control documentation from contractors and laboratories and ensure these protocols are consistent with state and/or federal guidelines.
- Routinely review incoming data for inaccurate or confusing data, and request third-party review when necessary.
- When appropriate, adopt SCDHEC protocols for sample collection including timing, sample size and number, collection and handling methodology.
- Ensure processing protocols are consistent across laboratories. When more than one laboratory is involved in processing samples, identical samples should be sent to each lab in order to identify inconsistencies and to provide for inter-laboratory calibration of data.
- Employ inter-calibration methods when changes in methodology occur. This can be accomplished by performing analyses using both methods on the same samples.

Structure future monitoring or research around clear and focused questions. The value of data can be greatly improved and associated costs often reduced by collecting only the necessary data in the appropriate locations at the best times. This requires a clear identification of the goal of a project. For example, managers and the local community may decide that the most pressing issue is the closure of shellfish beds due to bacterial contamination. This argues for allocating resources to quantifying and tracking sources of fecal coliform bacteria, rather than determining nutrient levels. Once a set of target systems potentially acting as sources have been identified, effort should then be placed on those systems (such as the current focus on Rose Dhu) rather than at locations distant (in the lower May River, for example). Wide-ranging collection of data without a clear application of that data often results in patterns that are difficult to interpret and the important questions are left unanswered. This basically argues for a structured application of the scientific method: 1) identify a question, 2) state a testable hypothesis (best guess of outcome), and 3) design a study to directly address that hypothesis. For example, the recommended station array above is meant to more directly address Questions I and II in this report.

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APPENDIX A: Data Summaries

Appendix A.1. Geometric means of fecal coliform levels for the SCDHEC Shellfish using all data available during the year (Year) and only during the June, July and August (Summer). Yearly averages exceeding 14 colonies/ml highlighted in red. Summer averages exceeding SCECAP averages for effluent free waters of similar size shown in bold italics.

	19-19		19-24		19-16		19-18	
Year	**Yearly**	**Summer**	**Yearly**	**Summer**	**Yearly**	**Summer**	**Yearly**	**Summer**
1994	7.7	13.3			6.0	3.1	6.5	4.6
1995	10.7	***9.4***			6.6	***4.7***	4.2	5.8
1996	4.9	6.8			7.8	***6.9***	3.2	2.7
1997	4.9	3.7			5.0	2.0	6.2	6.4
1998	5.8	3.2	5.8	4.1	9.1	***5.7***	3.9	2.0
1999	4.3	4.9	4.4	4.4	4.4	***8.8***	2.6	2.0
2000	3.3	6.8	3.7	***7.0***	3.0	***5.2***	2.5	2.7
2001	3.1	2.5	3.1	3.1	3.1	1.9	3.2	2.7
2002	3.4	1.9	3.0	2.0	3.3	3.1	4.3	2.7
2003	5.3	8.3	4.9	4.5	3.6	4.1	5.5	6.9
2004	5.3	***9.0***	7.5	5.5	6.5	***7.4***	5.4	***10.0***
2005	3.5	3.6	7.6	***7.2***	4.5	***7.9***	4.1	3.2
2006	7.8	6.6	10.1	***6.9***	7.3	3.8	6.7	5.3
2007	11.6	***113.3***	5.8	***7.2***	3.8	***6.0***	4.3	3.9
2008	30.3	***22.0***	7.7	4.8	5.7	***4.7***	5.8	4.2

	19-25		19-01		19-12		19-17A	
Year	**Yearly**	**Summer**	**Yearly**	**Summer**	**Yearly**	**Summer**	**Yearly**	**Summer**
1994			3.9	***3.9***	4.2	4.0		
1995			3.1	1.9	3.9	1.9		
1996			3.2	***3.4***	5.3	3.4		
1997	5.8		3.6	2.7	3.6	2.0	3.8	
1998	4.4	***6.5***	4.7	2.0	4.6	2.7	3.7	2.7
1999	3.8	***7.6***	2.4	2.0	4.9	5.0	3.7	2.7
2000	2.3	2.7	2.3	2.6	2.9	2.7	3.6	3.1
2001	2.5	2.0	2.6	2.7	2.5	2.0	3.8	5.5
2002	3.9	3.7	3.1	2.0	2.6	1.9	2.5	2.0
2003	3.9	4.8	2.5	2.7	2.5	2.5	2.3	2.7
2004	4.1	***5.6***	3.4	***4.2***	4.1	3.8	3.2	6.2
2005	4.1	3.7	3.3	***3.4***	3.7	3.1	3.3	3.1
2006	4.2	3.8	3.4	2.0	4.2	2.7	3.9	4.1
2007	3.4	3.4	3.5	***7.2***	2.5	2.6	2.7	2.9
2008	3.2	2.0	5.1	***4.3***	4.0	5.2	7.1	3.7

Appendix A-2. Average water quality conditions for the Main Stem stations (M1-M4) and the SCDHEC Ambient station each year using all data available during the year (Year) and only during the June, July and August (Summer). These data sets were compared to SCDHEC water quality criteria and/or to SCECAP thresholds and historical data as appropriate.

Fecal Coliforms (col/100 ml)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	6.8	5.5	17.9	7.2	13.6	17.0	61.8	***27.6***	12.4	18.2	4.5	2.0
M3	5.5	2.8	15.8	***20.0***	1.4	2.0	13.2	4.9	4.5	4.7	3.5	3.0
M2	7.3	4.0	4.9	2.0	3.6	***12.6***	7.7	6.6	4.4	***9.8***	1.6	1.0
M1	17.8	***7.7***	1.2	1.0	2.2	4.9	6.8	***7.1***	3.7	5.5	2.4	1.0
MD-173	2.8	2.5	1.9	1.6	3.4	4.0	2.3	4.7	3.4	2.4	NA	NA

red--yearly average exceeds SCDHEC avg criterion
bold italics--summer avg exceeds avg for SCECAP effluent fre

Total Nitrogen (mg/L)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	0.80	0.66	1.01	***1.42***	0.45	0.45	0.73	***0.93***	0.45	0.27	1.07	***1.33***
M3	0.63	0.48	0.62	***0.94***	0.61	***0.79***	0.44	0.56	0.43	0.60	0.50	0.58
M2	0.56	0.43	0.38	0.39	0.72	***1.00***	0.33	0.40	0.25	0.50	0.71	***0.95***
M1	0.64	***0.61***	0.42	0.58	0.57	***0.76***	0.40	0.53	0.78	***1.02***	0.51	***0.91***
MD-173	0.31	0.43	0.40	***0.53***	0.39	0.38	0.50	***0.58***	0.17	0.09	NA	NA

red/yellow--summer values exceeds SCECAP criteria
bold italics--summer avg exceeds avg for SCECAP effluent fre

Total Phosphorous (mg/L)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	0.087	0.092	0.167	***0.265***	0.076	0.070	0.148	***0.135***	0.093	0.098	0.088	0.096
M3	0.078	0.081	0.058	0.062	0.086	0.098	0.099	0.050	0.085	0.094	0.074	0.086
M2	0.069	***0.089***	0.049	0.071	0.064	0.084	0.077	0.044	0.081	***0.105***	0.055	0.052
M1	0.092	***0.089***	0.056	0.068	0.064	0.079	0.031	0.017	0.078	***0.099***	0.061	0.063
MD-173	0.056	0.065	0.090	***0.193***	0.149	***0.243***	0.101	***0.115***	0.045	0.066	NA	NA

red/yellow--summer values exceeds SCECAP criteria
bold italics--summer avg exceeds avg for SCECAP effluent fre

Appendix A-2 continued. Average water quality conditions for the Main Stem stations (M1-M4) and the SCDHEC Ambient station each year using all data available during the year (Year) and only during the June, July and August (Summer). These data sets were compared to SCDHEC water quality criteria and/or to SCECAP thresholds as appropriate.

Dissolved Oxygen (mg/L)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	5.68	5.55	5.57	4.99	6.19	4.94	7.49	7.00	5.91	5.64	6.00	3.68
M3	6.08	5.33	5.94	5.61	6.06	4.81	7.14	5.98	6.36	5.73	5.82	4.02
M2	6.18	5.50	5.83	5.55	6.53	5.25	7.89	7.45	6.53	6.09	6.36	4.39
M1	5.65	5.30	5.71	5.14	6.42	5.29	7.75	7.15	6.55	6.04	6.55	4.96
MD-173	6.89	4.84	7.17	5.41	8.13	NA	7.67	NA	6.08	***3.76***	NA	NA

red/yellow--summer values exceeds SCECAP criteria
bold italics--summer avg exceeds avg for SCECAP effluent fre

pH

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	7.44	7.47	6.86	***6.53***	7.12	***7.07***	7.19	***6.95***	7.34	7.38	7.47	7.30
M3	7.54	7.52	7.16	***6.90***	7.34	7.23	7.34	***7.02***	7.37	7.40	7.47	7.36
M2	7.61	7.53	7.44	***7.25***	7.57	7.46	7.57	7.32	7.46	7.37	7.48	7.52
M1	7.64	7.52	7.54	7.42	7.59	7.50	7.62	7.38	7.37	***7.13***	7.06	***6.90***
MD-173	7.53	7.48	7.46	***7.31***	7.52	NA	7.55	NA	7.47	7.39	NA	NA

red/yellow--summer values exceeds SCECAP criteria
bold italics--summer avg exceeds avg for SCECAP effluent fre

Total Suspended Solids (mg/L)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	38.3	39.0	85.0	***106.0***	42.8	43.5	37.8	34.5	27.8	32.5	44.3	28.0
M3	28.0	30.5	40.0	28.5	33.5	***48.5***	34.5	21.5	30.5	34.0	21.5	25.0
M2	39.0	***59.5***	40.5	30.5	23.3	29.0	20.8	21.0	35.0	***42.5***	17.6	18.0
M1	54.3	***84.5***	34.0	20.0	30.5	22.5	21.8	19.5	30.0	***40.0***	18.8	18.5
MD-173*	6.6	10.2	11.2	12.7	8.3	6.5	5.9	6.7	6.4	7.6	NA	NA

* = NTU
bold italics--summer avg exceeds avg for SCECAP effluent fre

Appendix A-2 continued. Average water quality conditions for the Main Stem stations (M1-M4) and the SCDHEC Ambient station each year using all data available during the year (Year) and only during the June, July and August (Summer). These data sets were compared to SCDHEC water quality criteria and/or to SCECAP thresholds as appropriate.

Total Organic Carbon (mg/L)

	2002		2003		2004		2005		2006		2007	
Site	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**	**Year**	**Summer**
M4	NA	NA	9.78	4.90	1.63	1.85	2.40	2.75	1.33	0.95	2.30	2.80
M3	NA	NA	2.28	3.10	1.38	1.65	1.55	2.00	1.10	0.80	1.93	2.30
M2	NA	NA	0.88	1.25	0.88	1.20	0.65	1.30	0.93	1.25	1.15	1.30
M1	NA	NA	0.60	1.20	0.93	1.25	0.63	1.25	0.75	0.90	0.68	1.35
MD-173	2.78	2.7	5.33	5.80	6.33	8.90	7.40	9.00	4.83	6.30	NA	NA

Appendix A-3. Average water quality conditions at stations included in the Phase Drainages data set. These data were collected between DATES by the second contractor hired by Palmetto Bluff Development (HSA).

		Total Nitrogen		**Total Phosphorus**		**Fecal Coliform**		**Turbidity**	
Site	**Classification**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
I-1	Developed	0.064	0.062	0.590	0.574	7.6	46.5	4.1	10.3
I-2	Developed	0.162	0.220	1.420	0.598	266.2	245.2	5.4	5.6
I-6	Developed	0.209	0.267	1.156	1.420	7.7	60.2	5.7	11.6
I-3	Impoundment	0.182	0.171	1.742	1.700	15.0	45.9	5.1	4.6
I-4	Impoundment	0.570	0.672	1.728	2.867	152.0	169.6	16.9	30.2
I-5	Impoundment	0.516	0.688	3.382	4.040	19.3	33.4	15.1	22.0
II-1	Undeveloped	0.161	0.119	1.360	1.082	411.4	872.4	11.6	6.2
II-2	Undeveloped	0.094	0.069	1.203	0.847	67.4	736.0	10.2	2.4
II-3	Undeveloped	0.082	0.071	0.970	0.992	23.1	256.1	19.4	6.3
II-4	Undeveloped	0.050	0.061	0.820	0.905	12.4	99.5	0.2	0.6
II-5	Undeveloped	0.050	0.053	0.960	1.010	15.2	150.6	2.2	0.5
II-6	Undeveloped	0.095	0.091	0.490	1.003	14.0	65.8	3.1	6.2

Appendix A-3. Average water quality conditions at stations in the Phase Drainages data set but that were not included in the analysis. These data were collected between DATES by the first contractor hired by Palmetto Bluff Development (T&H).

TnH Station	HSA Station	Fecal Coliform
I-1	I-1	25.7
I-3	I-3	77.3
I-4	I-4	284.7
I-5	I-5	177.9
II-1	II-1	453.6
II-2	II-2	785.5
II-3	II-3	492.6
II-4	II-4	357.0
II-5	II-5	705.9
II-6	II-6	764.8
Station7	7	15.7
TH1-3		58.2
TH1-7		23.8

Appendix A-4. Average water quality conditions at stations included in the Golf Course data set.

	Fecal Coliforms		**Total Nitrogen**		**Total Phosphorus**		**Turbidity**		**Salinity**	
Site	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
12-Culvert		244		7.27		0.28		29.28		0.0
3-Cistern	36	249	0.92	1.64	0.38	0.67	2.82	6.18	1.4	0.6
1-Headwater	129	491	1.18	0.94	0.09	0.23	7.90	12.09	27.3	18.9
2-Creek	60	309	0.73	0.66	0.22	0.15	8.63	17.92	29.3	22.8
8-Creek	20	181	0.85	0.77	0.06	0.09	5.38	12.37	30.7	27.8
10-Upriver	8	59	1.20	1.20	0.06	0.07	4.48	5.68	31.5	30.8
9-Downriver	4	33	0.81	1.09	0.06	0.08	4.38	7.79	31.5	31.0

Appendix A-5. Average water quality conditions at stations included in the Rain Event data set.

Station	Fecal Coliform	TN	Ammonia	TKN	NOx	TP	Turbidity
Bluffton Village	267	0.75	0.14	0.62	0.13	0.18	4.8
Verdier Cove	466	1.31	0.15	1.20	0.11	0.39	50.1
Rose Dhu Creek	625	1.37	0.14	1.22	0.15	0.25	22.2
Stoney Creek	1406	1.27	0.13	1.16	0.11	0.38	37.7

Appendix A-6. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Rose Dhu

Temperature

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	25.7	28.7	30.3	31.5	28.3	24.9	16.5	14.4	11.0	15.0	18.0	22.3	25.0
	First 5 days	26.1	26.2	29.1	29.6	28.4	24.9	19.3	15.8	9.3	12.6	16.1	22.2	24.1
	11 - 15 days	25.6	27.4	31.3	32.2	25.8	24.7	16.4	14.2	13.4	14.9	17.4	24.4	24.5
	Every other week	25.8	27.1	30.7	31.2	27.4	24.8	18.0	14.5	11.3	14.0	17.1	23.2	24.3
Average	All Data	25.5	28.7	30.4	31.4	28.0	24.6	16.7	14.7	11.6	14.9	17.7	22.0	25.2
	First 5 days	26.1	26.2	29.3	29.6	28.3	25.0	19.3	15.4	9.8	13.0	16.0	21.8	24.1
	11 - 15 days	25.5	28.0	31.3	32.3	26.0	24.9	16.5	14.2	13.6	14.8	17.5	24.3	24.7
	Every other week	25.8	27.0	30.3	30.9	27.1	25.0	17.9	14.8	11.6	13.9	16.8	23.0	24.4
Maximum	All Data	29.1	32.4	34.2	34.1	30.8	28.7	21.3	19.0	16.9	19.1	21.0	26.7	29.2
	First 5 days	28.3	28.7	32.2	31.5	30.2	26.4	21.3	17.1	14.1	16.6	18.8	24.8	27.6
	11 - 15 days	27.4	31.0	33.0	33.9	28.6	27.7	18.5	16.0	16.8	16.7	20.2	26.7	27.4
	Every other week	28.3	31.0	33.0	33.9	30.2	27.7	21.3	17.1	16.8	16.7	20.2	26.7	27.6
Minimum	All Data	20.3	23.6	26.6	26.5	24.7	17.6	13.1	11.7	7.1	10.9	12.9	17.0	21.0
	First 5 days	24.4	23.6	26.6	26.5	26.4	24.0	17.4	12.8	7.1	10.9	12.9	17.4	21.0
	11 - 15 days	23.3	26.1	29.7	31.0	24.7	23.1	14.9	12.5	10.3	11.9	15.5	20.7	22.2
	Every other week	23.3	23.6	26.6	26.5	24.7	23.1	14.9	12.5	7.1	10.9	12.9	17.4	21.0
Standard Deviation	All Data	1.6	2.0	1.3	1.3	1.4	2.2	1.6	1.5	2.4	1.7	1.7	2.3	1.5
	First 5 days	0.9	1.4	1.5	1.1	0.8	0.6	1.0	1.1	1.6	1.5	1.7	1.8	1.3
	11 - 15 days	0.9	1.4	0.6	0.7	1.0	1.1	0.9	0.7	2.0	1.1	1.0	1.3	1.2
	Every other week	1.0	1.7	1.5	1.7	1.5	0.9	1.7	1.1	2.6	1.6	1.6	2.0	1.3

Salinity

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	32.0	23.2	26.5	24.3	25.5	23.2	29.2	31.1	24.0	24.8	20.6	29.2	32.3
	First 5 days	32.0	28.4	24.7	21.0	26.0	25.9	27.8	31.3	24.2	22.7	18.4	27.5	31.5
	11 - 15 days	31.8	26.2	25.8	22.4	22.5	21.1	29.0	29.3	25.6	26.3	19.1	30.6	32.4
	Every other week	31.9	27.1	25.3	22.0	23.7	22.0	28.6	31.1	24.9	24.8	18.8	29.1	31.9
Average	All Data	32.1	23.2	26.1	23.3	25.1	22.8	29.3	29.6	23.6	23.9	20.1	29.1	32.2
	First 5 days	31.9	28.4	24.3	20.5	25.5	23.1	27.8	31.3	24.3	22.7	18.5	27.5	31.4
	11 - 15 days	31.8	25.3	25.4	22.2	22.6	21.0	29.1	27.9	25.6	26.3	19.3	30.5	32.3
	Every other week	31.8	27.1	24.8	21.3	24.0	22.1	28.4	29.6	24.9	24.4	18.9	29.0	31.8
Maximum	All Data	33.5	33.7	30.1	29.2	29.2	29.4	32.0	32.4	30.2	29.7	26.9	31.5	34.4
	First 5 days	32.1	33.7	27.3	26.3	29.2	29.4	29.5	32.0	28.9	27.2	25.1	28.9	32.6
	11 - 15 days	32.1	30.2	28.4	26.0	25.6	24.9	30.6	32.4	30.2	29.3	25.5	31.3	33.1
	Every other week	32.1	33.7	28.4	26.3	29.2	29.4	30.6	32.4	30.2	29.3	25.5	31.3	33.1
Minimum	All Data	28.0	11.8	13.7	10.7	18.2	9.4	25.7	17.8	11.0	6.4	6.4	24.8	28.8
	First 5 days	28.0	19.4	13.7	10.7	19.8	9.4	25.7	30.5	19.2	18.8	11.8	24.8	28.8
	11 - 15 days	31.2	17.3	16.6	17.2	19.4	15.8	27.8	17.8	18.0	22.8	13.5	29.4	31.3
	Every other week	28.0	17.3	13.7	10.7	19.4	9.4	25.7	17.8	18.0	18.8	11.8	24.8	28.8
Standard Deviation	All Data	0.6	5.3	2.5	3.8	2.3	4.1	1.3	3.1	3.2	3.7	3.5	1.4	0.7
	First 5 days	0.4	4.4	2.1	3.9	2.2	5.9	0.9	0.3	2.3	2.1	3.1	0.9	0.6
	11 - 15 days	0.2	3.4	2.1	2.0	1.5	2.0	0.5	3.9	2.2	1.4	2.9	0.3	0.4
	Every other week	0.3	4.3	2.2	3.2	2.4	4.5	1.0	3.3	2.3	2.5	3.0	1.7	0.7

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Rose Dhu

Dissolved Oxygen

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	4.44	3.72	3.62	4.08	4.51	4.69	7.73	7.53	8.64	5.92	6.30	5.99	5.30
	First 5 days	4.20	4.12	3.41	4.10	4.17	4.55	6.51	7.65	8.86	7.40	5.65	6.35	5.53
	11 - 15 days	4.42	4.07	3.59	4.27	4.40	5.41	7.77	7.26	7.61	5.88	7.41	5.43	5.40
	Every other week	4.29	4.10	3.46	4.16	4.25	5.08	7.09	7.43	8.21	6.49	6.21	5.81	5.51
Average	All Data	4.29	3.49	3.51	4.23	4.65	4.82	7.66	7.55	8.55	5.99	6.19	5.69	5.24
	First 5 days	4.11	4.01	3.29	4.23	4.48	4.69	6.46	7.63	8.77	7.32	5.54	5.88	5.42
	11 - 15 days	4.21	3.86	3.65	4.38	4.46	5.41	7.74	7.29	7.40	5.91	7.18	5.20	5.39
	Every other week	4.16	3.94	3.46	4.30	4.47	5.05	7.10	7.46	8.10	6.64	6.33	5.54	5.40
Maximum	All Data	6.86	6.96	6.77	7.36	7.96	7.14	11.88	8.61	10.63	8.12	8.52	9.42	6.79
	First 5 days	5.97	6.07	5.97	6.32	7.96	6.42	7.23	8.52	9.63	8.12	6.89	9.42	6.75
	11 - 15 days	6.01	6.62	6.77	6.20	6.69	6.72	11.88	8.30	8.42	6.68	8.13	6.92	6.79
	Every other week	6.01	6.62	6.77	6.32	7.96	6.72	11.88	8.52	9.63	8.12	8.13	9.42	6.79
Minimum	All Data	0.06	0.02	0.04	1.44	1.47	2.62	5.40	6.05	5.79	4.06	3.93	0.09	0.39
	First 5 days	0.56	0.06	0.04	2.61	2.09	3.15	5.44	6.44	7.49	6.08	4.45	0.10	0.39
	11 - 15 days	0.68	0.05	0.04	1.95	2.74	3.15	6.39	6.05	5.79	5.00	4.51	0.18	2.43
	Every other week	0.56	0.05	0.04	1.95	2.09	3.15	5.44	6.05	5.79	5.00	4.28	0.10	0.39
Standard Deviation	All Data	1.34	1.62	1.45	1.05	1.06	0.94	0.91	0.43	0.94	0.91	1.09	1.59	0.83
	First 5 days	1.18	1.26	1.45	0.89	1.31	0.75	0.45	0.43	0.35	0.45	0.58	1.80	0.83
	11 - 15 days	1.18	1.40	1.54	0.99	0.80	0.77	0.50	0.35	0.57	0.27	0.80	1.21	0.83
	Every other week	1.18	1.32	1.50	0.95	1.08	0.84	0.80	0.43	0.83	0.80	1.08	1.57	0.83

pH

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	7.43	7.20	7.27	7.31	7.38	7.40	7.49	7.59	7.90	7.77		7.39	7.40
	First 5 days	7.40	7.35	7.24	7.15	7.41	7.33	7.55	7.59	7.93	8.04			7.41
	11 - 15 days	7.43	7.27	7.31	7.34	7.30	7.54	7.47	7.63	7.80	7.68		7.38	7.47
	Every other week	7.41	7.32	7.27	7.25	7.36	7.46	7.51	7.61	7.86	7.92		7.38	7.44
Average	All Data	7.43	7.19	7.27	7.30	7.38	7.39	7.49	7.59	7.89	7.83		7.37	7.41
	First 5 days	7.41	7.35	7.24	7.15	7.41	7.32	7.55	7.59	7.93	8.03			7.41
	11 - 15 days	7.43	7.25	7.33	7.34	7.32	7.52	7.47	7.60	7.78	7.66		7.36	7.45
	Every other week	7.42	7.31	7.28	7.24	7.37	7.42	7.52	7.60	7.86	7.90		7.36	7.43
Maximum	All Data	7.66	7.59	7.63	7.69	7.75	7.68	7.72	7.77	8.27	8.60		7.62	7.83
	First 5 days	7.57	7.52	7.47	7.37	7.75	7.58	7.72	7.72	8.11	8.30			7.63
	11 - 15 days	7.63	7.53	7.62	7.55	7.60	7.68	7.57	7.77	8.03	7.83		7.58	7.70
	Every other week	7.63	7.53	7.62	7.55	7.75	7.68	7.72	7.77	8.11	8.30		7.58	7.70
Minimum	All Data	7.12	6.65	6.76	6.85	6.67	6.93	7.09	7.23	7.48	7.18		6.57	7.10
	First 5 days	7.22	7.01	7.03	6.86	7.16	6.93	7.09	7.43	7.64	7.66			7.14
	11 - 15 days	7.23	6.89	6.99	7.07	7.12	7.19	7.35	7.23	7.48	7.18		6.57	7.10
	Every other week	7.22	6.89	6.99	6.86	7.12	6.93	7.09	7.23	7.48	7.18		6.57	7.10
Standard Deviation	All Data	0.10	0.20	0.14	0.16	0.13	0.17	0.11	0.09	0.16	0.21		0.12	0.13
	First 5 days	0.08	0.11	0.11	0.13	0.13	0.18	0.10	0.06	0.10	0.14			0.10
	11 - 15 days	0.10	0.14	0.14	0.11	0.12	0.11	0.05	0.12	0.12	0.10		0.12	0.14
	Every other week	0.09	0.13	0.13	0.15	0.13	0.18	0.10	0.10	0.13	0.22		0.12	0.12

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Rose Dhu

Turbidity

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	5.1	5.9	7.5	21.7	16.6	15.6	7.3	4.1	4.0	4.6	6.2	5.8	11.5
	First 5 days	4.9	5.4	5.3	35.0	18.6	16.9	8.4	3.6	3.1	3.2	1.9	5.4	13.0
	11 - 15 days	6.8	8.5	7.8	25.2	13.3	14.7	6.2	6.4	4.2	4.3	4.8	6.0	10.3
	Every other week	5.7	6.2	6.4	28.5	15.3	15.7	7.3	4.2	3.4	3.7	3.6	5.8	11.4
Average	All Data	6.1	8.6	13.0	28.9	23.2	19.3	8.0	5.1	4.8	6.1	7.6	6.1	12.1
	First 5 days	5.1	6.7	6.2	53.4	35.4	24.7	8.7	3.7	3.1	3.7	2.7	5.8	13.6
	11 - 15 days	7.8	14.6	8.9	26.3	14.8	15.8	6.9	7.0	4.6	4.7	5.1	6.1	11.0
	Every other week	6.4	10.1	7.5	39.8	24.6	20.3	7.8	5.4	3.8	4.2	4.0	5.9	12.3
Maximum	All Data	49.1	155.3	235.3	487.4	485.3	244.2	80.3	93.9	74.5	89.7	95.7	24.6	73.7
	First 5 days	24.5	45.8	24.1	414.9	485.3	244.2	80.3	12.5	7.4	22.5	17.5	24.6	41.7
	11 - 15 days	49.1	155.3	45.1	100.0	74.8	46.6	35.6	23.9	15.5	16.1	20.7	11.7	34.5
	Every other week	49.1	155.3	45.1	414.9	485.3	244.2	80.3	23.9	15.5	22.5	20.7	24.6	41.7
Minimum	All Data	0.7	0.6	0.0	3.1	1.4	3.5	1.4	1.4	0.1	0.1	0.0	0.9	0.8
	First 5 days	0.7	1.4	0.3	6.6	3.2	3.5	1.7	1.7	0.5	1.4	0.0	1.2	2.8
	11 - 15 days	1.2	1.4	0.0	5.0	3.4	4.9	1.4	1.5	0.1	0.4	1.2	1.1	3.9
	Every other week	0.7	1.4	0.0	5.0	3.2	3.5	1.4	1.5	0.1	0.4	0.0	1.1	2.8
Standard Deviation	All Data	4.3	9.8	20.0	32.9	33.1	15.7	4.1	4.0	3.1	6.1	7.0	2.4	4.6
	First 5 days	2.7	4.8	4.4	59.3	63.2	26.3	4.5	1.1	0.9	1.9	2.7	2.5	4.6
	11 - 15 days	4.7	18.3	7.6	11.5	7.5	6.4	3.6	3.8	2.4	2.3	2.4	1.8	4.1
	Every other week	4.0	13.2	6.3	44.7	45.0	19.7	4.2	3.3	2.0	2.2	2.8	2.2	4.6

Chlorophyll

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008
Median	All Data	5.9	9.0	9.0	10.6	8.9	6.0	4.9	4.4	5.9	4.5	6.2	9.1	7.7
	First 5 days	6.9	6.4	12.7	10.9	8.7	7.1	5.6	3.4	5.9	4.4	6.8	10.4	7.8
	11 - 15 days	5.7	14.1	9.8	12.4	8.5	5.2	3.5	5.3	5.6	3.9	5.7	8.8	6.8
	Every other week	6.1	7.5	10.5	11.3	8.6	6.3	4.8	4.1	5.8	4.1	6.1	9.5	7.4
Average	All Data	6.1	10.9	9.6	11.4	9.7	6.2	4.8	4.7	6.0	4.8	6.3	10.1	9.2
	First 5 days	7.4	6.4	12.8	11.7	9.3	7.9	5.7	3.5	6.0	4.5	6.7	11.4	9.7
	11 - 15 days	5.7	14.3	10.1	13.3	9.1	5.5	3.7	5.5	5.8	3.9	5.8	10.4	8.1
	Every other week	6.6	9.9	11.5	12.5	9.2	6.7	4.7	4.5	5.9	4.2	6.3	10.9	8.9
Maximum	All Data	18.0	38.6	32.0	56.6	48.2	24.6	16.0	13.7	12.7	11.8	16.0	54.1	60.5
	First 5 days	18.0	13.5	32.0	34.0	48.2	24.6	8.9	12.5	9.9	6.4	11.1	42.3	48.6
	11 - 15 days	13.2	38.6	28.5	34.8	28.3	13.9	7.3	10.1	10.1	6.0	10.7	54.1	60.5
	Every other week	18.0	38.6	32.0	34.8	48.2	24.6	8.9	12.5	10.1	6.4	11.1	54.1	60.5
Minimum	All Data	0.6	0.8	1.4	5.3	3.8	0.2	2.0	2.1	2.9	1.7	2.2	1.7	1.4
	First 5 days	1.1	0.8	3.6	6.1	3.8	3.8	3.3	2.1	3.2	2.5	3.0	2.8	1.4
	11 - 15 days	0.8	1.3	2.2	5.4	4.8	1.1	2.0	3.0	2.9	1.9	2.7	1.9	2.4
	Every other week	0.8	0.8	2.2	5.4	3.8	1.1	2.0	2.1	2.9	1.9	2.7	1.9	1.4
Standard Deviation	All Data	2.9	7.1	4.8	4.1	3.1	2.7	1.2	1.4	1.4	1.4	1.7	4.8	6.5
	First 5 days	3.4	2.3	5.8	3.7	3.4	2.9	0.9	0.7	1.2	0.7	1.7	5.2	6.9
	11 - 15 days	2.3	8.0	5.0	5.0	2.7	2.5	0.9	1.4	1.2	0.7	1.3	6.2	5.2
	Every other week	3.0	6.8	5.6	4.4	3.1	2.9	1.4	1.5	1.2	0.7	1.6	5.7	6.2

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Verdier Cove

Temperature

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 2008	June 2008
Median	All Data	25.0	28.1	30.2	31.2	28.1	24.9				14.8	17.5	20.6	25.3	30.1
	First 5 days	25.1	25.7	30.4	29.4	28.3	24.9				12.0	15.6	19.6	23.3	28.1
	11 - 15 days	24.4	27.4	29.7	31.6	28.8	24.8				14.7	17.1	21.3	24.3	31.1
	Every other week	24.8	26.7	30.0	30.8	28.7	24.9				13.6	16.6	20.2	24.0	30.2
Average	All Data	24.8	28.1	30.3	31.1	27.8	24.6				14.6	17.4	20.9	25.2	29.9
	First 5 days	25.2	25.8	30.5	29.4	28.4	25.1				12.2	15.7	19.6	23.5	28.3
	11 - 15 days	24.3	27.8	29.6	31.7	28.8	25.0				14.7	17.1	21.0	24.6	31.0
	Every other week	24.7	26.7	30.1	30.5	28.6	25.0				13.4	16.4	20.3	24.0	29.6
Maximum	All Data	28.2	31.9	33.6	33.5	31.5	28.1				18.5	20.9	26.1	28.6	33.1
	First 5 days	27.3	28.1	32.3	31.6	30.0	26.6				14.9	17.7	21.4	26.9	31.7
	11 - 15 days	25.9	30.1	30.5	33.5	30.0	26.9				16.2	19.8	24.0	26.7	32.3
	Every other week	27.3	30.1	32.3	33.5	30.0	26.9				16.2	19.8	24.0	26.9	32.3
Minimum	All Data	20.9	24.3	27.1	27.6	20.8	18.8				10.9	13.5	17.5	21.4	27.2
	First 5 days	23.6	24.3	27.1	27.6	27.0	24.3				10.9	13.5	17.8	21.4	24.4
	11 - 15 days	22.2	26.4	28.7	30.7	28.0	23.9				12.9	15.5	17.9	23.0	30.0
	Every other week	22.2	24.3	27.1	27.6	27.0	23.9				10.9	13.5	17.8	21.4	24.4
Standard	All Data	1.4	1.7	0.9	1.0	1.2	1.8				1.4	1.3	1.8	1.3	1.2
Deviation	First 5 days	0.7	1.0	0.6	0.7	0.6	0.5				0.9	1.1	0.8	0.9	1.0
	11 - 15 days	0.8	1.1	0.3	0.6	0.4	0.8				0.7	0.8	1.3	0.9	0.4
	Every other week	0.9	1.4	0.6	1.3	0.6	0.7				1.5	1.2	1.3	1.1	1.6

Salinity

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 08	June 08
Median	All Data	31.2	28.6	29.8	27.2	28.8	29.3				31.3	29.0	30.7	33.0	31.9
	First 5 days	31.6	29.9	29.7	27.1	22.7	31.3				32.3	28.8	29.5	32.3	32.1
	11 - 15 days	30.8	27.9	30.4	27.9	27.7	28.1				32.2	28.7	30.4	33.6	32.4
	Every other week	31.4	29.6	30.1	27.4	24.9	29.4				32.3	28.8	30.0	32.6	32.3
Average	All Data	31.2	28.0	29.6	26.8	27.7	29.2				31.2	28.7	30.7	33.0	31.9
	First 5 days	31.6	30.4	29.3	26.9	23.3	31.0				32.3	28.8	29.4	32.2	31.0
	11 - 15 days	30.9	26.4	30.4	27.6	27.4	27.9				32.3	28.5	30.4	33.2	32.4
	Every other week	31.3	28.6	29.8	27.2	25.4	29.5				32.3	28.6	29.9	32.7	31.7
Maximum	All Data	32.1	32.1	31.3	31.2	34.0	34.2				34.3	30.8	32.7	34.2	33.3
	First 5 days	32.1	32.1	30.5	29.1	30.4	34.2				34.0	30.7	30.4	32.9	32.8
	11 - 15 days	31.5	30.9	31.3	30.7	29.9	30.3				34.0	30.8	31.6	33.9	33.0
	Every other week	32.1	32.1	31.3	30.7	30.4	34.2				34.0	30.8	31.6	33.9	33.0
Minimum	All Data	29.3	19.6	0.3	20.7	0.3	24.2				15.8	19.7	27.2	16.5	0.2
	First 5 days	31.2	28.5	0.3	20.7	21.9	25.9				30.3	25.9	27.6	16.5	0.2
	11 - 15 days	30.5	19.6	29.3	24.3	22.2	24.4				29.8	24.2	29.2	31.2	31.5
	Every other week	30.5	19.6	0.3	20.7	21.9	24.4				29.8	24.2	27.6	16.5	0.2
Standard	All Data	0.3	2.5	1.4	1.9	4.0	1.9				1.8	1.4	1.2	0.8	2.7
Deviation	First 5 days	0.2	1.1	2.4	1.6	2.1	2.1				1.0	1.3	0.7	1.0	5.9
	11 - 15 days	0.3	3.6	0.5	1.5	1.7	1.6				1.1	1.6	0.6	0.5	0.3
	Every other week	0.4	3.2	1.8	1.6	2.8	2.4				1.1	1.5	0.8	1.0	4.3

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Verdier Cove

Dissolved Oxygen

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 08	June 08
Median	All Data	5.44	4.58	4.71	4.41	4.66	4.70				6.60	7.73	5.01	5.52	3.55
	First 5 days	5.13	5.37	4.87	4.11	4.47	5.02				7.76	7.58	5.09	5.88	2.89
	11 - 15 days	5.45	4.55	4.96	4.21	3.90	5.40				6.40	7.73	4.88	5.82	4.65
	Every other week	5.27	5.11	4.90	4.16	4.04	5.26				7.22	7.69	4.98	5.86	3.07
Average	All Data	5.37	4.58	4.73	4.33	4.58	4.80				6.70	7.57	5.08	5.32	3.68
	First 5 days	5.00	5.41	4.96	4.03	4.41	5.04				7.72	7.60	5.09	5.85	3.00
	11 - 15 days	5.42	4.46	4.89	4.23	3.85	5.41				6.34	7.76	4.88	5.69	4.23
	Every other week	5.21	4.99	4.93	4.13	4.12	5.22				7.05	7.68	4.99	5.77	3.60
Maximum	All Data	7.10	7.28	8.01	6.12	9.70	7.25				9.72	9.93	7.52	6.76	9.26
	First 5 days	6.22	6.70	8.01	5.86	6.58	6.29				8.56	8.54	5.70	6.76	9.26
	11 - 15 days	7.00	5.98	6.04	5.39	5.16	6.52				7.45	8.75	5.72	6.61	5.75
	Every other week	7.00	6.70	8.01	5.86	6.58	6.52				8.56	8.75	5.72	6.76	9.26
Minimum	All Data	0.95	0.15	2.85	0.57	0.15	2.55				4.93	4.73	2.32	1.89	1.38
	First 5 days	0.95	2.72	3.23	0.73	0.83	3.55				6.70	6.46	4.33	3.60	2.17
	11 - 15 days	1.72	1.73	3.41	0.57	0.65	3.92				5.51	6.99	4.17	4.04	2.08
	Every other week	0.95	1.73	3.23	0.57	0.65	3.55				5.51	6.46	4.17	3.60	2.08
Standard Deviation	All Data	0.75	1.11	0.70	0.84	1.16	0.85				0.97	1.20	0.72	0.93	1.18
	First 5 days	0.79	0.55	0.66	0.91	1.17	0.58				0.25	0.47	0.25	0.45	0.88
	11 - 15 days	0.69	0.88	0.51	0.66	0.63	0.57				0.39	0.34	0.25	0.54	1.07
	Every other week	0.77	0.86	0.59	0.80	0.98	0.60				0.76	0.42	0.27	0.50	1.16

pH

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April	May 08	June 08
Median	All Data	7.49	7.38	7.46		7.89	7.74				8.16	8.13	8.12	7.52	7.86
	First 5 days	7.48	7.35				7.85				8.19	8.09	8.47	7.56	8.11
	11 - 15 days	7.57	7.51				7.84				7.95	7.80		7.59	7.78
	Every other week	7.51	7.36				7.85				8.16	7.86	8.47	7.57	8.08
Average	All Data	7.50	7.39	7.46		7.92	7.64				8.14	8.16	8.04	7.58	7.89
	First 5 days	7.48	7.35				7.84				8.18	8.06	8.47	7.57	8.12
	11 - 15 days	7.57	7.41				7.82				8.07	7.80		7.57	7.86
	Every other week	7.52	7.38				7.83				8.13	7.93	8.47	7.57	8.00
Maximum	All Data	7.79	8.17	7.95		9.23	8.00				8.58	9.02	8.85	8.16	8.66
	First 5 days	7.60	7.47				8.00				8.30	8.29	8.85	7.69	8.66
	11 - 15 days	7.76	7.88				7.92				8.58	8.17		7.73	8.25
	Every other week	7.76	7.88				8.00				8.58	8.29	8.85	7.73	8.66
Minimum	All Data	7.11	6.83	7.31		6.06	6.78				7.00	5.40	6.71	7.32	7.46
	First 5 days	7.22	7.17				7.52				8.00	7.74	8.08	7.37	7.98
	11 - 15 days	7.31	6.94				7.60				7.00	7.58		7.33	7.63
	Every other week	7.22	6.94				7.52				7.00	7.58	8.08	7.33	7.63
Standard Deviation	All Data	0.11	0.18	0.09		0.16	0.26				0.17	0.37	0.41	0.19	0.21
	First 5 days	0.06	0.06				0.11				0.06	0.15	0.19	0.06	0.08
	11 - 15 days	0.10	0.24				0.07				0.24	0.06		0.10	0.19
	Every other week	0.09	0.17				0.09				0.18	0.18	0.19	0.08	0.19

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Verdier Cove

Turbidity															
Statistic	**Dataset**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May 08**	**June 08**
Median	All Data	7.7	13.3	13.3	37.4	9.0	7.6				2.8	4.0	5.8	4.9	6.2
	First 5 days	8.5	12.1	9.4	51.4		7.6				1.4	2.3	6.5	6.3	7.5
	11 - 15 days	9.4	16.8	13.9	7.5		7.5				2.8	1.5	5.2	4.8	4.5
	Every other week	8.9	13.6	10.6	28.0		7.5				2.0	2.1	5.7	5.6	5.8
Average	All Data	7.7	31.6	31.5	58.9	10.2	8.3				3.0	4.3	7.3	5.7	6.5
	First 5 days	8.4	12.5	10.1	85.6		7.9				1.5	2.9	7.4	7.2	7.9
	11 - 15 days	9.4	39.0	36.2	8.4		7.5				3.1	1.8	5.4	5.2	4.7
	Every other week	8.9	24.0	22.7	62.6		7.7				2.3	2.4	6.4	6.2	6.6
Maximum	All Data	56.8	422.4	252.3	499.3	30.8	68.4				14.1	65.8	90.7	29.6	65.5
	First 5 days	12.3	31.6	24.3	499.3		63.1				2.9	12.3	57.4	29.6	65.5
	11 - 15 days	15.9	422.4	194.1	26.8		13.1				13.8	7.9	15.5	15.1	9.2
	Every other week	15.9	422.4	194.1	499.3		63.1				13.8	12.3	57.4	29.6	65.5
Minimum	All Data	0.8	0.0	0.0	1.6	1.6	2.2				0.8	0.0	0.5	0.3	2.3
	First 5 days	2.9	2.6	1.4	6.4		2.3				0.8	1.3	3.2	1.3	2.6
	11 - 15 days	3.6	3.7	4.0	1.8		3.0				1.5	0.0	2.3	0.7	2.3
	Every other week	2.9	2.6	1.4	1.8		2.3				0.8	0.0	2.3	0.7	2.3
Standard	All Data	2.6	53.7	42.3	80.9	4.9	4.3				1.4	3.4	5.9	3.2	2.9
Deviation	First 5 days	1.7	3.5	4.9	93.2		3.9				0.4	1.3	3.8	3.8	4.7
	11 - 15 days	2.2	61.7	40.6	4.5		2.1				1.3	1.4	1.4	2.4	1.1
	Every other week	2.1	42.7	31.3	85.7		3.1				1.2	1.5	3.1	3.4	4.0

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Alljoy

Temperature													
Statistic	**Dataset**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Median	All Data	24.4	27.8	29.7	31.0			16.2	14.7	11.2	14.5	17.2	19.7
	First 5 days	24.3	25.5	28.6	29.2			16.1	15.9	11.7	11.7	15.3	18.9
	11 - 15 days	23.9	27.1	30.0	31.2			15.7	16.5	14.0	14.4	17.8	20.9
	Every other week	24.1	26.5	29.8	30.4			16.0	16.1	13.8	13.4	17.0	19.7
Average	All Data	24.3	27.7	29.7	30.8			16.2	15.1	11.6	14.2	17.0	19.7
	First 5 days	24.3	25.6	28.8	29.3			16.4	15.8	12.4	11.8	15.4	19.0
	11 - 15 days	23.7	27.6	30.0	31.3			15.6	16.5	14.0	14.5	17.8	20.8
	Every other week	24.0	26.4	29.4	30.3			16.0	16.1	13.2	13.1	16.6	19.9
Maximum	All Data	27.6	31.7	31.9	33.2			17.6	17.9	15.5	16.6	19.3	22.3
	First 5 days	25.8	27.7	31.8	30.4			17.6	16.5	15.5	14.0	17.4	20.7
	11 - 15 days	25.4	29.4	31.8	32.5			16.6	17.6	14.8	15.4	19.1	22.3
	Every other week	25.8	29.4	31.8	32.5			17.6	17.6	15.5	15.4	19.1	22.3
Minimum	All Data	20.4	24.4	27.1	28.3			14.5	12.9	8.8	10.8	14.0	17.4
	First 5 days	23.0	24.4	27.1	28.3			15.6	14.6	10.1	10.8	14.0	17.4
	11 - 15 days	22.1	26.2	29.3	30.5			14.5	15.1	13.1	13.7	17.0	18.5
	Every other week	22.1	24.4	27.1	28.3			14.5	14.6	10.1	10.8	14.0	17.4
Standard Deviation	All Data	1.4	1.6	0.9	0.9			0.7	1.1	1.7	1.3	1.2	1.1
	First 5 days	0.6	0.8	1.1	0.5			0.6	0.5	1.9	0.7	0.8	0.7
	11 - 15 days	0.7	0.9	0.4	0.4			0.6	0.7	0.4	0.4	0.4	1.0
	Every other week	0.7	1.3	1.0	1.1			0.7	0.7	1.6	1.4	1.4	1.3

Salinity													
Statistic	**Dataset**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Median	All Data	31.9	31.1	30.2				32.7	32.9	32.7	31.9	30.7	32.1
	First 5 days	31.0	31.3	30.3				32.6	32.7	33.0	32.3	31.5	31.2
	11 - 15 days	31.5	30.8	29.4				32.7	33.1	33.2	32.2	30.4	32.3
	Every other week	31.2	31.2	30.3				32.7	32.9	33.1	32.2	30.8	31.7
Average	All Data	31.9	31.0	30.1				32.7	32.9	32.7	31.8	30.8	32.1
	First 5 days	31.0	31.9	30.4				32.6	32.7	33.0	32.3	31.4	31.2
	11 - 15 days	31.5	30.8	29.3				32.7	33.1	33.2	32.2	30.4	32.3
	Every other week	31.3	31.4	30.2				32.7	32.9	33.1	32.2	30.9	31.7
Maximum	All Data	33.3	33.3	31.3				33.8	33.8	33.6	32.8	31.7	33.3
	First 5 days	31.4	33.3	31.3				33.0	33.1	33.5	32.8	31.7	31.8
	11 - 15 days	32.0	31.5	29.9				33.8	33.4	33.6	32.5	30.8	32.9
	Every other week	32.0	33.3	31.3				33.8	33.4	33.6	32.8	31.7	32.9
Minimum	All Data	30.5	20.4	28.5				32.2	32.1	31.3	27.3	29.4	26.9
	First 5 days	30.5	30.5	29.8				32.2	32.1	32.4	31.7	30.8	26.9
	11 - 15 days	30.6	20.4	28.5				32.4	32.4	32.7	31.8	29.4	31.4
	Every other week	30.5	20.4	28.5				32.2	32.1	32.4	31.7	29.4	26.9
Standard Deviation	All Data	0.8	0.8	0.5				0.4	0.3	0.6	0.6	0.5	0.8
	First 5 days	0.2	0.9	0.3				0.2	0.3	0.3	0.3	0.2	0.4
	11 - 15 days	0.3	0.7	0.3				0.3	0.3	0.2	0.2	0.2	0.4
	Every other week	0.4	1.0	0.5				0.3	0.3	0.3	0.3	0.5	0.7

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Alljoy

Dissolved Oxygen

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April
Median	All Data	6.15	5.58	5.27				7.47	7.68	8.56	8.45	7.48	6.63
	First 5 days	6.04	5.92	5.13				7.49	8.24	8.12	9.49	8.46	6.91
	11 - 15 days	6.30	5.28	5.30				7.45	7.68	7.98	8.51	7.22	6.55
	Every other week	6.14	5.65	5.21				7.46	7.89	8.01	9.25	7.73	6.66
Average	All Data	6.22	5.63	5.29				7.46	7.74	8.73	8.52	7.61	6.63
	First 5 days	6.05	5.90	5.15				7.40	8.22	8.11	9.55	8.37	6.91
	11 - 15 days	6.41	5.25	5.32				7.47	7.65	7.97	8.53	7.20	6.57
	Every other week	6.23	5.62	5.23				7.43	7.94	8.04	9.05	7.78	6.74
Maximum	All Data	7.64	7.47	6.66				8.31	8.64	11.75	10.52	8.90	7.56
	First 5 days	6.83	7.02	6.37				7.99	8.51	9.12	10.52	8.90	7.56
	11 - 15 days	7.38	6.79	6.66				8.31	7.98	8.42	10.42	7.78	7.14
	Every other week	7.38	7.02	6.66				8.31	8.51	9.12	10.52	8.90	7.56
Minimum	All Data	3.93	4.24	4.10				6.52	6.85	7.22	7.50	6.63	5.28
	First 5 days	5.36	4.25	4.10				6.52	7.76	7.22	8.95	7.73	6.32
	11 - 15 days	5.01	4.24	4.29				6.92	7.28	7.49	8.04	6.70	5.98
	Every other week	5.01	4.24	4.10				6.52	7.28	7.22	8.04	6.70	5.98
Standard Deviation	All Data	0.56	0.60	0.44				0.34	0.40	0.72	0.57	0.49	0.37
	First 5 days	0.32	0.52	0.50				0.35	0.14	0.46	0.25	0.31	0.31
	11 - 15 days	0.44	0.54	0.46				0.26	0.15	0.21	0.20	0.19	0.21
	Every other week	0.42	0.62	0.49				0.31	0.32	0.36	0.56	0.64	0.31

pH

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April
Median	All Data	7.73	7.61	7.64	7.67			8.02	7.84	7.96	7.95	7.83	7.78
	First 5 days	7.73	7.67	7.54	7.62			8.02	7.85	7.95	8.04	7.87	
	11 - 15 days	7.75	7.62	7.66	7.70			8.03	7.81	7.95	7.95	7.82	7.76
	Every other week	7.74	7.65	7.60	7.66			8.03	7.84	7.95	7.96	7.86	7.76
Average	All Data	7.73	7.61	7.64	7.67			8.01	7.84	7.96	7.94	7.83	7.78
	First 5 days	7.73	7.67	7.54	7.61			8.02	7.86	7.93	8.05	7.87	
	11 - 15 days	7.75	7.61	7.65	7.70			8.03	7.81	7.95	7.88	7.83	7.75
	Every other week	7.74	7.64	7.59	7.66			8.03	7.84	7.94	7.92	7.85	7.75
Maximum	All Data	7.92	7.84	7.90	7.93			8.18	7.97	8.05	8.14	7.94	7.88
	First 5 days	7.85	7.77	7.69	7.75			8.13	7.94	8.03	8.14	7.94	
	11 - 15 days	7.88	7.81	7.82	7.88			8.18	7.97	8.02	8.07	7.93	7.83
	Every other week	7.88	7.81	7.82	7.88			8.18	7.97	8.03	8.14	7.94	7.83
Minimum	All Data	7.54	7.42	7.38	7.44			7.77	7.67	7.79	7.10	7.71	7.66
	First 5 days	7.64	7.52	7.38	7.48			7.84	7.78	7.79	7.79	7.80	
	11 - 15 days	7.63	7.42	7.51	7.54			7.77	7.67	7.88	7.10	7.74	7.66
	Every other week	7.63	7.42	7.38	7.48			7.77	7.67	7.79	7.10	7.74	7.66
Standard Deviation	All Data	0.06	0.09	0.11	0.08			0.08	0.05	0.05	0.10	0.05	0.04
	First 5 days	0.05	0.05	0.08	0.06			0.06	0.04	0.06	0.05	0.03	
	11 - 15 days	0.06	0.09	0.08	0.07			0.08	0.08	0.04	0.17	0.05	0.03
	Every other week	0.05	0.08	0.10	0.08			0.07	0.06	0.05	0.17	0.05	0.03

Appendix A-6 continued. Monthly median, average, maximum, minimum and standard deviation of data recorded by real-time data sondes. Values are shown for all data during each month ("All Data") and for three data subsets: the first five days of each month ("First 5 days"), the middle five days of each month ("11-15 days") and every other week within each month ("Every other week").

Alljoy

Turbidity

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April
Median	All Data	6.2	5.0	3.2	4.8				3.1	1.0	2.1	3.2	4.4
	First 5 days	7.5	6.8	4.5	8.7					0.9	0.3	1.1	4.0
	11 - 15 days	8.0	8.9	2.3	4.8					0.5	1.8	4.0	3.4
	Every other week	7.6	7.5	3.4	6.7					0.6	1.5	3.2	3.6
Average	All Data	6.9	6.0	4.3	6.2				4.1	1.8	3.0	4.4	6.3
	First 5 days	7.7	7.7	5.0	9.9					1.6	0.9	2.6	6.0
	11 - 15 days	9.3	10.5	3.5	5.8					1.4	2.4	5.0	4.1
	Every other week	8.5	8.9	4.4	7.9					1.5	2.1	3.9	5.0
Maximum	All Data	104.9	77.6	67.6	71.9				48.8	58.7	68.4	91.6	106.0
	First 5 days	31.8	49.1	39.2	71.9					9.2	34.5	47.5	106.0
	11 - 15 days	104.9	77.6	67.6	40.9					33.3	23.2	48.7	26.7
	Every other week	104.9	77.6	67.6	71.9					33.3	34.5	48.7	106.0
Minimum	All Data	0.1	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
	First 5 days	3.7	0.6	0.2	2.0					0.0	0.0	0.0	0.4
	11 - 15 days	1.2	0.4	0.0	0.1					0.0	0.0	0.3	0.0
	Every other week	1.2	0.4	0.0	0.1					0.0	0.0	0.0	0.0
Standard Deviation	All Data	4.4	5.3	4.5	5.2				4.0	3.1	4.2	5.3	6.8
	First 5 days	2.4	4.5	3.7	6.5					1.9	3.5	4.8	7.9
	11 - 15 days	7.2	6.1	6.1	4.7					3.9	2.4	4.6	3.2
	Every other week	5.4	15.8	5.0	6.1					3.3	2.7	4.8	6.1

Chlorophyll

Statistic	Dataset	May	June	July	August	September	October	November	December	January	February	March	April
Median	All Data	5.0	4.3	4.9	5.7			4.5	3.3	2.8	4.3	4.7	3.7
	First 5 days	5.1	3.4	3.6	5.3			5.0	3.4	2.9	3.5	3.9	
	11 - 15 days	5.0	4.5	5.5	6.1			4.0	3.3	2.8	4.2	5.3	3.5
	Every other week	5.1	3.8	4.5	5.6			4.5	3.4	2.9	3.8	4.6	3.5
Average	All Data	5.8	4.5	5.0	6.0			4.5	3.3	2.8	4.4	4.8	3.8
	First 5 days	5.2	3.7	3.8	5.5			5.0	3.5	3.0	3.5	3.9	
	11 - 15 days	5.2	4.8	5.6	6.2			4.0	3.3	2.9	4.2	5.3	3.5
	Every other week	5.2	4.1	4.7	5.9			4.5	3.4	2.9	3.9	4.6	3.5
Maximum	All Data	48.7	26.4	21.5	27.4			7.8	9.3	8.8	12.6	11.5	10.9
	First 5 days	7.8	26.4	7.9	14.4			7.8	9.3	8.7	8.4	7.7	
	11 - 15 days	26.1	23.2	15.9	17.8			6.4	8.7	5.0	6.4	8.5	9.1
	Every other week	26.1	26.4	15.9	17.8			7.8	9.3	8.7	8.4	8.5	9.1
Minimum	All Data	2.6	1.6	1.2	2.6			2.3	1.5	1.3	2.0	2.5	1.8
	First 5 days	3.1	1.7	1.2	2.6			3.0	2.2	1.7	2.0	2.5	
	11 - 15 days	3.0	1.6	1.9	3.5			2.3	1.9	1.3	2.6	3.8	1.8
	Every other week	3.0	1.6	1.2	2.6			2.3	1.9	1.3	2.0	2.5	1.8
Standard Deviation	All Data	4.5	1.4	1.6	1.8			0.9	0.6	0.5	0.8	0.9	0.9
	First 5 days	0.9	1.5	1.3	1.6			0.8	0.6	0.6	0.5	0.6	
	11 - 15 days	1.4	1.9	1.5	1.5			0.7	0.7	0.5	0.6	0.6	0.7
	Every other week	1.2	1.8	1.7	1.6			0.9	0.7	0.6	0.6	0.9	0.7

Appendix A-7. Average values for water quality measures collected by the Volunteer Monitoring Network.

Parameter	Crystal Beach	Osprey Alley	Rose Dhu	Stoney Creek
Water Temp. (C)	20.9	21.8	21.6	21.4
Clarity (cm)	63.2	27.5	22.8	22.0
Salinity (ppt)	32	30	28	28
Dissolved Oxygen (mg/l)		6.23	6.50	6.25

APPENDIX B: Statistical Tables

Appendix B-1. Results of ANCOVA salinity data in SCDHEC shellfish and ambient and main stem data sets. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	19-19				**19-24**				**19-16**				**19-18**		
Source	**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year	14	5.90	***<0.001***		11	7.16	***<0.001***		14	9.09	***<0.001***		14	10.05	***<0.001***
Month	11	0.92	0.523		11	1.38	0.194		11	1.37	0.193		11	1.20	0.290
Error	144				109				144				144		
	19-25				**19-01**				**19-12**				**MD-173**		
Source	**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year	11	8.58	***<0.001***		14	9.43	***<0.001***		14	9.78	***<0.001***		5	4.01	***0.006***
Month	11	1.29	0.241		11	1.14	0.336		11	1.65	*0.092*		11	0.86	0.588
Error	109				144				144				35		
	M1				**M2**				**M3**				**M4**		
Source	**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year	6	1.05	0.429		6	1.50	0.241		6	2.09	0.111		6	3.38	***0.024***
Season	3	0.75	0.539		3	1.01	0.416		3	0.50	0.686		3	1.12	0.370
Error	16				16				16				16		

Appendix B-2. Results of nested ACNOVA for differences in salinity between SCDHEC Shellfish stations in the middle and lower sections of the May River.			
Source	**Df**	**F**	**p**
Section	1	0.02	0.898
Year	1	24.89	<0.001
Station(Section)	4	0.02	0.999
Section X Year	1	0.02	0.896
Error	76		

Appendix B-3. Results of ANCOVA for differences salinity among Main Stem stations and years in the May River.			
Source	**df**	**F**	**p**
Station	3	0.35	0.792
Year	1	14.33	0.001
Station X Year	3	0.35	0.792
Error	20		

Appendix B-4. Results of nested ACNOVA for changes in salinity among SCDHEC Shellfish stations in the May River corrected for regional precipitation.			
Source	**Df**	**F**	**p**
Station	6	0.25	0.959
Rainfall	1	54.29	<0.001
Year	6	6.09	0.016
Station X Year	6	0.02	0.892
Error	84		

Appendix B-5. Results of ANCOVA for fecal coliform bacteria data in SCDHEC shellfish and ambient and main stem data sets. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	19-19			**19-24**			**19-16**			**19-18**		
Source	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**
Year	14	4.69	***<0.001***	11	1.75	*0.073*	14	1.48	0.127	14	2.1	***0.015***
Month	11	0.80	0.636	11	0.34	0.975	11	1.48	0.147	11	0.86	0.580
Salinity	1	33.7	***<0.001***	1	11.7	***0.001***	1	30.9	***<0.001***	141	19.5	***<0.001***
Error	141			108			140					
	19-25			**19-01**			**19-12**			**MD-173**		
Source	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**
Year	11	0.57	0.848	14	1.52	0.111	14	0.98	0.473	5	3.83	***0.007***
Month	11	0.30	0.985	11	0.98	0.470	11	0.82	0.616	11	1.89	*0.076*
Salinity	1	3.19	*0.077*	1	3.73	*0.055*	1	5.81	***0.017***	1	4.63	***0.039***
Error	106			140			140			34		
	M1			**M2**			**M3**			**M4**		
Source	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**	**df**	**F**	**p**
Year	6	1.23	0.346	6	0.29	0.932	6	1.34	0.301	6	0.64	0.698
Season	3	0.76	0.534	3	2.01	0.156	3	0.72	0.554	3	0.72	0.554
Salinity	1	0.05	0.822	1	1.05	0.322	1	0.62	0.443	1	0.02	0.901
Error	15			15			15			15		

Appendix B-6. Results of nested ACNOVA for differences in fecal coliform bacteria between SCDHEC Shellfish stations in the middle and lower sections of the May River.			
Source	**df**	**F**	**p**
Section	1	0.92	0.340
Year	1	6.99	***0.010***
Station(Section)	4	1.44	0.230
Section X Year	1	3.25	*0.076*
Error	76		

Appendix B-7. Results of ANCOVA for differences in fecal coliform bacteria among Main Stem stations and years in the May River.			
Source	**df**	**F**	**p**
Station	3	0.54	0.660
Year	1	1.35	0.259
Station X Year	3	0.04	0.987
Error	20		

Appendix B-9. Results of ANCOVA of nutrient levels in the Main Stem data set and SCDHEC Ambient data set. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Total Nitrogen

		MD-173				**M1**				**M2**				**M3**				**M4**		
Source		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year		5	6.15	***<0.001***		6	1.15	0.378		6	0.57	0.747		6	0.17	0.982		6	1.09	0.408
Month		11	3.04	***0.004***		3	5.49	***0.009***		3	0.60	0.624		3	2.01	0.154		3	0.65	0.593
Error		45				16				16				16				16		

Total Phosphorus

		MD-173				**M1**				**M2**				**M3**				**M4**		
Source		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year		4	2.52	*0.058*		6	0.75	6.180		6	0.36	0.890		6	0.31	0.921		6	0.77	0.603
Month		11	6.30	***<0.001***		3	6.40	***0.006***		3	1.93	0.175		3	2.11	0.139		3	4.60	***0.017***
Error		36				16				16				16				16		

Appendix B-9. Results of ANCOVA of nutrient levels in the Main Stem data set. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	Total Nitrogen (TN)		
Source	**df**	**F**	**p**
Station	3	0.49	0.695
Year	1	2.01	0.172
Station X Year	3	0.49	0.694
Error	20		
	Total Phosphorus (TP)		
Source	**df**	**F**	**p**
Station	3	0.37	0.773
Year	1	0.42	0.522
Station X Year	3	0.38	0.771
Error	20		

Appendix B-10. Results of ANCOVA of other water quality in the Main Stem data set and SCDHEC Ambient data set. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

Dissolved Oxygen (DO)

		MD-173				M1				M2				M3				M4		
Source		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year		5	4.16	***0.004***		6	3.57	***0.021***		6	1.45	0.261		6	0.76	0.611		6	1.18	0.369
Month		11	14.00	***<0.001***		3	23.12	***<0.001***		3	9.65	***0.001***		3	12.85	***<0.001***		3	9.50	***0.001***
Error		37				16				16				16				16		

pH

		MD-173				M1				M2				M3				M4		
Source		**df**	**F**	**P**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year		5	1.08	0.388		6	0.98	0.471		6	0.55	0.761		6	0.96	0.485		6	2.55	*0.066*
Month		11	2.87	***0.009***		3	1.42	0.278		3	2.83	*0.074*		3	3.28	*0.050*		3	2.26	0.123
Salinity		1	0.20	0.656		1	1.21	0.290		1	0.01	0.927		1	0.01	0.910		1	1.84	0.194
Error		35				16				16				16				16		

TSS/Turbidity

		MD-173				M1				M2				M3				M4		
Source		**df**	**F**	**P**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**		**df**	**F**	**p**
Year		5	1.85	0.119		6	1.05	0.433		6	1.34	0.298		6	2.17	0.105		6	1.36	0.290
Month		11	3.52	***0.001***		3	3.56	***0.042***		3	4.68	***0.016***		3	13.91	***<0.001***		3	2.10	0.141
Error		53				16				16				16				16		

Appendix B-11. Results of ANCOVA of other water quality measures in the main stem dataset. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	Dissolved Oxygen		
Source	**df**	**F**	**P**
Station	3	0.39	0.763
Year	1	1.17	0.291
Station X Year	3	0.39	0.763
Error	20		
	pH		
Source	**df**	**F**	**p**
Station	3	0.53	0.665
Year	1	0.06	0.811
Station X Year	3	0.53	0.667
Error	20		
	TSS/Turbidity		
Source	**df**	**F**	**p**
Station	3	0.04	0.989
Year	1	8.47	0.009
Station X Year	3	0.04	0.989
Error	20		

Appendix B-12. Results of ANOVA of water quality measures in the Phase Drainages dataset. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.			
	Fecal Coliform		
Source	**df**	**F**	**p**
Type	2	0.47	0.623
Event	1	18.80	***<0.001***
Station (Type)	10	5.56	***<0.001***
Error	146		
	TN		
Source	**df**	**F**	**p**
Type	2	20.72	***<0.001***
Event	1	0.95	0.332
Station (Type)	9	1.48	0.166
Error	94		
	TP		
Source	**df**	**F**	**p**
Type	2	42.62	***<0.001***
Event	1	0.97	0.326
Station (Type)	9	5.37	***<0.001***
Error	120		
	TSS/Turbidity		
Source	**df**	**F**	**P**
Type	2	12.32	***<0.001***
Event	1	0.00	0.954
Station (Type)	9	4.26	***<0.001***
Error	83		

Appendix B-13. Results of ANOVA of water quality measures in the Golf Course dataset. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	Fecal Coliform		
Source	**df**	**F**	**p**
Event	1	75.74	***<0.001***
Station	6	17.43	***<0.001***
Error	220		
	TN		
Source	**df**	**F**	**p**
Event	1	1.15	0.284
Station	6	3.82	***0.001***
Error	181		
	TP		
Source	**df**	**F**	**P**
Event	1	16.69	***<0.001***
Station	6	39.07	***<0.001***
Error	183		
	TSS/Turbidity		
Source	**df**	**F**	**P**
Event	1	43.85	***<0.001***
Station	6	14.14	***<0.001***
Error	226		

Appendix B-14. Results of ANOVA of water quality measures in the Rain Event dataset. P-values in bolded italics indicate significance at 0.05; p-values in italics indicate marginal significance at 0.10.

	Fecal Coliform		
Source	**df**	**F**	**p**
Data set	3	13.13	***<0.001***
Station (Data set)	14	3.43	***<0.001***
Error	105		
	TN		
Source	**df**	**F**	**p**
Data set	3	16.42	***<0.001***
Station (Data set)	14	4.56	***<0.001***
Error	99		
	TP		
Source	**df**	**F**	**p**
Data set	3	58.89	***<0.001***
Station (Data set)	14	4.47	***<0.001***
Error	108		
	TSS/Turbidity		
Source	**df**	**F**	**p**
Data set	3	27.64	***<0.001***
Station (Data set)	14	5.63	***<0.001***
Error	90		

APPENDIX C: Stations Cross-referenced with Baseline Study

Appendix C-1. Continuous Water Quality/Quantity stations monitored as part of the May River Baseline Study (Van Dolah et al. 2004) cross-referenced with stations monitored by the Town of Bluffton and the Palmetto Bluff Development. Shown are stations nearby Baseline Study stations, the parameters those data sets have in common and an assessment of the comparability of the data sets (Good, Moderate, Low or Very Low).

	May River Baseline Study: Continuous Water Quality/Quantity Station		
	Pritchardville 02176711	**Bluffton 02176720**	**Brighton Beach 02172035**
Bluffton			
Stations Nearby	Continuous Sonde—Rose Dhu (S-RD)	Continuous Sonde—Verdier Cover (S-VC)	Continuous Sonde—Alljoy (S-AJ)
Common Parameters	temperature, specific conductance, dissolved oxygen	temperature, specific conductance, dissolved oxygen	temperature, specific conductance, dissolved oxygen
Comparability	Good; only one year of data in each data set	Good; only one year of data in each data set	Good; only one year of data in each data set
Palmetto Bluff			
Stations Nearby	Main Stem—M3	None	None
Common Parameters	temperature, specific conductance, dissolved oxygen	--	--
Comparability	Moderate; Pritchardsville collected continuously, while M4 collected at discrete times seasonally	--	--

Appendix C-2. Headwater Creek stations monitored as part of the May River Baseline Study (Van Dolah et al. 2004) cross-referenced with stations monitored by the Town of Bluffton and the Palmetto Bluff Development. Shown are stations nearby Baseline Study stations, the parameters those data sets have in common and an assessment of the comparability of the data sets (Good, Moderate, Low or Very Low). Baseline stations located outside of primary May River system not shown (L-10/BC).

	May River Baseline Study: Headwater Creek Station				
	U-10 (SC)	**U-11 (RD)**	**U-12 (PB)**	**M-10 (HC)**	**M-11 (BB)**
Bluffton					
Stations Nearby	Rain Event—Stoney Creek (R-SC); Volunteer Network—Stoney Creek (V-SC)	Rain Event—Rose Dhu (R-RD); Volunteer Network—Rose Dhu (V-RD)	None	Rain Event—Bluffton Village (R-BV);	None
Common Parameters	R-SC—turbidity, total nitrogen, total phosphorus, fecal coliform V-SC—temperature, salninty, dissolved oxygen	R-SC—turbidity, total nitrogen, total phosphorus, fecal coliform V-SC—temperature, salninty, dissolved oxygen	--	R-SC—turbidity, total nitrogen, total phosphorus, fecal coliform	--
Comparability	R-SC Very Low; R-SC collected only after rain events, U-10 collected seasonally V-SC Low; VSC much further downstream	R-RD Very Low; R-RD collected only after rain events, U-11 collected seasonally. V-RD Low; V-RD much further downstream	--	Very Low; R-BV collected only after rain events, M-10 collected seasonally; R-BV located far upland, M-10 located near mouth of drainage to May River	--
Palmetto Bluff					
Stations Nearby	None	None	Golf Course—2 (Headwater)	Main Stem—M2	None
Common Parameters	--	--	temperature, specific conductance, dissolved oxygen, pH, turbidity, total nitrogen, total phosphorus, fecal coliform	temperature, specific conductance, dissolved oxygen, pH, turbidity, total nitrogen, total phosphorus, fecal coliform	--
Comparability	--	--	Good	Very Low; M2 located in main stem of river while M-10 located intertidally in Heyward Creek	--

Appendix C-3. Tidal Creek and Open Water stations monitored as part of the May River Baseline Study (Van Dolah et al. 2004) cross-referenced with stations monitored by the Town of Bluffton and the Palmetto Bluff Development. Shown are stations nearby Baseline Study stations, the parameters those data sets have in common and an assessment of the comparability of the data sets (Good, Moderate, Low or Very Low). Baseline stations located outside of primary May River system not shown (L-03 and L-04).

	May River Baseline Study: Tidal Creek or Open Water Station							
	U-01	**U-02**	**U-03**	**M-01**	**M-02**	**M-03**	**L-01**	**L-02**
Bluffton								
Stations nearby	Continuous Sonde—Rose Dhu (S-RD)	None	None	None	None	None	Continuous Sonde—Alljoy (S-AJ)	None
Common Parameters	temperature, specific conductance, dissolved oxygen	--	--	--	--	--	temperature, specific conductance, dissolved oxygen	--
Comparability	Moderate; S-RD data collected continuously, U-01 data collected at discrete times seasonally	--	--	--	--	--	Moderate; S-AJ further upstream; S-AJ data collected continuously, L-01 data collected at discrete times seasonally	--
Palmetto Bluff								
Stations Nearby	Main Stem—M3	None	None	M2	None	None	None	None
Common Parameters	temperature, specific conductance, dissolved oxygen, pH, turbidity, total nitrogen, total phosphorus, fecal coliform	--	--	temperature, specific conductance, dissolved oxygen, pH, turbidity, total nitrogen, total phosphorus, fecal coliform	--	--	--	--
Comparability	Good; M3 started same year as Baseline Study occurred	--	--	Good; M2 further upstream; M2 started same year as Baseline Study occurred	--	--	--	--