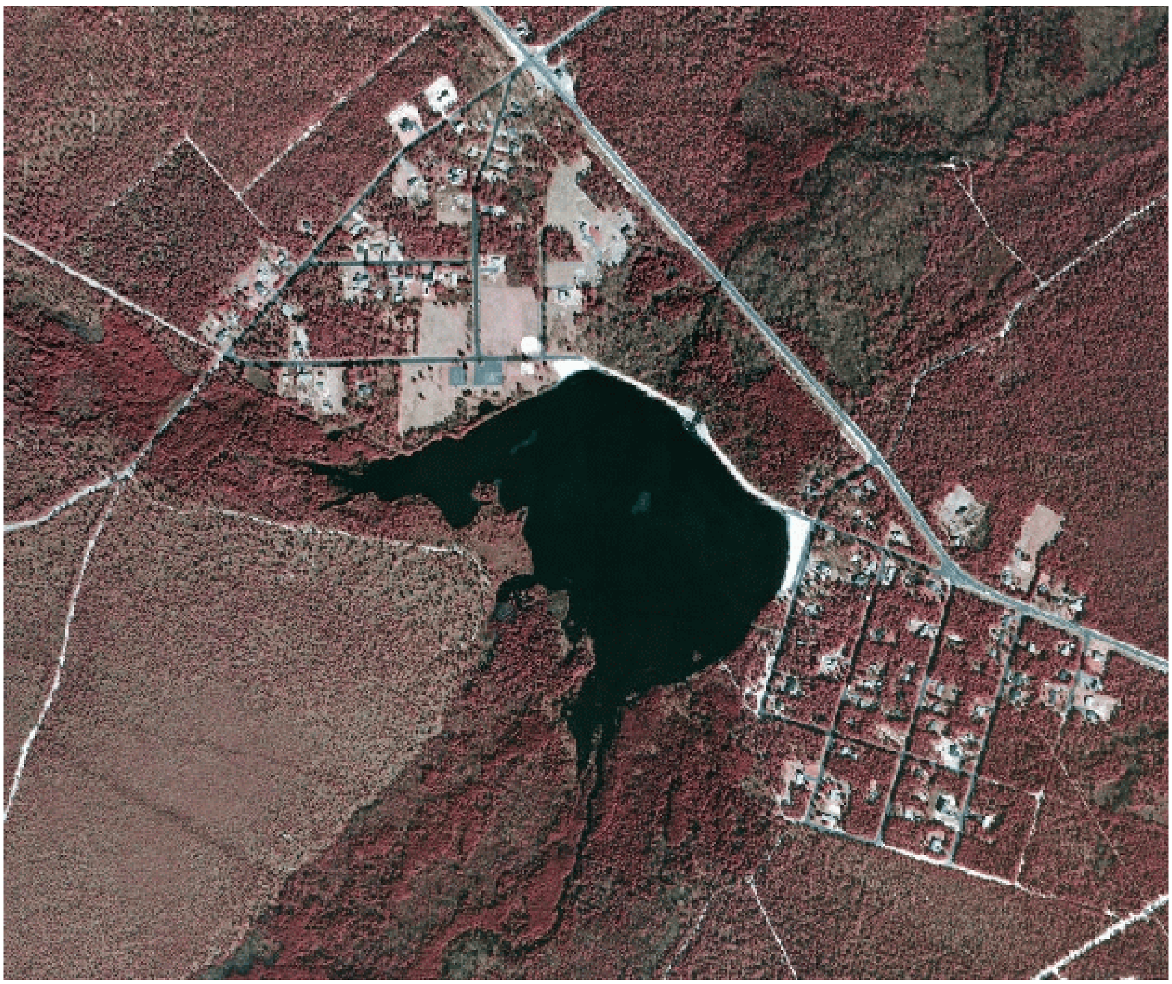
THE BARNEGAT BAY WATERSHED

A REPORT TO THE PINELANDS COMMISSION ON THE STATUS OF SELECTED AQUATIC AND WETLAND RESOURCES



Pinelands Commission
Long-term Environmental-monitoring Program
2006

Cover image is a 2002 color-infrared aerial photograph (by Keystone Aerial Surveys for the New Jersey Department of Environmental Protection) showing developed and forested land around Bamber Lake, which is located in the Cedar Creek drainage of the Barnegat Bay Watershed.

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A REPORT TO THE PINELANDS COMMISSION ON THE STATUS OF SELECTED AQUATIC AND WETLAND RESOURCES

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2006

Long-term Environmental-monitoring Program
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The study was supported with funds from the National Park Service. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U. S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U. S. Government.

INTRODUCTION

This report on the Barnegat Bay Watershed study area (Figure 1), which includes the Westecunk Creek, Cedar Creek, Toms River, Mill Creek, and Wrangel Brook study basins, is the fourth watershed assessment completed by the Pinelands Commission as part of a long-term environmental-monitoring program initiated in 1990. A study of the Mullica River Basin, which was the initial focus of the monitoring program, demonstrated that changes in the composition of stream vegetation, fish assemblages, and anuran (frog and toad) assemblages were associated with increasing land-use intensity and water-quality degradation (Zampella et al. 2001, Zampella et al. 2006). The presence of non-Pinelands plants and nonnative fish and anuran species characterized impacted stream and impoundment sites.

Based on the results of the Mullica River Basin study, less intense biological-sampling protocols were used to conduct assessments of the Rancocas Creek Basin and the Great Egg Harbor River Watershed Management Area (Zampella et al. 2003, 2005). Nonnative species, pH, and specific conductance were selected as the primary ecological indicators used to assess the status of surface waters in those two studies. Rather than completing multiple visits to 100-m stream reaches to inventory fish and vegetation as was done in the Mullica River Basin, Commission scientists targeted non-Pinelands plants and nonnative fish in 20-m stream reaches located at road crossings. By targeting the late-breeding bullfrog, a nonnative species that is generally found at degraded sites, anuran-vocalization surveys were limited to the latter part of the anuran-breeding season.

The Rancocas Creek Basin and Great Egg Harbor River Watershed Management Area sampling sites were co-located with New Jersey Department of Environmental Protection (NJDEP) ambient-biomonitoring-network (AMNET) sites. The NJDEP operates the AMNET program throughout the state. Benthic macroinvertebrate (aquatic insects and other macroscopic aquatic invertebrates) data collected through this program are used in the development of a federally required water-quality assessment and other watershed-based regulatory and planning programs.

In 2003, Commission scientists surveyed streams and impoundments in the Barnegat Bay Watershed study area. The same ecological indicators, sampling protocols, and sampling-network strategy used in the Rancocas Creek Basin and the Great Egg Harbor River Watershed Management Area were used in the Barnegat Bay Watershed assessment. The purpose of this report is to present the results of these surveys.

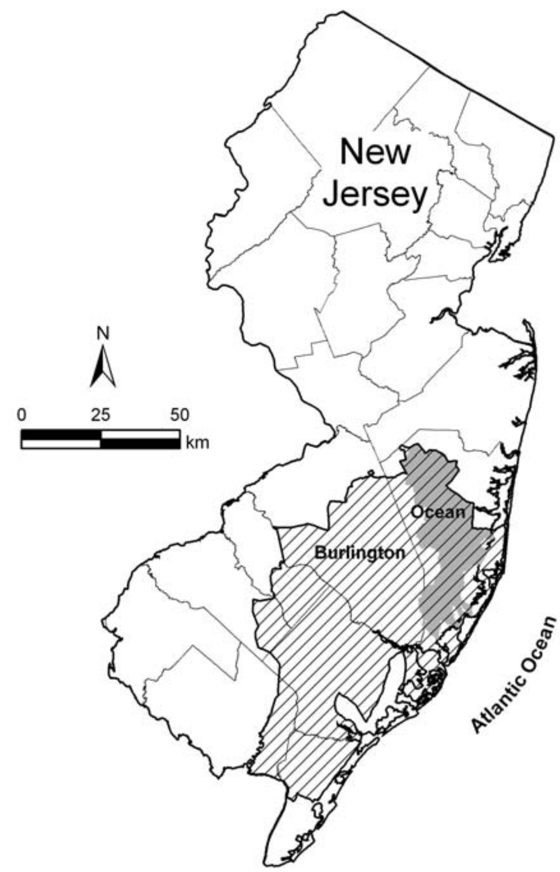

Figure 1. Regional location of the Barnegat Bay Watershed study area (shaded) in the Pinelands National Reserve (cross hatch).

All water-quality and biological data collected during the study are included in appendices to this report. Chapter 1 describes the landscape of the Barnegat Bay Watershed study area. Chapter 2 characterizes the status of the region's surface waters and relates water quality to land-use patterns. In Chapters 3 through 5, the composition of stream vegetation, fish assemblages, and anuran assemblages is described in relation to site-specific and regional drainage-basin characteristics. The report also includes a summary and synthesis that relates the results of the study to the Mullica River Basin, Rancocas Creek Basin, and Great Egg Harbor River Watershed Management Area assessments.

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1 THE BARNEGAT BAY WATERSHED STUDY AREA

INTRODUCTION

The 747 km^2 Barnegat Bay Watershed study area is located in the Pinelands National Reserve (PNR) and includes five major study basins: Westecunk Creek, Cedar Creek, Toms River, Mill Creek, and Wrangel Brook (Figure 1.1). These streams drain all or portions of 16 municipalities in Burlington County and Ocean County (Figure 1.2). Some Toms River study-basin streams originate outside the PNR or flow beyond the PNR boundary. The upstream portions of the other four study basins are located entirely within the PNR. In this chapter, the geology, land-use characteristics, and Pinelands management-area designations of each study basin are described.

DEVELOPMENT OF GEOLOGIC, LAND-USE, AND MANAGEMENT-AREA PROFILES

Geologic Profiles

A profile of the surficial geology associated with the study area was created using digital data obtained from the New Jersey Department of Environmental Protection (NJDEP 1996) (Figure 1.3). Each geologic unit was summed and expressed as a percentage of the entire study area.

Drainage-basin Delineations

Drainage-basin boundaries used throughout this report were prepared using ArcView software and digital hydrography data (NJDEP 1996). Basin boundaries were not available for some monitoring sites. These basins were delineated using digital-topographic maps, ArcView software, and on-screen digitizing.

Land-use Profiles

Land-use profiles were prepared for each monitoring site by summing the area of major NJDEP land-use/land-cover classes (1995/97 Land Use/Land Cover Update, released 2001) for the drainage area upstream from the site. Land-use profiles were also prepared for the five study basins and the entire Barnegat Bay Watershed study area. The NJDEP data set describes land use using both the general Anderson Level I classification and various subclasses (Anderson et al. 1976). Wetlands are classified according to Cowardin et al. (1979). The general classes include urban, agriculture, barren land, forest, wetlands, and water. A revised Pinelands terminology is used throughout this report (Figure 1.4, Table 1.1). Pinelands land-use types are developed land, upland agriculture (including orchards), wetland agriculture, barren land, upland forest, wetlands, and water. In this report, the combined area of upland forest, wetlands, and water is described as forest land. Upland agriculture and developed land are referred to as altered land.

Pinelands Management Areas

The Commission's regional-planning and land-allocation program divides the PNR into several management areas within which land uses of varying

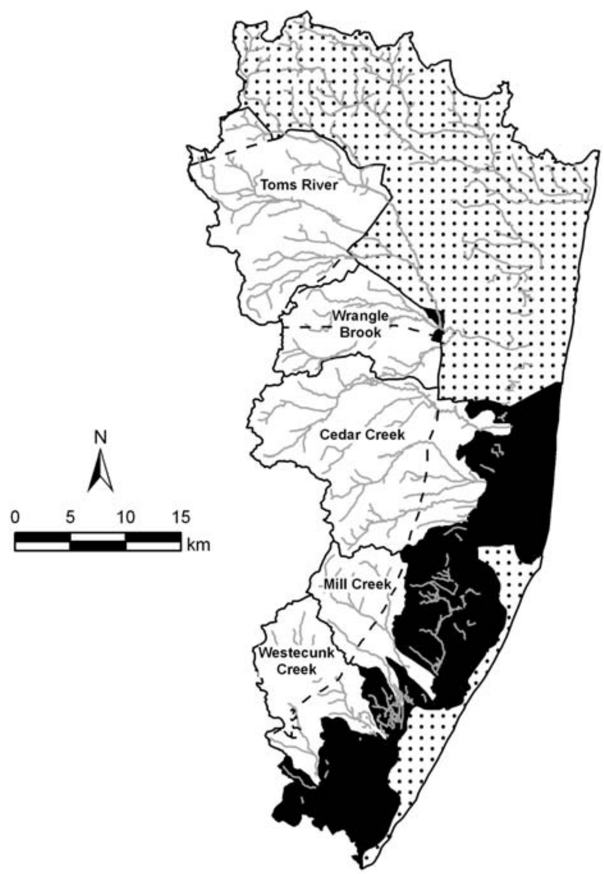

Figure 1.1 Five study basins in the Barnegat Bay Watershed study area. Areas in black are in the Pinelands National Reserve (PNR) but outside the study basins. Stippled areas are outside the PNR. The dashed line represents the Pinelands Area boundary. The outer boundary represents the Barnegat Bay Watershed Management Area (NJDEP 2000).

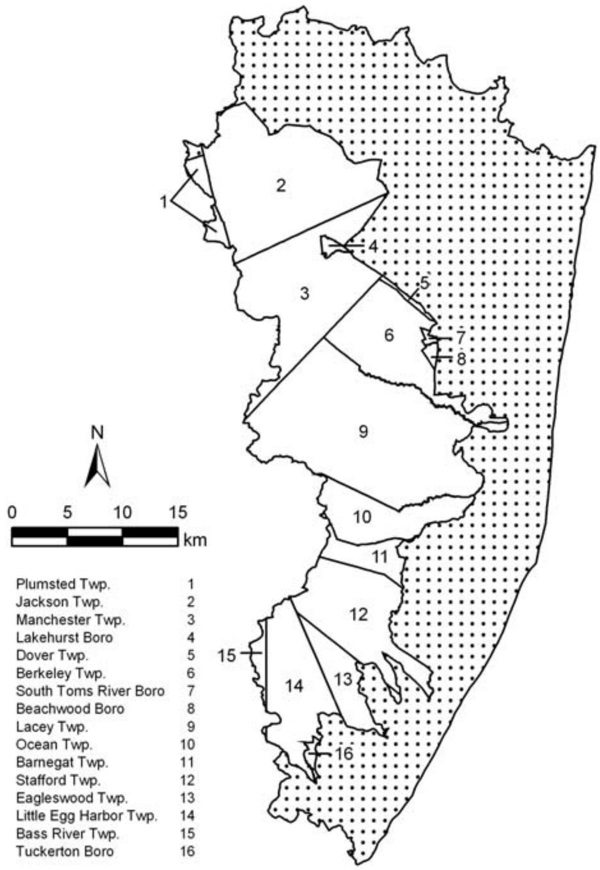

Figure 1.2. Municipalities in the Barnegat Bay Watershed study area. Stippled areas are outside the study area.

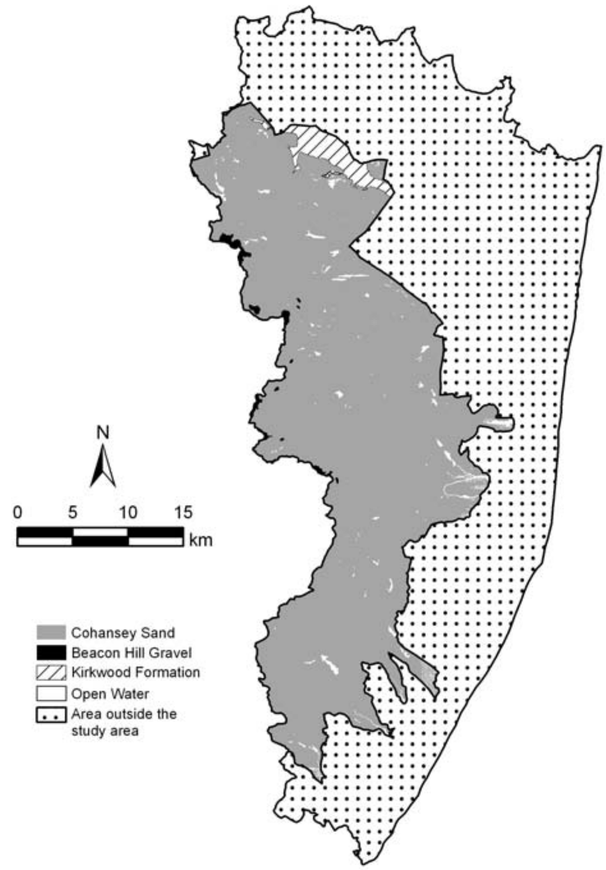

Figure 1.3. Surficial geology of the Barnegat Bay Watershed study area. Stippled areas are outside the study area.

intensities are permitted (Pinelands Commission 1980, Collins and Russell 1988). In order of increasing permitted-development intensity, management areas in the Barnegat Bay Watershed study area include the Preservation Area District, Forest Area, Agricultural Production Area, Rural Development Area, Pinelands Village, Pinelands Town, and Regional Growth Area (Figure 1.5). Military and Federal Installation Areas are also present in the study area. Management-area profiles were prepared for each study basin using ArcView software and a management-area coverage (Pinelands Commission, Land Capability Map, November 2005).

THE BARNEGAT BAY WATERSHED STUDY AREA

The Cohansey Sand underlies nearly all of the study area with the overlying Beacon Hill Gravel present in small areas totaling less than one percent of the study area (Figure 1.3). Underlying the Cohansey Sand is the Kirkwood Formation, which outcrops in the northern portion of the PNR, covering 2.9% of the study area.

Eighty-four percent of the Barnegat Bay Watershed study area is undeveloped forest land, including upland forest, wetlands, and water (Figures 1.4 and 1.6). Developed land and upland agriculture cover 12.6% and 1.0% of the area, respectively. About three percent is barren land. Less than one percent is wetland agriculture.

Thirty-six percent of the Barnegat Bay Watershed study area is classified as Forest Area and 29.3% is Preservation Area District (Figures 1.5 and 1.7). Nineteen percent is designated Regional Growth Area and 7.7% is classified as Rural Development Area. Pinelands Villages, Pinelands Towns, and Agricultural Production Areas represent a relatively small percentage of the study area. The Military and Federal Installation Areas represent 4.7% of the study area and include portions of Fort Dix and the Lakehurst Naval Air Engineering Station.

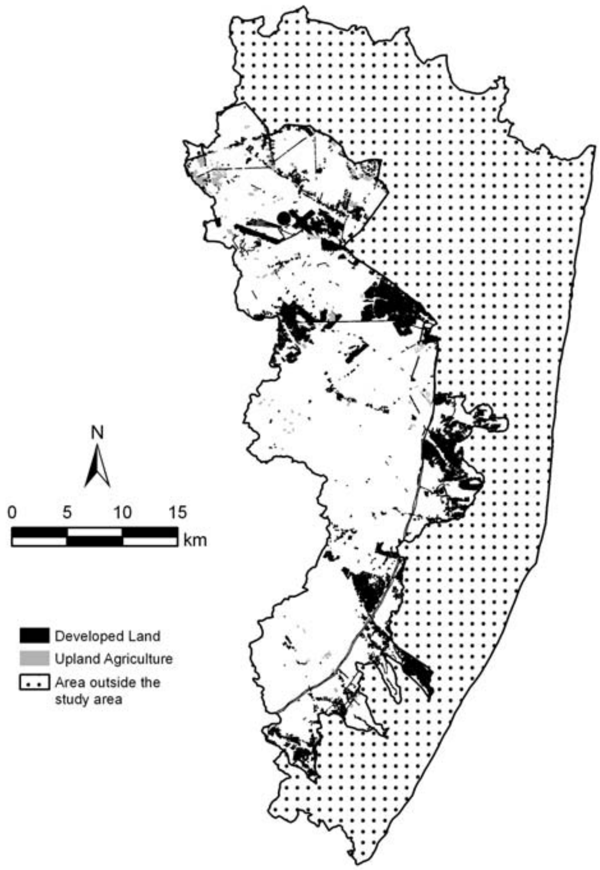

Figure 1.4. Developed land and upland agriculture in the Barnegat Bay Watershed study area. Unshaded areas represent forest land (uplands, wetlands, and water) and barren lands. Stippled areas are outside the study area.

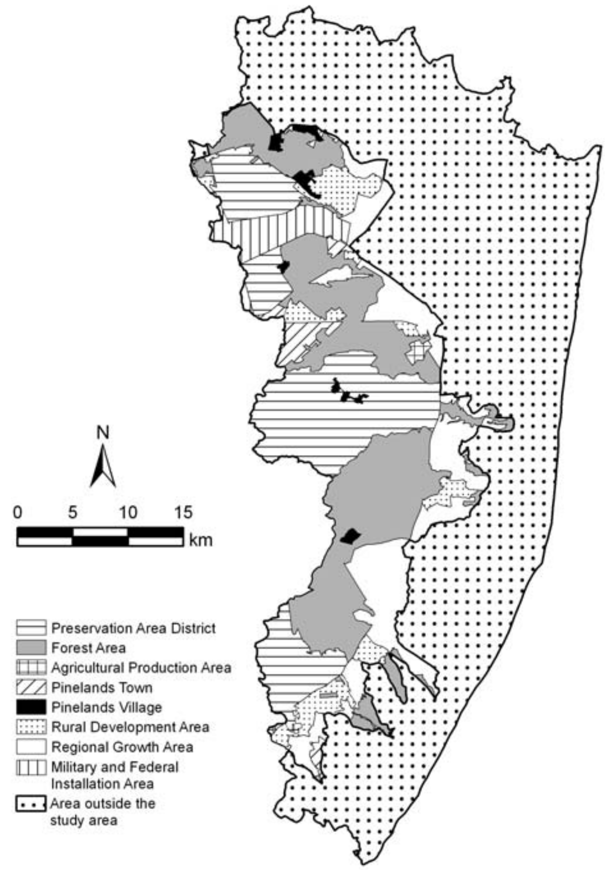

Figure 1.5. Pinelands Management Areas in the Barnegat Bay Watershed study area. Stippled areas are outside the study area.

Westecunk Creek

The 102-km^2 Westecunk Creek study basin lies entirely within the PNR within Burlington and Ocean Counties. The study basin includes the Westecunk Creek, Governors Branch, Threemile Branch, Log Swamp Branch, Rail Branch, Tuckerton Creek, and Giffords Mill Branch. Forest land covers 90.8% of the study area (Figures 1.4 and 1.6). The predominance of forest land is reflected in the classification of 43.1% of the basin as Preservation Area District and 23.3% as Forest Area (Figures 1.5 and 1.7). Regional Growth Areas and Rural Development Areas account for 16.1% and 14.9% of the study basin, respectively.

Cedar Creek

The 251-km^2 Cedar Creek study basin is located in Ocean County and lies almost entirely within the PNR. This study basin includes the Cedar Creek, Webbs Mill Branch, Chamberlain Branch, Factory Branch, Forked River, Oyster Creek, and Waretown Creek. About 89% of this study basin is forest land (Figures 1.4 and 1.6), which is reflected in the designation of the majority of the basin as Preservation Area District or Forest Area (Figures 1.5 and 1.7). About 14% of the study basin is classified as Regional Growth Area.

Toms River

The Toms River study basin lies entirely within Ocean County. Nearly 65% of the study basin is within the PNR. The 205-km^2 portion of the study basin in the PNR includes the Toms River, Mirey Run, Maple Root Branch, Dove Mill Branch, Cabin Branch, Ridgeway Branch, Shannae Brook, Bordens Mill Branch, Manapaqua Brook, Union Branch, Blacks Branch, and Old Hurricane Brook. Eighty-two percent of the study basin is composed of forest land (Figures 1.4 and 1.6). Altered land (upland agriculture and developed land) constitutes almost

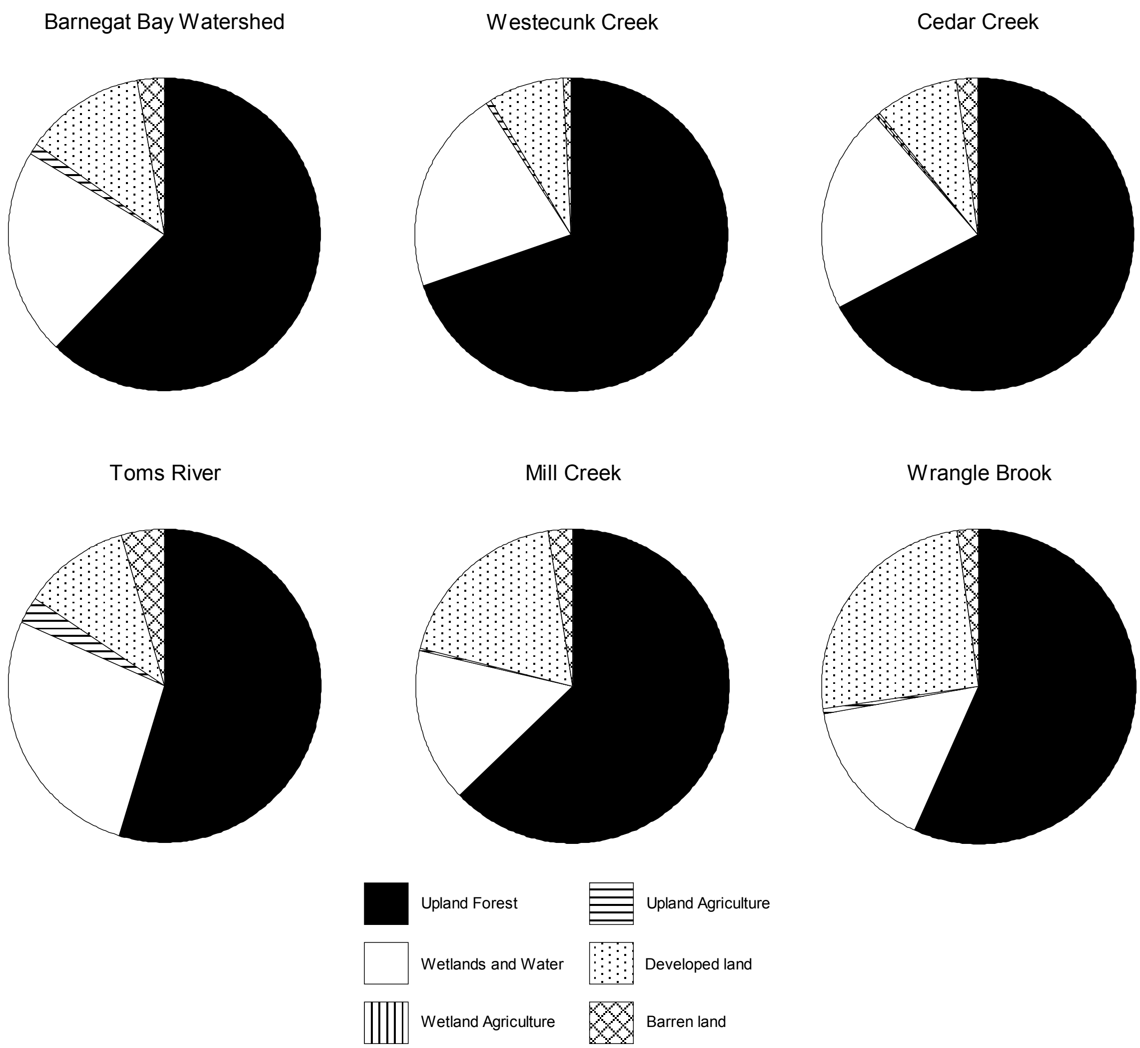

Figure 1.6. Land-use profiles for the Barnegat Bay Watershed study area and individual study basins. Refer to Table 1.1 for descriptions of each land-use/land-cover class.

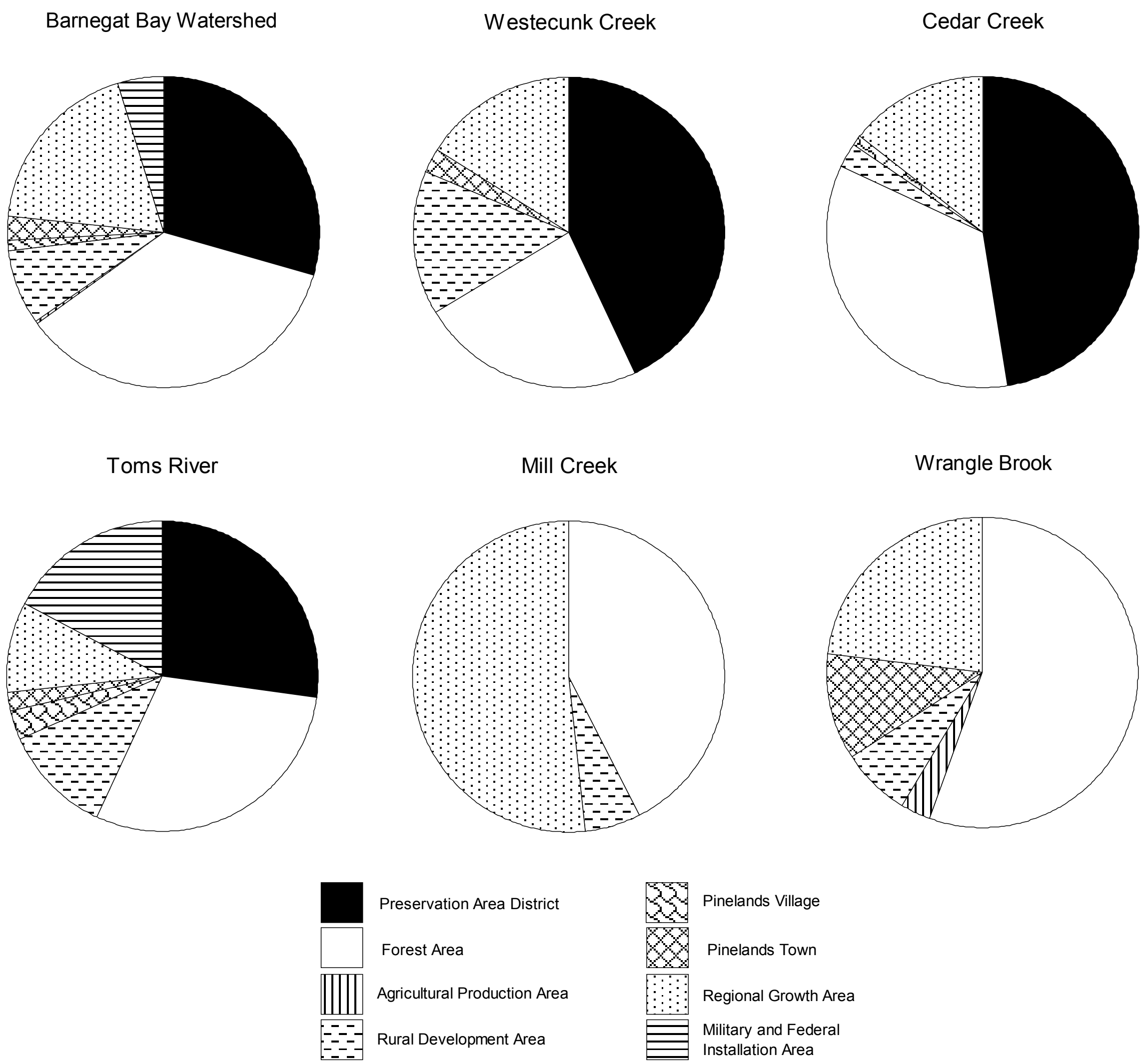

Figure 1.7. Management-area profiles for the Barnegat Bay Watershed study area and individual study basins.

Table 1.1. New Jersey Department of Environmental Protection land-use/land-cover classes and the revised Pinelands terminology.

Pinelands classes	NJDEP classes	Code	Subclasses (NJDEP 95 Label)
Developed land	Urban	1110	Residential, high density, multiple dwelling
		1120	Residential, single unit, medium density
		1130	Residential, single unit, low density
		1140	Residential, rural, single unit
		1150	Mixed residential
		1200	Commercial/services
		1211	Military reservations
		1300	Industrial
		1400	Transportation/communications/utilities
		1600	Mixed urban or built-up land
		1700	Other urban or built-up land
		1800	Recreational land
		1804	Athletic fields (schools)
Upland agriculture	Agriculture	2100	Cropland and pastureland
		2300	Confined feeding operations
		2400	Other agriculture
		2200	Orchards/vineyards/nurseries/horticultural areas
Wetland agriculture	Wetlands	2140	Agricultural wetlands (modified)
Barren land	Barren land	7100	Beaches
		7300	Extractive mining
		7400	Altered lands
		7500	Transitional areas
		7600	Undifferentiated barren lands
Upland forest	Forest	4110	Deciduous forest (10-50% crown closure)
		4120	Deciduous forest (>50% crown closure)
		4210	Coniferous forest (10-50% crown closure)
		4220	Coniferous forest (>50% crown closure)
		4230	Plantation
		4311	Mixed forest (>50% coniferous with 10%-50% crown closure)
		4312	Mixed forest (>50% coniferous with >50% crown closure)
		4321	Mixed forest (>50% deciduous with 10-50% crown closure)
		4322	Mixed forest (>50% deciduous with >50% crown closure)
		4410	Old field (< 25% brush covered)
		4420	Deciduous brush/shrubland
		4430	Coniferous brush/shrubland
		4440	Mixed deciduous/coniferous brush/shrubland
		4500	Severe burned upland vegetation
Water	Water	5100	Streams and canals
		5200	Natural lakes
		5300	Artificial lakes
		5410	Tidal rivers, inland bays, and other tidal waters
		5420	Dredged lagoon
		5430	Atlantic ocean
Wetlands	Wetlands	1461	Wetland rights-of-way (modified)
		1750	Managed wetland in maintained lawn greenspace
		1850	Managed wetland in built-up maintained rec area
		2150	Former agricultural wetland (becoming shrubby, not built-up)
		6210	Deciduous wooded wetlands
		6220	Coniferous wooded wetlands
		6221	Atlantic white cedar swamp
		6231	Deciduous scrub/shrub wetlands
		6232	Coniferous scrub/shrub wetlands
		6233	Mixed scrub/shrub wetlands (deciduous dom.)
		6234	Mixed scrub/shrub wetlands (coniferous dom.)
		6240	Herbaceous wetlands
		6251	Mixed forested wetlands (deciduous dom.)
		6252	Mixed forested wetlands (coniferous dom.)
		6500	Severe burned wetlands
		7430	Disturbed wetlands (modified)
		6110	Saline marshes
		6130	Vegetated dune communities

14% of the study basin and is concentrated in the Ridgeway Branch drainage. Much of the developed land in the study basin is associated with the Lakehurst Naval Air Engineering Station (Figures 1.4 and 1.5). About 55% of the study basin is designated as Preservation Area District and Forest Area. Rural Development Area and Regional Growth Area represent 20.5% of the study basin. Military and Federal Installation Area represents 17.3% of the study basin (Figures 1.5 and 1.7).

Mill Creek

The Mill Creek study basin includes Mill Creek, Eightmile Branch, Fourmile Branch, and Cedar Run. The entire 82.7-km^2 study basin is located within the PNR. About 78% of the study basin is forest land (Figures 1.4 and 1.6). Altered land accounts for 18.7% of the study basin. Fifty-two percent of the study basin is designated as Regional Growth Area and 5.9% is classified as Rural Development Area. Forest Area accounts for 42.5% of the study basin (Figures 1.5 and 1.7). This study basin does not contain Preservation Area District.

Wrangel Brook

The 107-km^2 Wrangel Brook study basin includes Sunken Branch, Wrangel Brook, Michaels Branch, Tice Van Horn Branch, Davenport Branch, and Jakes Branch. Nearly all of this study basin lies within the PNR. Forest land covers 72.2% of the study basin and altered land covers 25.5% of the study basin (Figures 1.4 and 1.6). Forty-two percent of the study basin is designated as Regional Growth Area, Rural Development Area, and Pinelands Town. Fifty-six percent of the study basin is designated as Forest Area (Figures 1.5 and 1.7). Preservation Area District represents less than one percent of this study basin.

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2 WATER QUALITY

INTRODUCTION

Throughout the Pinelands, variations in stream-water quality are associated with the extent of land-use disturbance in a watershed (Morgan and Good 1988, Zampella 1994, Dow and Zampella 2000, Zampella et al. 2001, 2003, 2005). Pinelands stream sites with extensive, upstream altered land (development and upland agriculture) generally display higher pH and specific conductance values and higher concentrations of dissolved solids than stream sites in basins with little altered land. Elevated pH in degraded streams appears to be related to an increase in primary productivity associated with nutrient enrichment (Morgan 1985) and increases in alkalinity. In most Pinelands waters, specific conductance, which is a measure of the ability of water to conduct an electrical current, is influenced by the presence of calcium, magnesium, sodium, potassium, chloride, and sulfate ions. The contribution of hydrogen ions to specific conductance becomes important at very low pH values (Dow and Zampella 2000, Zampella et al. 2001).

In the Pinelands, water-quality degradation, represented by changes in pH and specific conductance, has ecological consequences. Variations in pH and specific conductance are associated with variations in other water-quality parameters, such as increased nutrient and ion concentrations (Zampella 1994, Zampella et al. 2001), and changes in the composition of biological communities (Morgan and Philipp 1986, Zampella and Laidig 1997, Zampella and Bunnell 1998, Zampella and Bunnell 2000, Zampella et al. 2001, 2003, 2005, 2006).

In this chapter, the relationship between land use and pH and specific conductance is described for water-quality monitoring sites in the Barnegat Bay Watershed. Water-quality data collected through a cooperative Pinelands Commission-Ocean County Health Department water-quality program are also summarized.

METHODS

Field Measurements of pH and Specific Conductance

From January though November 2003, Pinelands Commission staff measured specific conductance and pH monthly at 64 stream sites throughout the Barnegat Bay Watershed study area (Table 2.1, Figure 2.1). At each monitoring site, grab samples were collected directly from the stream or lake outflow using a one-liter Nalgene plastic bottle that was rinsed three times with stream water. Samples were collected under baseflow or near baseflow conditions. Most sites were sampled on nine to ten occasions. Six sites were sampled on fewer than nine occasions.

An Orion model-250a pH meter with automatic temperature compensation and a ROSS combination electrode was used to measure pH. An Orion model-122 conductivity meter with temperature compensation was used to measure specific conductance. To ensure adequate stabilization of the pH meter, pH was measured in three separate 250 ml samples that were split from the grab sample and the third measurement was recorded. The specific conductance of the third sample was also measured and recorded. Using two pH buffers (4.0 and 7.0) that bracket the expected pH range found in Pinelands streams, the pH meter was calibrated at the beginning of every sampling day and after every three hours of use. The conductance meter was checked monthly against two United States Geological Survey standards (50 $\mu S\ cm^{-1}$ and 100 $\mu S\ cm^{-1}$). All calibration data were recorded.

Pinelands Commission-Ocean County Health Department Water-quality Data

The Pinelands Commission and the Ocean County Health Department conducted a cooperative water-quality monitoring program throughout the Barnegat Bay Watershed. Twenty sites were sampled quarterly from February 1988 through May 1992 (Table 2.2, Figure 2.1). Pinelands Commission staff collected all water samples and field pH and specific conductance data, and the Ocean County Health Department completed the nutrient analyses. Field and laboratory methods used in the program are described in Zampella et al. (1994).

Water-quality data collected at the Barnegat Bay Watershed stream sites from 1988 through 1991 were summarized and related to land use in an earlier Pinelands Commission report (Zampella et al. 1994). Hunchak-Kariouk and Nicholson (2001) also included the Pinelands Commission data in an assessment of Barnegat Bay streams.

Table 2.1 Water-quality monitoring sites in the Barnegat Bay Watershed. Median pH and specific conductance (SC, $\mu S\ cm^{-1}$) values for the period January through November 2003 for 64 sites are shown. Sites with a sample size (n) less than 9 are noted with an asterisk and were not included in the water-quality analyses and results. Altered land represents the combined percentage of developed land and upland agriculture. Refer to Figure 2.1 for site locations. Refer to Appendix 1 for full site descriptions and monthly water-quality data.

			Percentage Land Use					
Site Name	Site Code	Map Number	Developed Land	Upland Agriculture	Altered Land	pH	SC	n
Westecunk Creek Study Basin								
Mill Branch at Nugentown Road	WMINUGEN	63	2.4	0.0	2.4	4.4	61	10
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	64	9.0	0.1	9.1	4.4	67	9
Mill Branch at Poor Mans Parkway*	WMIPOORM	62	0.7	0.0	0.7	4.0	124	7
Three Mile Branch at Pollypod Road	WTHPOLLY	59	0.0	0.3	0.3	4.5	48	10
Westecunk Creek at Forge Road	WWEFORGS	60	0.8	0.5	1.2	4.7	39	10
Westecunk Creek at Railroad Avenue	WWERAILR	61	2.6	0.6	3.2	4.6	48	10
Cedar Creek Study Basin								
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	42	2.1	0.5	2.6	4.6	41	9
Cedar Creek at Double Trouble Road	CCEDOUBS	44	1.8	0.4	2.2	4.6	43	10
Cedar Creek at Route 614	CCELACEY	41	0.8	0.5	1.2	4.7	34	10
Cedar Creek at Route 9	CCEROUT9	45	5.6	0.5	6.1	4.4	53	10
Chamberlain Branch at an unnamed road	CCHSANDR	40	0.3	0.7	1.0	4.4	38	10
Factory Branch at Route 614	CFALACEY	43	0.0	0.0	0.0	4.3	55	10
Long Branch at Bryant Road	CLOBRYAN	46	0.4	0.0	0.4	4.0	87	10
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	48	3.2	0.0	3.2	4.5	64	9
North Branch Forked River at Parker Avenue (Lower Lake)*	CNOLOWER	49	10.3	0.0	10.3	5.0	64	4
North Branch Forked River at a powerline right-of-way	CNOPOWER	47	0.2	0.0	0.2	4.2	57	10
Oyster Creek at Route 532	COYRT532	51	2.7	0.2	2.9	4.4	53	10
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	50	4.0	0.4	4.4	4.7	56	9
Waretown Creek at Route 9	CWAROUT9	52	10.9	0.1	11.0	4.4	97	10
Webbs Mill Branch at Route 539	CWERT539	39	0.5	1.1	1.6	4.7	32	10
Toms River Study Basin								
Blacks Branch at Central Avenue	TBLCENTR	17	9.9	0.4	10.3	4.8	31	10
Blacks Branch at Route 70	TBLRTE70	20	5.6	0.6	6.1	4.3	46	10
Bordens Mill Branch impoundment - lower*	TBOHAWLW	11	7.0	27.1	34.1	4.6	37	8
Cabin Branch at New Jersey Central Railroad*	TCARAILR	16	10.3	8.2	18.5	6.1	120	6
Dove Mill Branch at Grawtown Road	TDOGRAWT	7	18.5	4.5	23.0	5.3	87	10
Dove Mill Branch impoundment at Route 528	TDOIM528	6	15.1	3.3	18.4	5.2	73	9
Maple Root Branch at Bowman Road	TMABOWMA	5	3.6	2.3	5.9	4.1	70	10
Manapaqua Brook at Route 70	TMARTE70	22	44.1	0.4	44.6	5.5	60	10
Mirey Run at Route 528	TMIRT528	3	20.3	5.9	26.2	6.0	180	10
Old Hurricane Brook at Beckerville Road	TOLBECKE	18	4.7	1.2	5.9	4.1	72	10
Old Hurricane Brook at Route 70	TOLRTE70	19	5.8	1.2	7.0	4.1	75	10
Ridgeway Branch at Hangar Road	TRIHANGA	14	7.4	5.4	12.8	4.3	65	10
Ridgeway Branch at High Bridge Road	TRIHIGHB	13	6.4	6.5	13.0	4.2	64	10
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	15	9.3	4.9	14.2	4.5	70	10
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	12	6.7	8.6	15.4	4.5	58	10
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	10	13.1	23.9	37.0	6.3	82	10
Shannae Brook impoundment	TSHUPPER	9	4.3	2.5	6.8	4.6	59	9
Toms River at Bowman Road*	TTOBOWMA	4	18.8	4.4	23.2	6.0	138	6
Toms River at Route 528	TTORT528	2	18.7	4.1	22.7	6.0	130	10
Toms River at Route 547	TTORT547	8	15.3	4.1	19.4	5.5	114	10
Toms River tributary at Route 571	TTOTR571	1	9.1	0.6	9.7	5.3	50	9
Union Branch at Colonial Drive	TUNCOLON	23	16.4	0.6	17.0	4.6	71	10
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	21	5.7	0.7	6.4	4.2	62	9
Mill Creek Study Basin								
Cedar Run at Route 9	MCEROUT9	58	5.2	0.1	5.3	4.5	76	10
Fourmile Branch at Lighthouse Drive	MFOLIGHT	53	12.5	0.1	12.6	5.2	59	10
Fourmile Branch at Oxycocus Street	MFOOXYCO	54	18.6	0.7	19.4	5.8	83	10
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	57	18.6	0.3	18.9	5.7	104	10
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	56	16.0	0.0	16.0	5.9	67	10
Mill Creek at Hay Road	MMIHAYRD	55	4.9	0.1	4.9	4.6	42	10
Wrangel Brook Study Basin								
Davenport Branch at Lake Road (Harry Wright Lake)*	RDAHARRY	31	22.7	0.0	22.7	6.1	62	2
Davenport Branch at Route 614	RDALACES	33	35.1	0.8	36.0	4.8	72	10
Davenport Branch at Mule Road	RDAMULER	35	27.9	0.3	28.2	4.4	61	10
Davenport Branch at Route 530	RDART530	34	22.9	0.5	23.4	4.3	67	10
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	32	18.0	0.0	18.0	4.6	64	9
Jakes Branch at Double Trouble Road	RJADOUBL	38	7.6	0.3	7.9	4.4	57	10
Jakes Branch at Dover Road	RJADOVER	37	0.0	0.0	0.0	4.0	104	10
Sunken Branch at Mule Road	RSUMULER	27	47.6	0.0	47.6	6.1	86	10
Sunken Branch at Township Line Road	RSUTOWNS	26	18.6	0.0	18.6	4.6	54	9
Tice Van Horn Branch at Keswick Lake	RTIKESWI	28	53.8	0.0	53.8	5.5	97	9
Tice Van Horn Branch tributary at Route 530	RTITR530	29	57.4	1.4	58.8	5.1	90	9
Wrangel Brook at Congasia Road	RWRCONGA	24	2.1	0.1	2.2	4.2	55	10
Wrangel Brook at Mule Road	RWRMULER	30	20.6	1.0	21.6	4.8	67	10
Wrangel Brook at South Hampton Road	RWRSOUTH	36	29.1	0.7	29.8	5.0	71	10
Wrangel Brook at Township Line Road	RWRTOWNS	25	1.0	0.0	1.0	4.3	57	9

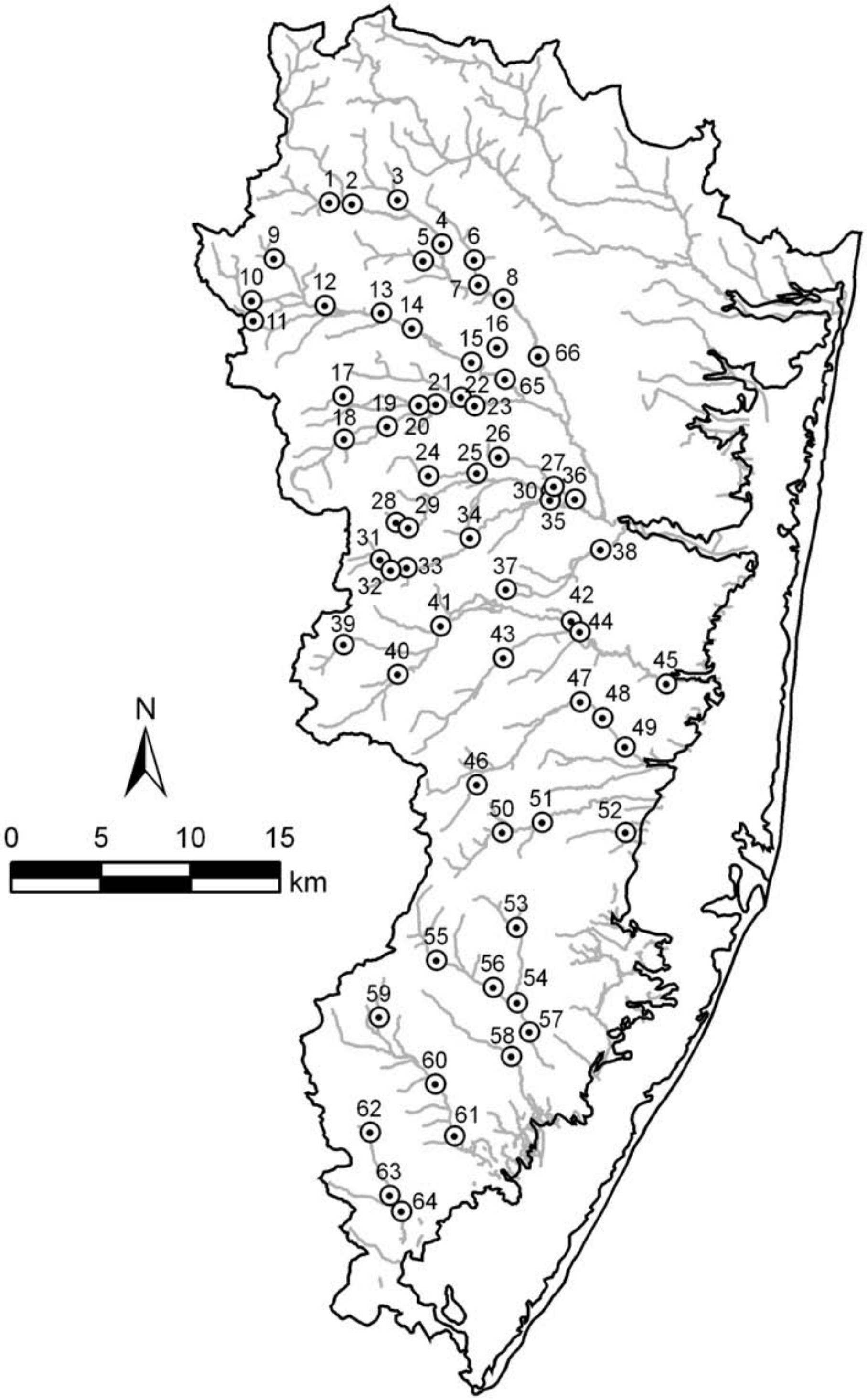

Figure 2.1. Location of 64 pH and specific conductance monitoring sites in the Barnegat Bay Watershed. Sites 1, 2, 3, 4, 6, 7, and 8 are located on streams that drain areas outside the Pinelands National Reserve (PNR). Sites 22 and 23 are located immediately outside of the PNR. Refer to Table 2.1 for site names. A subset of these 64 sites, along with sites 65 and 66, were sampled as part of a cooperative Pinelands Commission-Ocean County Health Department program. Sites 65 and 66 are outside of the PNR. Refer to Table 2.2 for the cooperative program site names.

Table 2.2. Twenty Pinelands Commission-Ocean County Health Department nutrient-monitoring sites in the Barnegat Bay Watershed. Median nitrite plus nitrate as nitrogen (NO_x), ammonia as nitrogen, and total phosphorus as phosphorus concentrations are expressed as mg L^{-1}. The number of samples (n) is shown in parentheses. All sites were sampled from February 1988 through May 1992. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin. Two codes are given for each sampling site, including the Barnegat Bay Watershed (BBW) site codes used throughout this report (e.g., RJADOVER) and the original Pinelands Commission-Ocean County (PC-OC) codes (e.g., OCN032) used by Zampella et al. (1994). Union Branch at Route 37 (PTR8) is approximately one mile downstream from the BBW study site (TUNHORIC). Refer to Figure 2.1 for site locations.

				Median Values					
Site Name	BBW Site Code	PC-OC Site Code	Map Number	pH	Specific Conductance	Nitrite + Nitrate as N	Ammonia as N	Total P as P	Altered Land
Westecunk Creek Study Basin									
Westecunk Creek at Forge Road	WWEFORGS	OCN059	60	4.9 (17)	28 (17)	0.02 (17)	<0.05 (16)	0.01 (18)	1.2
Cedar Creek Study Basin									
Cedar Creek at Double Trouble Road	CCEDOUBS	OCN044	44	4.6 (17)	32 (16)	0.02 (18)	<0.05 (15)	<0.01 (17)	2.2
Cedar Creek at Route 614	CCELACEY	OCN045	41	4.7 (17)	27 (16)	0.02 (18)	<0.05 (16)	<0.01 (18)	1.2
Factory Branch at Route 614	CFALACEY	PCC2	43	4.2 (17)	42 (16)	0.01 (18)	<0.05 (16)	<0.01 (17)	0.0
North Branch Forked River at a powerline right-of-way	CNOPOWER	PFR4A	47	4.3 (17)	41 (16)	0.03 (18)	<0.05 (16)	<0.01 (17)	0.2
Oyster Creek at Route 532	COYRT532	OCN051	51	4.5 (17)	38 (16)	0.03 (18)	<0.05 (16)	<0.01 (18)	2.9
Toms River Study Basin									
Maple Root Branch at Bowman Road	TMABOWMA	PTR2	5	4.0 (16)	68 (15)	0.02 (17)	<0.05 (14)	0.01 (17)	5.9
Old Hurricane Brook at Route 70	TOLRTE70	PTR7	19	4.1 (17)	62 (15)	0.03 (18)	<0.05 (15)	0.01 (17)	7.0
Ridgeway Branch at High Bridge Road	TRIHIGHB	PTR5	13	4.1 (17)	57 (16)	0.03 (18)	<0.05 (15)	0.01 (17)	13.0
Toms River at Route 528	TTORT528	OCN030	2	5.5 (17)	66 (16)	0.34 (18)	<0.05 (15)	0.04 (18)	22.7
Toms River at Route 547	TTORT547	OCN029	8	4.9 (17)	64 (16)	0.30 (18)	<0.05 (15)	0.03 (17)	19.4
Ridgeway Branch at Route 70		OCN028	65	5.1 (17)	68 (16)	0.40 (18)	0.19 (15)	0.02 (17)	15.7
Toms River at Route 70		OCN040	66	4.3 (16)	55 (16)	0.16 (18)	<0.05 (15)	0.01 (17)	19.8
Union Branch at Route 37	TUNHORIC	PTR8	21	4.3 (17)	54 (16)	0.07 (18)	<0.05 (15)	<0.01 (18)	7.2
Mill Creek Study Basin									
Fourmile Branch at Lighthouse Drive	MFOLIGHT	PMI6	53	4.9 (17)	43 (17)	0.24 (17)	<0.05 (16)	<0.01 (17)	12.6
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	OCN054	56	5.8 (17)	48 (17)	0.09 (17)	0.33 (16)	<0.01 (17)	16.0
Wrangel Brook Study Basin									
Davenport Branch at Mule Road	RDAMULER	OCN036	35	4.6 (17)	38 (16)	0.22 (18)	<0.05 (16)	<0.01 (18)	28.2
Davenport Branch at Route 530	RDART530	PTR10	34	4.5 (17)	43 (16)	0.05 (18)	<0.05 (16)	<0.01 (18)	23.4
Jakes Branch at Dover Road	RJADOVER	OCN032	37	4.3 (17)	40 (16)	0.03 (18)	<0.05 (16)	<0.01 (18)	0.0
Wrangel Brook at Mule Road	RWRMULER	PTR9	30	4.6 (17)	52 (16)	0.64 (18)	<0.05 (16)	0.01 (17)	21.6

Data Analysis

Summary statistics, including the first, second (median), and third quartiles and 10th and 90th percentiles, were calculated for the pH and specific conductance data for all 64 sites sampled in 2003. Using the Pinelands Commission-Ocean County data set, specific conductance, pH, nitrite plus nitrate as nitrogen (NO_x), ammonia as nitrogen, and total phosphorus as phosphorus summary statistics were calculated for the 1988-1992 period. Values below detection limits, which were 0.01 mg L^{-1} for NO_x, 0.05 mg L^{-1} for ammonia, and 0.01 mg L^{-1} for total phosphorus, were set to zero before calculating the statistics.

For each monitoring site, land-use profiles for the 1986 and 1995 periods were prepared from digital data obtained from the New Jersey Department of Environmental Protection (NJDEP, 1995/97 Land Use/Land Cover Update 2001, Chapter 1).

Six sites with fewer than nine samples were not included in the data analyses or the results. Using Spearman rank correlation and 1995 land-use data, median pH and specific conductance values for the remaining fifty-eight sites sampled in 2003 were related to the percentage of developed land, upland agriculture, and altered land in a basin. The same approach was used to explore the relationship between the pH and specific conductance values and altered land in each of the five study basins. Spearman rank correlation rather than Pearson correlation or regression was used because the pH data did not meet the assumptions of normality required for parametric statistical methods. Correlation analyses were completed using Statistica 7.1 (Statsoft Inc., Tulsa, OK, 2005).

To assess the effect of sampling period, we compared the median pH and specific conductance for the 1988-1992 and 2003 periods using Spearman rank correlation and scatter plots. Data for both the 1988-1992 and 2003 periods were available for eighteen sites.

Spearman rank correlation and 1986 land-use data were used to relate median NO_x, ammonia, and total phosphorus concentrations for the 1988-1992 period to the percentage of developed land, upland agriculture, and altered land in a basin. Because ammonia and phosphorus concentrations were generally low, both the median and third quartile concentrations for all three nutrients were correlated with land use.

RESULTS

pH and Specific Conductance

The percentage of altered land associated with most monitoring sites was low (Table 2.1). Developed land was the dominant altered land use in ninety-percent of the drainage basins. Upland agriculture comprised less than ten-percent of the drainage area for all but one site. The Cedar Creek and Westecunk Creek study basins were the least altered areas. The percentage of altered land associated with stream-monitoring sites in the Tom River and Wrangel Brook study basins varied widely. Both pH and specific conductance generally increased as the percentage of altered land in a drainage basin increased (Figure 2.2)

Median pH ranged from 4.0 to 6.3 and was less than 5.0 at 42 of the 58 sites analyzed (Table 2.1, Figures 2.2 and 2.3). Median specific conductance values ranged from 31 to 180 $\mu S\ cm^{-1}$ (Table 2.1, Figures 2.2 and 2.4).

The median pH for the thirty sites with less than ten percent altered land in the drainage ranged from 4.0 to 5.3, with a median value of 4.4 (Table 2.3). Specific conductance at the same thirty sites ranged from 33 to 104 $\mu S\ cm^{-1}$, with a median value of 56 $\mu S\ cm^{-1}$ (Table 2.3). The highest specific conductance value in this group is unusual since it was recorded at a stream site (Jakes Branch at Dover Road) with the lowest pH and one of the lowest altered-land values included in the analysis.

The median pH for the six sites with ≥ 30% altered land in the associated drainages ranged from 4.8 to 6.3, with a median value of 5.5 (Table 2.3). Specific conductance at the same six sites ranged from 60 to 97 $\mu S\ cm^{-1}$, with a median value of 84 $\mu S\ cm^{-1}$ (Table 2.3).

Both pH and specific conductance were correlated with the percentage of altered land in a drainage basin (Table 2.4, Figure 2.5). When developed land and upland agriculture were analyzed separately, a correlation was found between developed land and both water-quality variables. Upland agriculture was not associated with variations in pH or specific conductance, which may reflect the very low percentage of upland agriculture upstream from most monitoring sites.

The relationship between the two water-quality variables and land use varied among the five study basins (Table 2.5). When considered separately, the relationship between pH and altered land for the Toms River, Mill Creek, and Wrangel Brook study basins was stronger than that revealed when all study basins were included in a single analysis. Neither pH nor specific conductance was associated with the percentage of altered land in the relatively unaltered Cedar Creek and Westecunk Creek study basins.

The median pH values calculated using the 2003 data were generally similar to those based on the 1988-1992 data set (Figure 2.6). Median pH values for both periods are correlated ($r = 0.90$, $p < 0.001$). The median pH for nine of eighteen sites was slightly lower during the more recent sampling period, with a median between-period decrease of 0.08 pH units. The median between-year increase at the other nine sites was 0.17 pH units. The changes in pH were not related to an increase in the percentage of altered land in the drainage basins between 1986 and 1995.

Although specific conductance was higher at all sites during the most recent sampling period (Figure 2.6), median values for both periods were correlated ($r = 0.81$, $p < 0.001$). By excluding the anomalous Jakes Branch value, the rank correlation improved ($r = 0.92$, $p < 0.001$). The change in specific conductance between sampling periods was associated with an increase in altered land between 1986 and 1995 ($r = 0.60$, $p = 0.008$). This relationship also improved ($r = 0.78$, $p < 0.001$) when the extreme Jakes Branch specific conductance value was deleted from the analysis.

Nutrients

Nitrite plus nitrate as nitrogen (NO_x) concentrations increased as the percentage of altered land in a basin increased (Tables 2.2 and 2.6, Figure 2.7). The relationships between median and third-quartile NO_x concentrations and altered land were strong (Table 2.6). Median NO_x values, which ranged from 0.01 to 0.64 $mg\ L^{-1}$, were less than 0.05 $mg\ L^{-1}$ at ten stream sites.

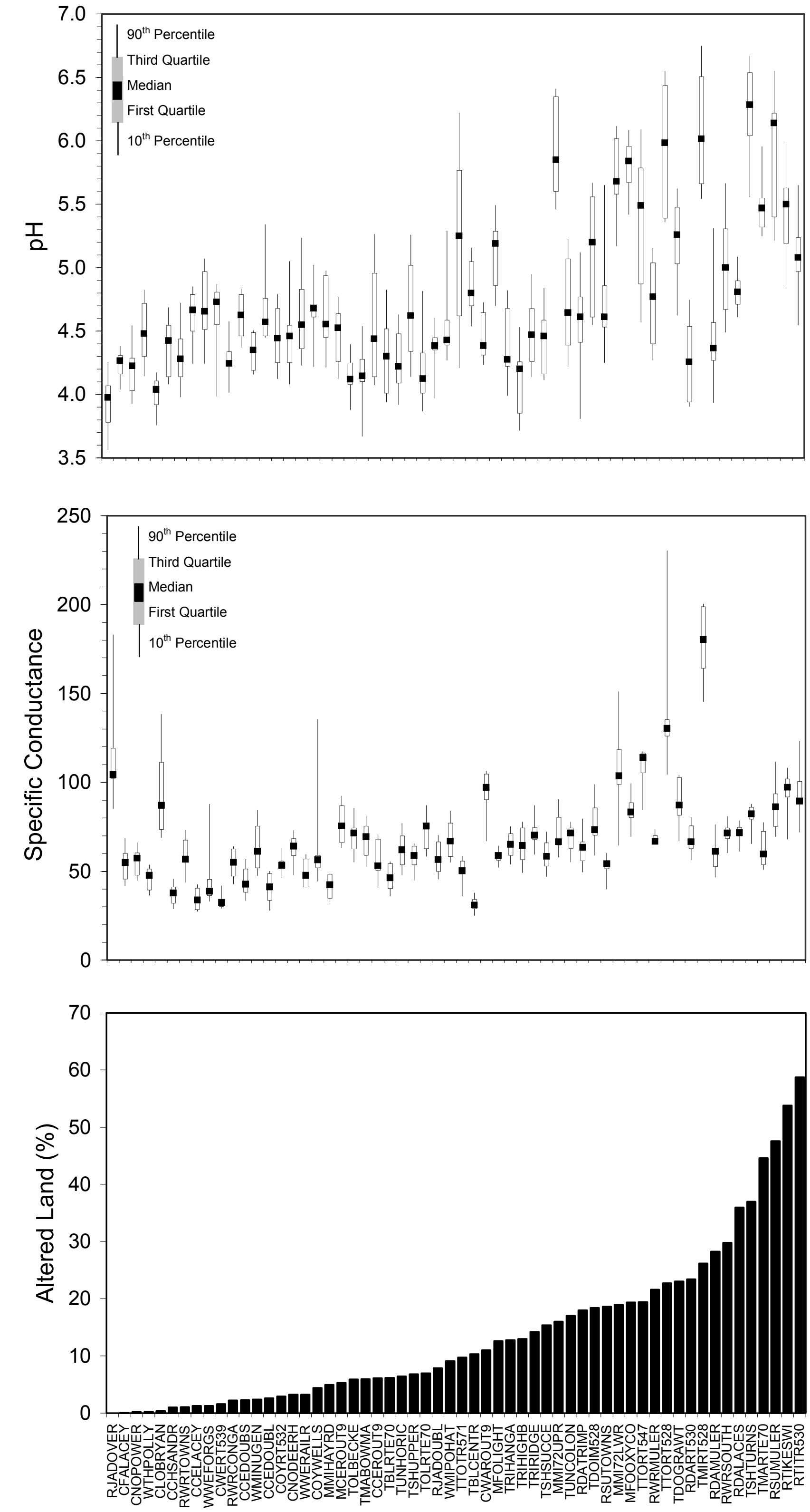

Figure 2.2. Barnegat Bay Watershed pH and specific conductance (μS cm^{-1}) gradients. Stream-monitoring sites are ordered along a watershed-disturbance gradient characterized by an increase in the percentage of altered land (developed land and upland agriculture) in the associated drainage basins. Water-quality data were collected from January through November 2003. Refer to Table 2.1 for site names.

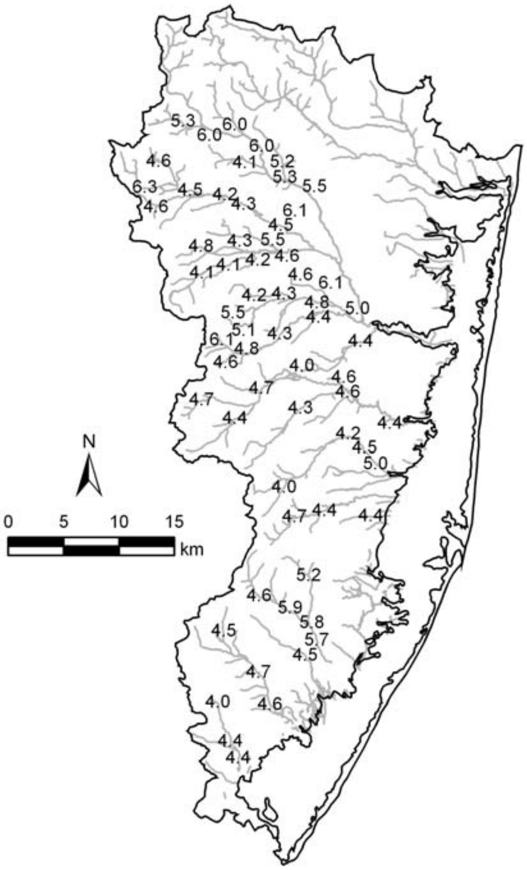

Figure 2.3. Median pH values for 64 stream-monitoring sites in the Barnegat Bay Watershed.

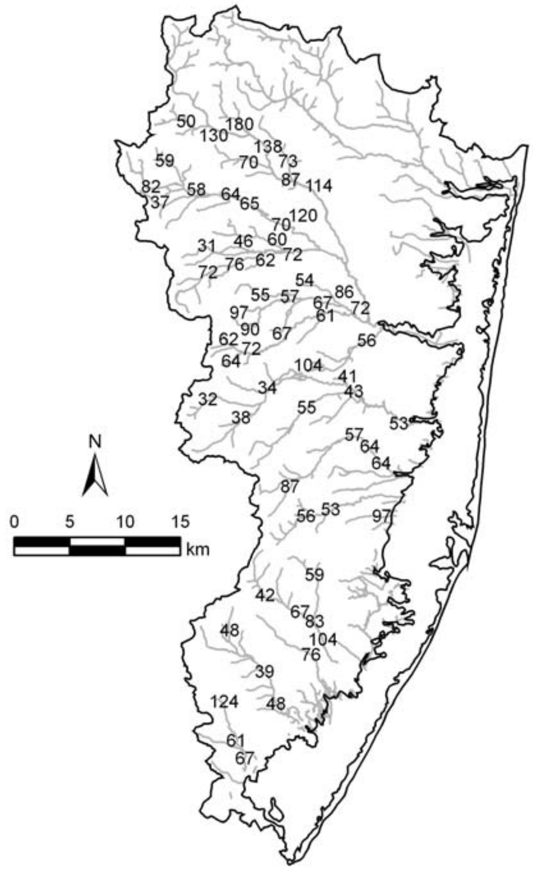

Figure 2.4. Median specific conductance ($\mu S\ cm^{-1}$) values for 64 stream-monitoring sites in the Barnegat Bay Watershed.

Table 2.3. Median pH, specific conductance ($\mu S\ cm^{-1}$), and altered-land values for 58 Barnegat Bay Watershed stream sites in four altered-land categories. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin.

Altered-land category (%)	n	Altered land	pH	Specific conductance
0-9.9	30	3.1	4.4	56
10-19.9	15	16.0	4.6	67
20-29.9	7	23.4	5.0	72
≥30	6	46.1	5.5	84

Table 2.4. Spearman rank correlations between land-use variables and pH and specific conductance ($\mu S\ cm^{-1}$) at 58 Barnegat Bay Watershed stream sites. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin.

	pH		Specific conductance	
Land use	r	*p*	r	*p*
Developed land	0.59	<0.001	0.56	<0.001
Upland agriculture	0.19	0.154	0.19	0.157
Altered land	0.60	<0.001	0.57	<0.001

Table 2.5. Spearman rank correlations between altered land and pH and specific conductance ($\mu S\ cm^{-1}$) for each Barnegat Bay Watershed study basin. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin. Correlations significant at $p \leq 0.05$ and $p \leq 0.10$ are indicated by a double and single asterisk, respectively.

Study basin	n	pH	Specific conductance
Toms River	20	0.83**	0.51**
Wrangel Brook	14	0.84**	0.50*
Cedar Creek	13	0.37	0.19
Mill Creek	6	0.77*	0.77*
Westecunk Creek	5	-0.30	0.67

Table 2.6. Spearman rank correlations between land-use variables and nitrite plus nitrate as nitrogen (NO_x), ammonia as nitrogen, and total phosphorus as phosphorus for 20 Barnegat Bay Watershed stream sites. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin. The 50th and 75th percentiles represent the median and third quartile, respectively. Correlations significant at $p \leq 0.05$ and $p \leq 0.10$ are indicated by a double and single asterisk, respectively.

Land use	Percentile	NO_x	Ammonia	Phosphorus
Developed land	50th	0.81**	0.20	0.19
	75th	0.84**	-0.04	0.33
Upland agriculture	50th	0.33	-0.05	0.71**
	75th	0.40*	0.09	0.65**
Altered land	50th	0.78**	0.14	0.29
	75th	0.83**	-0.01	0.40*

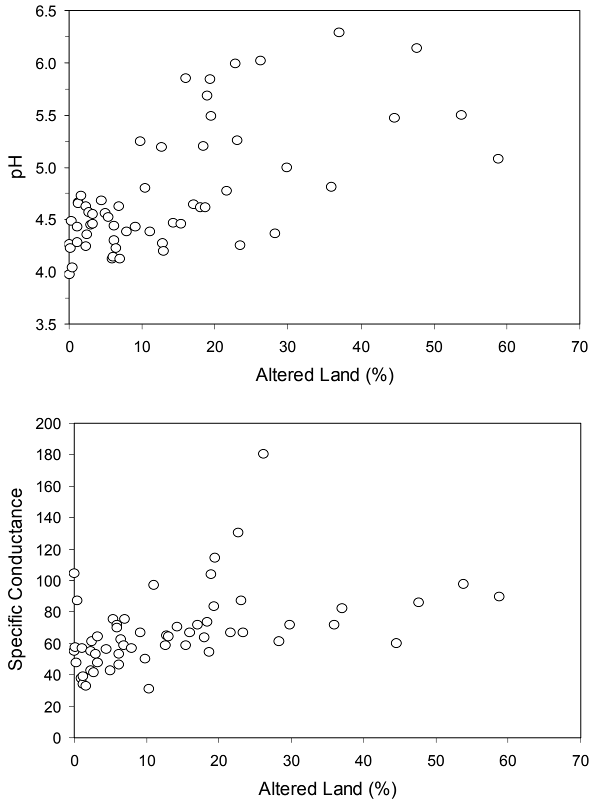

Figure 2.5. The relationship between pH and specific conductance (μS cm^{-1}) and the percentage of altered land (developed land and upland agriculture) in a drainage basin for 58 stream-monitoring sites in the Barnegat Bay Watershed.

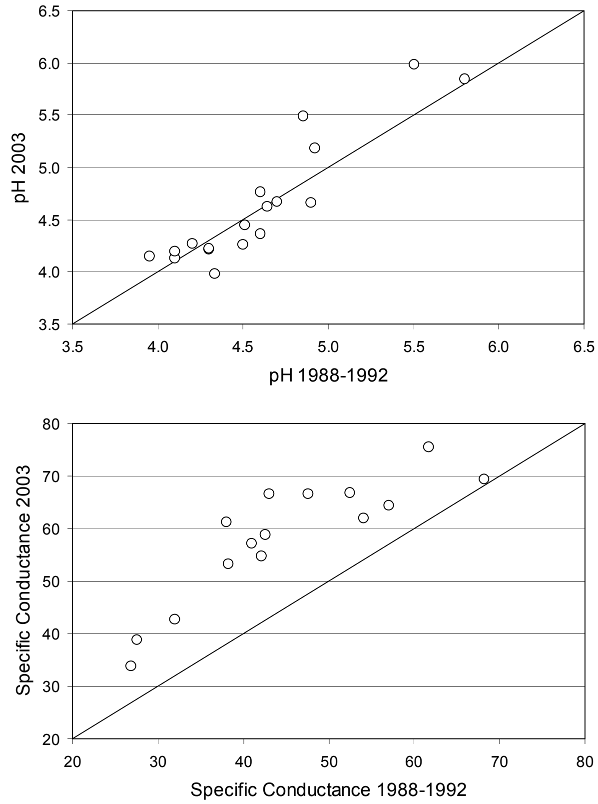

Figure 2.6. A comparison of median pH and specific conductance (μS cm^{-1}) values for 18 stream-monitoring sites based on data collected during two sampling periods (February 1988 through May 1992 and January through November 2003).

The 0.05 mg L^{-1} value is the threshold generally associated with minimally altered Pinelands reference-stream sites (Zampella et al. 2001).

Median ammonia concentrations exceeded the 0.05 mg L^{-1} detection limit at only two of twenty sites (Table 2.2, Figure 2.7). These two sites were Ridgeway Branch at Route 70 (0.19 mg L^{-1}) and Mill Creek at Route 72 above Manahawkin Lake (0.33 mg L^{-1}). Variations in ammonia concentrations were not associated with land use (Table 2.6). Median total phosphorus was below the 0.01 mg L^{-1} detection limit at eleven sites and ranged from 0.01 to 0.04 mg L^{-1} at the other nine sites. Phosphorus concentrations were associated with variations in the percentage of upland agriculture in the drainage basins (Table 2.6). Given the low percentage of upland agriculture in these basins, it is doubtful that agricultural activities are responsible for the variation in phosphorus levels.

Study-basin Characterizations

Westecunk Creek

Altered-land cover at the five Westecunk Creek study-basin monitoring sites, which was composed almost entirely of developed land, ranged from < 1% to 9.1% (Table 2.1, Figure 2.8). Median pH was low at all sites, with values ranging from 4.4 at Mill Branch at Nugentown Road and Mill Branch at Route 9 (Pohatcong Lake) to 4.7 at Westecunk Creek at Forge Road, with an overall median value of 4.5. Specific conductance values ranged from 39 μS cm^{-1} at Westecunk Creek at Forge Road to 67 μS cm^{-1} at Mill Branch at Route 9 (Pohatcong Lake), with an overall median of 48 μS cm^{-1}.

Nutrients were sampled at Westecunk Creek at Forge Road (Table 2.2, Figure 2.7). At 0.02 mg L^{-1}, median NO_x was below the 0.05 mg L^{-1} reference-

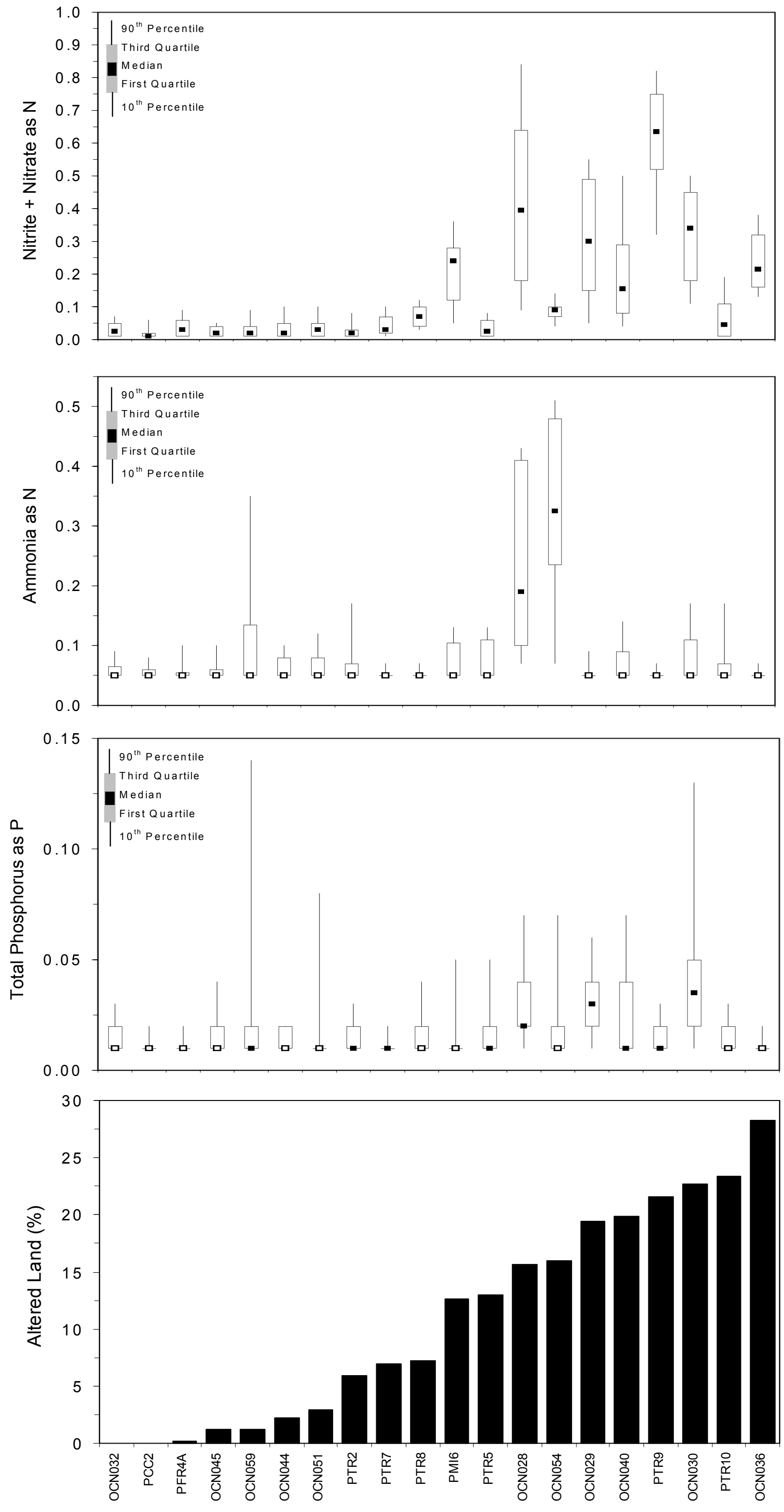

Figure 2.7. Barnegat Bay Watershed nutrient gradients. Twenty stream-monitoring sites are ordered along a watershed-disturbance gradient characterized by increasing percentage of altered land (developed land and upland agriculture) in the associated drainage basins. Values below detection limit for ammonia as nitrogen (0.05 mg L^{-1}), and total phosphorus as phosphorus (0.01 mg L^{-1}) are shown as open squares. Data were collected between February 1988 and May 1992. Refer to Table 2.2 for site names.

stream threshold. The median ammonia concentration was below the 0.05 mg L^{-1} detection limit and the median total phosphorus concentration was 0.01 mg L^{-1}.

Cedar Creek

Stream drainages in the Cedar Creek study basin, which includes the Cedar Creek, Forked River, and Oyster Creek systems, were among the least altered in the Barnegat Bay Watershed (Table 2.1, Figure 2.8). Altered-land cover at thirteen pH and specific conductance monitoring sites ranged from < 1% to 11%. With a median value of 0.4%, upland agriculture comprised a small percentage of the altered land. Median pH was low at all sites. Values ranged from 4.0 at Long Branch at Bryant Road to 4.7 at three other sites, with an overall median value of 4.5. Specific conductance values ranged from 32 μS cm^{-1} at Webbs Mill Branch at Route 539 to 97 μS cm^{-1} at Waretown Creek at Route 9, with an overall median of 53 μS cm^{-1}. The median specific conductance value of 97 μS cm^{-1} for Waretown Creek at Route 9 is high for a Pinelands stream and may be associated with land-use impacts occurring downstream from the Garden State Parkway. The second highest median conductance value recorded in the Cedar Creek study basin was reported for Long Branch at Bryant Road, which is located downstream from the Southern Ocean Landfill.

Nutrients were sampled at five Cedar Creek study-basin stream sites, including Factory Branch at Route 614, Cedar Creek at Double Trouble Road, Cedar Creek at Route 614, North Branch Forked River at a power-line right-of-way, and Oyster Creek at Route 532 (Table 2.2, Figure 2.7). NO_x was below the 0.05 mg L^{-1} reference-stream threshold at all five sites. Median ammonia and phosphorus were also below detection limits at all sites.

Toms River

Specific conductance and pH were measured at twenty monitoring sites in the Toms River study basin (Table 2.1, Figure 2.8). Altered land in the drainages associated with the monitoring sites ranged from 5.9% to 44.6%. Median pH values ranged from 4.1 at Maple Root Branch at Bowman Road and Old Hurricane Brook at both Beckerville Road and Route 70 to 6.3 at Shannae Brook tributary at Turn Mill Pond, with an overall study-basin median value of 4.6. Specific conductance values ranged from 31 μS cm^{-1} at Blacks Branch at Central Avenue to 180 μS cm^{-1} at Mirey Run at Route 528, with an overall study-basin median of 70 μS cm^{-1}. The three highest median conductance values recorded during the Barnegat Bay Watershed study were from Toms River study-basin streams, including two mainstem Toms River sites and Mirey Run at Route 528.

Nutrients were sampled at eight Toms River study-basin stream sites (Table 2.2, Figure 2.7). The median NO_x concentrations at these sites ranged from 0.02 mg L^{-1} to 0.40 mg L^{-1}. Median NO_x concentrations were elevated at all three mainstem Toms River sites, decreasing in a downstream order from Toms River at Route 528 (0.34 mg L^{-1}) to Toms River at Route 547 (0.30 mg L^{-1}) to Toms River at Rt. 70 (0.16 mg L^{-1}). Median NO_x concentrations were below the 0.05 mg L^{-1} reference-stream threshold at three sites, including Maple Root Branch at Bowman Road, Old Hurricane Brook at Route 70, and Ridgeway Branch at High Bridge Road. Elevated median NO_x (0.40 mg L^{-1}) was recorded for Ridgeway Branch at Route 70, which is below the High Bridge Road site, and a slightly elevated median concentration (0.07 mg L^{-1}) was recorded at Union Branch at Route 37. Median ammonia concentrations were below detection at all sites except Ridgeway Branch at Route 70, whereas median total phosphorus concentrations exceeded the 0.01 mg L^{-1} detection limit at all but one site, ranging from 0.01 to 0.04 mg L^{-1}.

Mill Creek

Specific conductance and pH were sampled at six Mill Creek study-basin stream sites. The percentage of altered land ranged from 4.9 to 19% (Table 2.1, Figure 2.8). Median pH ranged from 4.5 at Cedar Run at Route 9 to 5.9 at Mill Creek at Route 72 above Manahawkin Lake, with a basin-wide median of 5.4. Specific conductance ranged from 42 μS cm^{-1} at Mill Creek at Hay Road to 104 μS cm^{-1} at Mill Creek at Route 72 below Manahawkin Lake.

Nutrients were measured at Fourmile Branch at Lighthouse Drive and Mill Creek at Route 72 above Manahawkin Lake (Table 2.2, Figure 2.7). Median NO_x concentrations were elevated at both sites. The highest median ammonia concentration reported for the twenty Barnegat Bay Watershed sites monitored during the 1988-1992 sampling period was recorded at the Mill Creek at Route 72 above Manahawkin Lake

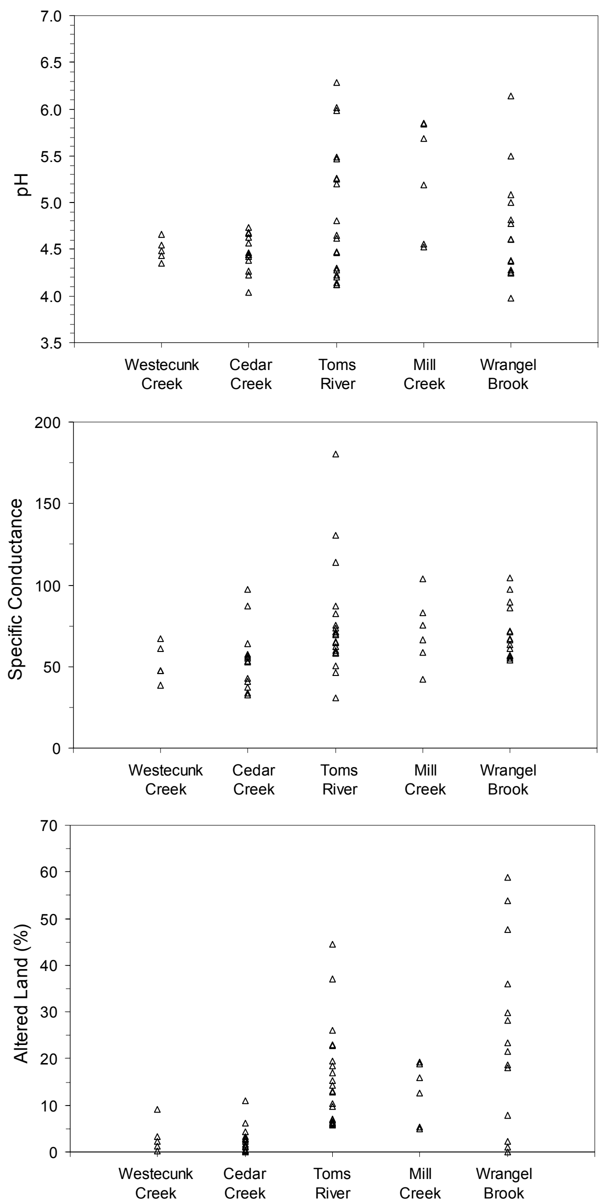

Figure 2.8. Comparison of median pH and specific conductance (μS cm^{-1}) and the percentage of altered land (developed land and upland agriculture) recorded for 58 stream-monitoring sites in the five Barnegat Bay Watershed study basins.

site (0.33 mg L^{-1}). The Stafford Township municipal landfill, located upstream from the site, is a potential source of this nutrient. Total phosphorus was below detection at both Mill Creek study-basin stream sites.

Wrangel Brook

Like the Toms River, altered land in the basins associated with the fourteen Wrangel Brook pH and specific conductance monitoring sites varied widely, ranging from <1% to 59% (Table 2.1, Figure 2.8). Median pH values ranged from 4.0 at Jakes Branch at Dover Road to 6.1 at Sunken Branch at Mule Road, with an overall median value of 4.6. Compared to the Toms River and Mill Creek study basin streams, the pH of some streams in the Wrangel Brook study basin appeared lower than expected given the relatively high percentage of altered land in the associated drainages (Figures 2.8). However, like the Toms River and Mill Creek study basins, pH in Wrangel Brook streams increased as the percentage of altered land in the associated drainages increased (Table 2.5).

Specific conductance values ranged from 54 μS cm^{-1} at Sunken Branch at Township Line Road to 104 μS cm^{-1} at Jakes Branch at Dover Road, with an overall median of 67 μS cm^{-1}. The exceptionally high specific conductance value for Jakes Branch at Dover Road is unusual considering that the altered land value for the drainage is 0%. The land use profile for this site, the lower conductance recorded downstream at Double Trouble Road, and the lower median value recorded during the 1988-1992 period (40 μS cm^{-1}) all suggest that the high conductance measured during 2003 is localized and recent. The intermittent nature of this stream, which dried up following the sampling period, may contribute to the anomalous specific conductance readings.

Nutrients were measured at four Wrangel Brook study-basin stream sites (Table 2.2, Figure 2.7). Elevated median NO_x concentrations were recorded for Davenport Branch at Mule Road (0.22 mg L^{-1}) and Wrangel Brook at Mule Road (0.64 mg L^{-1}). Median NO_x values were at or below the 0.05 mg L^{-1} reference-stream threshold at Jakes Branch at Dover Road (0.03 mg L^{-1}) and Davenport Branch at Route 530 (0.05 mg L^{-1}). Median ammonia concentrations were below the 0.05 mg L^{-1} detection limit at all sites, and total phosphorus was below the 0.01 mg L^{-1} detection limit at three sites.

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3 Stream Vegetation

Introduction

Results from Commission stream-vegetation studies in the Mullica River Basin, Rancocas Creek Basin, and Great Egg Harbor River Watershed Management Area indicated that plant-species composition varied along watershed-disturbance gradients characterized by an increase in the extent of upland agriculture and developed land and increasing surface-water pH and specific conductance (Zampella and Laidig 1997, Zampella et al. 2001, 2003, 2005, 2006). Plant communities in streams associated with heavily farmed and developed watersheds were characterized by the presence of exotic species and a high percentage of plants associated with the region to the north and west of the Pine Barrens, referred to by Stone (1911) as the Middle District. Stream sites in more heavily degraded watersheds also supported a higher percentage of a subset of Middle District and exotic plants, referred to by Zampella and Laidig (1997) as disturbance-indicator species (Table 3.1). Plants classified by Stone (1911) as Pine Barrens District species dominated the flora of streams in forested watersheds.

In 2003, Commission scientists surveyed aquatic and wetland vegetation at stream sites in the Barnegat Bay Watershed. These surveys and the evaluation methods developed in the Mullica River, Rancocas Creek, and Great Egg Harbor River studies were then used to assess the status of vegetation in the streams within the Barnegat Bay Watershed. The results of the assessment are presented in this chapter.

Methods

Study Sites

Fifty Barnegat Bay Watershed stream sites were surveyed as part of the stream-vegetation monitoring program (Table 3.2). Most of the survey sites were located at New Jersey Department of Environmental Protection Ambient Biomonitoring Network (NJDEP AMNET) stations. A few of the survey sites were located near the approximate boundaries of Stone's (1911) Middle District and Coastal Strip regions. Criteria used to select additional survey stations were drainage-area land-use characteristics, accessibility, and suitability as plant-survey sites. Sites consisted of a 20-m length of stream divided into two 10-m sections located upstream and downstream from a bridge or road crossing or a single 20-m section located upstream or downstream from a crossing. The sampling area at each site included the channel and a two-meter wide belt transect along each bank. The coordinates of each survey site were determined using NJDEP AMNET stations, orthophotoquads, and a geographic information system.

Table 3.1. Twenty-nine disturbance-indicator plant species identified by Zampella and Laidig (1997) and their frequency of occurrence at 50 Barnegat Bay Watershed stream-vegetation survey sites.

Scientific Name	Common Name	Number of Sites
Asclepias incarnata	swamp milkweed	1
Bidens connata	purple-stemmed beggar ticks	-
Bidens frondosa	beggar ticks	-
Boehmeria cylindrica	false nettle	3
Callitriche heterophylla	larger water starwort	4
Carex lurida	sallow sedge	8
Cinna arundinacea	wood-reed	1
Cyperus strigosus	straw-colored cyperus	4
Dioscorea villosa	common wild yam	-
Echinochloa muricata	American barnyard grass	1
Erechtites hieracifolia	pilewort	1
Eupatorium dubium	eastern joe-pye weed	7
Galium tinctorium	stiff marsh bedstraw	4
Impatiens capensis	spotted touch-me-not	6
Lindernia dubia	short-stalked false pimpernel	3
Lobelia cardinalis	cardinal flower	4
Ludwigia palustris	water purslane	9
Microstegium vimineum	stiltgrass	9
Mikania scandens	climbing hempweed	4
Panicum clandestinum	deertongue grass	9
Polygonum arifolium	halberd-leaved tearthumb	-
Polygonum hydropiperoides	mild water pepper	10
Polygonum punctatum	dotted smartweed	1
Polygonum sagittatum	arrow-leaved tearthumb	5
Potamogeton epihydrus	Nuttall's pondweed	6
Potamogeton pusillus	small pondweed	1
Sambucus canadensis	common elder or elderberry	6
Thelypteris palustris	marsh fern	4
Typha latifolia	broad-leaved cattail	-

Characterizing Stream Conditions

Several drainage-basin and site-specific attributes were characterized at each stream site (Table 3.2). The variables included pH, specific conductance, upland agriculture, and developed land. Upstream land-use profiles were prepared using ArcView software and NJDEP 1995/1997 land-use data (Chapter 1). Specific conductance was measured with an Orion model-122 conductivity meter with temperature compensation, and pH was measured with an Orion model-250a pH meter with automatic temperature compensation and a ROSS combination electrode (Chapter 2).

Plant-species Surveys

Plant-survey methods were the same as those used in the Rancocas Creek Basin and Great Egg Harbor River Watershed Management Area studies (Zampella et al. 2003, 2005). At most sites, channel and bank plants were surveyed on a single occasion during each of two time periods (July-August and September-October) in 2003. Cedar Run at Route 9, Davenport Branch at Mule Road, Mill Branch at Poor Mans Parkway, Ridgeway Branch at Hangar Road, Shannae Brook tributary at Turn Mill Pond, Toms River tributary at 571, and Waretown Creek at Route 9 were surveyed during only one of the two time periods. Two sites, Sunken Branch at Mule Road and Toms River at Route 547, were sampled in 2005. Following Stone (1911), all plants were classified as either a Pine Barrens District species, Middle District species, or species found in both the Pine Barrens District and the Middle District. The latter are referred to as wide-ranging species. Pine Barrens District species and wide-ranging species represent native Pinelands species. Southern New Jersey plants not included in Stone's biogeographic lists, but described in his individual species accounts as uncharacteristic of the Pine Barrens District, were assigned to the Middle District category. Using Gleason and Cronquist (1991), species that are not native to North America were classified as exotic. Both Middle District and exotic species represent non-Pinelands species.

The complete plant-survey data set and distribution maps for species that were found at two or more sites are presented in Appendix 2. Taxonomic nomenclature follows Gleason and Cronquist (1991). Both scientific and common names are given in Appendix 2. The appendix also describes the location of each site, including latitude and longitude. The Commission maintains a herbarium collection that includes voucher specimens for many of the plant species encountered during the Barnegat Bay Watershed stream surveys.

Table 3.2. Median pH and specific conductance (μS cm^{-1}) values and the percentage of developed land, upland agriculture, and altered land (developed and upland agriculture) for 50 Barnegat Bay Watershed stream-vegetation survey sites. Refer to Chapter 2 for details regarding water-quality monitoring.

Site Code	pH	SC	Developed	Upland Ag.	Altered Land
CCEDOUBS	4.6	43	1.8	0.4	2.2
CCELACEY	4.7	34	0.8	0.5	1.2
CCEROUT9	4.4	53	5.6	0.5	6.1
CCHSANDR	4.4	38	0.3	0.7	1.0
CFALACEY	4.3	55	0.0	0.0	0.0
CLOBRYAN	4.0	87	0.4	0.0	0.4
CNOPOWER	4.2	57	0.2	0.0	0.2
COYRT532	4.4	53	2.7	0.2	2.9
CWAROUT9	4.4	97	10.9	0.1	11.0
CWERT539	4.7	32	0.5	1.1	1.6
MCEROUT9	4.5	76	5.2	0.1	5.3
MFOLIGHT	5.2	59	12.5	0.1	12.6
MFOOXYCO	5.8	83	18.6	0.7	19.4
MMI72LWR	5.7	104	18.6	0.3	18.9
MMI72UPR	5.9	67	16.0	0.0	16.0
MMIHAYRD	4.6	42	4.9	0.1	4.9
RDALACES	4.8	72	35.1	0.8	36.0
RDAMULER	4.4	61	27.9	0.3	28.2
RDART530	4.3	67	22.9	0.5	23.4
RJADOUBL	4.4	57	7.6	0.3	7.9
RSUMULER	6.1	86	47.6	0.0	47.6
RSUTOWNS	4.6	54	18.6	0.0	18.6
RTITR530	5.1	90	57.4	1.4	58.8
RWRCONGA	4.2	55	2.1	0.1	2.2
RWRMULER	4.8	67	20.6	1.0	21.6
RWRSOUTH	5.0	71	29.1	0.7	29.8
RWRTOWNV	4.3	57	1.0	0.0	1.0
TBLCENTR	4.8	31	9.9	0.4	10.3
TBLRTE70	4.3	46	5.6	0.6	6.1
TCARAILR	6.1	120	10.3	8.2	18.5
TDOGRAWT	5.3	87	18.5	4.5	23.0
TMABOWMA	4.1	70	3.6	2.3	5.9
TMARTE70	5.5	60	44.1	0.4	44.6
TMIRT528	6.0	180	20.3	5.9	26.2
TOLBECKE	4.1	72	4.7	1.2	5.9
TOLRTE70	4.1	75	5.8	1.2	7.0
TRIHANGA	4.3	65	7.4	5.4	12.8
TRIHIGHB	4.2	64	6.4	6.5	13.0
TRIRIDGE	4.5	70	9.3	4.9	14.2
TSHTURNS	6.3	82	13.1	23.9	37.0
TTOBOWMA	6.0	138	18.8	4.4	23.2
TTORT528	6.0	130	18.7	4.1	22.7
TTORT547	5.5	114	15.3	4.1	19.4
TTOTR571	5.3	50	9.1	0.6	9.7
TUNCOLON	4.6	71	16.4	0.6	17.0
WMINUGEN	4.4	61	2.4	0.0	2.4
WMIPOORM	4.0	124	0.7	0.0	0.7
WTHPOLLY	4.5	48	0.0	0.3	0.3
WWEFORGS	4.7	39	0.8	0.5	1.2
WWERAILR	4.6	48	2.6	0.6	3.2

Stream-vegetation Gradients

Detrended correspondence analysis (DCA, Hill 1979a, Hill and Gauch 1980) and TWINSPAN (Hill 1979b) were used to ordinate and classify plant species and sampling sites based on presence/absence data. With DCA, sites are ordered along axes based on species-composition data. TWINSPAN is a classification technique that groups sites based on species composition. The use of both methods in the Commission's monitoring program is more fully described in Zampella et al. (2001).

To limit the effect of rare species, only species occurring at two or more sites were included in the DCA and TWINSPAN analyses. Specimens of *Sagittaria* with broad leaves and no fruit were classified as *Sagittaria* cf. *latifolia* and combined with *S. latifolia* in the analyses. Aquatic *Utricularia* that could not be conclusively identified, but resembled *U. fibrosa*, were classified as *Utricularia* cf. *fibrosa* and combined with *U. fibrosa* in the analyses. Panic grasses from several sites were classified as *Panicum* cf. *dichotomum* and combined with *P. dichotomum* in the analyses. Other plant specimens that were identified only to genus were eliminated from the analyses if the genus was represented by a known species. Excluding these plants from the analyses had very little effect on the results.

Spearman rank correlation was used to determine if species composition, represented by the DCA axes, varied in relation to plant biogeography and environmental variables. Plant biogeography factors included the percentage of native, non-Pinelands, and disturbance-indicator species. Values for disturbance-indicator species were calculated using the total number of species at a site, whereas native and non-Pinelands species values were calculated using only those species classified using Stone (1911). Environmental factors included the percentage of upland agriculture, developed land, and altered land (upland agriculture and developed land) in a basin, pH, and specific conductance. Selection of these variables was based on the results of previous Commission stream-vegetation studies (Zampella and Laidig 1997, Zampella et al. 2001, 2003, 2005, 2006). Differences in biogeography and watershed conditions between the TWINSPAN-derived site classes were evaluated using Mann-Whitney U tests. The percentage of native species, percentage of disturbance-indicator species, pH, specific conductance, and the percentage of altered land (developed land and upland agriculture) were compared between the first two site classes. The probability of finding two or more disturbance-indicator species at various pH, specific conductance, and altered-land values was estimated using logistic regression. An alpha level of 0.05 was used to identify important results revealed by the Spearman rank correlations, Mann-Whitney tests, and logistic regression analyses.

RESULTS

Plant-species Surveys

A total of 226 vascular-plant species, including 166 herbaceous and 60 woody species, were found at the 50 Barnegat Bay Watershed stream-vegetation monitoring sites. Total and herbaceous plant-species richness ranged from 14 to 62 and 4 to 44, respectively. The mean (± 1 SD) number of species found at the 50 sites was 35 ± 10. Median species richness was 35.

Twenty-four disturbance-indicator species (Table 3.1) were found during the plant surveys. Twenty-two of 50 survey sites supported disturbance-indicator species (Figure 3.1). Sixteen sites yielded 2 to 16 indicator species. *Polygonum hydropiperoides*, *Panicum clandestinum*, *Microstegium vimineum*,

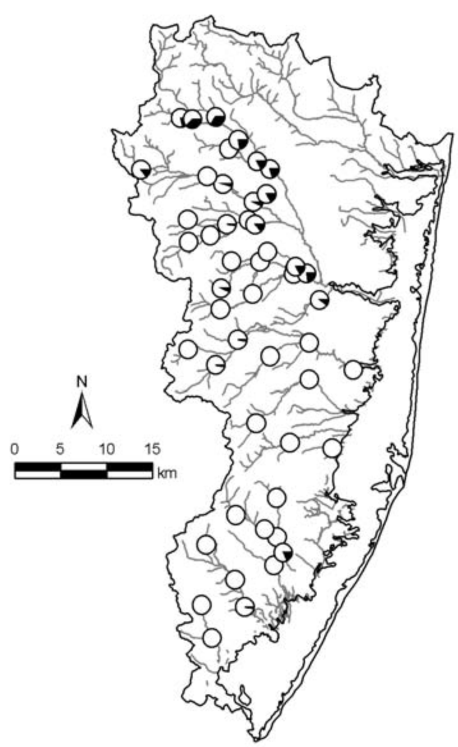

Figure 3.1. Pie charts showing as black the percentage of disturbance-indicator species found at 50 Barnegat Bay Watershed stream sites.

Ludwigia palustris, *Carex lurida*, and *Eupatorium dubium* occurred at seven or more sites. *Impatiens capensis*, *Potamogeton epihydrus*, and *Sambucus canadensis* each occurred at six sites.

Nine percent of the total species inventory could not be assigned a biogeographic classification based on Stone (1911). Of the remaining species, approximately 32% were classified as Pine Barrens District plants, 32% were considered wide-ranging plants (Pine Barrens and Middle District species), and nearly 37% consisted of plants characteristic of Stone's Middle District, other non-Pinelands biogeographic regions, and exotic species. Eight plant species were exotics. *Microstegium vimineum* occurred at nine sites, and *Agrostis stolonifera*, *Lonicera japonica*, and *Rosa multiflora* each occurred at three sites. The other exotic species, including *Acer platanoides*, *Catalpa bignonioides*, *Ligustrum obtusifolium*, and *Lythrum salicaria*, each occurred at a single site. Though non-Pinelands species were found at all but four sites, non-Pinelands plants comprised the majority of species at only six sites (Figure 3.2).

Twenty-four herbaceous species and 21 woody species were present at twenty-five percent or more of the 50 stream sites (Table 3.3). Most of these

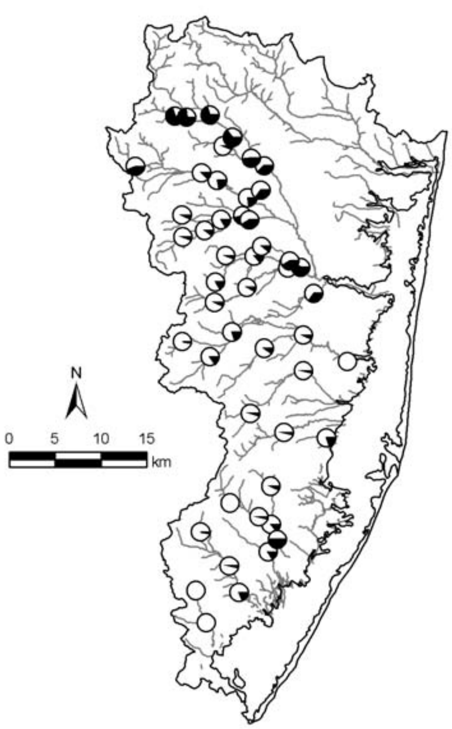

Figure 3.2. Pie charts showing as black the percentage of non-Pinelands species found at 50 Barnegat Bay Watershed stream sites.

Table 3.3. Biogeography of the most frequently occuring (≥25% of sites) herbaceous and woody species in the Barnegat Bay Watershed. Codes refer to Stone's (1911) Pine Barrens District (PB) and Middle District (M). Plants characteristic of both districts are listed as PB & M. Middle District species represent non-Pinelands species.

Species	Biogeography	Number of Sites
Herbaceous species:		
Sparganium americanum	PB	37
Triadenum virginicum	PB & M	35
Leersia oryzoides	M	29
Osmunda cinnamomea	PB & M	29
Juncus canadensis	PB & M	28
Aster novi-belgii	PB & M	25
Juncus effusus	PB & M	25
Dulichium arundinaceum	M	23
Peltandra virginica	M	23
Scirpus subterminalis	PB	22
Lysimachia terrestris	PB & M	21
Scirpus cyperinus	PB & M	21
Juncus pelocarpus	PB & M	18
Drosera intermedia	PB & M	17
Drosera rotundifolia	PB & M	17
Glyceria obtusa	PB & M	16
Carex striata	PB	15
Nymphaea odorata	PB & M	15
Panicum virgatum	M	15
Rhexia virginica	PB & M	15
Decodon verticillatus	PB & M	13
Eriocaulon aquaticum	PB	13
Nuphar variegata	PB	13
Xyris difformis	PB	13
Woody species:		
Clethra alnifolia	PB & M	49
Acer rubrum	PB	48
Vaccinium corymbosum	PB	40
Chamaecyparis thyoides	PB	37
Eubotrys racemosa	PB & M	34
Rhododendron viscosum	PB	34
Smilax rotundifolia	PB & M	33
Nyssa sylvatica	PB & M	23
Chamaedaphne calyculata	PB	22
Rubus hispidus	PB & M	21
Gaylussacia frondosa	PB & M	20
Ilex glabra	PB	18
Kalmia angustifolia	PB	18
Magnolia virginiana	PB & M	18
Myrica pensylvanica	PB	16
Alnus serrulata	PB & M	15
Lyonia ligustrina	PB & M	15
Vaccinium macrocarpon	PB	15
Aronia arbutifolia	PB & M	14
Pinus rigida	PB	14
Amelanchier canadensis	PB & M	13

frequently occurring herbaceous species are native to the Pinelands. Only six of these herbaceous species, including *Sparganium americanum*, *Scirpus subterminalis*, *Carex striata*, *Eriocaulon aquaticum*, *Nuphar variegata*, and *Xyris difformis* are considered Pine Barrens District species. Fourteen of these herbaceous species are wide ranging. Four other herbaceous species, including *Leersia oryzoides*, *Dulichium arundinaceum*, *Peltandra virginica*, and *Panicum virgatum*, are considered non-Pinelands species by Stone (1911). These four species are now widely distributed throughout the Pinelands and do not appear to be associated with watershed disturbance (Zampella and Laidig 1997, Zampella et al. 2001, 2003, 2005). All of the most frequently occurring woody species are considered native to the Pinelands.

Stream-vegetation Gradients

A total of 166 species were found at two or more sites. The first DCA axis produced by ordinating the 50 sites contrasted streams with a high percentage of native species with streams supporting a high percentage of non-Pinelands species (Figure 3.3, Table 3.4). Three trends, representing a decrease in the percentage of native species (r = -0.88, $p < 0.001$), an increase in the percentage of non-Pinelands species (r = 0.88, $p < 0.001$), and an increase in the percentage of disturbance-indicator plant species (r = 0.85, $p < 0.001$), were evident along this stream-community gradient (Figures 3.4 and 3.5). These trends were related to differences in the range of pH, specific conductance, and the percentage of altered land (upland agriculture and developed land) in the drainage basins associated with each plant species (Figure 3.6, Table 3.5).

First-axis site scores produced by the DCA were associated with increasing pH (r = 0.46, $p = 0.001$), specific conductance (r = 0.54, $p < 0.001$), and the percentage of altered land (r = 0.61, $p < 0.001$), developed land (r = 0.56, $p < 0.001$), and upland agriculture (r = 0.61, $p < 0.001$, Figure 3.7). With the exception of a weak association with increasing pH (r = 0.32, $p = 0.023$), the order of sites along the second DCA axis was not related to the environmental factors.

A decrease in the percentage of native species was associated with increasing pH (r = -0.55, $p < 0.001$), specific conductance (r = -0.44, $p = 0.001$), and the percentage of altered land (r = -0.60, $p < 0.001$), developed land (r = -0.56, $p < 0.001$), and upland agriculture (r = -0.47, $p = 0.001$) in a basin. Opposite trends were observed for non-Pinelands species.

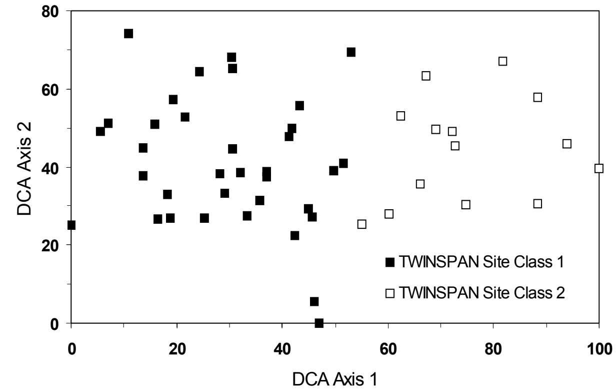

Figure 3.3. DCA ordination diagram and TWINSPAN classification for 50 Barnegat Bay Watershed stream sites. Refer to Table 3.4 for a list of sites ordered by DCA axis 1 scores.

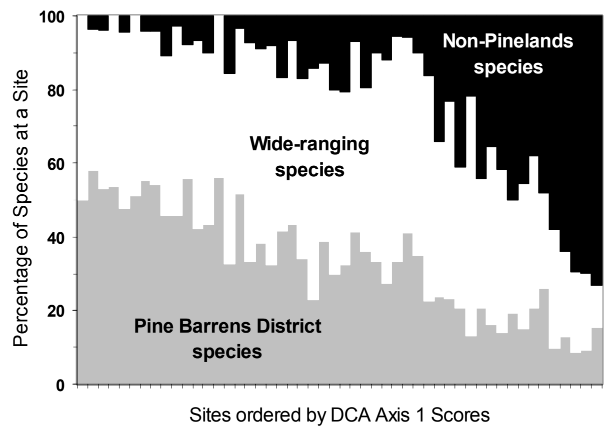

Figure 3.4. Biogeography of plants found at 50 Barnegat Bay Watershed stream sites. Wide-ranging species are native to both the Pine Barrens District and the Middle District. Non-Pinelands species include Middle District and exotic species. Refer to Table 3.4 for a list of sites ordered by DCA axis 1 scores.

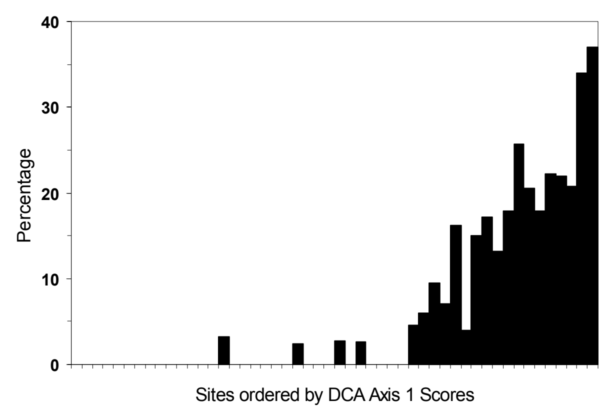

Figure 3.5. Percentage of disturbance-indicator plant species at 50 Barnegat Bay Watershed stream sites. Refer to Table 3.4 for a list of sites ordered by DCA axis 1 scores.

Table 3.4. Raw DCA axis 1 and axis 2 site scores for 50 stream-vegetation survey sites in the Bargegat Bay Watershed based on an ordination of species presence/absence data. Sites are ordered by axis 1 scores. Refer to Appendix 2 for additional information on each site.

Study Basin	Site Name	Site Code	Axis 1	Axis 2
Mill Creek	Mill Creek at Hay Road	MMIHAYRD	0	83
Cedar Creek	Webbs Mill Branch at Route 539	CWERT539	18	162
Cedar Creek	Oyster Creek at Route 532	COYRT532	23	169
Cedar Creek	Cedar Creek at Route 9	CCEROUT9	36	245
Mill Creek	Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	45	125
Westecunk Creek	Mill Branch at Nugentown Road	WMINUGEN	45	148
Cedar Creek	North Branch Forked River at a powerline right-of-way	CNOPOWER	52	168
Cedar Creek	Long Branch at Bryant Road	CLOBRYAN	54	88
Wrangel Brook	Sunken Branch at Township Line Road	RSUTOWNS	60	109
Westecunk Creek	Three Mile Branch at Pollypod Road	WTHPOLLY	62	89
Cedar Creek	Cedar Creek at Double Trouble Road	CCEDOUBS	64	189
Wrangel Brook	Davenport Branch at Route 614	RDALACES	71	174
Cedar Creek	Factory Branch at Route 614	CFALACEY	80	213
Westecunk Creek	Mill Branch at Poor Mans Parkway	WMIPOORM	83	89
Cedar Creek	Chamberlain Branch at an unnamed road	CCHSANDR	93	126
Westecunk Creek	Westecunk Creek at Forge Road	WWEFORGS	96	110
Mill Creek	Fourmile Branch at Lighthouse Drive	MFOLIGHT	100	225
Wrangel Brook	Davenport Branch at Mule Road	RDAMULER	101	215
Wrangel Brook	Davenport Branch at Route 530	RDART530	101	147
Mill Creek	Cedar Run at Route 9	MCEROUT9	106	127
Wrangel Brook	Wrangel Brook at Congasia Road	RWRCONGA	110	91
Toms River	Blacks Branch at Route 70	TBLRTE70	118	104
Mill Creek	Fourmile Branch at Oxycocus Street	MFOOXYCO	122	124
Wrangel Brook	Wrangel Brook near Township Line Road	RWRTOWNV	122	128
Cedar Creek	Waretown Creek at Route 9	CWAROUT9	136	158
Cedar Creek	Cedar Creek at Route 614	CCELACEY	138	165
Toms River	Blacks Branch at Central Avenue	TBLCENTR	140	74
Westecunk Creek	Westecunk Creek at Railroad Avenue	WWERAILR	143	184
Toms River	Old Hurricane Brook at Route 70	TOLRTE70	148	97
Toms River	Ridgeway Branch at High Bridge Road	TRIHIGHB	151	90
Toms River	Old Hurricane Brook at Beckerville Road	TOLBECKE	152	18
Toms River	Maple Root Branch at Bowman Road	TMABOWMA	155	0
Wrangel Brook	Wrangel Brook at Mule Road	RWRMULER	164	129
Wrangel Brook	Tice Van Horn Branch tributary at Route 530	RTITR530	170	135
Wrangel Brook	Jakes Branch at Double Trouble Road	RJADOUBL	175	229
Toms River	Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	182	84
Wrangel Brook	Sunken Branch at Mule Road	RSUMULER	184	304
Toms River	Ridgeway Branch at Hangar Road	TRIHANGA	199	92
Toms River	Shannae Brook tributary at Turn Mill Pond	TSHTURNS	206	175
Toms River	Cabin Branch at New Jersey Central railroad	TCARAILR	218	118
Toms River	Union Branch at Colonial Drive	TUNCOLON	222	209
Mill Creek	Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	228	164
Toms River	Manapaqua Brook at Route 70	TMARTE70	238	162
Toms River	Toms River at Route 547	TTORT547	240	150
Toms River	Dove Mill Branch at Grawtown Road	TDOGRAWT	247	100
Wrangel Brook	Wrangel Brook at South Hampton Road	RWRSOUTH	270	221
Toms River	Toms River at Bowman Road	TTOBOWMA	292	101
Toms River	Toms River tributary at Route 571	TTOTR571	292	191
Toms River	Mirey Run at Route 528	TMIRT528	310	152
Toms River	Toms River at Route 528	TTORT528	330	131

Table 3.5. Raw DCA axis 1 and axis 2 species scores for 166 taxa included in the stream-vegetation analysis based on an ordination of species presence/absence data. Species are ordered by axis 1 scores.

Species	Axis 1	Axis 2	Species	Axis 1	Axis 2	Species	Axis 1	Axis 2
Schizaea pusilla	-183	49	*Aronia arbutifolia*	57	11	*Cuscuta sp.*	249	327
Eriophorum virginicum	-163	72	*Chamaecyparis thyoides*	63	112	*Thelypteris simulata*	250	-74
Agrostis perennans	-163	204	*Viburnum nudum v. nudum*	64	2	*Glyceria canadensis*	259	177
Carex trisperma	-160	11	*Glyceria obtusa*	87	139	*Juncus biflorus*	260	259
Quercus ilicifolia	-158	-36	*Oxypolis rigidior*	90	177	*Iris versicolor*	264	230
Carex exilis	-129	121	*Rhus copallina*	93	-3	*Parthenocissus quinquefolia*	272	124
Polygala brevifolia	-119	209	*Eubotrys racemosa*	93	25	*Myriophyllum humile*	280	466
Utricularia subulata	-118	256	*Rhexia virginica*	94	257	*Ilex opaca*	283	45
Lophiola aurea	-113	258	*Scirpus pungens*	94	277	*Potamogeton epihydrus*	283	337
Sabatia difformis	-111	130	*Sagittaria engelmanniana*	97	292	*Cephalanthus occidentalis*	286	-9
Carex livida	-108	81	*Dulichium arundinaceum*	100	134	*Lonicera japonica*	288	357
Orontium aquaticum	-99	47	*Lyonia ligustrina*	102	-5	*Carex stricta*	289	75
Pogonia ophioglossoides	-95	108	*Helonias bullata*	109	-166	*Rosa multiflora*	291	390
Drosera filiformis	-95	156	*Juncus canadensis*	109	237	*Salix sp.*	292	223
Carex collinsii	-84	48	*Utricularia fibrosa*	109	240	*Potamogeton diversifolius*	293	460
Sarracenia purpurea	-84	84	*Smilax glauca*	114	-45	*Hypericum mutilum*	296	287
Gaylussacia dumosa	-81	57	*Aster novi-belgii*	122	157	*Carex lurida*	305	132
Eleocharis tuberculosa	-80	323	*Carex folliculata*	131	-18	*Solidago sp.*	306	149
Aster nemoralis	-78	158	*Rhododendron viscosum*	132	12	*Bidens sp.*	307	179
Bartonia paniculata	-72	305	*Kalmia latifolia*	134	-154	*Cyperus strigosus*	313	431
Muhlenbergia uniflora	-71	307	*Lysimachia terrestris*	134	169	*Toxicodendron radicans*	315	-16
Andropogon virginicus v. abbre.	-69	212	*Panicum virgatum*	138	295	*Carex albolutescens*	315	193
Lachnanthes caroliniana	-50	289	*Schizachyrium scoparium*	145	370	*Thelypteris palustris*	317	48
Myrica pensylvanica	-46	85	*Nuphar variegata*	147	73	*Ilex verticillata*	319	111
Juncus militaris	-44	244	*Vaccinium corymbosum*	148	55	*Scutellaria lateriflora*	329	136
Rhynchospora alba	-41	232	*Cyperus dentatus*	161	351	*Hibiscus moscheutos*	333	529
Carex atlantica	-31	90	*Andropogon virginicus v. virg.*	161	473	*Viburnum dentatum*	338	262
Ilex glabra	-29	164	*Viola lanceolata*	164	211	*Sagittaria latifolia*	340	148
Eriocaulon aquaticum	-24	117	*Osmunda cinnamomea*	165	13	*Quercus velutina*	345	102
Kalmia angustifolia	-22	15	*Alnus serrulata*	165	170	*Viola sp.*	347	15
Drosera intermedia	-22	273	*Pontederia cordata*	166	287	*Galium tinctorium*	352	392
Panicum longifolium	-20	310	*Triadenum virginicum*	173	189	*Vitis labrusca*	353	148
Carex striata	-15	143	*Rubus hispidus*	180	155	*Onoclea sensibilis*	356	173
Ilex laevigata	-14	13	*Quercus alba*	182	-259	*Prunus serotina*	357	182
Drosera rotundifolia	-14	150	*Betula populifolia*	186	-30	*Smilax herbacea*	358	-185
Woodwardia virginica	-5	64	*Clethra alnifolia*	186	103	*Polygonum hydropiperoides*	362	257
Chamaedaphne calyculata	-3	93	*Acer rubrum*	186	124	*Polygonum sagittatum*	369	191
Vaccinium macrocarpon	6	263	*Itea virginica*	189	-51	*Boehmeria cylindrica*	371	203
Juncus pelocarpus	9	274	*Hypericum densiflorum*	190	201	*Apios americana*	377	190
Amelanchier canadensis	10	41	*Juncus effusus*	196	237	*Microstegium vimineum*	378	163
Osmunda regalis	15	183	*Panicum dichotomum*	198	159	*Agrostis stolonifera*	385	118
Xyris difformis	15	317	*Smilax rotundifolia*	205	27	*Impatiens capensis*	385	275
Gaylussacia frondosa	21	-9	*Phragmites australis*	205	328	*Panicum clandestinum*	387	147
Hypericum canadense	23	309	*Sassafras albidum*	206	404	*Ludwigia palustris*	388	245
Nymphaea odorata	34	248	*Nyssa sylvatica*	207	10	*Eupatorium dubium*	389	48
Eleocharis tenuis	40	219	*Sparganium americanum*	208	158	*Cornus amomum*	400	327
Potamogeton confervoides	43	295	*Ludwigia alternifolia*	208	346	*Grass sp.*	401	202
Eleocharis robbinsii	44	324	*Scirpus cyperinus*	211	223	*Sambucus canadensis*	411	141
Euthamia tenuifolia	44	344	*Decodon verticillatus*	213	156	*Lycopus virginicus*	413	20
Scirpus subterminalis	45	228	*Agrostis sp.*	218	305	*Liquidambar styraciflua*	416	-92
Magnolia virginiana	46	7	*Peltandra virginica*	225	176	*Mikania scandens*	419	125
Panicum verrucosum	48	246	*Woodwardia areolata*	229	-100	*Lindernia dubia*	428	95
Pinus rigida	49	57	*Eleocharis ovata*	234	514	*Callitriche heterophylla*	448	204
Carex atlantica v. capillacea	51	234	*Lycopus uniflorus*	235	297	*Lobelia cardinalis*	454	104
Eleocharis flavescens v. olivacea	54	392	*Eleocharis acicularis*	237	232			
Rhynchospora capitellata	55	325	*Leersia oryzoides*	243	154			

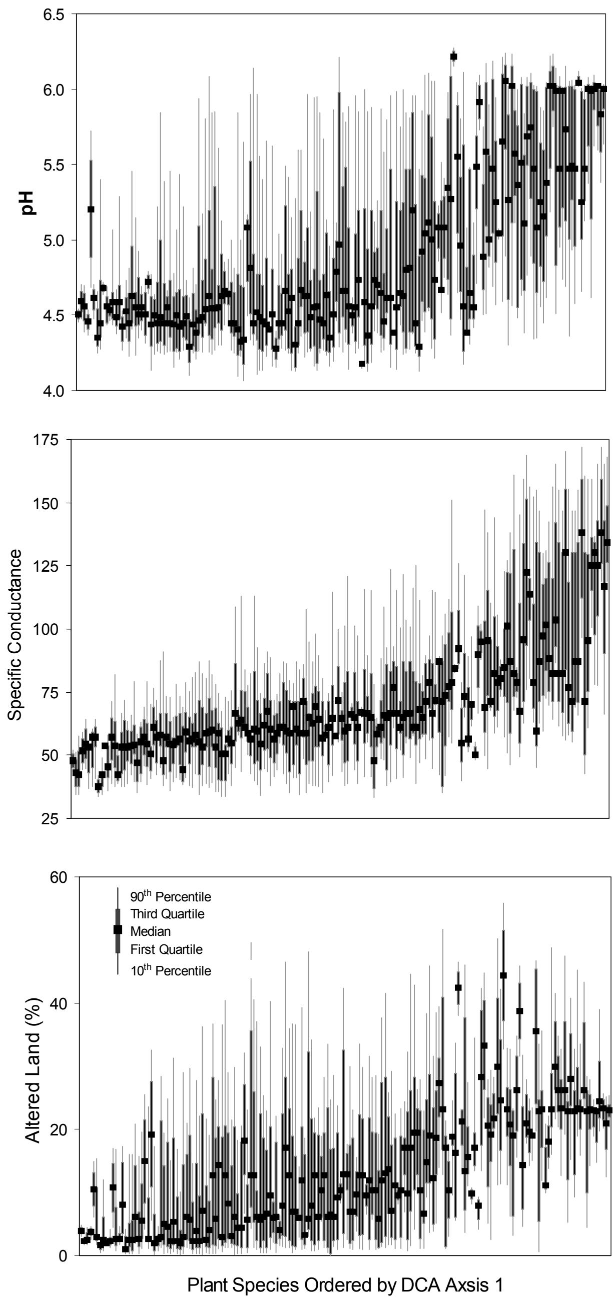

Figure 3.6. The pH, specific conductance (μS cm^{-1}) and percentage of altered land (developed land and upland agriculture) associated with plant species found at 50 Barnegat Bay Watershed stream sites. Refer to Table 3.5 for a list of species ordered by DCA axis 1 scores.

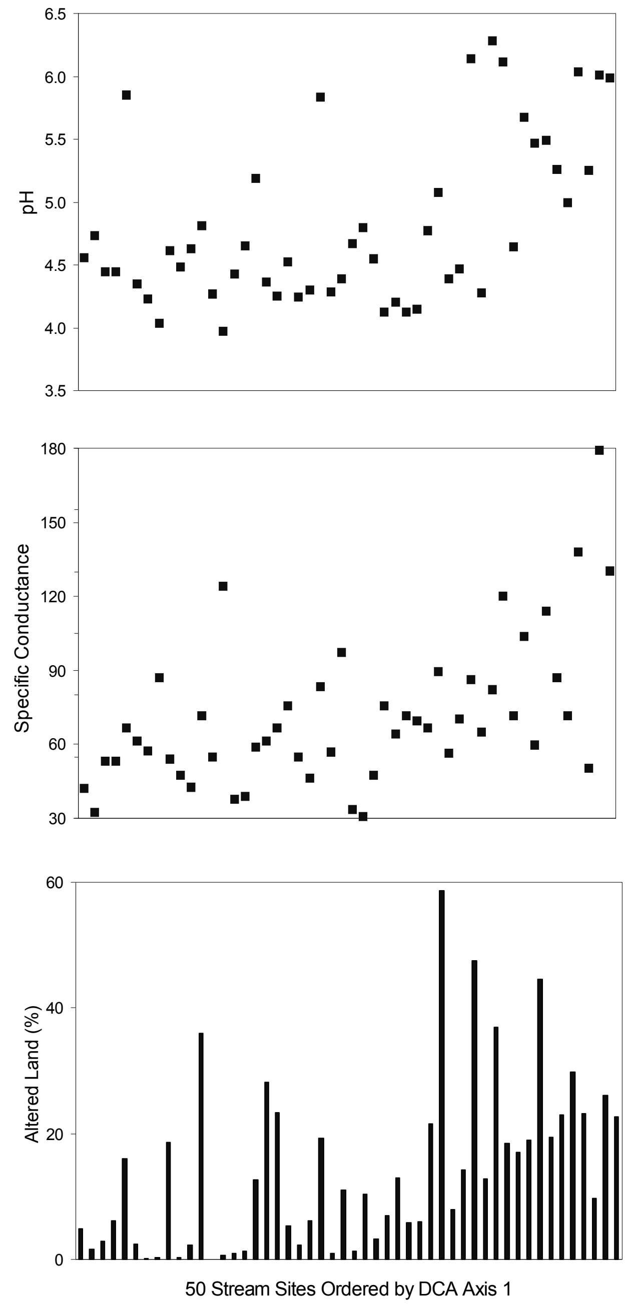

Figure 3.7. The pH, specific conductance (μS cm^{-1}) and percentage of altered land (developed land and upland agriculture) for 50 Barnegat Bay Watershed stream sites. DCA axis 1 represents a stream-vegetation community gradient. Refer to Table 3.4 for a list of sites ordered by DCA axis 1 scores.

The TWINSPAN classification revealed patterns similar to those obtained using DCA (Figure 3.3). The first TWINSPAN division separated a group of 35 sites with a higher percentage of native Pine Barrens District and wide-ranging plants and few to no disturbance-indicator species (Site Class 1) from 15 sites characterized by a lower percentage of native plants and a higher percentage of disturbance-indicator species (Site Class 2, Figures 3.3 and 3.8). The two site classes were also distinguished by

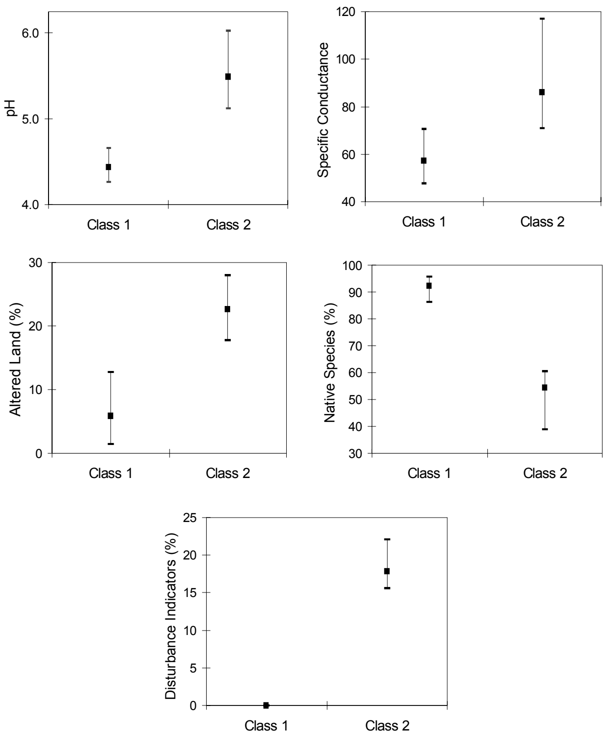

Figure 3.8. Median and first and third quartile specific conductance (μS cm^{-1}), pH, percentage of altered land (developed land and upland agriculture), percentage of native plant species, and percentage of disturbance-indicator plant species for two TWINSPAN-derived site classes for 50 Barnegat Bay Watershed stream sites.

contrasting pH, specific conductance, and the percentage of altered land (Figure 3.8). Based on Mann-Whitney tests, there were differences ($p < 0.001$) in the percentage of native species, the percentage of disturbance-indicator species, pH, specific conductance, and the percentage of altered land between the two site classes.

Logistic regression results indicated a strong ($p < 0.001$) relationship between the presence of two or more disturbance indicators at a site and pH, specific conductance, and the percentage of altered land. The probability of finding two or more disturbance-indicator species at a stream site increased with increasing pH, specific conductance, and altered land (Figure 3.9).

Study-basin Characterizations

Westecunk Creek

Most Westecunk Creek study-basin sites were associated with the end of the stream-vegetation community gradient characterized by a high

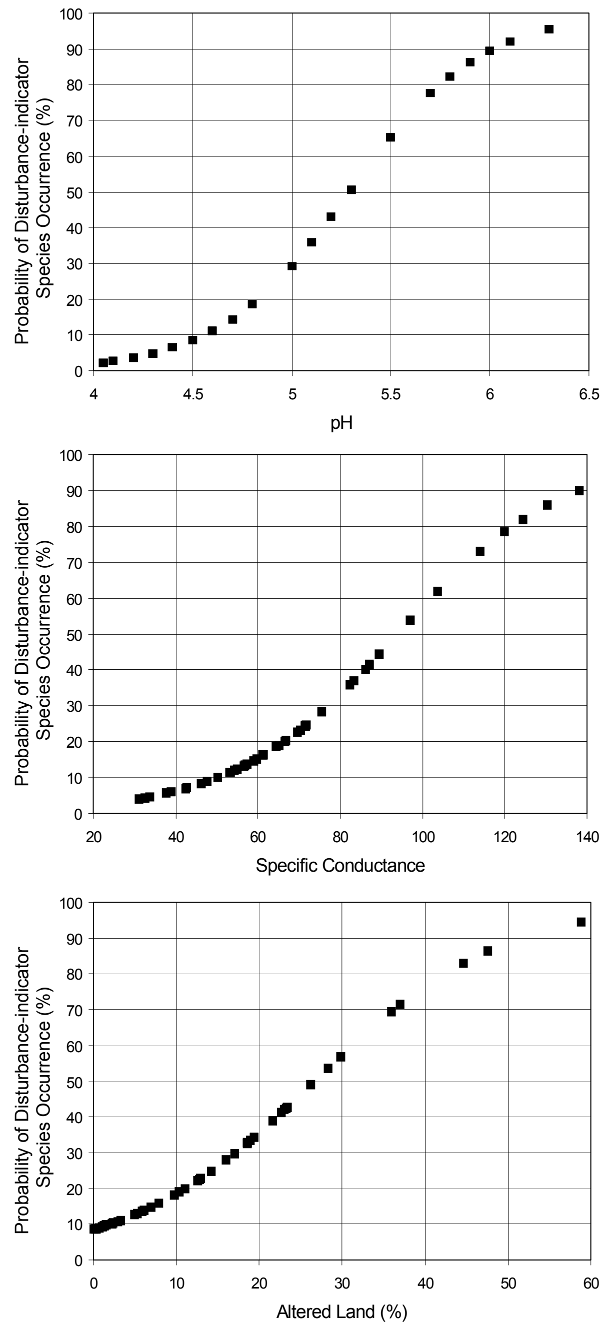

Figure 3.9. Logistic regression results showing the predicted probability of finding two or more disturbance-indicator species in relation to pH, specific conductance (μS cm^{-1}), and altered land (developed and upland agriculture) for 50 Barnegat Bay Watershed stream sites.

percentage of native Pinelands plant species, a low percentage of non-Pinelands species, and few disturbance-indicator species (Table 3.4, Figure 3.10). Both Mill Branch sites (Mill Branch at Poor Mans Parkway and Mill Branch at Nugentown Road) supported native Pinelands species exclusively (Figure

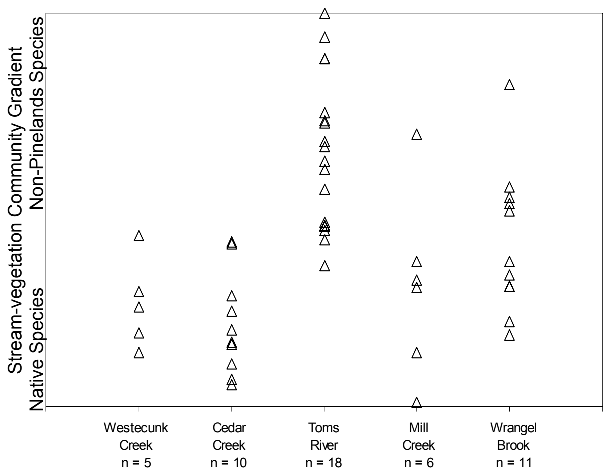

Figure 3.10. Position of stream sites along the native to non-Pinelands species stream-vegetation community gradient, represented by DCA axis 1 site scores, in five Barnegat Bay Watershed study basins. Refer to Table 3.4 for a list of sites ordered by DCA axis 1 scores.

3.11). Vegetation found at two other sites (Three Mile Branch at Pollypod Road and Westecunk Creek at Forge Road) consisted of greater than 95% native Pinelands species. The remaining site in the study basin (Westecunk Creek at Railroad Avenue) supported several non-Pinelands species and a single disturbance-indicator species.

Cedar Creek

Similar to the Westecunk Creek study basin, sites in the Cedar Creek study basin were generally associated with the native Pinelands-species end of the stream-vegetation community gradient (Table 3.4, Figure 3.10). Five sites in this study basin (Webbs Mill Branch at Route 539, Oyster Creek at Route 532, Cedar Creek at Route 9, North Branch Forked River at a powerline right-of-way, and Long Branch at Bryant Road) supported a flora composed of 95 to 100% native Pinelands species (Figure 3.11). Waretown Creek at Route 9 and Cedar Creek at Route 614 supported the highest percentage of non-Pinelands species (20 and 21%, respectively) in the Cedar Creek study basin. Few disturbance-indicator species were found at sites in this study basin. Chamberlain Branch at an unnamed road supported the highest total-species richness (62 species) and Cedar Creek at Double Trouble Road supported the highest herbaceous-species richness (44 species) of all Barnegat Bay Watershed stream sites.

Toms River

In contrast to the Westecunk Creek and Cedar Creek study basins, most of the stream sites in the Toms River study basin were associated with the end of the stream-vegetation community gradient characterized by a relatively low percentage of native Pinelands species and a high percentage of non-Pinelands species (Table 3.4, Figure 3.10). Ten stream sites in this study basin supported from 5 to 16 disturbance-indicator species (Figure 3.11). The highest percentages of non-Pinelands species found at Barnegat Bay Watershed study sites occurred at four Toms River study-basin sites, including Toms River at Route 528, Mirey Run at Route 528, Toms River tributary at Route 571, and Toms River at Bowman Road. A majority of the drainage areas associated with these four sites are located outside the Pinelands National Reserve but within Stone's Pine Barrens District. The highest percentages of native Pinelands species in the Toms River study basin were found at six sites, including Blacks Branch at Route 70, Blacks Branch at Central Avenue, Old Hurricane Brook at Route 70, Old Hurricane Brook at Beckerville Road, Ridgeway Branch at High Bridge Road, and Maple Root Branch at Bowman Road. Ridgeway Branch at Ridgeway Boulevard had the lowest total-species richness (14 species) and Maple Root Branch at Bowman Road had the lowest herbaceous-species richness (4 species) of all Barnegat Bay Watershed stream sites.

Mill Creek

Five of the six sites surveyed in the Mill Creek study basin were associated with the native Pinelands-species end of the stream-vegetation community gradient (Table 3.4, Figure 3.10). No disturbance-indicator species were found at these five sites, where native species comprised from 84 to 100% of the flora (Figure 3.11). Only native species were found at Mill Creek at Hay Road. In contrast, non-Pinelands species represented 50% of all species at Mill Creek at Route 72 below Manahawkin Lake. Five disturbance-indicator plant species were found at this site.

Wrangel Brook

The vegetation composition of the eleven Wrangel Brook study-basin stream sites was highly variable, with sites distributed along much of the stream-vegetation community gradient (Table 3.4, Figures 3.10 and 3.11). Three sites (Jakes Branch at Double Trouble Road, Sunken Branch at Mule Road, and Wrangel Brook at South Hampton Road), located toward the non-Pinelands species end of the

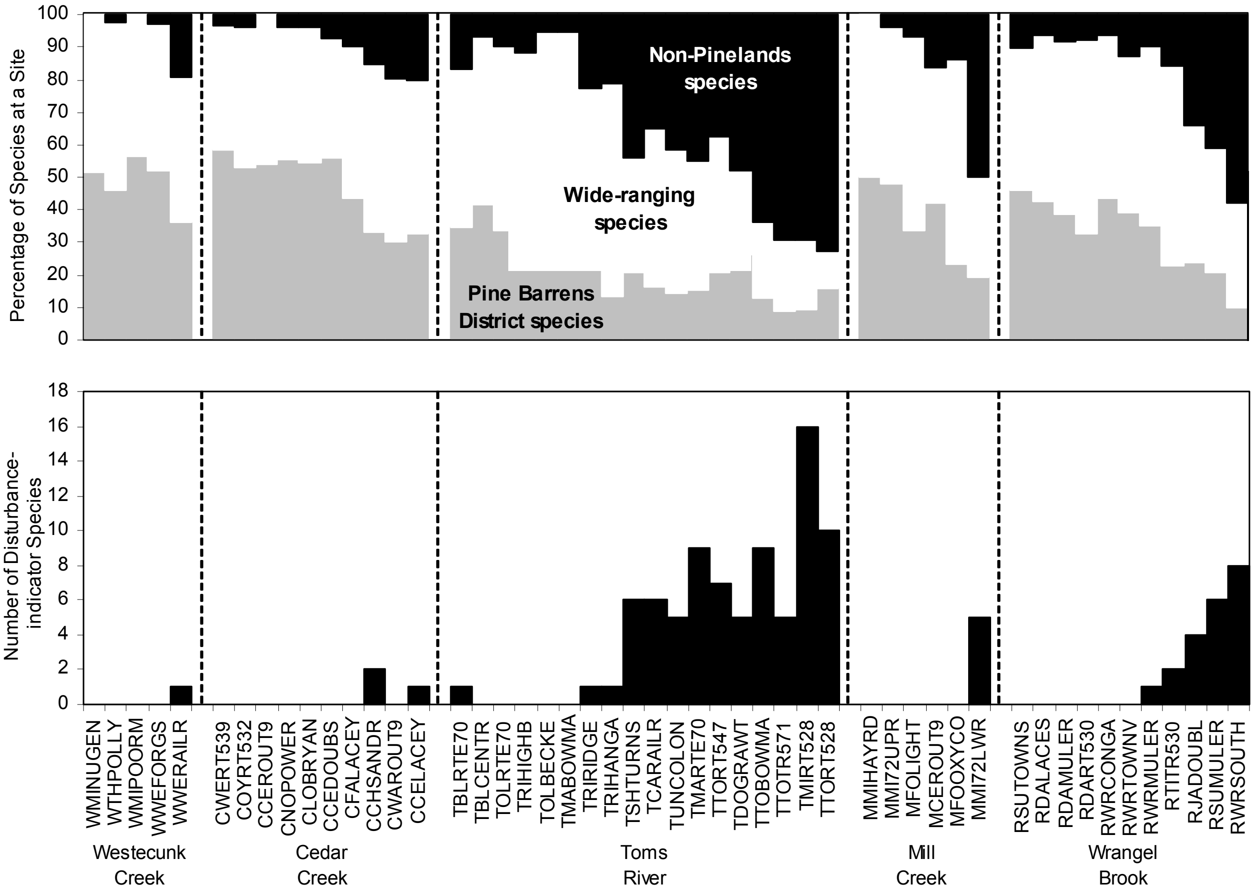

Figure 3.11. The percentage of Pine Barrens District, wide-ranging, and non-Pinelands species and numbers of disturbance-indicator species present at 50 stream sites in the Barnegat Bay Watershed. Stream-site codes are ordered by DCA axis 1 scores within each study basin. Refer to Table 3.4 for stream names represented by site codes.

vegetation gradient, were characterized by a relatively high percentage of non-Pinelands species, ranging from 34 to 58%, and by the presence of four to eight disturbance-indicator species. Native Pinelands species comprised from 84 to 93% of the flora at the remaining eight Wrangel Brook sites. Two disturbance-indicator species were found at one of these sites and a single indicator was found at another site. No disturbance-indicator species were found at the remaining six Wrangel Brook sites.

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4 Fish Assemblages

Introduction

Commission studies in the Mullica River Basin, Rancocas Creek Basin, and Great Egg Harbor River Watershed Management Area (WMA) indicated that the presence of nonnative-fish species was associated with basins characterized by a high percentage of upland agriculture and developed land and surface waters with elevated pH and specific conductance values (Zampella and Bunnell 1998, Zampella et al. 2001, 2003, 2005, 2006). Relatively unaltered basins generally supported fish assemblages composed only of native Pinelands species. In 2003, Commission scientists surveyed fish in Barnegat Bay Watershed streams and impoundments. The results of this assessment are presented in this chapter.

Methods

Study Sites

Forty-two stream sites and 17 impoundments were surveyed in the Barnegat Bay Watershed (Tables 4.1 and 4.2). Stream sites were typically located at road crossings, where the water tended to be relatively deep and where pools were more common. Nonnative fish are more likely to be found in pool habitats because most of these species are generally associated with lake and pond environments (Hastings 1984, Zampella et al. 2001). The majority of the stream sites were located at New Jersey Department of Environmental Protection Ambient Biomonitoring Network (NJDEP AMNET) stations. Other criteria used to select survey sites were drainage-area land-use characteristics, accessibility, and suitability as fish-survey sites. Sampling reaches consisted of a 20-m length of stream divided into two 10-m sections located upstream and downstream of a bridge or road crossing or a single 20-m upstream or downstream section. The coordinates of each sampling station were determined using NJDEP AMNET stations, orthophotoquads, and a geographic information system.

Characterizing Survey-site Conditions

Several site-specific and regional watershed-disturbance variables were used to characterize each fish-survey site (Tables 4.1 and 4.2). The variables included pH, specific conductance, developed land

Table 4.1. Median pH and specific conductance (μS cm^{-1}) values and the percentage of developed land, upland agriculture, and altered land (developed land and upland agriculture) for 42 Barnegat Bay Watershed stream sites. Refer to Chapter 2 for details regarding water-quality monitoring.

Site Code	pH	SC	Developed	Upland Ag.	Altered Land
CCEDOUBS	4.6	43	1.8	0.4	2.2
CCELACEY	4.7	34	0.8	0.5	1.2
CCEROUT9	4.4	53	5.6	0.5	6.1
CCHSANDR	4.4	38	0.3	0.7	1.0
CFALACEY	4.3	55	0.0	0.0	0.0
CNOPOWER	4.2	57	0.2	0.0	0.2
COYRT532	4.4	53	2.7	0.2	2.9
CWAROUT9	4.4	97	10.9	0.1	11.0
CWERT539	4.7	32	0.5	1.1	1.6
MCEROUT9	4.5	76	5.2	0.1	5.3
MFOLIGHT	5.2	59	12.5	0.1	12.6
MMIHAYRD	4.6	42	4.9	0.1	4.9
MMI72LWR	5.7	104	18.6	0.3	18.9
MMI72UPR	5.9	67	16.0	0.0	16.0
RDALACES	4.8	72	35.1	0.8	36.0
RDAMULER	4.4	61	27.9	0.3	28.2
RDART530	4.3	67	22.9	0.5	23.4
RJADOUBL	4.4	57	7.6	0.3	7.9
RSUMULER	6.1	86	47.6	0.0	47.6
RSUTOWNS	4.6	54	18.6	0.0	18.6
RTITR530	5.1	90	57.4	1.4	58.8
RWRCONGA	4.2	55	2.1	0.1	2.2
RWRMULER	4.8	67	20.6	1.0	21.6
RWRSOUTH	5.0	71	29.1	0.7	29.8
RWRTOWNS	4.3	57	1.0	0.0	1.0
TBLRTE70	4.3	46	5.6	0.6	6.1
TDOGRAWT	5.3	87	18.5	4.5	23.0
TMARTE70	5.5	60	44.1	0.4	44.6
TMIRT528	6.0	180	20.3	5.9	26.2
TOLRTE70	4.1	75	5.8	1.2	7.0
TRIHANGA	4.3	65	7.4	5.4	12.8
TRIHIGHB	4.2	64	6.4	6.5	13.0
TRIRIDGE	4.5	70	9.3	4.9	14.2
TSHTURNS	6.3	82	13.1	23.9	37.0
TTOBOWMA	6.0	138	18.8	4.4	23.2
TTORT528	6.0	130	18.7	4.1	22.7
TTORT547	5.5	114	15.3	4.1	19.4
TTOTR571	5.3	50	9.1	0.6	9.7
TUNCOLON	4.6	71	16.4	0.6	17.0
WMINUGEN	4.4	61	2.4	0.0	2.4
WWEFORGS	4.7	39	0.8	0.5	1.2
WWERAILR	4.6	48	2.6	0.6	3.2

Table 4.2. Median pH and specific conductance (μS cm^{-1}) values and the percentage of developed land, upland agriculture, and altered land (developed land and upland agriculture) for 17 Barnegat Bay Watershed impoundments. Water quality was measured at the outflow of impoundments, except for MFOOCEAN (measured upstream at MFOLIGHT) and MMIMANAH (measured downstream at MMI72LWR). Water quality was not measured at WWEFORG3. Refer to Chapter 2 for details regarding water-quality monitoring.

Site Code	pH	SC	Developed	Upland Ag.	Altered Land
CCEBAMBR	4.7	34	0.7	0.5	1.1
CCEDOUBL	4.6	41	2.1	0.5	2.6
CNOLOWER	5.0	64	10.3	0.0	10.3
COYWELLS	4.7	56	4.0	0.4	4.4
MFOOCEAN	5.2	59	16.8	0.0	16.8
MMIMANAH	5.7	104	18.4	0.3	18.7
RDAHARRY	6.1	62	22.7	0.0	22.7
RDALACEL	4.8	72	35.1	0.8	36.0
RTIKESWI	5.5	97	53.8	0.0	53.8
TDOIM528	5.2	73	15.1	3.3	18.4
TSHSUCCE	4.5	58	6.7	8.6	15.4
TSHTURNL	6.3	82	13.1	23.9	37.0
TSHUPPER	4.6	59	4.3	2.5	6.8
TTOIM571	5.3	50	9.1	0.6	9.7
TUNHORIC	4.2	62	5.7	0.7	6.4
WMIPOHAT	4.4	67	9.0	0.1	9.1
WWEFORG3	-	-	0.8	0.5	1.3

and upland agriculture. Specific conductance and pH were measured at or near baseflow conditions at or near stream and impoundment sampling sites (Chapter 2). Upstream land-use profiles were prepared using ArcView software and NJDEP 1995/1997 land-use data (Chapter 1).

Fish Surveys

Fish-sampling methods were the same as those used in the Rancocas Creek Basin and Great Egg Harbor River WMA studies (Zampella et al. 2003, 2005). At each stream site, all habitats within the 20-m long stream reach were sampled using a 4-mm mesh nylon seine. Stream sites were sampled for 15 minutes on one occasion between June and October 2003. Impoundments were sampled on a single occasion for 30 minutes between August and October 2003. Four impoundments were sampled more intensely (Bamber Lake, Horicon Lake, Success Lake, and Turnmill Pond).

The fish-survey data, which include the number of individuals of each species collected at each site and distribution maps for each species, are presented in Appendix 3. This appendix also describes the location of each sampling site and includes latitude and longitude. The Commission maintains voucher specimens collected at each site.

The number of individuals collected at a site was used to determine presence-absence and to calculate relative abundance. Relative abundance was calculated as: (number of individuals of a species at a site/total number of individuals at a site) × 100. Some juvenile *Esox* species (*E. niger* or *E. americanus*), *Enneacanthus* species (*E. obesus* or *E. gloriosus*), and *Lepomis* species (*L. gibbosus* or *L. macrochirus*) could not be identified to species and were not included in subsequent data analyses.

Fish-community Gradients

Detrended correspondence analysis (DCA) was used to order fish species and survey sites based on presence-absence data. The same data were used to classify or group species and sites using TWINSPAN. These techniques are described in greater detail in Zampella et al. (2001). Stream sites and impoundments were analyzed separately. Because rare species can have a disproportionate effect on ordinations, only species occurring at more than one site were included in the gradient analyses. Two stream sites, Wrangel Brook at Congasia Road and Mill Creek at Hay Road, were excluded from the analysis. Only one species (swamp darter) was found at Wrangel Brook at Congasia Road and no fish were collected from Mill Creek at Hay Road.

Spearman rank correlation was used to determine if the fish-community composition of streams and impoundments, represented by the DCA-ordination axes, varied in relation to environmental factors. The environmental variables included median pH and specific conductance values and the percentages of upstream developed land, upland agriculture, and altered land (developed land and upland agriculture).

For streams and impoundments, differences in biogeography and watershed conditions between the first two TWINSPAN-derived site classes were compared using Mann-Whitney U tests. Watershed conditions were represented by pH, specific conductance, and the percentage of upstream altered land (developed land and upland agriculture). Biogeography was represented by the percentage composition of native and nonnative fish species, which was determined using presence-absence data. Native species included those generally limited to the Pinelands (restricted species) and those distributed throughout most of the state (widespread species) (Table 4.3). Nonnative species included those normally distributed outside the Pinelands (peripheral species) and species not native to New Jersey (introduced species). An alpha level of 0.05 was used to identify important relationships revealed by the correlation analysis and to evaluate differences between the site classes.

RESULTS

Stream-fish Surveys

A total of 21 fish species were collected at the 41 stream sites where fish were found. These included 13 native Pinelands species, five peripheral species, and three introduced species (Table 4.3). Species richness ranged from 1 to 13 species per site, with a mean (± 1 SD) and median richness of 7 ± 3 and 7, respectively. The number of individuals collected per site ranged from 2 to 79. The mean (± 1 SD) and median number of individuals per site was 28 ± 18 and 26, respectively.

Native species were present at all stream sites (Figures 4.1 and 4.2). The most frequently encountered native species were the chain pickerel, banded sunfish, swamp darter, and American eel,

Table 4.3. Common and scientific names for 22 fish species collected from Barnegat Bay Watershed streams and impoundments. A positive sign (+) indicates that a species was present and a negative sign (-) indicates that a species was not collected during the surveys. Nomenclature follows Page and Burr (1991). Biogeographic classification is from Hastings (1979, 1984).

Scientific Name	Species Code	Common Name	Streams	Imps.
Native Species				
Restricted Species				
Acantharchus pomotis	AcanPomo	mud sunfish	+	+
Ameiurus natalis	AmeiNata	yellow bullhead	+	+
Aphredoderus sayanus	AphrSaya	pirate perch	+	+
Enneacanthus chaetodon	EnneChae	blackbanded sunfish	+	+
Enneacanthus obesus	EnneObes	banded sunfish	+	+
Etheostoma fusiforme	EtheFusi	swamp darter	+	+
Widespread Species				
Anguilla rostrata	AnguRost	American eel	+	+
Enneacanthus gloriosus	EnneGlor	bluespotted sunfish	+	+
Erimyzon oblongus	ErimOblo	creek chubsucker	+	+
Esox americanus	EsoxAmer	redfin pickerel	+	-
Esox niger	EsoxNige	chain pickerel	+	+
Noturus gyrinus	NotuGyri	tadpole madtom	+	+
Umbra pygmaea	UmbrPygm	eastern mudminnow	+	+
Nonnative Species				
Peripheral Species				
Ameiurus nebulosus	AmeiNebu	brown bullhead	+	-
Etheostoma olmstedi	EtheOlms	tessellated darter	+	-
Fundulus diaphanus	FundDiap	banded killifish	+	+
Lepomis gibbosus	LepoGibb	pumpkinseed	+	+
Notemigonus crysoleucas	NoteChry	golden shiner	+	+
Perca flavescens	PercFlav	yellow perch	-	+
Introduced Species				
Lepomis macrochirus	LepoMacr	bluegill	+	+
Micropterus salmoides	MicrSalm	largemouth bass	+	+
Pomoxis nigromaculatus	PomoNigr	black crappie	+	-

which were each collected from over 60% of the sites (Figure 4.2). The mean relative abundance of native fish was 89% (Figure 4.3). The swamp darter and eastern mudminnow were the most abundant native species.

Nonnative species were present at 41% of the stream sites (Figures 4.1 and 4.2). The most frequently encountered nonnative species were the pumpkinseed, tessellated darter, and bluegill (Figure 4.2). The banded killifish was only collected from one stream site. Mean relative abundance for nonnative fish was 11% (Figure 4.3). The peripheral tessellated darter was the most abundant nonnative species.

Impoundment-fish Surveys

A total of 18 fish species were collected from the 17 impoundments, including 12 native Pinelands species, four peripheral species, and two introduced species (Table 4.3). Species richness ranged from 5 to 11 species per site, with a mean (± 1 SD) and median richness of 9 ± 2 and 9, respectively. The number of individuals collected per site ranged from 66 to 307. The mean (± 1 SD) and median number of individuals per site was 147 ± 76 and 125.

Native species were present in all 17 impoundments (Figure 4.4). The most frequently occurring native species were the banded sunfish and swamp darter. Both species occurred at more than 85% of the sites. The mean relative abundance of native fish was 68% (Figure 4.5). The banded sunfish was the most abundant native species in the impoundment assemblages. The redfin pickerel was the only native species not collected from the impoundments.

Nonnative species were present at 82% of the impoundments (Figure 4.6). The most frequently encountered nonnative species were the bluegill, largemouth bass, and pumpkinseed (Figure 4.4). The mean relative abundance of nonnative fish was 32% (Figure 4.5). The bluegill was the most abundant nonnative species. Although present at some stream sites, the brown bullhead, tessellated darter, and black crappie were absent from all 17 impoundments (Table 4.3). An important difference between the stream and impoundment survey results was a greater frequency of occurrence and greater relative abundance for pumpkinseed, bluegill, and largemouth bass in impoundments. Similar results were found during fish surveys in the Mullica River Basin and Great Egg Harbor River WMA (Zampella et al. 2001, 2005).

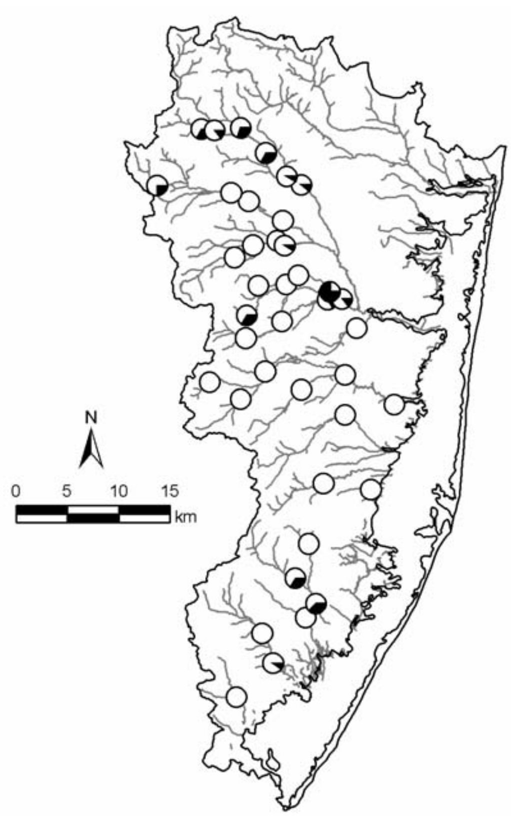

Figure 4.1. Pie charts showing the percentage of native species (white) and nonnative species (black) present at Barnegat Bay Watershed stream sites.

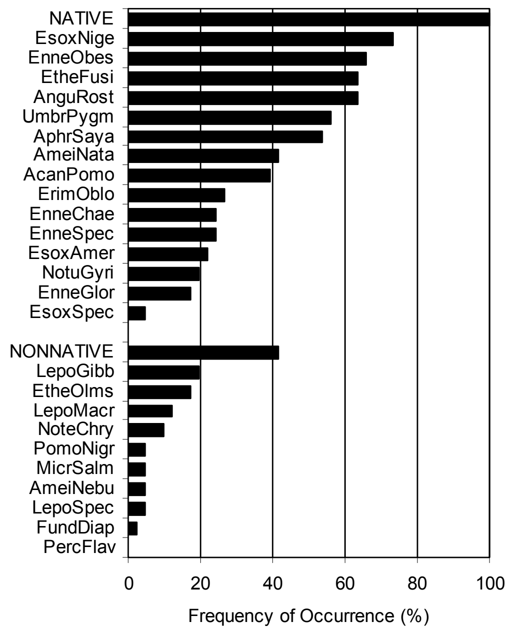

Figure 4.2. Frequency of occurrence of fish species at 41 Barnegat Bay Watershed stream sites. Refer to Table 4.3 for key to fish names.

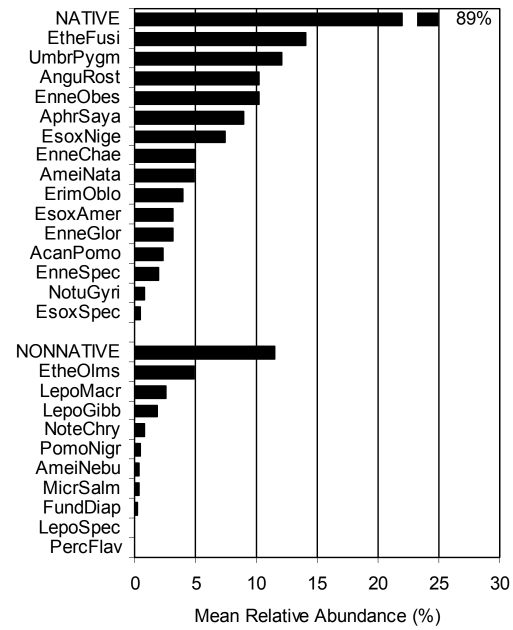

Figure 4.3. Mean relative abundance of fish species at 41 Barnegat Bay Watershed stream sites. Refer to Table 4.3 for key to fish names.

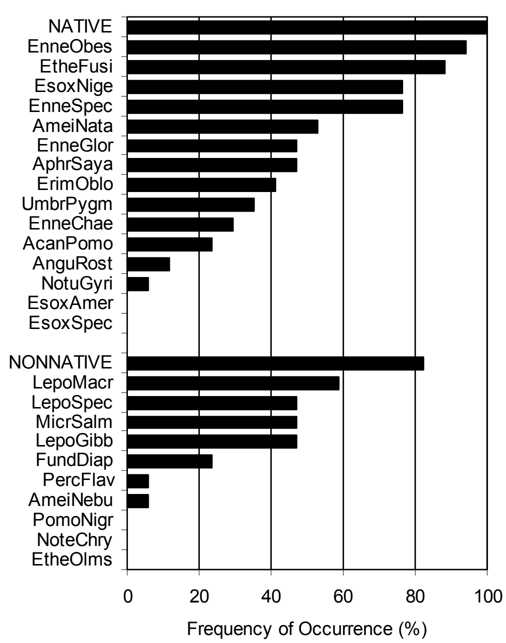

Figure 4.4. Frequency of occurrence of fish species at 17 Barnegat Bay Watershed impoundments. Refer to Table 4.3 for key to fish names.

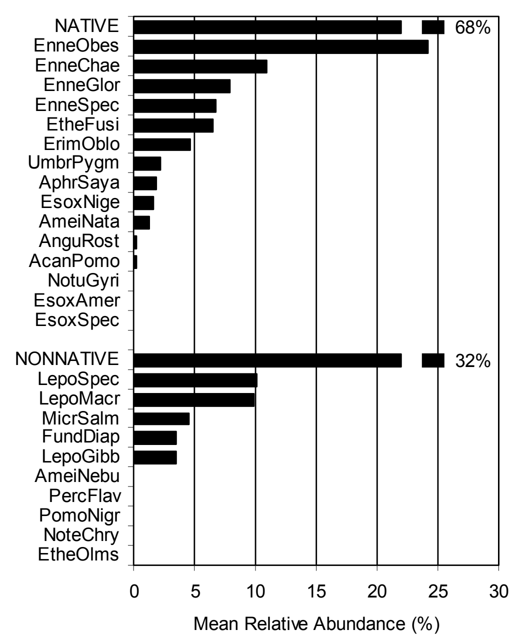

Figure 4.5. Mean relative abundance of fish species at 17 Barnegat Bay Watershed impoundments. Refer to Table 4.3 for key to fish names.

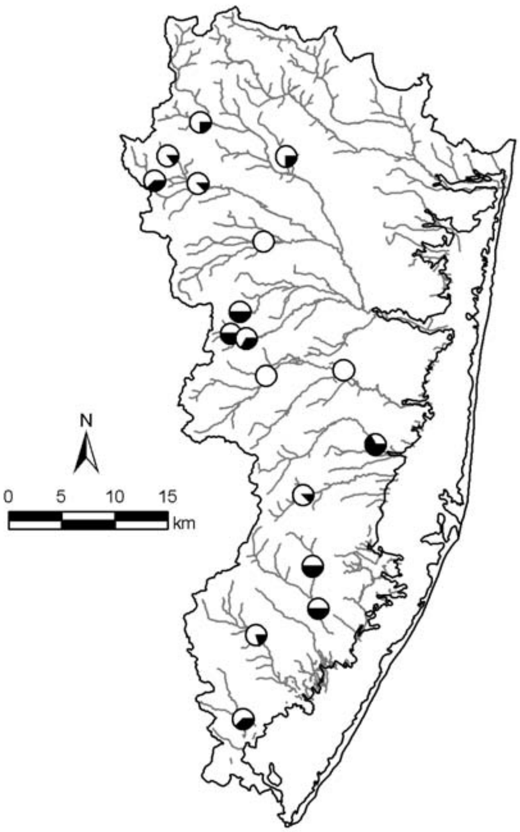

Figure 4.6. Pie charts showing the percentage of native species (white) and nonnative species (black) present at Barnegat Bay Watershed impoundments.

Stream-fish Community Gradient

The first DCA axis of the site ordination contrasted stream sites with fish assemblages composed entirely of native species with those supporting a relatively high percentage of nonnative species (Tables 4.4 and 4.5, Figure 4.7). The percentage of nonnative species increased ($r = 0.72$, $p < 0.001$) and the percentage of native species decreased ($r = -0.72$, $p < 0.001$) along this community gradient (Figure 4.8). The decrease in native species along the community gradient was due to a decrease in the percentage of restricted species ($r = -0.71$, $p < 0.001$) along the gradient rather than variations in the percentage of widespread species ($r = 0.31$, $p = 0.052$) (Figure 4.8). Restricted-fish species were only absent from sites that supported nonnative-fish species. Nonnative fish were generally found at stream sites with higher pH, specific conductance, and altered-land values (Figure 4.9).

The order of stream sites along the first DCA axis was related to increasing pH ($r = 0.64$, $p < 0.001$), specific conductance ($r = 0.46$, $p = 0.003$), developed land ($r = 0.56$, $p < 0.001$), and altered land ($r = 0.55$, $p < 0.001$) (Figure 4.10). Upland agriculture was not related to the stream-fish community gradient.

A decrease in the percentage of native species at a site was associated with increasing pH ($r = -0.75$, $p < 0.001$), specific conductance ($r = -0.54$, $p < 0.001$), developed land ($r = -0.65$, $p < 0.001$), and altered land ($r = -0.67$, $p < 0.001$). Opposite trends were observed for nonnative species. There was no relationship between the percentage of native or nonnative species at a site and upland agriculture.

Table 4.4. Raw DCA axis 1 and axis 2 site scores for 20 stream-fish species and 15 impoundment-fish species in the Barnegat Bay Watershed. Species are ordered by axis 1 scores. Nonnative species are indicated with an asterisk. Refer to Table 4.3 for key to fish names.

Stream Fish				Impoundment Fish			
Species	Species Code	Axis 1	Axis 2	Species	Species Code	Axis 1	Axis 2
Enneacanthus chaetodon	EnneChae	-118	140	*Erimyzon oblongus*	ErimOblo	-116	87
Esox americanus	EsoxAmer	-90	318	*Acantharchus pomotis*	AcanPomo	-91	88
Etheostoma fusiforme	EtheFusi	1	28	*Enneacanthus chaetodon*	EnneChae	-88	17
Umbra pygmaea	UmbrPygm	11	162	*Esox niger*	EsoxNige	44	100
Acantharchus pomotis	AcanPomo	19	-37	*Aphredoderus sayanus*	AphrSaya	71	318
Aphredoderus sayanus	AphrSaya	25	135	*Enneacanthus obesus*	EnneObes	76	23
Enneacanthus obesus	EnneObes	79	9	*Etheostoma fusiforme*	EtheFusi	85	21
Anguilla rostrata	AnguRost	113	134	*Ameiurus natalis*	AmeiNata	122	-30
Erimyzon oblongus	ErimOblo	134	-162	*Umbra pygmaea*	UmbrPygm	140	85
Ameiurus natalis	AmeiNata	146	4	*Anguilla rostrata*	AnguRost	162	-159
Etheostoma olmstedi	EtheOlms *	182	255	*Lepomis gibbosus*	LepoGibb *	166	211
Esox niger	EsoxNige	194	73	*Enneacanthus gloriosus*	EnneGlor	190	51
Noturus gyrinus	NotuGyri	205	143	*Lepomis macrochirus*	LepoMacr *	204	-16
Enneacanthus gloriosus	EnneGlor	241	288	*Micropterus salmoides*	MicrSalm *	282	140
Lepomis gibbosus	LepoGibb *	261	241	*Fundulus diaphanus*	FundDiap *	330	-185
Notemigonus crysoleucas	NoteChry *	295	165				
Lepomis macrochirus	LepoMacr *	322	123				
Ameiurus nebulosus	AmeiNebu *	333	141				
Micropterus salmoides	MicrSalm *	372	-11				
Pomoxis nigromaculatus	PomoNigr *	372	-11				

Table 4.5. Raw DCA axis 1 and axis 2 site scores for 40 stream sites in the Barnegat Bay Watershed based on an ordination of species presence-absence data. Sites are ordered by axis 1 scores.

Study Basin	Site Name	Site Code	Axis 1	Axis 2
Cedar Creek	Factory Branch at Route 614	CFALACEY	0	163
Wrangle Brook	Wrangle Brook at Township Line Road	RWRTOWNS	4	96
Toms River	Blacks Branch at Route 70	TBLRTE70	30	73
Cedar Creek	Webbs Mill Branch at Route 539	CWERT539	32	91
Cedar Creek	North Branch Forked River at a powerline right-of-way	CNOPOWER	33	0
Toms River	Toms River at Route 547	TTORT547	37	134
Wrangle Brook	Sunken Branch at Township Line Road	RSUTOWNS	45	111
Toms River	Ridgeway Branch at High Bridge Road	TRIHIGHB	54	154
Toms River	Old Hurricane Brook at Route 70	TOLRTE70	55	62
Cedar Creek	Cedar Creek at Route 614	CCELACEY	56	47
Wrangle Brook	Jakes Branch at Double Trouble Road	RJADOUBL	56	62
Cedar Creek	Cedar Creek at Route 9	CCEROUT9	64	39
Cedar Creek	Chamberlain Branch at an unnamed road	CCHSANDR	70	90
Toms River	Dove Mill Branch at Grawtown Road	TDOGRAWT	72	137
Toms River	Ridgeway Branch at Hangar Road	TRIHANGA	73	79
Cedar Creek	Cedar Creek at Double Trouble Road	CCEDOUBS	78	32
Mill Creek	Fourmile Branch at Lighthouse Drive	MFOLIGHT	79	58
Westecunk Creek	Mill Branch at Nugentown Road	WMINUGEN	84	103
Wrangle Brook	Davenport Branch at Route 530	RDART530	85	44
Toms River	Union Branch at Colonial Drive	TUNCOLON	86	94
Toms River	Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	88	18
Wrangle Brook	Wrangel Brook at South Hampton Road	RWRSOUTH	89	190
Toms River	Manapaqua Brook at Route 70	TMARTE70	91	70
Mill Creek	Cedar Run at Route 9	MCEROUT9	98	102
Wrangle Brook	Davenport Branch at Route 614	RDALACES	98	7
Westecunk Creek	Westecunk Creek at Railroad Avenue	WWERAILR	102	51
Wrangle Brook	Davenport Branch at Mule Road	RDAMULER	106	114
Westecunk Creek	Westecunk Creek at Forge Road	WWEFORGS	107	50
Cedar Creek	Waretown Creek at Route 9	CWAROUT9	109	57
Toms River	Mirey Run at Route 528	TMIRT528	120	165
Wrangle Brook	Tice Van Horn Branch tributary at Route 530	RTITR530	128	179
Cedar Creek	Oyster Creek at Route 532	COYRT532	130	14
Toms River	Toms River at Route 528	TTORT528	135	155
Wrangle Brook	Wrangel Brook at Mule Road	RWRMULER	149	93
Toms River	Toms River at Bowman Road	TTOBOWMA	163	154
Toms River	Toms River tributary at Route 571	TTOTR571	167	137
Mill Creek	Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	170	122
Toms River	Shannae Brook tributary at Turn Mill Pond	TSHTURNS	176	48
Mill Creek	Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	210	110
Wrangle Brook	Sunken Branch at Mule Road	RSUMULER	278	91

Table 4.6. Raw DCA axis 1 and axis 2 site scores for 17 impoundments in the Barnegat Bay Watershed based on an ordination of species presence-absence data. Sites are ordered by axis 1 scores.

Study Basin	Site Name	Site Code	Axis 1	Axis 2
Cedar Creek	Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	0	50
Cedar Creek	Bamber Lake	CCEBAMBR	13	78
Toms River	Horicon Lake	TUNHORIC	40	49
Toms River	Dove Mill Branch impoundment at Route 528	TDOIM528	58	95
Toms River	Toms River tributary impoundment at Route 571	TTOIM571	74	116
Wrangle Brook	Davenport Branch impoundment at Route 614	RDALACEL	76	71
Cedar Creek	Wells Mills Lake	COYWELLS	90	14
Toms River	Success Lake	TSHSUCCE	106	60
Westecunk Creek	Westecunk Creek impoundment at Stafford Forge	WWEFORG3	106	20
Toms River	Shannae Brook impoundment	TSHUPPER	108	99
Wrangle Brook	Keswick Lake	RTIKESWI	148	0
Wrangle Brook	Harry Wright Lake	RDAHARRY	151	140
Westecunk Creek	Pohatcong Lake	WMIPOHAT	156	40
Cedar Creek	Lower Lake	CNOLOWER	173	223
Mill Creek	Holiday Lake	MFOOCEAN	177	33
Toms River	Turnmill Pond	TSHTURNL	180	12
Mill Creek	Manahawkin Lake	MMIMANAH	195	6

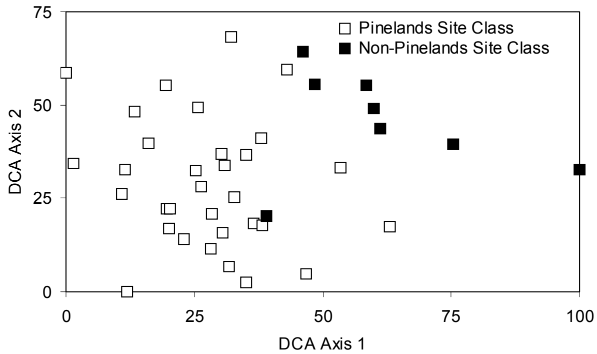

Figure 4.7. DCA ordination diagram and TWINSPAN classification for 40 Barnegat Bay Watershed stream sites. Refer to Table 4.5 for a list of sites ordered by DCA axis 1 scores.

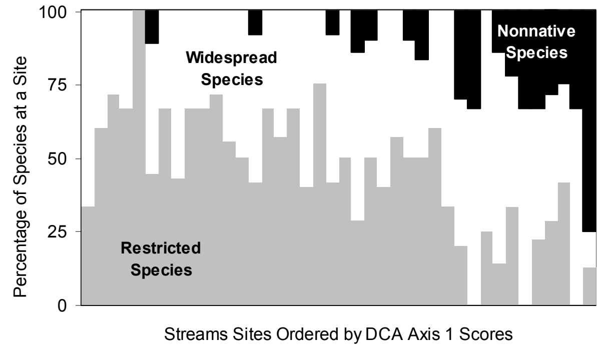

Figure 4.8. Percentage of native (restricted and widespread) and nonnative fish species found at 40 Barnegat Bay Watershed streams sites. Refer to Table 4.5 for a list of sites ordered by DCA axis 1 scores.

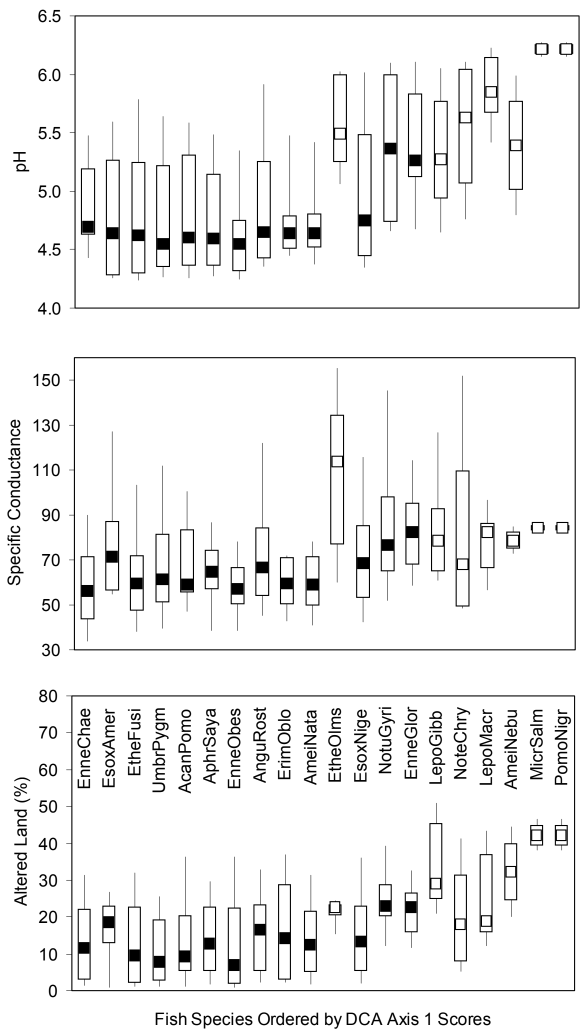

Figure 4.9. The pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) associated with fish species found at 40 Barnegat Bay Watershed stream sites. Box plots show the first, second (median), and third quartiles and the 10th and 90th percentiles for each variable. Open squares denote nonnative fish species. Refer to Table 4.3 for key to fish names.

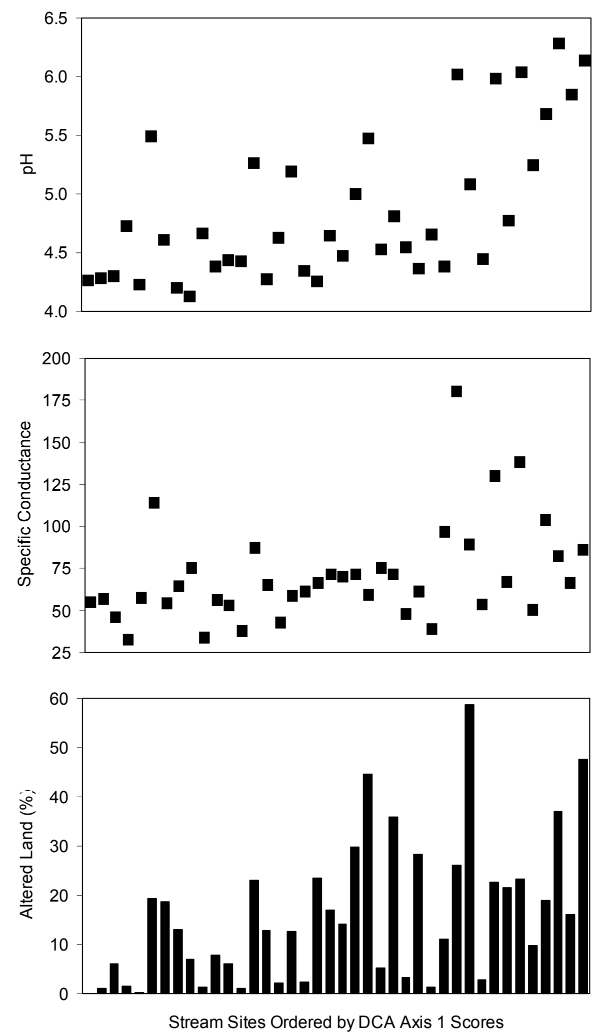

Figure 4.10. Median pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) for 40 Barnegat Bay Watershed stream sites. DCA axis 1 represents a stream-fish community gradient. Refer to Table 4.5 for a list of sites ordered by DCA axis 1 scores.

The first division of the TWINSPAN classification separated a group of eight stream sites, characterized by a higher percentage of nonnative species (non-Pinelands sites class), from 32 stream sites, characterized by a higher percentage of native species (Pinelands site class) (Figures 4.7 and 4.11). The non-Pinelands site class displayed elevated pH and specific conductance values and a higher percentage of altered land compared to the Pinelands site class (Figures 4.7 and 4.11). Based on Mann-Whitney tests, there was a difference in the percentage of native and nonnative species ($p < 0.001$), pH ($p = 0.003$), specific conductance ($p = 0.006$), and the percentage of altered land ($p = 0.046$) between the two site classes.

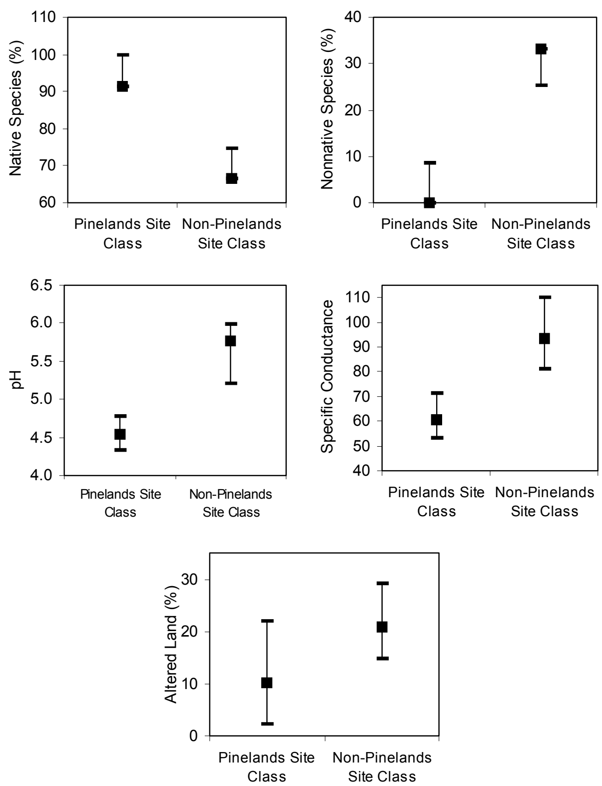

Figure 4.11. Median and 1st and 3rd quartile percentage of native and nonnative fish species, pH, specific conductance (μS cm^{-1}), and altered land (developed and upland agriculture) values for two TWINSPAN-derived site classes for 40 Barnegat Bay Watershed stream sites.

Impoundment-fish Community Gradient

Similar to the ordination of stream sites, the first DCA axis of the impoundment ordination contrasted sites with fish assemblages composed entirely of native species with those that supported a relatively high percentage of nonnative species (Tables 4.4 and 4.6, Figure 4.12). The percentage of native species decreased (r = -0.87, $p < 0.001$) and the percentage of nonnative species increased (r = 0.87, $p < 0.001$) along this community gradient (Figure 4.13). The decrease in native species along the impoundment-fish community gradient was due to a decrease in the percentage of restricted species (r = -0.67, $p = 0.003$) and widespread species (r = -0.52, $p = 0.032$) (Figure 4.13). Nonnative fish were generally found at impoundments with higher pH, specific conductance, and altered-land values (Figure 4.14).

The order of impoundments along the first DCA axis was related to increasing pH (r = 0.56, $p = 0.025$), specific conductance (r = 0.67, $p = 0.005$), developed land (r = 0.54, $p = 0.026$), and altered land (r = 0.56, $p = 0.019$) (Figure 4.15). Upland agriculture was not related to the impoundment-community gradient.

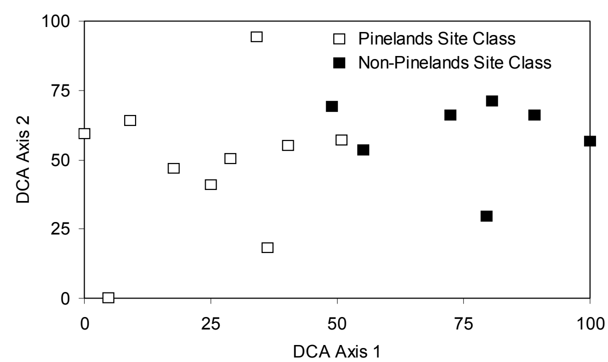

Figure 4.12. DCA ordination diagram and TWINSPAN classification for 17 Barnegat Bay Watershed impoundments. Refer to Table 4.6 for a list of sites ordered by DCA axis 1 scores.

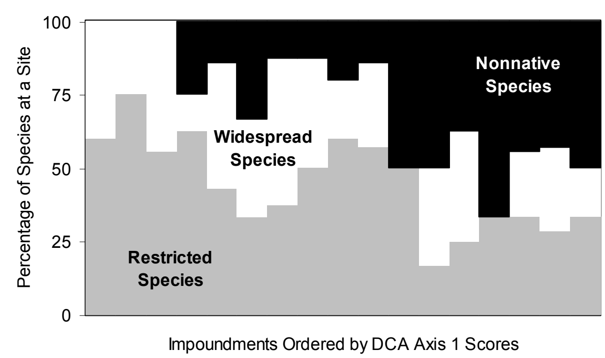

Figure 4.13. Percentage of native (restricted and widespread) and nonnative species found at 17 Barnegat Bay Watershed impoundments. Refer to Table 4.6 for a list of sites ordered by DCA axis 1 scores.

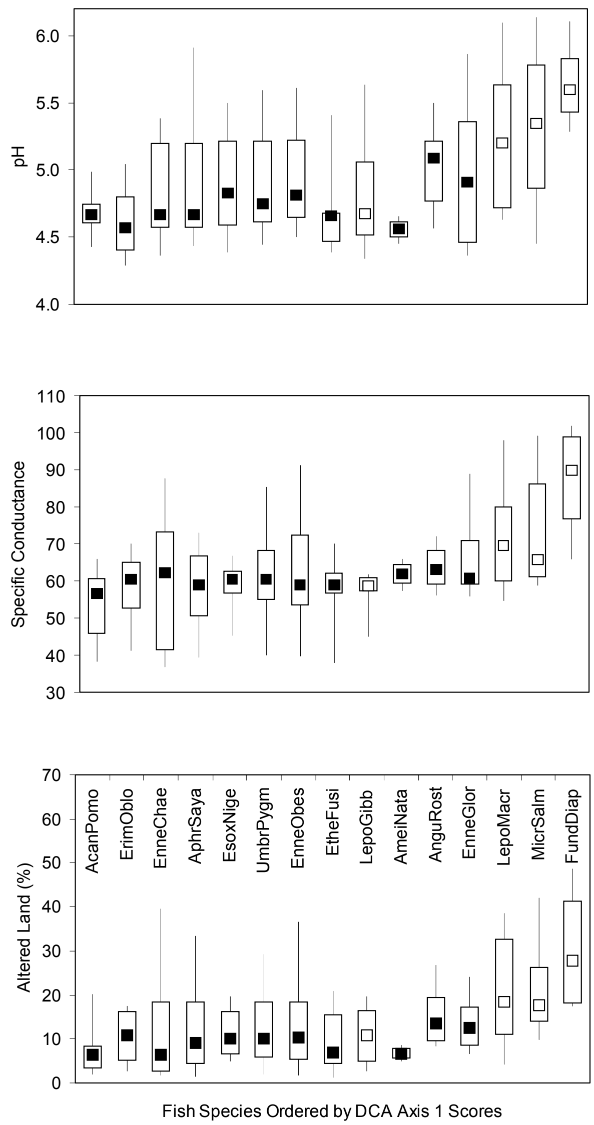

Figure 4.14. The pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) associated with fish species found at 17 Barnegat Bay Watershed impoundments. Box plots show the first, second (median), and third quartiles and the 10th and 90th percentiles for each variable. Open squares denote nonnative fish species. Refer to Table 4.3 for key to fish names.

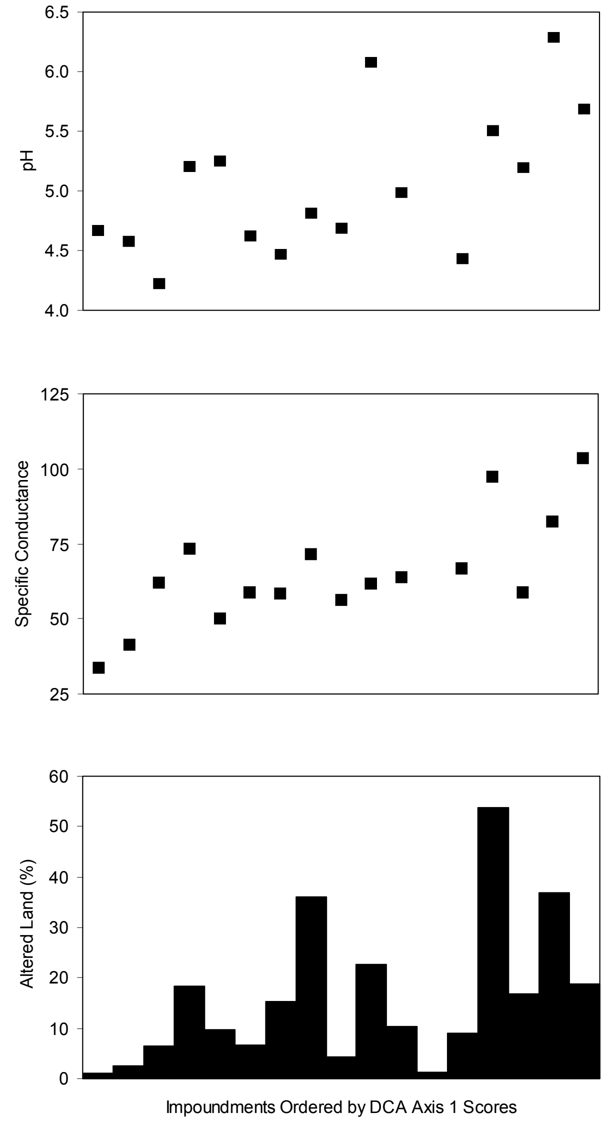

Figure 4.15. Median pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) for 17 Barnegat Bay Watershed impoundments. DCA axis 1 represents an impoundment-fish community gradient. Refer to Table 4.6 for a list of sites ordered by DCA axis 1 scores.

A decrease in the percentage of native species was associated with a decrease in the percentage of upland agriculture (r = 0.48, $p = 0.049$) and an increase in pH (r = -0.75, $p = 0.001$), specific conductance (r = -0.74, $p = 0.001$), and the percentage of developed land (r = -0.82, $p < 0.001$) and altered land (r = -0.78, $p < 0.001$). Opposite trends were observed for nonnative species.

The first division of the TWINSPAN classification separated a group of seven impoundments that supported a high percentage of nonnative species (non-Pinelands site class) from the remaining ten impoundments, which supported mostly native species (Pinelands site class) (Figures 4.12 and 4.16). The non-Pinelands site class displayed elevated pH and specific conductance values and a higher percentage of altered land compared to the Pinelands site class (Figures 4.12 and 4.16). Based on Mann-Whitney tests, there was a difference in the percentage of native and nonnative species ($p = 0.002$), pH ($p = 0.039$), and specific conductance ($p = 0.030$) between the two site classes. There was no difference in altered land between site classes.

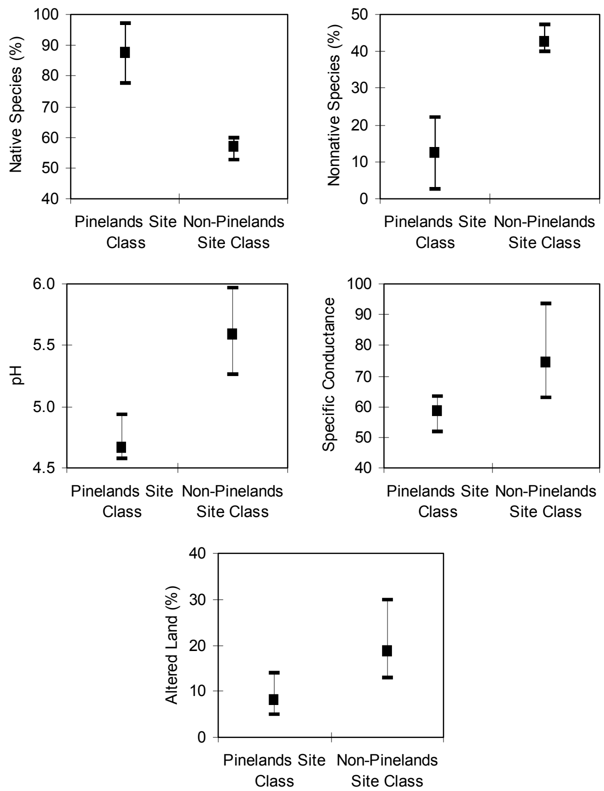

Figure 4.16. Median and 1st and 3rd quartile percentage of native and nonnative species, pH, specific conductance ($\mu S\ cm^{-1}$), and altered land (developed and upland agriculture) values for two TWINSPAN-derived site classes for 17 Barnegat Bay Watershed impoundments.

Study-basin Characterizations

Westecunk Creek

Three stream sites and two impoundments were surveyed in the Westecunk Creek study basin. Fourteen fish species were collected, including 10 native and four nonnative species. The average percentage of nonnative species per site was 14% (Figure 4.17). The three stream sites surveyed were associated with the native-species end of the stream-community gradient (Figure 4.18). Two of the stream sites supported fish assemblages composed entirely of native species (Figure 4.20). The golden shiner was the only nonnative species collected from the third site. In contrast to the stream sites, the two impoundments surveyed, Westecunk Creek at Stafford Forge and Pohatcong Lake, were associated with the nonnative-species end of the impoundment-community gradient due to the presence of nonnative-fish species (Figure 4.19). The nonnative bluegill was collected from the Westecunk Creek impoundment at Stafford Forge, located in the Stafford Forge Wildlife Management Area. The nonnative pumpkinseed, bluegill, and largemouth bass were collected from Pohatcong Lake.

Cedar Creek

A total of 15 fish species were found in the nine stream sites and four impoundments surveyed in the Cedar Creek study basin, including 12 native species and three nonnative species. This study basin exhibited the lowest mean percentage of nonnative species per site (Figure 4.17). Most sites surveyed in this study basin were associated with the native-species end of both fish-community gradients because all but two sites supported fish assemblages composed entirely of native species (Figures 4.18, 4.19, 4.20). Nonnative fish were found only in two impoundments, Wells Mills Lake and Lower Lake. Bluegill were found at Wells Mills Lake, located in Wells Mills County Park. Pumpkinseed and largemouth bass were collected from Lower Lake, which is located in a developed landscape in the Pinelands National Reserve portion of the Barnegat Bay Watershed.

Toms River

Fourteen stream sites and six impoundments were surveyed in the Toms River study basin. Twenty-one species of fish were present in this study basin, including 13 native species and eight nonnative species. Restricted-fish species were absent from one site (Figure 4.20). The fish-community composition of sites in this study basin was variable (Figures 4.18 and 4.19). Five of the 14 stream sites supported fish assemblages composed entirely of native species, whereas the other nine stream sites supported

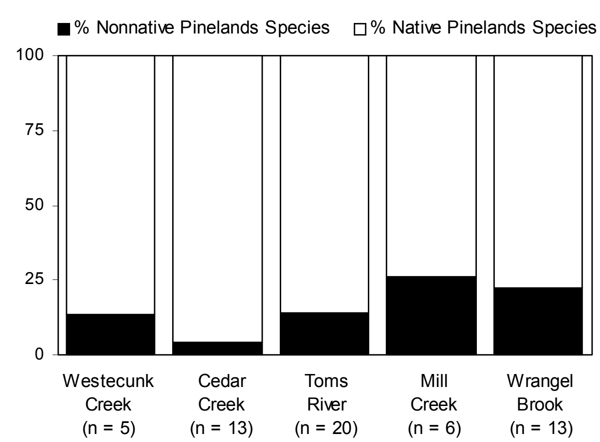

Figure 4.17. Mean percentage of native and nonnative fish species from stream sites in each study basin in the Barnegat Bay Watershed.

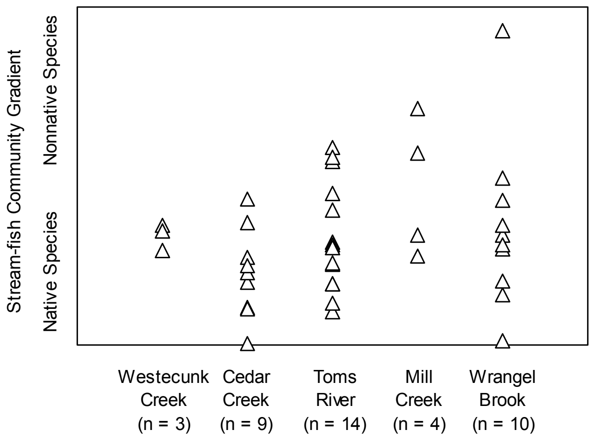

Figure 4.18. Position of fish-survey sites along the native to nonnative species stream-fish community gradient, represented by DCA axis 1 site scores, in the five Barnegat Bay Watershed study basins. Refer to Table 4.5 for a list of sites ordered by the first DCA axis. Individual triangles may represent more than one site.

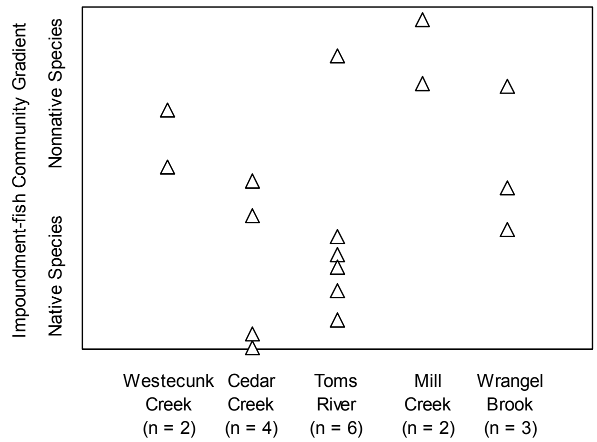

Figure 4.19. Position of fish-survey sites along the native to nonnative species impoundment-fish community gradient, represented by DCA axis 1 site scores, in the five Barnegat Bay Watershed study basins. Refer to Table 4.6 for a list of sites ordered by the first DCA axis. Individual triangles may represent more than one site.

relatively high percentages of nonnative species (Figure 4.20). The mean percentage of nonnative species per site was 14% (Figure 4.17). The tessellated darter, a peripheral species, was the only nonnative-fish species present at four of the stream sites. Of the six impoundments surveyed, nonnative fish were present at all but Horicon Lake. Turnmill Pond displayed the highest percentage of nonnative-fish species in the Toms River study basin (Figure 4.20).

Mill Creek

Five stream sites and two impoundments were surveyed in the Mill Creek study basin. No fish were collected from one stream site, Mill Creek at Hay Road. Fourteen fish species were collected from the remaining four stream sites and two impoundments surveyed in the study basin, including nine native species and five nonnative species. Restricted-fish species were absent from one site (Figure 4.20). Two stream sites supported fish assemblages composed

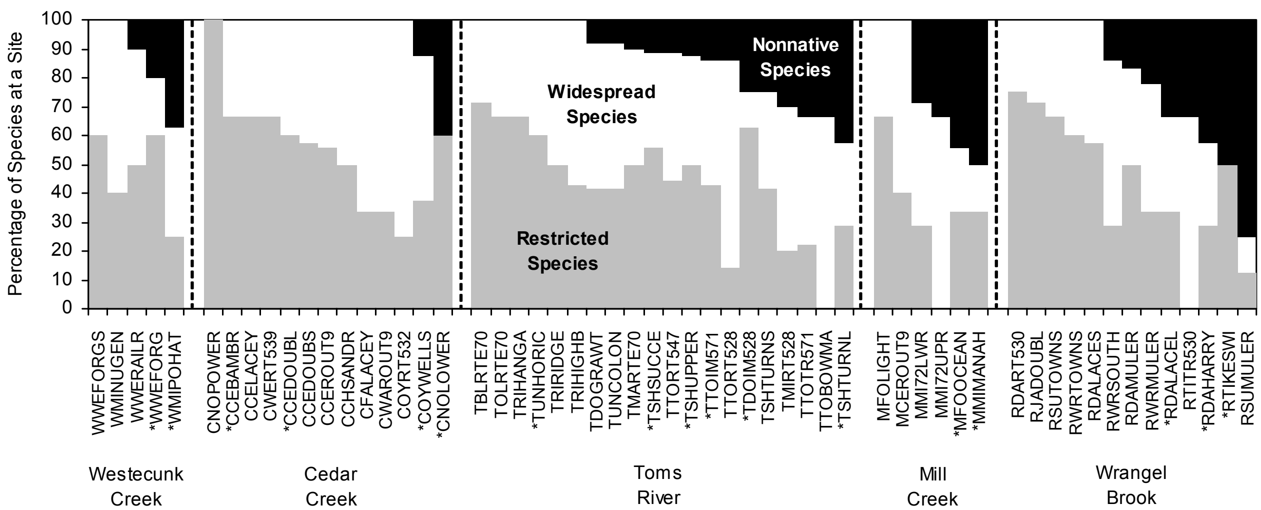

Figure 4.20. The percentage of native (restricted and widespread) and nonnative species present at Barnegat Bay Watershed stream and impoundment sites. Sites with an asterisk are impoundments. To allow for a direct comparison of stream and impoundment assemblages, sites are ordered by the percentage of nonnative species. Refer to Tables 4.5 and 4.6 for site names represented by site codes.

entirely of native species (Figure 4.20) and were more closely associated with the native-species end of the stream-community gradient (Figure 4.18). The other four stream and impoundment sites supported nonnative fish and were associated with the nonnative-species end of the fish-community gradients (Figure 4.18 and 4.19). The Mill Creek study basin displayed the highest mean percentage of nonnative-fish species (Figure 4.17). The two highest values for the percentage of nonnative-fish species were found for the two impoundments, Holiday Lake and Manahawkin Lake (Figure 4.20).

Wrangel Brook

Eleven stream sites and three impoundments were surveyed in the Wrangel Brook study basin. The Wrangel Brook at Congasia Road site was excluded from the gradient analysis because the native swamp darter was the only species collected from this site. A total of 21 fish species were collected from the remaining 13 sites in the study basin, including 13 native species and eight nonnative species. Restricted-fish species were absent from one site (Figure 4.20). Fish-community composition at survey sites in this study basin was highly variable (Figures 4.18 and 4.19). Five stream sites supported fish assemblages composed entirely of native species, whereas the other five stream sites and all three impoundments supported nonnative fishes (Figure 4.20). The mean percentage of nonnative species per site was 22% (Figure 4.17). One stream site, Sunken Branch at Mule Road, displayed the second highest percentage of upstream altered land, the greatest nonnative-species richness (five species), and the highest percentage of nonnative species of all the sites surveyed in Barnegat Bay Watershed. Aside from four sites in the Toms River study basin, the Wrangel Brook at Mule Road site was the only other Barnegat Bay Watershed site where the peripheral tessellated darter was collected.

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5 ANURAN ASSEMBLAGES

INTRODUCTION

Results from Commission studies conducted in the Mullica River and Rancocas Creek basins indicated that the presence of nonnative anuran species was associated with basins characterized by a high percentage of upland agriculture and developed land and surface waters with elevated pH and specific conductance values (Bunnell and Zampella 1999, Zampella and Bunnell 2000, Zampella et al. 2001, 2003, 2006). Relatively unaltered basins generally supported anuran assemblages composed only of native Pinelands species. Although results from the Great Egg Harbor River Watershed Management Area study (Zampella et al. 2005) were not as clear as those from the Rancocas Creek and Mullica River basins, the percentage of nonnative anurans heard at Great Egg Harbor River Watershed Management Area sites increased as pH increased. Furthermore, the probability of native carpenter frog occurrence and the number of calling carpenter frogs decreased as pH and altered land increased. In 2003, Commission scientists surveyed anurans in the Barnegat Bay Watershed. The results of the assessment are presented in this chapter.

METHODS

Study Sites

Forty stream impoundments were surveyed for vocalizing anurans in the Barnegat Bay Watershed (Table 5.1). Sites were selected based on land-use characteristics, accessibility, and suitability as survey sites. The survey sites ranged from small impoundments to abandoned cranberry bogs and large lakes. The coordinates of each sampling station were determined using orthophotoquads and a geographic information system.

Characterizing Survey-site Conditions

Several site-specific and regional watershed-disturbance variables were used to characterize anuran-survey sites. The variables included pH, specific conductance, developed land, and upland agriculture (Table 5.1). Specific conductance and pH were measured at or near most anuran-survey sites (Chapter 2). Upstream land-use profiles were prepared using ArcView software and NJDEP 1995/97 land-use data (Chapter 1).

Anuran-vocalization Surveys

Anuran surveys were conducted during the calling season of carpenter frogs and bullfrogs (Figure 5.1), two species that were the focus of the study-basin inventory. Previous Commission studies indicated that the native carpenter frog is generally absent from sites with the nonnative bullfrog (Zampella and Bunnell 2000, Zampella et al. 2001, 2003, 2006). Both species prefer permanent-water habitats and share a similar breeding period. However, the bullfrog is associated with degraded waters with elevated pH, whereas the carpenter frog is usually found in Pinelands habitats that are more acidic.

Nighttime anuran-vocalization surveys were conducted between June 9 and July 9, 2003. Each site was visited on at least one occasion. Fifteen sites were surveyed a second time because neither bullfrogs nor carpenter frogs were heard during the first visit. One site was visited a third time for the same reason. The number of calling individuals heard during a five-minute period was estimated using a ranking system where 0 = none, 1 = 1 calling, 2 = 2-5 calling, 3 = 6-10 calling, and 4 = >10 calling individuals. This ranking system is the same as that used in earlier Commission studies (Bunnell and Zampella 1999, Zampella and Bunnell 2000, Zampella et al. 2001, 2003, 2005, 2006).

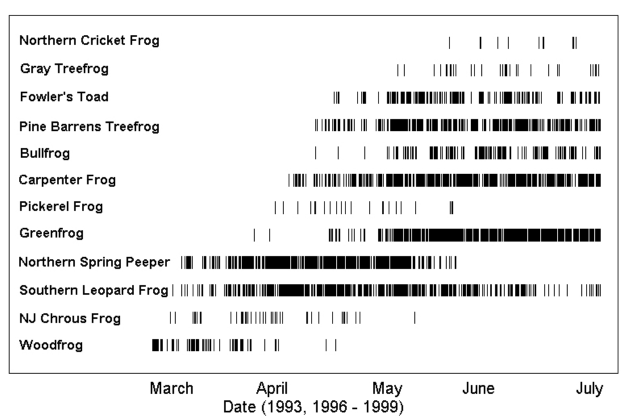

Figure 5.1. Breeding phenology of 12 anurans in the Mullica River Basin. Each vertical bar represents a survey night when a species was heard calling (Zampella et al. 2001).

Table 5.1. Median pH and specific conductance (μS cm^{-1}) values and the percentage of developed land, upland agriculture, and altered land (developed and upland agriculture) for 40 Barnegat Bay Watershed impoundments. Water quality was measured at the outflow of the impoundments, except for CWAPARKL (measured downstream at CWAROUT9), MFOOCEAN (measured upstream at MFOLIGHT), MMIMANAH (measured downstream at MMI72LWR), and RTITRCRE (measured downstream at RTITR530). A dash indicates that water-quality data were not available for a particular anuran site. Refer to Chapter 2 for details regarding water-quality monitoring.

Site Code	pH	SC	Developed	Upland Ag.	Altered Land
CCEBAMBR	4.7	34	0.7	0.5	1.1
CCEDOUBL	4.6	41	2.1	0.5	2.6
CFALACEY	4.3	55	0.0	0.0	0.0
CNOBARNE	-	-	9.0	0.0	9.0
CNODEERH	4.5	64	3.2	0.0	3.2
CNOLOWER	5.0	64	10.3	0.0	10.3
COYTRBRO	-	-	6.2	0.2	6.4
COYWELLS	4.7	56	4.0	0.4	4.4
CWAPARKL	4.4	97	8.8	0.1	8.9
MCEROUT9	4.5	76	5.2	0.1	5.3
MEIIMP72	-	-	21.7	0.0	21.7
MFOOCEAN	5.2	59	16.8	0.0	16.8
MMIMANAH	5.7	104	18.4	0.3	18.7
RDABG530	4.3	67	22.9	0.5	23.4
RDAHARRY	6.1	62	22.7	0.0	22.7
RDALACEL	4.8	72	35.1	0.8	36.0
RDATRIMP	4.6	64	18.0	0.0	18.0
RJATRBOG	-	-	4.2	0.1	4.3
RMIWHWMA	-	-	23.8	0.0	23.8
RSUJAMAI	-	-	31.0	0.0	31.0
RTIKESWI	5.5	97	53.8	0.0	53.8
RTISCHOO	-	-	89.0	0.0	89.0
RTITRCRE	5.1	90	69.2	1.8	71.0
RWRTOWNL	4.3	57	1.0	0.0	1.0
TBOHAWLW	4.6	37	7.0	27.1	34.1
TBOHAWUP	-	-	9.9	38.6	48.5
TDOIM528	5.2	73	15.1	3.3	18.4
TSHSUCCE	4.5	59	6.7	8.6	15.4
TSHTURNL	6.3	83	13.1	23.9	37.0
TSHUPPER	4.6	59	4.3	2.5	6.8
TTOIM527	-	-	25.5	9.2	34.7
TTOIM571	5.3	50	9.1	0.6	9.7
TUNHORIC	4.2	62	5.7	0.7	6.4
WGIGIFFL	-	-	29.1	0.8	29.9
WGOWATER	-	-	0.3	0.0	0.3
WLOMUNIO	-	-	0.8	0.0	0.8
WMIPOHAT	4.4	67	9.0	0.1	9.1
WRAMUNIO	-	-	0.1	0.0	0.1
WTUTRBAY	-	-	13.3	0.0	13.3
WWEFORG4	-	-	0.9	0.1	1.0

Anuran-survey data for the Barnegat Bay Watershed sites are presented in Appendix 4. The appendix includes the number of individuals of each species heard at each site, distribution maps for each species, the air temperature and relative humidity recorded during site visits, the individuals who conducted the surveys, site-location descriptions, and latitude and longitude. Taxonomic nomenclature follows Conant and Collins (1998).

Anuran-community Gradient

Presence-absence was determined for each species heard at a site. Detrended correspondence analysis (DCA) was used to order anuran species and survey sites based on presence-absence data. The same data were used to classify or group species and sites using TWINSPAN. These techniques are described in greater detail in Zampella et al. (2001).

Spearman rank correlation was used to determine if anuran-species composition, represented by the first DCA axis, varied in relation to environmental factors. The environmental variables included pH, specific conductance, and the percentage of upstream developed land, upland agriculture, and altered land (developed land and upland agriculture).

Table 5.2. Common and scientific names for Pine Barrens, wide-ranging, and border-entrant anuran species found in the New Jersey Pinelands (Conant 1962, 1979). Nomenclature follows Conant and Collins (1998).

Scientific Name	Common Name
Native Species	
Pine Barrens Species	
Hyla andersonii	Pine Barrens treefrog
Rana virgatipes	carpenter frog
Wide-ranging Species	
Bufo woodhousii fowleri	Fowler's toad
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana utricularia	southern leopard frog
Scaphiopus h. holbrooki	eastern spadefoot
Nonnative Species	
Border-entrant Species	
Acris c. crepitans	northern cricket frog
Hyla versicolor	northern gray treefrog
Pseudacris triseriata kalmi	New Jersey chorus frog
Rana catesbeiana	bullfrog
Rana palustris	pickerel frog
Rana sylvatica	wood frog

Differences in biogeography and watershed conditions between the first two TWINSPAN-derived site classes were evaluated using Mann-Whitney U tests. Watershed conditions were represented by pH, specific conductance, and the percentage of upstream altered land. Biogeography was represented by the percentage of native and nonnative anuran species, which was determined using presence-absence data. Native species included those restricted to the Pinelands (Pine Barrens species) and those distributed throughout southern New Jersey (wide-ranging species) (Table 5.2). Nonnative species included those anurans that usually do not occur in the Pinelands except in habitats altered by human activity (border-entrant species).

Kruskall-Wallis analysis of variance (ANOVA) was used to compare pH, specific conductance, and the percentage of upstream-altered land between sites with bullfrogs only, sites with carpenter frogs only, and sites with both species. An alpha level of 0.05 was used to identify important relationships revealed by the correlation analysis and to assess differences between the TWINSPAN-derived site groups and between sites with bullfrogs, carpenter frogs, and both species.

RESULTS

Anurans were heard calling from 39 of the 40 sites surveyed. No anurans were heard at Keswick Lake. A total of eight species were heard calling from the 39 sites, including the two Pine Barrens species, four wide-ranging species, and two border-entrant species (Figure 5.2). Native-anuran species were heard at 97% of the sites (Figures 5.2 and 5.3). The Fowler's toad was the most frequently occurring native species, whereas the spring peeper was the least frequently occurring native species (Figure 5.2). The carpenter frog was present at about one-third of the sites, but was not heard calling at the fourteen southernmost sites surveyed in the Barnegat Bay Watershed, including all of the sites surveyed in the Oyster Creek, Waretown Creek, Mill Creek, Cedar Run, Westecunk Creek, and Tuckerton Creek basins.

Nonnative-anuran species were heard at 56% of the sites (Figures 5.2 and 5.3). The bullfrog was the most frequently occurring nonnative species (Figure 5.2). The northern gray treefrog was the only other nonnative frog heard during the surveys and was only present at sites with bullfrogs.

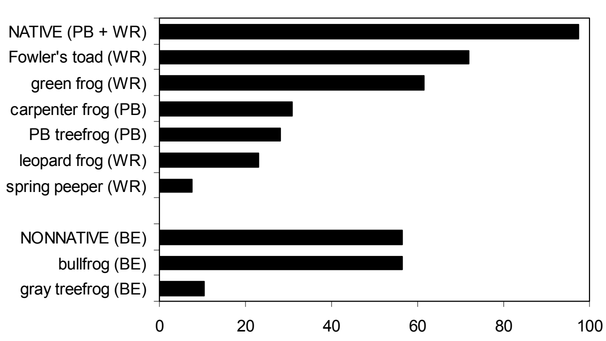

Figure 5.2. Frequency of occurrence and geographic affinity of eight anuran species heard at 39 Barnegat Bay Watershed impoundments. For geographic affinity, PB = Pine Barrens species, WR = wide-ranging species, and BE = border-entrant species (Conant 1979).

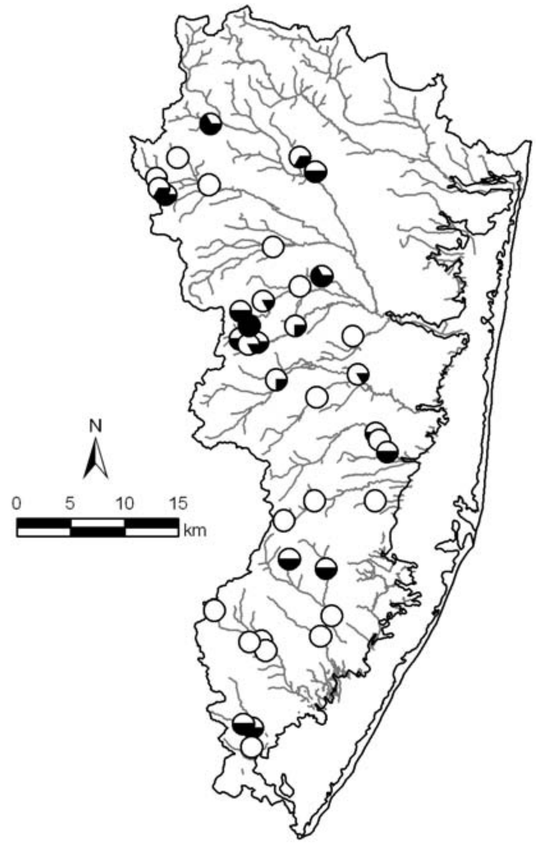

Figure 5.3. Pie charts showing the percentage of native species (white) and nonnative species (black) present at 39 Barnegat Bay Watershed impoundment sites where anurans were heard vocalizing.

Prior to the gradient analysis, five sites were excluded from the pool of 39 sites because only a single species was heard calling. Of these five sites, green frogs were heard calling at two sites and Fowler's toads, carpenter frogs, and bullfrogs were each heard at one site. The northern spring peeper was excluded from the gradient analysis because the breeding period for this species did not completely coincide with the anuran-survey period (Figure 5.1). Spring peepers were only heard at three sites at the beginning of June. The remaining 34 sites and seven anuran species were included in the gradient analysis.

The first DCA axis of the ordination of 34 sites contrasted sites where only native species were heard with those that supported nonnative-anuran species (Tables 5.3 and 5.4, Figure 5.4). The percentage of native species decreased ($r = -0.87$, $p < 0.001$) and the percentage of nonnative species increased ($r = 0.87$, $p < 0.001$) along this community gradient (Figure 5.5). The decrease in native species along the community gradient was due to a decrease in the percentage of Pine Barrens species (r = -0.80, $p < 0.001$) and wide-ranging species (r = -0.38, $p = 0.025$) (Figure 5.5). Nonnative anurans were generally heard at sites with higher pH and altered-land values (Figure 5.6).

Land-use data were available for all 34 sites included in the gradient analysis, whereas specific conductance and pH data were only available for 19 of the 34 sites. The order of sites along the first DCA axis was related to increasing pH (r = 0.68, $p = 0.001$) and the percentage of upstream developed land (r = 0.55, $p = 0.001$) and altered land (r = 0.64, $p < 0.001$) (Figure 5.7). Specific conductance and upland agriculture were not related to the anuran-community gradient.

A decrease in the percentage of native species was associated with an increase in pH (r = -0.56, $p = 0.013$) and the percentage of upstream developed land (r = -0.60, $p < 0.001$) and altered land (r = -0.61, $p < 0.001$). The opposite trend was observed for the percentage of nonnative species and pH, developed land, and altered land. There was no relationship between the percentage of native or nonnative species and specific conductance or upland agriculture.

Table 5.3. Raw DCA axis 1 and 2 scores for species heard at anuran-survey sites in the Barnegat Bay Watershed. Species are ordered by axis 1 scores.

Species	Axis 1	Axis 2
Pine Barrens treefrog	-62	120
green frog	62	-48
carpenter frog	106	279
southern leopard frog	112	156
Fowler’s toad	176	153
bullfrog	259	48
northern gray treefrog	393	164

Table 5.4. Raw DCA axis 1 and 2 site scores for 34 anuran-survey sites in the Barnegat Bay Watershed based on an ordination of species presence-absence data. Sites are ordered by axis 1 scores. Refer to Appendix 4 for additional information on each site.

Study Basin	Site Name	Site Code	Axis 1	Axis 2
Cedar Creek	Factory Branch at Route 614	CFALACEY	0	36
Cedar Creek	Oyster Creek tributary impoundment at Brookville Road	COYTRBRO	0	36
Westecunk Creek	Rail Branch impoundment at Munion Field Road	WRAMUNIO	37	76
Westecunk Creek	Governors Branch at Watering Place	WGOWATER	59	75
Westecunk Creek	Log Swamp Branch impoundment at Munion Field Road	WLOMUNIO	59	75
Westecunk Creek	Westecunk Creek impoundment at Stafford Forge	WWEFORG4	72	95
Toms River	Horicon Lake	TUNHORIC	73	184
Wrangel Brook	Davenport Branch bog at Route 530	RDABG530	109	68
Cedar Creek	Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	109	118
Wrangel Brook	Davenport Branch tributary impoundment at Lake Road	RDATRIMP	109	118
Wrangel Brook	Michaels Branch impoundment	RMIWHWMA	109	118
Toms River	Success Lake	TSHSUCCE	114	135
Cedar Creek	Lake Barnegat	CNOBARNE	115	128
Cedar Creek	Waretown Lake	CWAPARKL	119	53
Westecunk Creek	Tuckerton Creek tributary impoundment at Great Bay Boulevard	WTUTRBAY	119	53
Wrangel Brook	Jakes Branch bog near Route 530	RJATRBOG	141	216
Toms River	Shannae Brook impoundment	TSHUPPER	141	216
Cedar Creek	Bamber Lake	CCEBAMBR	151	108
Wrangel Brook	Davenport Branch impoundment at Route 614	RDALACEL	151	108
Cedar Creek	Deer Head Lake	CNODEERH	161	0
Cedar Creek	Lower Lake	CNOLOWER	161	0
Toms River	Toms River tributary impoundment at Route 527	TTOIM527	161	0
Westecunk Creek	Gifford Mill Branch impoundment	WGIGIFFL	161	0
Toms River	Turnmill Pond	TSHTURNL	166	51
Toms River	Dove Mill Branch impoundment at Route 528	TDOIM528	182	119
Toms River	Bordens Mill Branch impoundment - upper	TBOHAWUP	185	125
Mill Creek	Eightmile Branch impoundment at Route 72	MEIIMP72	217	100
Mill Creek	Holiday Lake	MFOOCEAN	217	100
Wrangel Brook	Harry Wright Lake	RDAHARRY	217	100
Wrangel Brook	Tice Van Horn Branch impoundment at Schoolhouse Road	RTISCHOO	217	100
Westecunk Creek	Pohatcong Lake	WMIPOHAT	217	100
Toms River	Bordens Mill Branch impoundment - lower	TBOHAWLW	235	130
Wrangel Brook	Sunken Branch impoundment near Jamaica Road	RSUJAMAI	276	121
Toms River	Toms River tributary impoundment at Route 571	TTOIM571	276	121

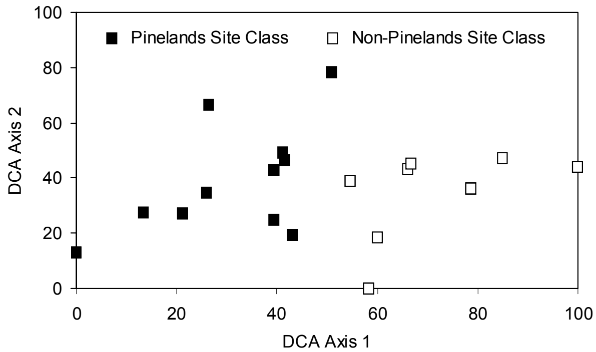

Figure 5.4. DCA ordination diagram and TWINSPAN classification for 34 Barnegat Bay Watershed impoundments. Refer to Table 5.4 for a list of sites ordered by DCA axis 1 scores. Individual squares may represent more than one site.

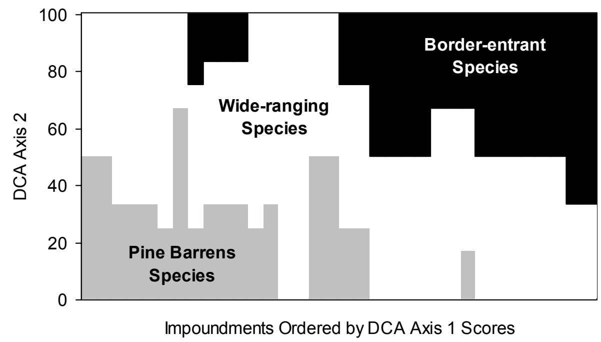

Figure 5.5. Percentage of native (Pine Barrens and wide-ranging) and nonnative (border-entrant) species heard at 34 Barnegat Bay Watershed impoundments. Refer to Table 5.4 for a list of sites ordered by DCA axis 1 scores.

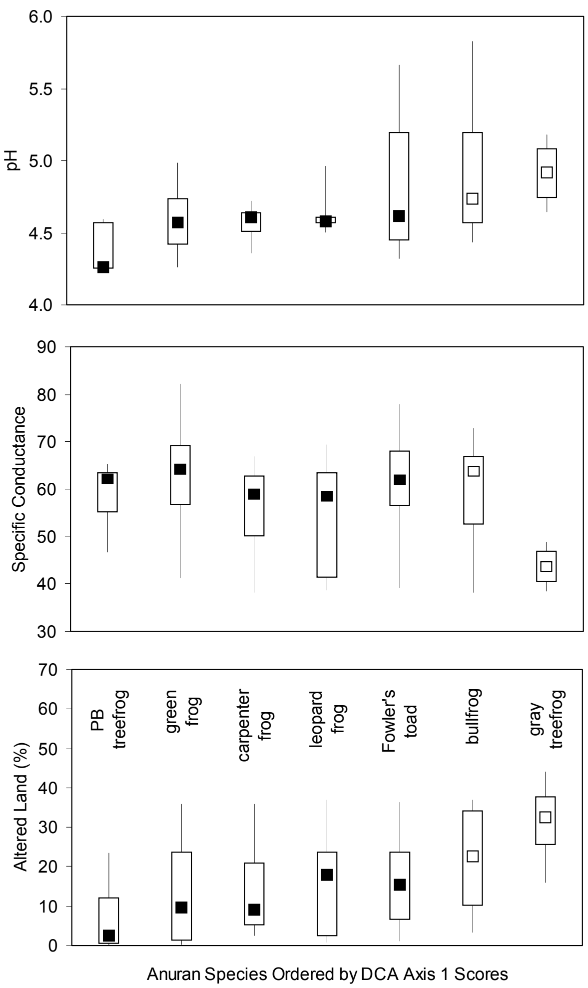

Figure 5.6. The pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) associated with anuran species heard at 34 Barnegat Bay Watershed impoundments. Box plots show the first, second (median), and third quartiles and the 10th and 90th percentiles for each variable. Open squares denote nonnative species.

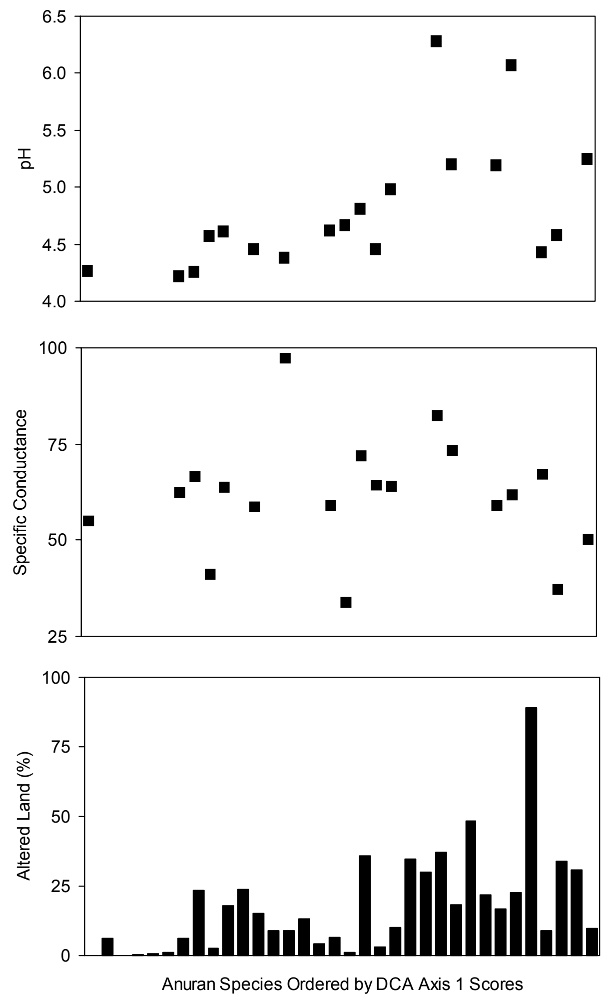

Figure 5.7. Median pH, specific conductance (μS cm^{-1}), and percentage of altered land (developed land and upland agriculture) for 34 Barnegat Bay Watershed impoundments. DCA axis 1 represents an anuran-community gradient. Refer to Table 5.4 for a list of sites ordered by DCA axis 1 scores.

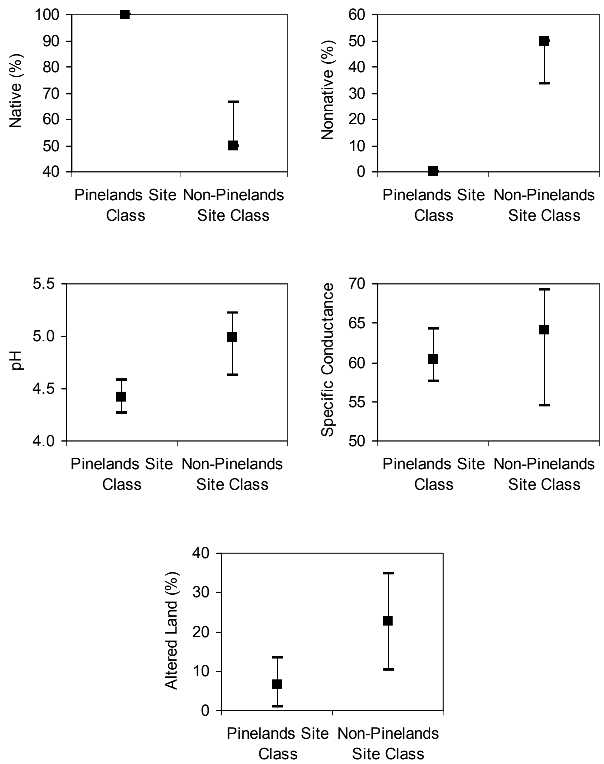

Figure 5.8. First, second (median), and third quartiles for the percentage of native and nonnative species, pH, specific conductance (μS cm^{-1}), and altered land (developed land and upland agriculture) for two TWINSPAN-derived site classes for 34 Barnegat Bay Watershed impoundments.

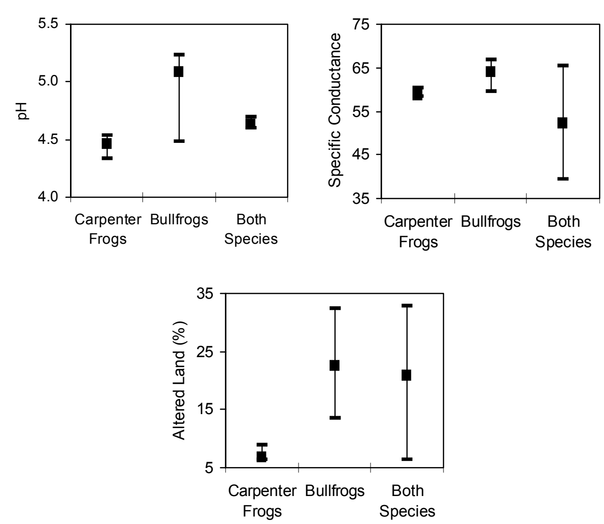

Figure 5.9. First, second (median), and third quartiles for pH, specific conductance (μS cm^{-1}) and altered land (developed and upland agriculture) for Barnegat Bay Watershed impoundments with carpenter frogs only (n = 5), bullfrogs only (n = 15), and both species (n = 6). Specific conductance and pH data were available for three of the five sites with carpenter frogs only, ten of the fifteen sites with bullfrogs only, and four of the six sites with both species. Altered-land values were available for all sites.

The first division of the TWINSPAN classification separated the 34 sites into two groups of 17 sites each. One group of sites displayed a greater percentage of native species (Pinelands site class), whereas the other group was characterized by a higher percentage of nonnative species (non-Pinelands site class) (Figures 5.4 and 5.8). Compared to the Pinelands site class, the non-Pinelands site class displayed higher pH and altered-land values (Figure 5.8). Based on Mann-Whitney tests, there was a difference in the percentage of native and nonnative species ($p < 0.001$), pH ($p = 0.004$), and altered land ($p = 0.001$) between site classes. There was no difference in specific conductance between site classes.

Twenty-six of the 34 sites included in the gradient analysis supported carpenter frogs, bullfrogs, or both species. Carpenter frogs were heard vocalizing from 11 (42%) of the 26 sites, bullfrogs were heard calling from 21 (81%) sites, and both species were present at 6 (23%) sites. The 26 sites were grouped into those with carpenter frogs only (n = 5), those with bullfrogs only (n = 15), and those with both species (n = 6) to compare watershed conditions between these three groups. Median pH, specific conductance, and altered-land values were lower for sites that supported only carpenter frogs compared to sites that supported only bullfrogs (Figure 5.9). Sites with both species present displayed variable conditions. ANOVA results indicated no significant difference in pH, specific conductance, or altered land between these three groups.

Study-basin Characterizations

Westecunk Creek

A total of five species were heard calling from the seven sites surveyed in the Westecunk Creek study basin, including four native species and the nonnative bullfrog. The seven survey sites were spread across the anuran-community gradient (Figure 5.10). Five sites supported anuran assemblages composed entirely of native species (Figure 5.11). Although the native Pine Barrens treefrog was heard calling at four of these sites, the native carpenter frog was absent from all sites surveyed in the study basin. The lack of carpenter frogs is puzzling because the Westecunk Creek study basin displayed the lowest percentage of upstream-altered land and the lowest mean percentage of nonnative-anuran species per site (Figure 5.12). The nonnative bullfrog was present only at the Gifford

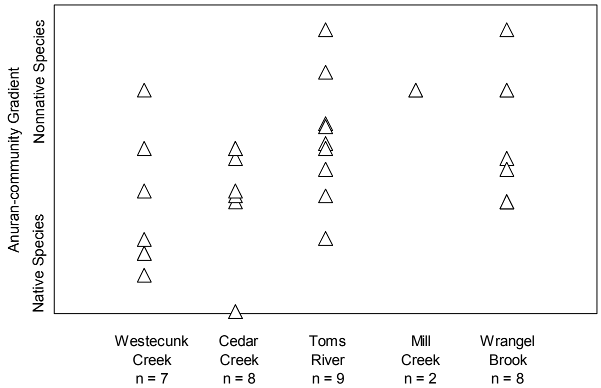

Figure 5.10. Position of anuran-survey sites along the native to nonnative species anuran-community gradient, represented by DCA axis 1 site scores, in the six Barnegat Bay Watershed study basins. Refer to Table 5.4 for a list of sites ordered by the first DCA axis. Individual triangles may represent more than one site.

Mill Branch impoundment and Pohatcong Lake. These two sites are located in the Tuckerton Creek drainage and the Gifford Mill Branch impoundment is immediately upstream from Pohatcong Lake. Pine Barrens treefrogs were absent from these two sites and one other site surveyed in the Tuckerton Creek drainage (Figure 5.11).

Cedar Creek

A total of six species were heard calling at the nine sites surveyed in the Cedar Creek study basin, including five native species and the nonnative bullfrog. Wells Mills Lake was excluded from the gradient analysis because the only species heard calling was the green frog. Of the eight sites included in the gradient analysis, two sites were associated with the native-species end of the anuran-community gradient and six sites were associated with the middle of the gradient (Figure 5.10). Four of the eight sites analyzed supported anuran assemblages composed entirely of native species and four sites supported both native species and bullfrogs (Figure 5.11). Pine Barrens species were absent from three sites in the study basin. Two of these sites supported bullfrogs. This study basin displayed the second lowest mean percentage of nonnative species per site (Figure 5.12).

Toms River

All eight species heard during the Barnegat Bay Watershed anuran surveys were present in the Toms River study basin. The native spring peeper, which was excluded from the gradient analysis, was present at one site. The nine sites surveyed in this study basin were spread across the anuran-community gradient (Figure 5.10). Three of the nine sites supported assemblages composed entirely of native species, and carpenter frogs were present at all three sites (Figure 5.11). At the other six sites, from 33 to 67% of the species present were nonnative species, including bullfrogs, northern gray treefrogs, or both species. Carpenter frogs were heard calling at only one of the six sites with nonnative anurans present. The mean percentage of nonnative species per site was 30% (Figure 5.12).

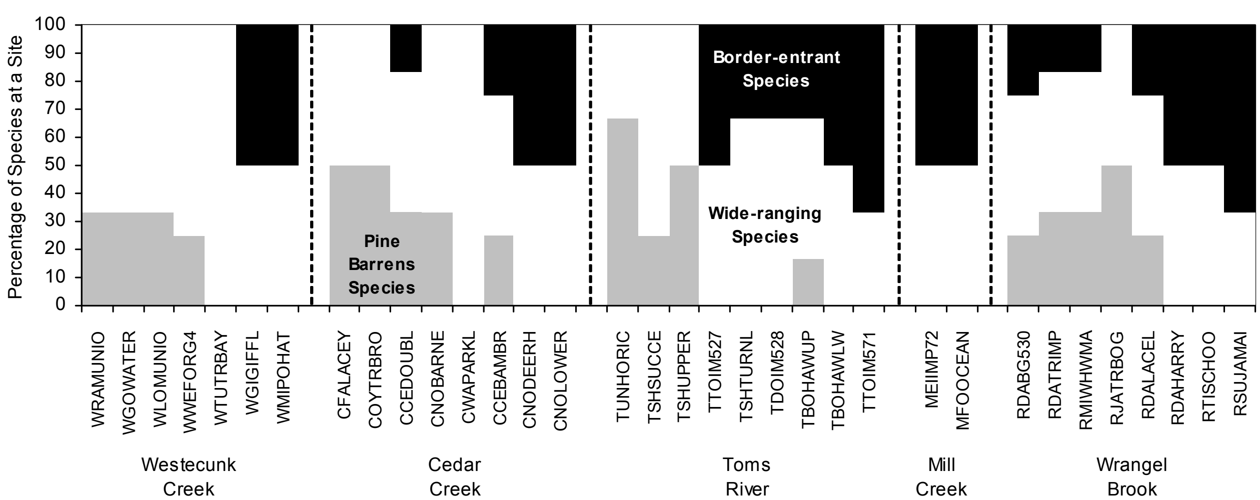

Figure 5.11. The percentage of native (Pine Barrens and wide-ranging) and nonnative (border-entrant) species present at Barnegat Bay Watershed anuran sites. Sites are ordered by DCA axis 1 scores within each study basin. Refer to Table 5.4 for site names represented by site codes.

Mill Creek

A total of three species were heard calling from the four sites surveyed in the Mill Creek study basin, including two native species and the nonnative bullfrog. Two sites, Cedar Run bog above Route 9 and Manahawkin Lake, were excluded from the gradient analysis because only one species was heard calling at each site. The Fowler's toad was heard at Cedar Run bog above Route 9 and the green frog at Manahawkin Lake. Two sites, Holiday Lake and Eightmile Branch impoundment at Route 72, were included in the gradient analysis. These two sites supported the native Fowler's toad and nonnative bullfrog and were associated with the nonnative-species end of the anuran-community gradient (Figure 5.10). The Mill Creek study basin displayed the highest mean percentage of nonnative species per site (Figure 5.12) and was the only study basin in the entire Barnegat Bay Watershed where no Pine Barrens treefrogs or carpenter frogs were heard during the surveys.

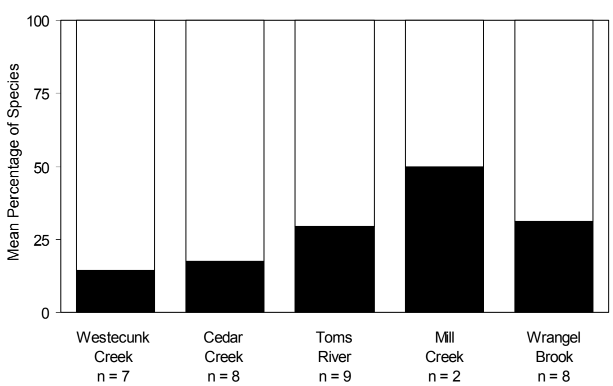

Figure 5.12. Mean percentage of native species (white) and nonnative species (black) at impoundments in each study basin in the Barnegat Bay Watershed.

Wrangel Brook

As with the Toms River study basin, all eight anuran species heard during the Barnegat Bay Watershed surveys were also present in the Wrangel Brook study basin. The spring peeper, which was excluded from the gradient analysis, was heard calling at two sites. Three of the 11 sites surveyed in this study basin were excluded from the gradient analysis because only one species was heard calling or no anurans were heard. These three sites included the Tice Van Horn Branch tributary impoundment in Crestwood Village, which supported only bullfrogs, the Wrangle Brook impoundment at Township Line Road, which supported only carpenter frogs, and Keswick Lake, where no anurans were heard calling. Anuran-community composition at the eight sites included in the gradient analysis was variable (Figure 5.10). Although Pine Barrens species were present at five of the eight sites analyzed, only one site in the study basin supported anuran assemblages composed entirely of native species (Figure 5.11). In contrast, bullfrogs were present at seven sites and one of these sites also supported northern gray treefrogs. The mean percentage of nonnative species per site was similar to that for the Toms River study basin (Figure 5.12).

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SUMMARY AND SYNTHESIS

MAJOR FINDINGS

Unlike in the Mullica River Basin, Rancocas Creek Basin, and Great Egg Harbor River Watershed Management Area studies (Zampella et al. 2001, 2003, 2005), rank correlation rather than multiple regression was used to relate pH and specific conductance to land use in the Barnegat Bay Watershed. To allow a comparison of all four major watersheds, pH and specific conductance data from the three earlier studies were used to prepare a correlation table relating the two field measurements to altered land (Table 1). The correlation between pH and altered land was weakest in the Barnegat Bay Watershed compared to the other three watersheds. The strength of the relationship between specific conductance and altered land for the Barnegat Bay Watershed was similar to that of the Mullica River Basin and Great Egg Harbor River Watershed Management Area. As noted in Chapter 3 (Water Quality), the relationship between the two water-quality variables and land use varied among the five Barnegat Bay Watershed study basins. When considered separately, the relationships between pH and altered land for the Toms River, Mill Creek, and Wrangel Brook study basins were stronger than that revealed when all study basins were included in a single analysis and were similar to the relationships found in the other three major watershed studies.

Nitrite plus nitrate as nitrogen (NO_x) concentrations increased as the percentage of altered land associated with Barnegat Bay Watershed monitoring sites increased. Similar relationships were found in the other three watershed studies (Table 2). Ammonia concentrations, which were elevated in the most heavily altered basins in the Rancocas Creek Basin and the Great Egg Harbor River Watershed Management Area and which were correlated with altered land in the Rancocas Creek Basin, were not related to variations in the percentage of altered land associated with Barnegat Bay Watershed monitoring sites. No clear relationship between altered land and phosphorus concentrations existed in any of the four major watershed study areas.

As in the Mullica River, Rancocas Creek, and Great Egg Harbor River studies, the Barnegat Bay Watershed stream-vegetation gradient, characterized by a decrease in the percentage of native-plant species and an increase in the percentage of non-Pinelands species and disturbance-indicator plant species, was positively associated with an increase in pH, specific conductance, and the percentage of altered land in a basin (Table 3). The percentage of survey sites where non-Pinelands plant species comprised at least 10 or 20% of all species was lowest in the Barnegat Bay Watershed (Table 4).

In the Mullica River and Rancocas Creek basins, the stream-fish-community and anuran-community gradients, represented by an increase in the percentage of nonnative species, varied along watershed-disturbance gradients characterized by an increase in pH, specific conductance, and the percentage of altered land (Table 3). The Rancocas Creek impoundment-fish-community gradient was

Table 1. Spearman rank correlation coefficients (r) relating pH and specific conductance to the percentage of altered land associated with monitoring sites (n) in the four major Pinelands watersheds. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin. For all correlations, $p < 0.001$.

Watershed	n	pH	Specific conductance
Mullica River	103	0.83	0.59
Rancocas Creek	49	0.86	0.84
Great Egg Harbor River	49	0.79	0.55
Barnegat Bay	58	0.60	0.57

Table 2. Spearman rank correlation coefficients (r) relating altered land to median nitrite plus nitrate as nitrogen (NO_x), ammonia as nitrogen, and total phosphorus as phosphorus (Total P) concentrations at monitoring sites (n) in the four major Pinelands watersheds. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin. Median total-phosphorus concentrations at all Great Egg Harbor River sites were below the 0.05 mg L^{-1} detection limit.

Watershed	Nutrient	n	r	*p*
Mullica River				
	NO_x	25	0.77	<0.001
	Ammonia	25	-0.07	0.746
	Total P	25	0.05	0.822
Rancocas Creek				
	NO_x	51	0.50	<0.001
	Ammonia	51	0.37	0.008
	Total P	51	0.01	0.969
Great Egg Harbor River				
	NO_x	12	0.77	0.003
	Ammonia	12	0.45	0.144
	Total P	12	--	--
Barnegat Bay				
	NO_x	20	0.78	<0.001
	Ammonia	20	0.14	0.552
	Total P	20	0.29	0.222

Table 3. Spearman rank correlation coefficients (r) relating altered land, pH, and specific conductance to biological-community gradients represented by the first axis of DCA ordinations. Altered land represents the combined percentage of developed land and upland agriculture in a drainage basin.

Watershed	Stream vegetation			Anurans			Stream fish			Impoundment fish		
Variable	n	r	*p*	n	r	*p*	n	r	*p*	n	r	*p*
Mullica River												
Altered land	72	0.79	<0.001	78	0.77	<0.001	54	0.82	<0.001	30	0.90	<0.001
pH	72	0.73	<0.001	41	0.77	<0.001	54	0.82	<0.001	30	0.89	0.000
Specific conductance	72	0.68	<0.001	41	0.61	<0.001	54	0.62	<0.001	30	0.41	0.024
Rancocas Creek												
Altered land	44	0.75	<0.001	42	0.71	<0.001	41	0.75	<0.001	15	0.50	0.057
pH	44	0.66	<0.001	29	0.74	<0.001	41	0.87	<0.001	11	0.65	0.029
Specific conductance	44	0.70	<0.001	29	0.62	<0.001	41	0.63	<0.001	11	0.32	0.332
Great Egg Harbor River												
Altered land	36	0.61	<0.001	27	0.15	0.456	32	0.31	0.081	10	0.66	0.038
pH	36	0.73	<0.001	23	0.28	0.197	32	0.36	0.046	10	0.64	0.048
Specific conductance	36	0.33	<0.001	23	0.11	0.611	32	0.05	0.806	10	0.01	0.987
Barnegat Bay												
Altered land	50	0.61	<0.001	34	0.64	<0.001	40	0.55	<0.001	17	0.56	0.019
pH	50	0.46	<0.001	19	0.68	0.001	40	0.64	<0.001	16	0.56	0.025
Specific conductance	50	0.54	<0.001	19	0.00	1.000	40	0.46	0.003	16	0.67	0.005

Table 4. The percentage of survey sites in each major watershed where nonative plants, fish, and bullfrogs were found. Stream-vegetation values represent the percentage of sites where at least 10% or 20% of the classified species were non-Pinelands species.

	Stream vegetation			Bullfrogs		Stream fish		Impoundment fish	
Watershed	n	% ≥10%	% ≥20%	n	%	n	%	n	%
Mullica River	72	75	40	67	49	56	44	30	50
Rancocas Creek	45	96	84	42	52	41	54	15	40
Great Egg Harbor River	36	97	89	27	89	32	78	10	50
Barnegat Bay	50	60	36	34	62	40	43	17	82

related to variations in pH. The Great Egg Harbor River anuran-community gradient did not vary in relation to any of the three watershed-disturbance variables, the stream-fish-community gradient was weakly related to pH, and the impoundment-fish-community gradient was associated with variations in both pH and altered land. The percentage of nonnative stream-fish species in Great Egg Harbor streams was weakly associated with pH, specific conductance, and altered land and the percentage of nonnative impoundment-fish species was positively correlated with altered land. The Barnegat Bay Watershed anuran-community gradient was associated with altered land and pH gradients, and both stream-fish and impoundment-fish community gradients were related to variations in all three watershed-disturbance variables.

The percentage of Barnegat Bay Watershed anuran-survey sites where bullfrogs were heard was higher compared to the Mullica River and Rancocas Creek basins but lower than that of the Great Egg Harbor River Watershed Management Area (Table 4). The percentage of Barnegat Bay Watershed survey sites where nonnative stream fish were collected was relatively low and similar to that of the Mullica River Basin, whereas the percentage of impoundment-survey sites where nonnative fish were collected was highest in the Barnegat Bay Watershed (Table 4).

ECOLOGICAL INTEGRITY

Zampella et al. (2006) demonstrated the use of multiple indicators to characterize the ecological integrity of streams in the Mullica River Basin in relation to human-induced watershed alterations. The individual indicators included pH, specific conductance, and stream-vegetation, stream-fish, impoundment-fish, and anuran assemblages. A similar approach was used in the Rancocas Creek Basin study, except that altered land was included in the characterization. In the Mullica River Basin, with the exception of impoundment fish, the association between altered land and the ecological-integrity scores based on the two water-quality indicators and the four biological indicators was stronger than that displayed by any of the individual variables.

Following the same approach used in Zampella et al. (2006), multiple-indicator ecological-integrity scores were determined for survey sites in the Barnegat Bay

Watershed. Scores were calculated for 58 monitoring sites by ranking pH values, specific conductance values, and the stream-vegetation, stream-fish, impoundment-fish, and anuran community-ordination DCA scores, converting each set of scores to a relative scale of 0 (low ecological integrity) to 100 (high ecological integrity), and using the rescaled variable scores to calculate a median multiple-indicator ecological-integrity score for each site. Although only biological monitoring sites where water-quality was measured were included in the analysis, monitoring sites were ranked using the order of all sites included in the original DCA ordinations. Only pH and specific conductance data were available for one site. The mean (± 1 SD) number of biological indicators ranged from 1.8 (± 0.45) in the Wrangel Brook study basin to 2.2 (± 1.17) in the Mill Creek study basin. The overall watershed mean was 2.0 (± 0.84).

The association between altered land and the ecological-integrity scores based on the two water-quality indicators and the four biological-community indicators was stronger than that displayed by any of the individual variables (Table 5). Because some biological-monitoring sites were excluded from the multiple-indicator analysis due to the need to match stream and impoundment sites with the same water-quality monitoring site, it is not possible to compare the results based on the full community-ordination data sets (Table 3) with those obtained by relating altered land to the biological-community samples included in the multiple-indicator analysis (Table 5).

Table 5. Spearman rank correlations between altered land and ranked and rescaled water-quality scores, community-ordination scores, and multiple-indicator ecological-integrity scores. Ranking and rescaling sites from 0 (low ecological integrity) to 100 (high ecological integrity) to develop the multiple-indicator scores produced correlations with signs opposite of those obtained using the original water-quality data and ordination scores.

Variable	n	r	*p*
pH	58	-0.60	<0.001
Specific conductance	58	-0.57	<0.001
Stream vegetation	47	-0.59	<0.001
Anurans	16	-0.24	0.364
Stream fish	39	-0.54	<0.001
Impoundment fish	14	-0.67	0.008
Ecological-integrity score	57	-0.71	<0.001

Comparison of Study Basins

Westecunk Creek

The Westecunk Creek study basin was among the least disturbed basins in the Barnegat Bay Watershed. This study basin displayed the second highest median multiple-indicator ecological-integrity score (Figure 1). Median pH was low at all sites. Specific conductance varied, with the highest value recorded at a site located east of the Garden State Parkway, which is an area within the Pinelands National Reserve but outside the Pinelands Area. Median pH and specific conductance values were generally lower and varied less compared to the other study basins. NO_X and ammonia concentrations at the single Westecunk Creek nutrient-monitoring site were below reference-stream thresholds.

Most Westecunk Creek study-basin stream-vegetation-survey sites were characterized by a relatively high percentage of native Pinelands plant species. The one exception was located east of the Garden State Parkway. Fish assemblages at two of three stream sites were composed entirely of native species. Golden shiner, a common bait fish, was the only nonnative species found at the third site. In contrast, both of the impoundments surveyed were associated with the nonnative-species end of the impoundment-fish community gradient due to the presence of nonnative sunfishes. Anuran assemblages composed entirely of native species were found at five of seven Westecunk Creek anuran-survey sites. Bullfrogs were heard at the two remaining sites, which were located east of the Garden State Parkway. Of special interest was the absence of the native carpenter frog from all sites in this study basin.

Cedar Creek

Most streams in the Cedar Creek study basin were minimally altered by development and upland agriculture, which is reflected by the high multiple-indicator ecological-integrity scores (Figure 1). Median pH was low at all sites. Specific conductance was also low at most sites, with the exceptions including Long Branch at Bryant Road, which is located below the Southern Ocean Landfill, and sites located east of the Garden State Parkway. The range of pH and specific conductance values reported for the Cedar Creek study basin was most similar to that of the Westecunk Creek study basin. Median NO_x concentrations were below the reference-site threshold and ammonia and phosphorus concentrations were below detection at all five sites where nutrients were sampled.

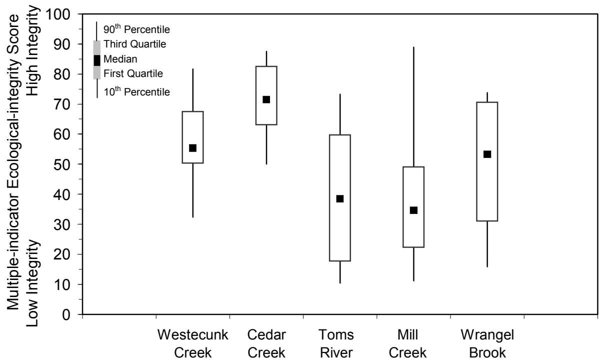

Figure 1. Multiple-indicator ecological-integrity scores for the five Barnegat Bay Watershed study basins. The ecological-integrity scores represent the median of pH, specific conductance, and biological-community ranks for each survey site. The mean (± SD) number of biological indicators included in each score was 2.0 (± 0.84).

Plant-survey sites in the Cedar Creek study basin were generally associated with the native-species end of the stream-vegetation gradient. The majority of the thirteen fish-survey sites supported fish assemblages composed entirely of native species. The exceptions were two lakes where nonnative sunfishes were collected. Only native anurans were heard vocalizing at four of eight anuran-survey sites included in the anuran analysis. The nonnative bullfrog was heard at the remaining four sites.

Toms River

The overall ecological integrity of the Toms River study basin was similar to that of the Mill Creek study basin and lower than that of the other three study basins (Figure 1). The widest range of specific conductance, pH, and altered-land values reported for the Barnegat Bay Watershed was recorded for the Toms River study basin. Both pH and specific conductance were positively related to the percentage of altered land associated with the monitoring sites. Median NO_X concentrations for the eight Toms River study-basin nutrient sampling sites also varied widely, ranging from reference-stream conditions to moderately elevated levels. Although median ammonia concentrations were below detection at all but one site, median total-phosphorus concentrations were above the detection limit at all but one site.

Most of the plant-survey sites in the Toms River study basin were associated with the end of the stream-vegetation community gradient characterized by a relatively high percentage of non-Pinelands species. Nonnative fish were found in all but one of the six impoundments surveyed in the Toms River study basin. The percentage of nonnative fishes at fourteen stream sites ranged from 0% to 33%. Stream-fish assemblages composed entirely of native species were found at only five sites. Bullfrogs were heard vocalizing at six of the nine Toms River anuran-survey sites.

Mill Creek

Most median specific conductance and pH values for the six Mill Creek study-basin stream sites were elevated in comparison to reference-site conditions. Increases in pH and specific conductance were associated with an increase in the percentage of altered land. NO_X concentrations were elevated at both nutrient monitoring sites, and the highest median ammonia concentrations reported for the Barnegat Bay Watershed were recorded in this study basin.

Five of the six plant-survey sites surveyed in the Mill Creek study basin were associated with the native-species end of the stream-vegetation community gradient. The exception, where native and non-Pinelands plant species were equally represented, was located east of the Garden State Parkway. More than half of the Mill Creek fish-survey sites supported nonnative fish. Bullfrogs were found at both of the survey sites included in the anuran analysis. Mill Creek was the only Barnegat Bay Watershed study basin where no Pine Barrens treefrogs or carpenter frogs were heard calling during the survey.

Wrangel Brook

Although the range of ecological-integrity scores was similar to that of the Toms River and Mill Creek study basins (Figure 1), the median Wrangel Brook score was similar to that of the Westecunk Creek study basin. Like the Toms River study basin, altered land, pH, and specific conductance associated with Wrangel Brook monitoring sites varied widely. Both pH and specific conductance were positively related to the percentage of altered land. Median NO_x concentrations were elevated at two of the four stream sites where nutrients were measured. Median ammonia concentrations were below detection at all sites and total phosphorus was below detection at three of the four nutrient-monitoring sites.

The vegetation composition of the eleven Wrangel Brook study-basin plant-survey sites was highly variable, with sites distributed along much of the stream-vegetation community gradient. Stream-fish assemblages composed entirely of native species and those that included nonnative species were equally represented in the Wrangel Brook study basin. A relatively high percentage of nonnative fish were found at all three impoundments that were surveyed. Bullfrogs were present at seven of the eight Wrangel Brook sites included in the analysis.

CONCLUSION

Although the relationship between pH and altered land in the Barnegat Bay Watershed was not as strong as that found in the Mullica River Basin, Rancocas Creek Basin, and Great Egg Harbor River Watershed Management Area, the relationship was similar to those found in the other watersheds when several Barnegat Bay Watershed study basins were considered separately. The positive association of nitrite plus nitrate as nitrogen to altered land was generally similar in all four major watersheds. Variations in the composition of Barnegat Bay Watershed anuran assemblages were associated with altered land and pH gradients, and stream-fish, impoundment-fish, and stream-vegetation community gradients were related to variations in pH, specific conductance, and altered land.

The ecological integrity of the five study basins varied, with the overall highest ecological integrity associated with the Cedar Creek and Westecunk Creek study basins. Many Barnegat Bay Watershed survey sites displayed some level of biological impairment. Nonnative fish and bullfrogs were widely distributed in the Barnegat Bay Watershed. The nonnative bullfrog occurred at nearly twice as many sites as the native carpenter frog. Nonnative fish were present at a relatively high percentage of impoundments. However, compared to the other three major watersheds, the percentage of non-Pinelands plant species was lower at Barnegat Bay Watershed sites.

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APPENDIX 1. pH AND SPECIFIC CONDUCTANCE DATA

Appendix 1.1. Water-quality monitoring sites in the Barnegat Bay Watershed. Latitude, longitude, and USGS 7.5 minute topographic quadrangle names are in parentheses. Sites are ordered alphabetically by site code.

Site Name and Description	Site Code
Cedar Creek impoundment at Double Trouble State Park Berkeley and Lacey Twps., Ocean Co. (lat 39°53'57.95", long 74°13'50.94", Toms River quad).	CCEDOUBL
Cedar Creek at Double Trouble Road Berkeley and Lacey Twps., Ocean Co. (lat 39°53'38.64", long 74°13'30.75", Toms River quad).	CCEDOUBS
Cedar Creek at Route 614 Lacey Twp., Ocean Co. (lat 39°53'50.25", long 74°18'58.63", Keswick Grove quad).	CCELACEY
Cedar Creek at Route 9 Berkeley and Lacey Twps., Ocean Co. (lat 39°52'03.70", long 74°10'08.08", Forked River quad).	CCEROUT9
Chamberlain Branch at an unnamed road Lacey Twp., Ocean Co. (lat 39°52'22.11", long 74°20'40.06", Brookville quad).	CCHSANDR
Factory Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°52'52.18", long 74°16'30.65", Keswick Grove quad).	CFALACEY
Long Branch at Bryant Road Lacey Twp., Ocean Co. (lat 39°49'02.14", long 74°17'34.18", Brookville quad).	CLOBRYAN
North Branch Forked River at Deer Head Drive (Deer Head Lake) Lacey Twp., Ocean Co. (lat 39°51'02.80", long 74°12'37.57", Forked River quad).	CNODEERH
North Branch Forked River at Parker Avenue (Lower Lake) Lacey Twp., Ocean Co. (lat 39°50'09.98", long 74°11'46.18", Forked River quad).	CNOLOWER
North Branch Forked River at a powerline right-of-way Lacey Twp., Ocean Co. (lat 39°51'31.38", long 74°13'29.85", Forked River quad).	CNOPOWER
Oyster Creek at Route 532 Ocean Twp., Ocean Co. (lat 39°47'53.91", long 74°15'00.33", Brookville quad).	COYRT532
Oyster Creek at Wells Mills County Park (Wells Mills Lake) Ocean Twp., Ocean Co. (lat 39°47'35.67", long 74°16'34.11", Brookville quad).	COYWELLS
Waretown Creek at Route 9 Ocean Twp., Ocean Co. (lat 39°47'34.87", long 74°11'45.57", Forked River quad).	CWAROUT9
Webbs Mill Branch at Route 539 Lacey Twp., Ocean Co. (lat 39°53'16.50", long 74°22'46.54", Whiting quad).	CWERT539
Cedar Run at Route 9 Stafford Twp., Ocean Co. (lat 39°40'48.95", long 74°16'15.05", West Creek quad).	MCEROUT9
Fourmile Branch at Lighthouse Drive Stafford Twp., Ocean Co. (lat 39°44'42.81", long 74°16'01.86", West Creek quad).	MFOLIGHT
Fourmile Branch at Oxycocus Street Stafford Twp., Ocean Co. (lat 39°42'26.78", long 74°16'00.96", West Creek quad).	MFOOXYCO
Mill Creek at Route 72 below Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°41'33.72", long 74°15'31.93", West Creek quad).	MMI72LWR
Mill Creek at Route 72 above Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°42'54.39", long 74°16'56.30", West Creek quad).	MMI72UPR
Mill Creek at Hay Road Stafford Twp., Ocean Co. (lat 39°43'43.43", long 74°19'09.52", West Creek quad).	MMIHAYRD
Davenport Branch at Lake Road (Harry Wright Lake) Manchester Twp., Ocean Co. (lat 39°55'50.66", long 74°21'19.81", Keswick Grove quad).	RDAHARRY
Davenport Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°55'35.97", long 74°20'17.97", Keswick Grove quad).	RDALACES
Davenport Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'37.78", long 74°14'40.17", Toms River quad).	RDAMULER

Site Name and Description	Site Code
Davenport Branch at Route 530 Berkeley Twp., Ocean Co. (lat 39°56'29.25", long 74°17'48.60", Keswick Grove quad).	RDART530
Davenport Branch tributary impoundment at Lake Road Manchester Twp., Ocean Co. (lat 39°55'31.22", long 74°20'55.92", Keswick Grove quad).	RDATRIMP
Jakes Branch at Double Trouble Road Beachwood and South Toms River Boros, Ocean Co. (lat 39°56'07.45", long 74°12'41.58", Toms River	RJADOUBL
Jakes Branch at Dover Road Berkeley Twp., Ocean Co. (lat 39°54'55.66", long 74°16'24.66", Keswick Grove quad).	RJADOVER
Sunken Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°58'02.91", long 74°14'31.13", Toms River quad).	RSUMULER
Sunken Branch at Township Line Road Manchester Twp., Ocean Co. (lat 39°58'55.48", long 74°16'41.07", Keswick Grove quad).	RSUTOWNS
Tice Van Horn Branch at Keswick Lake Manchester Twp., Ocean Co. (lat 39°56'57.40", long 74°20'42.72", Keswick Grove quad).	RTIKESWI
Tice Van Horn Branch tributary at Route 530 Manchester Twp., Ocean Co. (lat 39°56'48.37", long 74°20'14.18", Keswick Grove quad).	RTITR530
Wrangel Brook at Congasia Road Manchester Twp., Ocean Co. (lat 39°58'22.14", long 74°19'26.46", Keswick Grove quad).	RWRCONGA
Wrangel Brook at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'53.69", long 74°14'36.99", Toms River quad).	RWRMULER
Wrangel Brook at South Hampton Road Berkeley Twp., Ocean Co. (lat 39°57'39.48", long 74°13'41.26", Toms River quad).	RWRSOUTH
Wrangle Brook at Township Line Road Manchester Twp., Ocean Co. (lat 39°58'26.61", long 74°17'32.09", Keswick Grove quad).	RWRTOWNS
Blacks Branch at Central Avenue Manchester Twp., Ocean Co. (lat 40°00'46.74", long 74°22'47.78", Cassville quad).	TBLCENTR
Blacks Branch at Route 70 Manchester Twp., Ocean Co. (lat 40°00'30.66", long 74°19'47.86", Lakehurst quad).	TBLRTE70
Bordens Mill Branch impoundment - lower Jackson Twp., Ocean Co. (lat 40°03'04.14", long 74°26'18.30", Cassville quad).	TBOHAWLW
Cabin Branch at New Jersey Central railroad Manchester Twp., Ocean Co. (lat 40°02'15.32", long 74°16'44.31", Lakehurst quad).	TCARAILR
Dove Mill Branch at Grawtown Road Jackson Twp., Ocean Co. (lat 40°04'08.82", long 74°17'28.18", Lakehurst quad).	TDOGRAWT
Dove Mill Branch impoundment at Route 528 Jackson Twp., Ocean Co. (lat 40°04'53.76", long 74°17'37.83", Lakehurst quad).	TDOIM528
Maple Root Branch at Bowman Road Jackson Twp., Ocean Co. (lat 40°04'52.48", long 74°19'37.72", Lakehurst quad).	TMABOWMA
Manapaqua Brook at Route 70 Manchester Twp., Ocean Co. (lat 40°00'44.35", long 74°18'08.89", Lakehurst quad).	TMARTE70
Mirey Run at Route 528 Jackson Twp., Ocean Co. (lat 40°06'43.05", long 74°20'38.03", Lakehurst quad).	TMIRT528
Old Hurricane Brook at Beckerville Road Manchester Twp., Ocean Co. (lat 39°59'28.90", long 74°22'44.71", Whiting quad).	TOLBECKE
Old Hurricane Brook at Route 70 Manchester Twp., Ocean Co. (lat 39°59'51.78", long 74°21'03.30", Keswick Grove quad).	TOLRTE70
Ridgeway Branch at Hangar Road Jackson Twp., Ocean Co. (lat 40°02'50.29", long 74°20'04.83", Lakehurst quad).	TRIHANGA

Site Name and Description	Site Code
Ridgeway Branch at High Bridge Road Jackson Twp., Ocean Co. (lat 40°03'17.51", long 74°21'17.16", Lakehurst quad).	TRIHIGHB
Ridgeway Branch at Ridgeway Boulevard Manchester Twp., Ocean Co. (lat 40°01'47.86", long 74°17'44.49", Lakehurst quad).	TRIRIDGE
Shannae Brook at Success Road (Success Lake) Jackson Twp., Ocean Co. (lat 40°03'31.48", long 74°23'29.58", Cassville quad).	TSHSUCCE
Shannae Brook tributary at Turn Mill Pond Jackson Twp., Ocean Co. (lat 40°03'40.41", long 74°26'22.54", Cassville quad).	TSHTURNS
Shannae Brook impoundment Jackson Twp., Ocean Co. (lat 40°04'56.37", long 74°25'30.03", Cassville quad).	TSHUPPER
Toms River at Bowman Road Jackson Twp., Ocean Co. (lat 40°05'22.70", long 74°18'54.00", Lakehurst quad).	TTOBOWMA
Toms River at Route 528 Jackson Twp., Ocean Co. (lat 40°06'35.24", long 74°22'25.32", Lakehurst quad).	TTORT528
Toms River at Route 547 Jackson Twp., Ocean Co. (lat 40°03'42.06", long 74°16'28.46", Lakehurst quad).	TTORT547
Toms River tributary at Route 571 Jackson Twp., Ocean Co. (lat 40°06'38.66", long 74°23'19.46", Cassville quad).	TTOTR571
Union Branch at Colonial Drive Manchester Twp., Ocean Co. (lat 40°00'29.38", long 74°17'37.40", Lakehurst quad).	TUNCOLON
Union Branch at Lake Street (Horicon Lake) Lakehurst Boro, Ocean Co. (lat 40°00'34.82", long 74°19'06.74", Lakehurst quad).	TUNHORIC
Mill Branch at Nugentown Road Little Egg Harbor Twp., Ocean Co. (lat 39°36'37.50", long 74°20'59.83", Tuckerton quad).	WMINUGEN
Mill Branch at Route 9 (Pohatcong Lake) Tuckerton Boro, Ocean Co. (lat 39°36'08.72", long 74°20'33.31", Tuckerton quad).	WMIPOHAT
Mill Branch at Poor Mans Parkway Little Egg Harbor Twp., Ocean Co. (lat 39°38'32.43", long 74°21'46.52", West Creek quad).	WMIPOORM
Three Mile Branch at Pollypod Road Little Egg Harbor Twp., Ocean Co. (lat 39°42'00.43", long 74°21'24.52", West Creek quad).	WTHPOLLY
Westecunk Creek at Forge Road Eagleswood Twp., Ocean Co. (lat 39°39'59.59", long 74°19'12.92", West Creek quad).	WWEFORGS
Westecunk Creek at Railroad Avenue Eagleswood Twp., Ocean Co. (lat 39°38'24.94", long 74°18'28.61", West Creek quad).	WWERAILR

Appendix 1.2. Specific conductance (SC, μS cm^{-1}) and pH values for 64 water-quality sites in the Barnegat Bay Watershed. Refer to Chapter 2 (Water Quality) for methodology. Data were collected by Nicholas A. Procopio, Tina L. Burns, and Jennifer L. Ciraolo. A dash (-) indicates that a stream was dry except for TBOHAWLW on 01/30/03 and WMIPOORM on 01/28/03 which were frozen.

Site Name	Site Code	Date	pH	SC
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	03/18/03	4.46	50.1
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	04/15/03	4.57	49.2
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	05/12/03	5.21	34.1
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	06/17/03	4.45	48.9
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	07/08/03	4.57	28.0
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	08/19/03	4.45	41.2
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	09/09/03	4.76	44.3
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	10/06/03	5.34	29.7
Cedar Creek impoundment at Double Trouble State Park	CCEDOUBL	11/18/03	4.56	33.7
Cedar Creek at Double Trouble Road	CCEDOUBS	01/29/03	4.46	45.4
Cedar Creek at Double Trouble Road	CCEDOUBS	03/18/03	4.45	51.4
Cedar Creek at Double Trouble Road	CCEDOUBS	04/15/03	4.53	57.5
Cedar Creek at Double Trouble Road	CCEDOUBS	05/12/03	4.88	42.4
Cedar Creek at Double Trouble Road	CCEDOUBS	06/17/03	4.79	56.1
Cedar Creek at Double Trouble Road	CCEDOUBS	07/08/03	4.29	33.0
Cedar Creek at Double Trouble Road	CCEDOUBS	08/19/03	4.79	38.3
Cedar Creek at Double Trouble Road	CCEDOUBS	09/09/03	4.59	43.1
Cedar Creek at Double Trouble Road	CCEDOUBS	10/06/03	4.75	34.1
Cedar Creek at Double Trouble Road	CCEDOUBS	11/18/03	4.66	41.4
Cedar Creek at Route 614	CCELACEY	01/28/03	4.06	34.5
Cedar Creek at Route 614	CCELACEY	03/18/03	4.65	39.0
Cedar Creek at Route 614	CCELACEY	04/15/03	4.52	43.7
Cedar Creek at Route 614	CCELACEY	05/12/03	4.68	32.9
Cedar Creek at Route 614	CCELACEY	06/17/03	4.75	40.6
Cedar Creek at Route 614	CCELACEY	07/08/03	4.50	27.0
Cedar Creek at Route 614	CCELACEY	08/19/03	4.79	28.6
Cedar Creek at Route 614	CCELACEY	09/08/03	4.43	41.3
Cedar Creek at Route 614	CCELACEY	10/06/03	4.90	27.8
Cedar Creek at Route 614	CCELACEY	11/17/03	4.80	33.0
Cedar Creek at Route 9	CCEROUT9	01/28/03	4.53	54.3
Cedar Creek at Route 9	CCEROUT9	03/17/03	4.10	63.5
Cedar Creek at Route 9	CCEROUT9	04/14/03	4.14	68.9
Cedar Creek at Route 9	CCEROUT9	05/12/03	5.25	51.9
Cedar Creek at Route 9	CCEROUT9	06/17/03	4.96	68.2
Cedar Creek at Route 9	CCEROUT9	07/08/03	4.35	39.0
Cedar Creek at Route 9	CCEROUT9	08/19/03	5.28	72.7
Cedar Creek at Route 9	CCEROUT9	09/08/03	4.05	51.5
Cedar Creek at Route 9	CCEROUT9	10/06/03	4.16	42.7
Cedar Creek at Route 9	CCEROUT9	11/17/03	4.61	50.6
Chamberlain Branch at an unnamed road	CCHSANDR	01/29/03	4.55	38.6
Chamberlain Branch at an unnamed road	CCHSANDR	03/18/03	4.44	45.1
Chamberlain Branch at an unnamed road	CCHSANDR	04/15/03	4.13	46.5
Chamberlain Branch at an unnamed road	CCHSANDR	05/12/03	4.79	36.7
Chamberlain Branch at an unnamed road	CCHSANDR	06/17/03	4.41	41.4
Chamberlain Branch at an unnamed road	CCHSANDR	07/08/03	4.21	29.0
Chamberlain Branch at an unnamed road	CCHSANDR	08/19/03	4.58	32.1
Chamberlain Branch at an unnamed road	CCHSANDR	09/09/03	4.03	33.6
Chamberlain Branch at an unnamed road	CCHSANDR	10/06/03	4.14	28.5
Chamberlain Branch at an unnamed road	CCHSANDR	11/17/03	4.53	38.9
Factory Branch at Route 614	CFALACEY	01/28/03	4.29	65.3
Factory Branch at Route 614	CFALACEY	03/18/03	4.32	60.1
Factory Branch at Route 614	CFALACEY	04/15/03	4.16	71.9
Factory Branch at Route 614	CFALACEY	05/12/03	4.27	57.1

Site Name	Site Code	Date	pH	SC
Factory Branch at Route 614	CFALACEY	06/17/03	4.08	54.7
Factory Branch at Route 614	CFALACEY	07/08/03	4.00	39.0
Factory Branch at Route 614	CFALACEY	08/19/03	4.26	45.7
Factory Branch at Route 614	CFALACEY	09/08/03	4.26	47.9
Factory Branch at Route 614	CFALACEY	10/06/03	4.44	44.5
Factory Branch at Route 614	CFALACEY	11/17/03	4.31	55.1
Long Branch at Bryant Road	CLOBRYAN	01/28/03	4.10	91.3
Long Branch at Bryant Road	CLOBRYAN	03/17/03	3.92	78.6
Long Branch at Bryant Road	CLOBRYAN	04/14/03	4.11	73.5
Long Branch at Bryant Road	CLOBRYAN	05/09/03	4.11	82.8
Long Branch at Bryant Road	CLOBRYAN	06/16/03	4.18	71.6
Long Branch at Bryant Road	CLOBRYAN	07/07/03	3.96	66.0
Long Branch at Bryant Road	CLOBRYAN	08/18/03	3.98	138.9
Long Branch at Bryant Road	CLOBRYAN	09/08/03	3.67	111.5
Long Branch at Bryant Road	CLOBRYAN	10/06/03	3.85	137.8
Long Branch at Bryant Road	CLOBRYAN	11/17/03	4.17	108.5
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	03/17/03	4.21	68.6
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	04/14/03	4.08	71.7
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	05/12/03	4.50	64.1
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	06/17/03	4.56	73.0
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	07/07/03	4.25	48.0
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	08/18/03	5.05	62.9
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	09/08/03	4.55	58.9
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	10/06/03	4.46	55.9
North Branch Forked River at Deer Head Drive (Deer Head Lake)	CNODEERH	11/17/03	4.40	65.1
North Branch Forked River at Parker Avenue (Lower Lake)	CNOLOWER	08/19/03	5.25	67.8
North Branch Forked River at Parker Avenue (Lower Lake)	CNOLOWER	09/08/03	4.12	60.3
North Branch Forked River at Parker Avenue (Lower Lake)	CNOLOWER	10/06/03	5.49	59.5
North Branch Forked River at Parker Avenue (Lower Lake)	CNOLOWER	11/17/03	4.72	68.7
North Branch Forked River at a powerline right-of-way	CNOPOWER	01/28/03	4.21	65.2
North Branch Forked River at a powerline right-of-way	CNOPOWER	03/17/03	4.00	60.5
North Branch Forked River at a powerline right-of-way	CNOPOWER	04/14/03	4.03	67.2
North Branch Forked River at a powerline right-of-way	CNOPOWER	05/12/03	4.24	54.9
North Branch Forked River at a powerline right-of-way	CNOPOWER	06/17/03	4.60	59.4
North Branch Forked River at a powerline right-of-way	CNOPOWER	07/07/03	3.86	46.8
North Branch Forked River at a powerline right-of-way	CNOPOWER	08/18/03	4.08	60.4
North Branch Forked River at a powerline right-of-way	CNOPOWER	09/08/03	4.29	47.9
North Branch Forked River at a powerline right-of-way	CNOPOWER	10/06/03	4.49	42.7
North Branch Forked River at a powerline right-of-way	CNOPOWER	11/17/03	4.29	55.2
Oyster Creek at Route 532	COYRT532	01/28/03	4.44	52.1
Oyster Creek at Route 532	COYRT532	03/17/03	4.16	54.4
Oyster Creek at Route 532	COYRT532	04/14/03	4.25	63.9
Oyster Creek at Route 532	COYRT532	05/09/03	4.45	52.9
Oyster Creek at Route 532	COYRT532	06/16/03	4.80	55.9
Oyster Creek at Route 532	COYRT532	07/07/03	4.78	62.0
Oyster Creek at Route 532	COYRT532	08/18/03	4.68	53.8
Oyster Creek at Route 532	COYRT532	09/08/03	4.62	47.0
Oyster Creek at Route 532	COYRT532	10/06/03	4.09	45.4
Oyster Creek at Route 532	COYRT532	11/17/03	4.35	51.8
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	03/17/03	4.70	56.4
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	04/14/03	4.22	82.6
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	05/09/03	5.02	58.2
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	06/16/03	4.70	59.2
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	07/07/03	4.54	45.0
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	08/18/03	4.68	44.4
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	09/08/03	4.61	51.9
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	10/06/03	4.68	135.4
Oyster Creek at Wells Mills County Park (Wells Mills Lake)	COYWELLS	11/17/03	4.84	53.1

Site Name	Site Code	Date	pH	SC
Waretown Creek at Route 9	CWAROUT9	01/28/03	4.32	107.7
Waretown Creek at Route 9	CWAROUT9	03/17/03	4.26	105.1
Waretown Creek at Route 9	CWAROUT9	04/14/03	4.21	104.8
Waretown Creek at Route 9	CWAROUT9	05/09/03	4.31	56.9
Waretown Creek at Route 9	CWAROUT9	06/16/03	4.50	95.8
Waretown Creek at Route 9	CWAROUT9	07/07/03	4.34	77.0
Waretown Creek at Route 9	CWAROUT9	08/18/03	4.77	99.1
Waretown Creek at Route 9	CWAROUT9	09/08/03	4.68	90.3
Waretown Creek at Route 9	CWAROUT9	10/06/03	4.43	95.7
Waretown Creek at Route 9	CWAROUT9	11/17/03	4.65	98.4
Webbs Mill Branch at Route 539	CWERT539	01/29/03	4.92	30.0
Webbs Mill Branch at Route 539	CWERT539	03/18/03	4.55	45.1
Webbs Mill Branch at Route 539	CWERT539	04/15/03	3.85	38.6
Webbs Mill Branch at Route 539	CWERT539	05/12/03	4.78	33.5
Webbs Mill Branch at Route 539	CWERT539	06/17/03	4.64	33.9
Webbs Mill Branch at Route 539	CWERT539	07/08/03	4.68	32.0
Webbs Mill Branch at Route 539	CWERT539	08/19/03	4.81	28.5
Webbs Mill Branch at Route 539	CWERT539	09/09/03	4.12	32.9
Webbs Mill Branch at Route 539	CWERT539	10/06/03	4.82	31.5
Webbs Mill Branch at Route 539	CWERT539	11/17/03	4.80	30.3
Cedar Run at Route 9	MCEROUT9	01/28/03	4.63	76.2
Cedar Run at Route 9	MCEROUT9	03/17/03	4.64	87.0
Cedar Run at Route 9	MCEROUT9	04/14/03	4.26	87.4
Cedar Run at Route 9	MCEROUT9	05/09/03	4.20	74.8
Cedar Run at Route 9	MCEROUT9	06/16/03	4.50	82.3
Cedar Run at Route 9	MCEROUT9	07/07/03	4.05	62.0
Cedar Run at Route 9	MCEROUT9	08/18/03	4.87	97.3
Cedar Run at Route 9	MCEROUT9	09/08/03	4.42	66.2
Cedar Run at Route 9	MCEROUT9	10/06/03	4.67	64.5
Cedar Run at Route 9	MCEROUT9	11/17/03	4.55	70.8
Fourmile Branch at Lighthouse Drive	MFOLIGHT	01/28/03	4.69	62.3
Fourmile Branch at Lighthouse Drive	MFOLIGHT	03/17/03	5.01	59.8
Fourmile Branch at Lighthouse Drive	MFOLIGHT	04/14/03	4.86	58.9
Fourmile Branch at Lighthouse Drive	MFOLIGHT	05/09/03	5.33	58.9
Fourmile Branch at Lighthouse Drive	MFOLIGHT	06/16/03	5.19	55.3
Fourmile Branch at Lighthouse Drive	MFOLIGHT	07/07/03	4.71	49.0
Fourmile Branch at Lighthouse Drive	MFOLIGHT	08/18/03	5.19	56.7
Fourmile Branch at Lighthouse Drive	MFOLIGHT	09/08/03	5.21	59.2
Fourmile Branch at Lighthouse Drive	MFOLIGHT	10/06/03	5.65	66.3
Fourmile Branch at Lighthouse Drive	MFOLIGHT	11/17/03	5.29	56.3
Fourmile Branch at Oxycocus Street	MFOOXYCO	01/28/03	5.46	96.2
Fourmile Branch at Oxycocus Street	MFOOXYCO	03/17/03	5.69	102.5
Fourmile Branch at Oxycocus Street	MFOOXYCO	04/14/03	5.38	80.2
Fourmile Branch at Oxycocus Street	MFOOXYCO	05/09/03	5.84	88.7
Fourmile Branch at Oxycocus Street	MFOOXYCO	06/16/03	5.96	74.1
Fourmile Branch at Oxycocus Street	MFOOXYCO	07/07/03	5.67	65.0
Fourmile Branch at Oxycocus Street	MFOOXYCO	08/18/03	5.84	82.8
Fourmile Branch at Oxycocus Street	MFOOXYCO	09/08/03	6.07	83.8
Fourmile Branch at Oxycocus Street	MFOOXYCO	10/06/03	6.10	86.3
Fourmile Branch at Oxycocus Street	MFOOXYCO	11/17/03	5.91	81.8
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	01/28/03	5.63	102.8
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	03/17/03	5.65	117.1
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	04/14/03	5.36	119.4
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	05/09/03	6.02	104.0
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	06/16/03	5.58	182.8
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	07/07/03	5.71	80.0
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	08/18/03	4.98	49.3
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	09/08/03	6.02	98.9

Site Name	Site Code	Date	pH	SC
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	10/06/03	6.07	118.6
Mill Creek at Route 72 below Manahawkin Lake	MMI72LWR	11/17/03	6.16	103.3
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	01/28/03	5.65	63.9
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	03/17/03	5.51	67.4
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	04/14/03	5.60	83.5
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	05/09/03	6.43	80.6
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	06/16/03	6.39	69.8
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	07/07/03	5.41	52.0
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	08/18/03	5.68	97.4
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	09/08/03	6.02	64.9
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	10/06/03	6.15	65.7
Mill Creek at Route 72 above Manahawkin Lake	MMI72UPR	11/17/03	6.35	65.1
Mill Creek at Hay Road	MMIHAYRD	01/28/03	4.50	42.2
Mill Creek at Hay Road	MMIHAYRD	03/17/03	4.45	49.0
Mill Creek at Hay Road	MMIHAYRD	04/14/03	4.50	48.4
Mill Creek at Hay Road	MMIHAYRD	05/09/03	4.29	44.1
Mill Creek at Hay Road	MMIHAYRD	06/16/03	4.96	48.8
Mill Creek at Hay Road	MMIHAYRD	07/07/03	4.14	31.0
Mill Creek at Hay Road	MMIHAYRD	08/18/03	4.99	42.5
Mill Creek at Hay Road	MMIHAYRD	09/08/03	4.61	34.7
Mill Creek at Hay Road	MMIHAYRD	10/06/03	4.79	34.8
Mill Creek at Hay Road	MMIHAYRD	11/17/03	4.94	38.9
Davenport Branch at Lake Road (Harry Wright Lake)	RDAHARRY	10/06/03	6.04	61.6
Davenport Branch at Lake Road (Harry Wright Lake)	RDAHARRY	11/17/03	6.10	61.8
Davenport Branch at Route 614	RDALACES	01/28/03	4.78	79.1
Davenport Branch at Route 614	RDALACES	03/18/03	4.55	74.8
Davenport Branch at Route 614	RDALACES	04/15/03	4.67	77.9
Davenport Branch at Route 614	RDALACES	05/12/03	4.84	70.0
Davenport Branch at Route 614	RDALACES	06/17/03	4.90	71.1
Davenport Branch at Route 614	RDALACES	07/08/03	4.71	56.0
Davenport Branch at Route 614	RDALACES	08/19/03	4.85	66.3
Davenport Branch at Route 614	RDALACES	09/09/03	4.75	74.2
Davenport Branch at Route 614	RDALACES	10/06/03	5.14	72.3
Davenport Branch at Route 614	RDALACES	11/17/03	5.03	70.8
Davenport Branch at Mule Road	RDAMULER	01/29/03	3.99	62.5
Davenport Branch at Mule Road	RDAMULER	03/18/03	4.27	62.3
Davenport Branch at Mule Road	RDAMULER	04/15/03	3.88	62.6
Davenport Branch at Mule Road	RDAMULER	05/12/03	4.57	63.4
Davenport Branch at Mule Road	RDAMULER	06/17/03	4.39	60.3
Davenport Branch at Mule Road	RDAMULER	07/08/03	4.37	45.0
Davenport Branch at Mule Road	RDAMULER	08/19/03	5.23	89.1
Davenport Branch at Mule Road	RDAMULER	09/09/03	4.36	55.9
Davenport Branch at Mule Road	RDAMULER	10/07/03	5.39	48.5
Davenport Branch at Mule Road	RDAMULER	11/18/03	4.27	52.6
Davenport Branch at Route 530	RDART530	01/29/03	3.90	84.2
Davenport Branch at Route 530	RDART530	03/18/03	3.94	76.6
Davenport Branch at Route 530	RDART530	04/15/03	4.43	75.7
Davenport Branch at Route 530	RDART530	05/12/03	4.31	72.3
Davenport Branch at Route 530	RDART530	06/17/03	4.12	69.6
Davenport Branch at Route 530	RDART530	07/08/03	4.20	54.0
Davenport Branch at Route 530	RDART530	08/19/03	4.54	63.5
Davenport Branch at Route 530	RDART530	09/09/03	3.91	63.2
Davenport Branch at Route 530	RDART530	10/07/03	4.67	58.7
Davenport Branch at Route 530	RDART530	11/18/03	4.82	62.8
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	03/18/03	4.61	66.7
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	04/15/03	4.17	69.4
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	05/12/03	4.77	79.5
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	06/17/03	4.82	62.6

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Davenport Branch tributary impoundment at Lake Road	RDATRIMP	07/08/03	4.41	56.0
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	08/19/03	4.43	65.3
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	09/09/03	3.81	49.6
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	10/06/03	4.72	63.5
Davenport Branch tributary impoundment at Lake Road	RDATRIMP	11/17/03	5.12	52.1
Jakes Branch at Double Trouble Road	RJADOUBL	01/29/03	3.83	62.8
Jakes Branch at Double Trouble Road	RJADOUBL	03/18/03	4.39	67.5
Jakes Branch at Double Trouble Road	RJADOUBL	04/15/03	4.37	72.9
Jakes Branch at Double Trouble Road	RJADOUBL	05/12/03	4.35	59.7
Jakes Branch at Double Trouble Road	RJADOUBL	06/17/03	4.40	66.6
Jakes Branch at Double Trouble Road	RJADOUBL	07/08/03	4.38	43.0
Jakes Branch at Double Trouble Road	RJADOUBL	08/19/03	4.70	53.3
Jakes Branch at Double Trouble Road	RJADOUBL	09/09/03	4.51	50.0
Jakes Branch at Double Trouble Road	RJADOUBL	10/06/03	4.11	48.3
Jakes Branch at Double Trouble Road	RJADOUBL	11/18/03	4.45	53.0
Jakes Branch at Dover Road	RJADOVER	01/29/03	3.78	186.9
Jakes Branch at Dover Road	RJADOVER	03/18/03	3.98	179.1
Jakes Branch at Dover Road	RJADOVER	04/15/03	4.07	100.1
Jakes Branch at Dover Road	RJADOVER	05/12/03	4.23	102.4
Jakes Branch at Dover Road	RJADOVER	06/17/03	4.28	103.6
Jakes Branch at Dover Road	RJADOVER	07/08/03	3.44	70.0
Jakes Branch at Dover Road	RJADOVER	08/19/03	3.92	102.3
Jakes Branch at Dover Road	RJADOVER	09/09/03	3.97	104.9
Jakes Branch at Dover Road	RJADOVER	10/06/03	3.99	119.3
Jakes Branch at Dover Road	RJADOVER	11/18/03	3.69	118.9
Sunken Branch at Mule Road	RSUMULER	01/29/03	5.10	83.0
Sunken Branch at Mule Road	RSUMULER	03/18/03	5.40	93.7
Sunken Branch at Mule Road	RSUMULER	04/15/03	6.14	125.8
Sunken Branch at Mule Road	RSUMULER	05/12/03	6.87	87.5
Sunken Branch at Mule Road	RSUMULER	06/17/03	6.19	93.2
Sunken Branch at Mule Road	RSUMULER	07/08/03	5.86	68.0
Sunken Branch at Mule Road	RSUMULER	08/19/03	6.14	97.2
Sunken Branch at Mule Road	RSUMULER	09/09/03	5.33	71.0
Sunken Branch at Mule Road	RSUMULER	10/07/03	6.23	84.7
Sunken Branch at Mule Road	RSUMULER	11/18/03	6.22	75.3
Sunken Branch at Township Line Road	RSUTOWNS	03/18/03	4.53	60.1
Sunken Branch at Township Line Road	RSUTOWNS	04/15/03	4.58	55.9
Sunken Branch at Township Line Road	RSUTOWNS	05/12/03	4.61	53.7
Sunken Branch at Township Line Road	RSUTOWNS	06/17/03	4.37	54.2
Sunken Branch at Township Line Road	RSUTOWNS	07/08/03	4.25	40.0
Sunken Branch at Township Line Road	RSUTOWNS	08/19/03	5.65	54.9
Sunken Branch at Township Line Road	RSUTOWNS	09/09/03	4.77	44.8
Sunken Branch at Township Line Road	RSUTOWNS	10/07/03	5.03	56.6
Sunken Branch at Township Line Road	RSUTOWNS	11/18/03	4.86	51.5
Tice Van Horn Branch at Keswick Lake	RTIKESWI	03/18/03	5.19	91.9
Tice Van Horn Branch at Keswick Lake	RTIKESWI	04/15/03	4.84	85.3
Tice Van Horn Branch at Keswick Lake	RTIKESWI	05/12/03	5.11	98.7
Tice Van Horn Branch at Keswick Lake	RTIKESWI	06/17/03	5.63	102.1
Tice Van Horn Branch at Keswick Lake	RTIKESWI	07/08/03	5.50	68.0
Tice Van Horn Branch at Keswick Lake	RTIKESWI	08/19/03	5.63	97.3
Tice Van Horn Branch at Keswick Lake	RTIKESWI	09/09/03	5.87	95.8
Tice Van Horn Branch at Keswick Lake	RTIKESWI	10/07/03	5.46	108.1
Tice Van Horn Branch at Keswick Lake	RTIKESWI	11/18/03	5.99	104.8
Tice Van Horn Branch tributary at Route 530	RTITR530	03/18/03	4.88	112.3
Tice Van Horn Branch tributary at Route 530	RTITR530	04/15/03	4.55	123.2
Tice Van Horn Branch tributary at Route 530	RTITR530	05/12/03	5.18	100.7
Tice Van Horn Branch tributary at Route 530	RTITR530	06/17/03	5.54	94.3
Tice Van Horn Branch tributary at Route 530	RTITR530	07/08/03	4.97	72.0

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Tice Van Horn Branch tributary at Route 530	RTITR530	08/19/03	5.65	89.5
Tice Van Horn Branch tributary at Route 530	RTITR530	09/09/03	5.08	81.7
Tice Van Horn Branch tributary at Route 530	RTITR530	10/07/03	5.08	88.0
Tice Van Horn Branch tributary at Route 530	RTITR530	11/18/03	5.24	88.5
Wrangel Brook at Congasia Road	RWRCONGA	01/29/03	4.25	62.7
Wrangel Brook at Congasia Road	RWRCONGA	03/18/03	4.18	63.0
Wrangel Brook at Congasia Road	RWRCONGA	04/15/03	4.43	64.9
Wrangel Brook at Congasia Road	RWRCONGA	05/12/03	4.22	57.7
Wrangel Brook at Congasia Road	RWRCONGA	06/17/03	4.24	55.6
Wrangel Brook at Congasia Road	RWRCONGA	07/08/03	3.85	39.0
Wrangel Brook at Congasia Road	RWRCONGA	08/19/03	4.23	47.3
Wrangel Brook at Congasia Road	RWRCONGA	09/09/03	4.34	46.9
Wrangel Brook at Congasia Road	RWRCONGA	10/07/03	4.72	53.0
Wrangel Brook at Congasia Road	RWRCONGA	11/18/03	4.30	54.5
Wrangel Brook at Mule Road	RWRMULER	01/29/03	4.26	70.3
Wrangel Brook at Mule Road	RWRMULER	03/18/03	4.40	68.9
Wrangel Brook at Mule Road	RWRMULER	04/15/03	4.70	72.4
Wrangel Brook at Mule Road	RWRMULER	05/12/03	5.04	66.0
Wrangel Brook at Mule Road	RWRMULER	06/17/03	4.51	74.7
Wrangel Brook at Mule Road	RWRMULER	07/08/03	5.10	65.0
Wrangel Brook at Mule Road	RWRMULER	08/19/03	5.03	66.7
Wrangel Brook at Mule Road	RWRMULER	09/09/03	4.28	65.3
Wrangel Brook at Mule Road	RWRMULER	10/07/03	5.21	65.5
Wrangel Brook at Mule Road	RWRMULER	11/18/03	4.84	67.0
Wrangel Brook at South Hampton Road	RWRSOUTH	01/29/03	4.67	74.5
Wrangel Brook at South Hampton Road	RWRSOUTH	03/18/03	4.50	71.5
Wrangel Brook at South Hampton Road	RWRSOUTH	04/15/03	4.48	72.8
Wrangel Brook at South Hampton Road	RWRSOUTH	05/12/03	5.13	68.3
Wrangel Brook at South Hampton Road	RWRSOUTH	06/17/03	4.86	65.6
Wrangel Brook at South Hampton Road	RWRSOUTH	07/08/03	4.87	55.0
Wrangel Brook at South Hampton Road	RWRSOUTH	08/19/03	5.73	75.4
Wrangel Brook at South Hampton Road	RWRSOUTH	09/09/03	5.31	70.9
Wrangel Brook at South Hampton Road	RWRSOUTH	10/07/03	5.60	86.6
Wrangel Brook at South Hampton Road	RWRSOUTH	11/18/03	5.18	71.4
Wrangle Brook at Township Line Road	RWRTOWNS	03/18/03	4.28	70.8
Wrangle Brook at Township Line Road	RWRTOWNS	04/15/03	4.43	73.2
Wrangle Brook at Township Line Road	RWRTOWNS	05/12/03	4.20	64.0
Wrangle Brook at Township Line Road	RWRTOWNS	06/17/03	4.72	43.7
Wrangle Brook at Township Line Road	RWRTOWNS	07/08/03	4.03	44.0
Wrangle Brook at Township Line Road	RWRTOWNS	08/19/03	4.14	55.5
Wrangle Brook at Township Line Road	RWRTOWNS	09/09/03	3.98	56.0
Wrangle Brook at Township Line Road	RWRTOWNS	10/07/03	4.60	56.8
Wrangle Brook at Township Line Road	RWRTOWNS	11/18/03	4.44	67.8
Blacks Branch at Central Avenue	TBLCENTR	01/29/03	4.71	34.4
Blacks Branch at Central Avenue	TBLCENTR	03/19/03	4.82	35.9
Blacks Branch at Central Avenue	TBLCENTR	04/16/03	5.05	39.6
Blacks Branch at Central Avenue	TBLCENTR	05/13/03	4.97	30.8
Blacks Branch at Central Avenue	TBLCENTR	06/23/03	4.48	29.0
Blacks Branch at Central Avenue	TBLCENTR	07/09/03	4.78	22.0
Blacks Branch at Central Avenue	TBLCENTR	08/20/03	4.70	30.0
Blacks Branch at Central Avenue	TBLCENTR	09/10/03	4.60	28.2
Blacks Branch at Central Avenue	TBLCENTR	10/07/03	5.24	31.2
Blacks Branch at Central Avenue	TBLCENTR	11/18/03	5.07	32.0
Blacks Branch at Route 70	TBLRTE70	01/29/03	4.01	55.8
Blacks Branch at Route 70	TBLRTE70	03/18/03	4.27	55.0
Blacks Branch at Route 70	TBLRTE70	04/15/03	3.94	54.5
Blacks Branch at Route 70	TBLRTE70	05/13/03	4.52	47.4
Blacks Branch at Route 70	TBLRTE70	06/23/03	4.16	45.0

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Blacks Branch at Route 70	TBLRTE70	07/09/03	4.33	35.0
Blacks Branch at Route 70	TBLRTE70	08/19/03	4.77	44.3
Blacks Branch at Route 70	TBLRTE70	09/09/03	3.94	40.3
Blacks Branch at Route 70	TBLRTE70	10/07/03	4.88	37.1
Blacks Branch at Route 70	TBLRTE70	11/18/03	4.49	52.0
Bordens Mill Branch impoundment - lower	TBOHAWLW	01/30/03	-	-
Bordens Mill Branch impoundment - lower	TBOHAWLW	03/19/03	4.55	38.3
Bordens Mill Branch impoundment - lower	TBOHAWLW	04/16/03	4.79	38.7
Bordens Mill Branch impoundment - lower	TBOHAWLW	05/13/03	4.65	40.5
Bordens Mill Branch impoundment - lower	TBOHAWLW	06/23/03	4.35	30.0
Bordens Mill Branch impoundment - lower	TBOHAWLW	07/09/03	4.48	31.0
Bordens Mill Branch impoundment - lower	TBOHAWLW	08/20/03	4.61	35.8
Bordens Mill Branch impoundment - lower	TBOHAWLW	09/10/03	4.55	27.9
Bordens Mill Branch impoundment - lower	TBOHAWLW	10/08/03	5.70	46.2
Bordens Mill Branch impoundment - lower	TBOHAWLW	11/19/03	-	-
Cabin Branch at New Jersey Central railroad	TCARAILR	06/23/03	5.75	121.0
Cabin Branch at New Jersey Central railroad	TCARAILR	07/09/03	5.92	119.0
Cabin Branch at New Jersey Central railroad	TCARAILR	08/20/03	6.21	118.6
Cabin Branch at New Jersey Central railroad	TCARAILR	09/10/03	6.03	134.3
Cabin Branch at New Jersey Central railroad	TCARAILR	10/07/03	6.27	133.1
Cabin Branch at New Jersey Central railroad	TCARAILR	11/18/03	6.42	106.1
Dove Mill Branch at Grawtown Road	TDOGRAWT	01/30/03	5.41	105.0
Dove Mill Branch at Grawtown Road	TDOGRAWT	03/19/03	4.57	103.2
Dove Mill Branch at Grawtown Road	TDOGRAWT	04/16/03	5.04	102.9
Dove Mill Branch at Grawtown Road	TDOGRAWT	05/13/03	5.19	94.1
Dove Mill Branch at Grawtown Road	TDOGRAWT	06/23/03	4.68	64.0
Dove Mill Branch at Grawtown Road	TDOGRAWT	07/09/03	5.33	70.0
Dove Mill Branch at Grawtown Road	TDOGRAWT	08/20/03	5.03	86.8
Dove Mill Branch at Grawtown Road	TDOGRAWT	09/10/03	5.51	81.6
Dove Mill Branch at Grawtown Road	TDOGRAWT	10/08/03	5.48	87.6
Dove Mill Branch at Grawtown Road	TDOGRAWT	11/19/03	5.74	83.3
Dove Mill Branch impoundment at Route 528	TDOIM528	03/19/03	4.55	98.9
Dove Mill Branch impoundment at Route 528	TDOIM528	04/16/03	4.61	95.9
Dove Mill Branch impoundment at Route 528	TDOIM528	05/13/03	4.93	85.8
Dove Mill Branch impoundment at Route 528	TDOIM528	06/23/03	4.55	59.0
Dove Mill Branch impoundment at Route 528	TDOIM528	07/09/03	5.64	65.0
Dove Mill Branch impoundment at Route 528	TDOIM528	08/20/03	5.67	72.7
Dove Mill Branch impoundment at Route 528	TDOIM528	09/10/03	5.20	70.3
Dove Mill Branch impoundment at Route 528	TDOIM528	10/08/03	5.31	73.3
Dove Mill Branch impoundment at Route 528	TDOIM528	11/19/03	5.56	73.3
Maple Root Branch at Bowman Road	TMABOWMA	01/30/03	4.28	77.2
Maple Root Branch at Bowman Road	TMABOWMA	03/19/03	4.13	75.6
Maple Root Branch at Bowman Road	TMABOWMA	04/16/03	4.10	85.7
Maple Root Branch at Bowman Road	TMABOWMA	05/13/03	4.53	72.1
Maple Root Branch at Bowman Road	TMABOWMA	06/23/03	3.78	59.0
Maple Root Branch at Bowman Road	TMABOWMA	07/09/03	4.16	47.0
Maple Root Branch at Bowman Road	TMABOWMA	08/20/03	4.18	58.1
Maple Root Branch at Bowman Road	TMABOWMA	09/10/03	3.56	66.8
Maple Root Branch at Bowman Road	TMABOWMA	10/08/03	4.55	67.2
Maple Root Branch at Bowman Road	TMABOWMA	11/19/03	4.11	71.8
Manapaqua Brook at Route 70	TMARTE70	01/29/03	5.27	73.8
Manapaqua Brook at Route 70	TMARTE70	03/18/03	5.32	68.1
Manapaqua Brook at Route 70	TMARTE70	04/15/03	5.37	56.6
Manapaqua Brook at Route 70	TMARTE70	05/12/03	5.78	61.2
Manapaqua Brook at Route 70	TMARTE70	06/17/03	5.45	53.9
Manapaqua Brook at Route 70	TMARTE70	07/08/03	5.55	52.0
Manapaqua Brook at Route 70	TMARTE70	08/19/03	5.55	81.2
Manapaqua Brook at Route 70	TMARTE70	09/09/03	5.49	58.1

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Manapaqua Brook at Route 70	TMARTE70	10/07/03	6.13	72.6
Manapaqua Brook at Route 70	TMARTE70	11/18/03	5.23	50.1
Mirey Run at Route 528	TMIRT528	01/30/03	5.92	199.0
Mirey Run at Route 528	TMIRT528	03/19/03	5.66	180.9
Mirey Run at Route 528	TMIRT528	04/16/03	5.89	164.3
Mirey Run at Route 528	TMIRT528	05/13/03	6.88	179.9
Mirey Run at Route 528	TMIRT528	06/23/03	5.63	130.0
Mirey Run at Route 528	TMIRT528	07/09/03	5.46	199.0
Mirey Run at Route 528	TMIRT528	08/20/03	6.51	199.6
Mirey Run at Route 528	TMIRT528	09/10/03	6.11	164.8
Mirey Run at Route 528	TMIRT528	10/08/03	6.47	201.0
Mirey Run at Route 528	TMIRT528	11/19/03	6.62	161.0
Old Hurricane Brook at Beckerville Road	TOLBECKE	01/29/03	4.08	71.5
Old Hurricane Brook at Beckerville Road	TOLBECKE	03/19/03	4.11	87.1
Old Hurricane Brook at Beckerville Road	TOLBECKE	04/16/03	4.13	83.9
Old Hurricane Brook at Beckerville Road	TOLBECKE	05/13/03	4.25	74.5
Old Hurricane Brook at Beckerville Road	TOLBECKE	06/23/03	3.93	72.0
Old Hurricane Brook at Beckerville Road	TOLBECKE	07/09/03	4.10	51.0
Old Hurricane Brook at Beckerville Road	TOLBECKE	08/20/03	4.34	62.7
Old Hurricane Brook at Beckerville Road	TOLBECKE	09/10/03	3.83	71.5
Old Hurricane Brook at Beckerville Road	TOLBECKE	10/07/03	4.45	59.4
Old Hurricane Brook at Beckerville Road	TOLBECKE	11/18/03	4.15	71.1
Old Hurricane Brook at Route 70	TOLRTE70	01/29/03	4.06	77.1
Old Hurricane Brook at Route 70	TOLRTE70	03/18/03	4.14	86.5
Old Hurricane Brook at Route 70	TOLRTE70	04/15/03	3.81	87.3
Old Hurricane Brook at Route 70	TOLRTE70	05/13/03	4.82	75.5
Old Hurricane Brook at Route 70	TOLRTE70	06/23/03	3.93	73.0
Old Hurricane Brook at Route 70	TOLRTE70	07/09/03	4.11	55.0
Old Hurricane Brook at Route 70	TOLRTE70	08/20/03	4.81	62.8
Old Hurricane Brook at Route 70	TOLRTE70	09/09/03	4.01	75.4
Old Hurricane Brook at Route 70	TOLRTE70	10/07/03	4.33	62.1
Old Hurricane Brook at Route 70	TOLRTE70	11/18/03	4.14	77.0
Ridgeway Branch at Hangar Road	TRIHANGA	01/30/03	4.24	75.8
Ridgeway Branch at Hangar Road	TRIHANGA	03/19/03	4.22	74.5
Ridgeway Branch at Hangar Road	TRIHANGA	04/16/03	4.02	67.9
Ridgeway Branch at Hangar Road	TRIHANGA	05/13/03	4.24	71.2
Ridgeway Branch at Hangar Road	TRIHANGA	06/23/03	3.96	59.0
Ridgeway Branch at Hangar Road	TRIHANGA	07/09/03	4.31	49.0
Ridgeway Branch at Hangar Road	TRIHANGA	08/20/03	4.78	58.9
Ridgeway Branch at Hangar Road	TRIHANGA	09/10/03	4.37	62.2
Ridgeway Branch at Hangar Road	TRIHANGA	10/08/03	4.86	62.3
Ridgeway Branch at Hangar Road	TRIHANGA	11/19/03	4.68	69.1
Ridgeway Branch at High Bridge Road	TRIHIGHB	01/30/03	4.23	80.7
Ridgeway Branch at High Bridge Road	TRIHIGHB	03/19/03	3.74	75.0
Ridgeway Branch at High Bridge Road	TRIHIGHB	04/16/03	3.69	74.6
Ridgeway Branch at High Bridge Road	TRIHIGHB	05/13/03	4.21	69.9
Ridgeway Branch at High Bridge Road	TRIHIGHB	06/23/03	3.85	60.0
Ridgeway Branch at High Bridge Road	TRIHIGHB	07/09/03	4.19	45.0
Ridgeway Branch at High Bridge Road	TRIHIGHB	08/20/03	4.55	53.3
Ridgeway Branch at High Bridge Road	TRIHIGHB	09/10/03	4.17	58.3
Ridgeway Branch at High Bridge Road	TRIHIGHB	10/08/03	4.51	56.5
Ridgeway Branch at High Bridge Road	TRIHIGHB	11/19/03	4.26	68.8
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	01/29/03	4.24	97.6
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	03/19/03	4.26	74.8
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	04/16/03	4.43	76.3
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	05/13/03	4.31	73.4
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	06/23/03	4.04	61.0
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	07/09/03	4.51	58.0

Site Name	Site Code	Date	pH	SC
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	08/20/03	4.86	69.9
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	09/10/03	4.61	67.9
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	10/07/03	5.04	70.2
Ridgeway Branch at Ridgeway Boulevard	TRIRIDGE	11/18/03	4.68	70.3
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	01/30/03	4.21	76.1
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	03/19/03	4.16	66.2
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	04/16/03	4.12	68.3
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	05/13/03	5.05	62.2
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	06/23/03	4.11	53.0
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	07/09/03	4.52	43.0
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	08/20/03	4.59	50.9
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	09/10/03	4.40	58.0
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	10/08/03	4.63	55.8
Shannae Brook at Success Road (Success Lake)	TSHSUCCE	11/19/03	4.59	58.9
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	01/30/03	6.04	85.8
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	03/19/03	5.27	79.4
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	04/16/03	5.84	81.3
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	05/13/03	6.69	87.4
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	06/23/03	6.15	66.0
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	07/09/03	6.23	65.0
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	08/20/03	6.42	88.1
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	09/10/03	6.34	83.3
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	10/08/03	6.65	86.1
Shannae Brook tributary at Turn Mill Pond	TSHTURNS	11/19/03	6.54	80.6
Shannae Brook impoundment	TSHUPPER	03/19/03	4.34	62.7
Shannae Brook impoundment	TSHUPPER	04/16/03	4.33	65.2
Shannae Brook impoundment	TSHUPPER	05/13/03	4.62	58.8
Shannae Brook impoundment	TSHUPPER	06/23/03	4.14	48.0
Shannae Brook impoundment	TSHUPPER	07/09/03	4.67	45.0
Shannae Brook impoundment	TSHUPPER	08/20/03	5.02	64.3
Shannae Brook impoundment	TSHUPPER	09/10/03	4.57	53.6
Shannae Brook impoundment	TSHUPPER	10/08/03	5.26	65.6
Shannae Brook impoundment	TSHUPPER	11/19/03	5.10	56.3
Toms River at Bowman Road	TTOBOWMA	06/23/03	5.19	104.0
Toms River at Bowman Road	TTOBOWMA	07/09/03	5.73	121.0
Toms River at Bowman Road	TTOBOWMA	08/20/03	6.10	176.2
Toms River at Bowman Road	TTOBOWMA	09/10/03	5.97	138.1
Toms River at Bowman Road	TTOBOWMA	10/08/03	6.29	151.2
Toms River at Bowman Road	TTOBOWMA	11/19/03	6.14	138.3
Toms River at Route 528	TTORT528	01/30/03	5.78	324.0
Toms River at Route 528	TTORT528	03/19/03	5.37	136.6
Toms River at Route 528	TTORT528	04/16/03	5.39	130.9
Toms River at Route 528	TTORT528	05/13/03	6.13	135.4
Toms River at Route 528	TTORT528	06/23/03	5.35	99.0
Toms River at Route 528	TTORT528	07/09/03	5.96	110.0
Toms River at Route 528	TTORT528	08/20/03	6.46	127.7
Toms River at Route 528	TTORT528	09/10/03	6.01	126.2
Toms River at Route 528	TTORT528	10/08/03	6.44	135.5
Toms River at Route 528	TTORT528	11/19/03	6.64	129.7
Toms River at Route 547	TTORT547	01/29/03	5.28	116.6
Toms River at Route 547	TTORT547	03/19/03	4.51	116.7
Toms River at Route 547	TTORT547	04/16/03	4.87	112.3
Toms River at Route 547	TTORT547	05/13/03	5.46	116.9
Toms River at Route 547	TTORT547	06/23/03	4.63	81.0
Toms River at Route 547	TTORT547	07/09/03	5.52	88.0
Toms River at Route 547	TTORT547	08/20/03	6.13	117.7
Toms River at Route 547	TTORT547	09/10/03	5.79	105.5
Toms River at Route 547	TTORT547	10/08/03	5.68	115.5

Site Name	Site Code	Date	pH	SC
Toms River at Route 547	TTORT547	11/19/03	6.05	107.8
Toms River tributary at Route 571	TTOTR571	03/19/03	4.62	55.9
Toms River tributary at Route 571	TTOTR571	04/16/03	4.21	58.6
Toms River tributary at Route 571	TTOTR571	05/13/03	5.25	50.2
Toms River tributary at Route 571	TTOTR571	06/23/03	4.28	50.0
Toms River tributary at Route 571	TTOTR571	07/09/03	5.27	36.0
Toms River tributary at Route 571	TTOTR571	08/20/03	5.77	58.3
Toms River tributary at Route 571	TTOTR571	09/10/03	5.05	47.3
Toms River tributary at Route 571	TTOTR571	10/08/03	6.22	49.4
Toms River tributary at Route 571	TTOTR571	11/19/03	6.20	51.1
Union Branch at Colonial Drive	TUNCOLON	01/29/03	4.39	74.1
Union Branch at Colonial Drive	TUNCOLON	03/18/03	4.08	70.3
Union Branch at Colonial Drive	TUNCOLON	04/15/03	4.36	75.7
Union Branch at Colonial Drive	TUNCOLON	05/12/03	4.81	63.0
Union Branch at Colonial Drive	TUNCOLON	06/17/03	5.07	79.7
Union Branch at Colonial Drive	TUNCOLON	07/08/03	4.63	49.0
Union Branch at Colonial Drive	TUNCOLON	08/19/03	5.21	72.6
Union Branch at Colonial Drive	TUNCOLON	09/09/03	4.53	61.4
Union Branch at Colonial Drive	TUNCOLON	10/07/03	5.24	74.5
Union Branch at Colonial Drive	TUNCOLON	11/18/03	4.66	65.6
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	03/18/03	4.09	73.1
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	04/15/03	4.14	76.9
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	05/13/03	4.63	61.9
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	06/17/03	4.09	67.9
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	07/08/03	4.32	48.0
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	08/19/03	4.48	53.5
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	09/09/03	3.92	62.1
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	10/07/03	4.54	53.6
Union Branch at Lake Street (Horicon Lake)	TUNHORIC	11/18/03	4.22	70.1
Mill Branch at Nugentown Road	WMINUGEN	01/28/03	4.38	61.6
Mill Branch at Nugentown Road	WMINUGEN	03/17/03	4.35	79.9
Mill Branch at Nugentown Road	WMINUGEN	04/14/03	4.32	88.8
Mill Branch at Nugentown Road	WMINUGEN	05/09/03	4.35	74.4
Mill Branch at Nugentown Road	WMINUGEN	06/16/03	4.19	75.6
Mill Branch at Nugentown Road	WMINUGEN	07/07/03	4.13	45.0
Mill Branch at Nugentown Road	WMINUGEN	08/18/03	4.49	60.5
Mill Branch at Nugentown Road	WMINUGEN	09/08/03	4.51	52.0
Mill Branch at Nugentown Road	WMINUGEN	10/06/03	4.50	49.8
Mill Branch at Nugentown Road	WMINUGEN	11/17/03	4.19	60.8
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	03/17/03	4.40	83.9
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	04/14/03	4.46	82.4
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	05/09/03	4.59	66.9
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	06/16/03	4.39	70.4
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	07/07/03	4.43	55.0
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	08/18/03	4.96	77.2
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	09/08/03	5.29	58.4
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	10/06/03	4.38	55.0
Mill Branch at Route 9 (Pohatcong Lake)	WMIPOHAT	11/17/03	4.27	64.4
Mill Branch at Poor Mans Parkway	WMIPOORM	01/28/03	-	-
Mill Branch at Poor Mans Parkway	WMIPOORM	03/17/03	4.04	213.0
Mill Branch at Poor Mans Parkway	WMIPOORM	04/14/03	3.96	184.8
Mill Branch at Poor Mans Parkway	WMIPOORM	05/09/03	3.87	177.9
Mill Branch at Poor Mans Parkway	WMIPOORM	06/16/03	4.27	124.3
Mill Branch at Poor Mans Parkway	WMIPOORM	07/07/03	3.96	100.0
Mill Branch at Poor Mans Parkway	WMIPOORM	08/18/03	3.97	118.3
Mill Branch at Poor Mans Parkway	WMIPOORM	09/08/03	-	-
Mill Branch at Poor Mans Parkway	WMIPOORM	10/06/03	-	-
Mill Branch at Poor Mans Parkway	WMIPOORM	11/17/03	4.03	94.0

Site Name	Site Code	Date	pH	SC
Three Mile Branch at Pollypod Road	WTHPOLLY	01/28/03	4.72	51.5
Three Mile Branch at Pollypod Road	WTHPOLLY	03/17/03	4.49	50.8
Three Mile Branch at Pollypod Road	WTHPOLLY	04/14/03	4.45	55.5
Three Mile Branch at Pollypod Road	WTHPOLLY	05/09/03	4.18	46.9
Three Mile Branch at Pollypod Road	WTHPOLLY	06/16/03	4.73	51.7
Three Mile Branch at Pollypod Road	WTHPOLLY	07/07/03	4.11	34.0
Three Mile Branch at Pollypod Road	WTHPOLLY	08/18/03	4.47	40.8
Three Mile Branch at Pollypod Road	WTHPOLLY	09/08/03	4.58	39.1
Three Mile Branch at Pollypod Road	WTHPOLLY	10/06/03	4.92	39.4
Three Mile Branch at Pollypod Road	WTHPOLLY	11/17/03	4.30	48.5
Westecunk Creek at Forge Road	WWEFORGS	01/28/03	5.00	36.4
Westecunk Creek at Forge Road	WWEFORGS	03/17/03	4.68	40.4
Westecunk Creek at Forge Road	WWEFORGS	04/14/03	4.63	45.7
Westecunk Creek at Forge Road	WWEFORGS	05/09/03	4.51	80.9
Westecunk Creek at Forge Road	WWEFORGS	06/16/03	4.57	40.6
Westecunk Creek at Forge Road	WWEFORGS	07/07/03	4.32	37.0
Westecunk Creek at Forge Road	WWEFORGS	08/18/03	5.14	94.6
Westecunk Creek at Forge Road	WWEFORGS	09/08/03	4.17	33.4
Westecunk Creek at Forge Road	WWEFORGS	10/06/03	4.97	32.9
Westecunk Creek at Forge Road	WWEFORGS	11/17/03	4.75	37.3
Westecunk Creek at Railroad Avenue	WWERAILR	01/28/03	5.26	46.5
Westecunk Creek at Railroad Avenue	WWERAILR	03/17/03	4.55	57.1
Westecunk Creek at Railroad Avenue	WWERAILR	04/14/03	4.15	61.2
Westecunk Creek at Railroad Avenue	WWERAILR	05/09/03	4.55	53.1
Westecunk Creek at Railroad Avenue	WWERAILR	06/16/03	4.36	57.6
Westecunk Creek at Railroad Avenue	WWERAILR	07/07/03	4.54	41.0
Westecunk Creek at Railroad Avenue	WWERAILR	08/18/03	4.79	41.2
Westecunk Creek at Railroad Avenue	WWERAILR	09/08/03	4.31	40.9
Westecunk Creek at Railroad Avenue	WWERAILR	10/06/03	5.21	43.2
Westecunk Creek at Railroad Avenue	WWERAILR	11/17/03	4.83	48.8

APPENDIX 2. STREAM-VEGETATION DATA

Appendix 2.0. Stream-vegetation survey sites in the Barnegat Bay Watershed. Two 10-m sections were surveyed at each stream site. Latitude, longitude, and USGS 7.5 minute topographic quadrangle names are given in parentheses. Sites are ordered alphabetically by site code.

Site Name and Description	Site Code
Cedar Creek at Double Trouble Road Berkeley and Lacey Twps., Ocean Co. (lat 39°53'38.64", long 74°13'30.75", Toms River quad). Sections located upstream from Double Trouble Road.	CCEDOUBS
Cedar Creek at Route 614 Lacey Twp., Ocean Co. (lat 39°53'50.25", long 74°18'58.63", Keswick Grove quad). Sections located upstream and downstream from Route 614 (Whiting-Lacey Road).	CCELACEY
Cedar Creek at Route 9 Berkeley and Lacey Twps., Ocean Co. (lat 39°52'03.70", long 74°10'08.08", Forked River quad). Sections located upstream from Route 9 at Dudley Park.	CCEROUT9
Chamberlain Branch at an unnamed road Lacey Twp., Ocean Co. (lat 39°52'22.11", long 74°20'40.06", Brookville quad). Sections located upstream and downstream from unnamed road.	CCHSANDR
Factory Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°52'52.18", long 74°16'30.65", Keswick Grove quad). Sections located upstream and downstream from Route 614 (Whiting-Lacey Road).	CFALACEY
Long Branch at Bryant Road Lacey Twp., Ocean Co. (lat 39°49'02.14", long 74°17'34.18", Brookville quad). Sections located upstream and downstream from Bryant Road.	CLOBRYAN
North Branch Forked River at a powerline right-of-way Lacey Twp., Ocean Co. (lat 39°51'31.38", long 74°13'29.85", Forked River quad). Sections located upstream and downstream from powerline right-of-way.	CNOPOWER
Oyster Creek at Route 532 Lacey and Ocean Twps., Ocean Co. (lat 39°47'53.91", long 74°15'00.33", Brookville quad). Sections located upstream and downstream from Route 532 (Waretown-Brookville Road).	COYRT532
Waretown Creek at Route 9 Ocean Twp., Ocean Co. (lat 39°47'34.87", long 74°11'45.57", Forked River quad). Sections located upstream and downstream from Route 9.	CWAROUT9
Webbs Mill Branch at Route 539 Lacey Twp., Ocean Co. (lat 39°53'16.50", long 74°22'46.54", Whiting quad). Sections located downstream from Route 539.	CWERT539
Cedar Run at Route 9 Stafford Twp., Ocean Co. (lat 39°40'48.95", long 74°16'15.05", West Creek quad). Sections located downstream from Route 9.	MCEROUT9
Fourmile Branch at Lighthouse Drive Stafford Twp., Ocean Co. (lat 39°44'42.81", long 74°16'01.86", West Creek quad). Sections located upstream and downstream from Lighthouse Drive.	MFOLIGHT
Fourmile Branch at Oxycocus Street Stafford Twp., Ocean Co. (lat 39°42'26.78", long 74°16'00.96", West Creek quad). Sections located downstream from Oxycocus Street.	MFOOXYCO
Mill Creek at Route 72 below Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°41'33.72", long 74°15'31.93", West Creek quad). Sections located downstream from Route 72 below Manahawkin Lake.	MMI72LWR
Mill Creek at Route 72 above Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°42'54.39", long 74°16'56.30", West Creek quad). Sections located upstream from path near Route 72 above Manahawkin Lake.	MMI72UPR
Mill Creek at Hay Road Stafford Twp., Ocean Co. (lat 39°43'43.43", long 74°19'09.52", West Creek quad). Sections located upstream and downstream from path near Hay Road.	MMIHAYRD
Davenport Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°55'35.97", long 74°20'17.97", Keswick Grove quad). Sections located downstream from Route 614 (Lacey Road).	RDALACES

Site Name and Description	Site Code
Davenport Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'37.78", long 74°14'40.17", Toms River quad). Sections located upstream from Mule Road.	RDAMULER
Davenport Branch at Route 530 Berkeley Twp., Ocean Co. (lat 39°56'29.25", long 74°17'48.60", Keswick Grove quad). Sections located upstream and downstream from Route 530 (Pinewald-Keswick Road).	RDART530
Jakes Branch at Double Trouble Road Beachwood and South Toms River Boros, Ocean Co. (lat 39°56'07.45", long 74°12'41.58", Toms River quad). Sections located upstream and downstream from Double Trouble Road.	RJADOUBL
Sunken Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°58'02.91", long 74°14'31.13", Toms River quad). Sections located upstream from Mule Road.	RSUMULER
Sunken Branch at Township Line Road Berkeley and Manchester Twp., Ocean Co. (lat 39°58'55.48", long 74°16'41.07", Keswick Grove quad). Sections located downstream from Township Line Road.	RSUTOWNS
Tice Van Horn Branch tributary at Route 530 Manchester Twp., Ocean Co. (lat 39°56'48.37", long 74°20'14.18", Keswick Grove quad). Sections located upstream from Route 530 (Pinewald-Keswick Road).	RTITR530
Wrangel Brook at Congasia Road Manchester Twp., Ocean Co. (lat 39°58'22.14", long 74°19'26.46", Keswick Grove quad). Sections located upstream and downstream from Congasia Road.	RWRCONGA
Wrangel Brook at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'53.69", long 74°14'36.99", Toms River quad). Sections located upstream from Mule Road.	RWRMULER
Wrangel Brook at South Hampton Road Berkeley Twp., Ocean Co. (lat 39°57'39.48", long 74°13'41.26", Toms River quad). Sections located upstream and downstream from South Hampton Road.	RWRSOUTH
Wrangel Brook near Township Line Road Berkeley and Manchester Twp., Ocean Co. (lat 39°58'20.38", long 74°17'15.55", Keswick Grove quad). Sections located downstream from Township Line Road and below cranberry bogs.	RWRTOWNV
Blacks Branch at Central Avenue Manchester Twp., Ocean Co. (lat 40°0'46.74", long 74°22'47.78", Cassville quad). Sections located upstream and downstream from Central Avenue.	TBLCENTR
Blacks Branch at Route 70 Manchester Twp. and Lakehurst Boro, Ocean Co. (lat 40°0'30.66", long 74°19'47.86", Lakehurst quad). Sections located upstream and downstream from Route 70.	TBLRTE70
Cabin Branch at New Jersey Central railroad Manchester Twp., Ocean Co. (lat 40°2'15.32", long 74°16'44.31", Lakehurst quad). Sections located downstream from New Jersey Central railroad tracks.	TCARAILR
Dove Mill Branch at Grawtown Road Jackson Twp., Ocean Co. (lat 40°4'08.82", long 74°17'28.18", Lakehurst quad). Sections located upstream from Grawtown Road.	TDOGRAWT
Maple Root Branch at Bowman Road Jackson Twp., Ocean Co. (lat 40°4'52.48", long 74°19'37.72", Lakehurst quad). Sections located upstream and downstream from Bowman Road.	TMABOWMA
Manapaqua Brook at Route 70 Manchester Twp. and Lakehurst Boro, Ocean Co. (lat 40°0'44.35", long 74°18'08.89", Lakehurst quad). Sections located upstream and downstream from Route 70.	TMARTE70
Mirey Run at Route 528 Jackson Twp., Ocean Co. (lat 40°6'43.05", long 74°20'38.03", Lakehurst quad). Sections located upstream and downstream from Route 528.	TMIRT528

Site Name and Description	Site Code
Old Hurricane Brook at Beckerville Road Manchester Twp., Ocean Co. (lat 39°59'28.90", long 74°22'44.71", Whiting quad). Sections located upstream and downstream from Beckerville Road.	TOLBECKE
Old Hurricane Brook at Route 70 Manchester Twp., Ocean Co. (lat 39°59'51.78", long 74°21'03.30", Keswick Grove quad). Sections located upstream and downstream from Route 70.	TOLRTE70
Ridgeway Branch at Hangar Road Jackson Twp., Ocean Co. (lat 40°2'50.29", long 74°20'04.83", Lakehurst quad). Sections located upstream from Hangar Road.	TRIHANGA
Ridgeway Branch at High Bridge Road Jackson Twp., Ocean Co. (lat 40°3'17.51", long 74°21'17.16", Lakehurst quad). Sections located upstream and downstream from High Bridge Road.	TRIHIGHB
Ridgeway Branch at Ridgeway Boulevard Manchester Twp., Ocean Co. (lat 40°1'47.86", long 74°17'44.49", Lakehurst quad). Sections located upstream and downstream from Ridgeway Boulevard.	TRIRIDGE
Shannae Brook tributary at Turn Mill Pond Jackson Twp., Ocean Co. (lat 40°3'40.41", long 74°26'22.54", Cassville quad). Sections located downstream from Turn Mill Pond.	TSHTURNS
Toms River at Bowman Road Jackson Twp., Ocean Co. (lat 40°5'22.70", long 74°18'54.00", Lakehurst quad). Sections located upstream and downstream from Bowman Road.	TTOBOWMA
Toms River at Route 528 Jackson Twp., Ocean Co. (lat 40°6'35.24", long 74°22'25.32", Lakehurst quad). Sections located upstream and downstream from Route 528.	TTORT528
Toms River at Route 547 Jackson Twp., Ocean Co. (lat 40°3'42.06", long 74°16'28.46", Lakehurst quad). Sections located upstream from Route 547 (Lakehurst-Whitesville Road).	TTORT547
Toms River tributary at Route 571 Jackson Twp., Ocean Co. (lat 40°6'38.66", long 74°23'19.46", Cassville quad). Sections located downstream from Route 571 (Cassville-Toms River Road).	TTOTR571
Union Branch at Colonial Drive Manchester Twp., Ocean Co. (lat 40°0'29.38", long 74°17'37.40", Lakehurst quad). Sections located upstream and downstream from Colonial Drive.	TUNCOLON
Mill Branch at Nugentown Road Little Egg Harbor Twp. and Tuckerton Boro, Ocean Co. (lat 39°36'37.50", long 74°20'59.83", Tuckerton quad). Sections located upstream and downstream from Nugentown Road.	WMINUGEN
Mill Branch at Poor Mans Parkway Little Egg Harbor Twp., Ocean Co. (lat 39°38'32.43", long 74°21'46.52", West Creek quad). Sections located upstream and downstream from Poor Mans Parkway.	WMIPOORM
Three Mile Branch at Pollypod Road Little Egg Harbor Twp., Ocean Co. (lat 39°42'00.43", long 74°21'24.52", West Creek quad). Sections located upstream and downstream from Pollypod Road.	WTHPOLLY
Westecunk Creek at Forge Road Eagleswood Twp., Ocean Co. (lat 39°39'59.59", long 74°19'12.92", West Creek quad). Sections located downstream from Forge Road.	WWEFORGS
Westecunk Creek at Railroad Avenue Eagleswood Twp., Ocean Co. (lat 39°38'24.94", long 74°18'28.61", West Creek quad). Sections located upstream and downstream from Railroad Avenue.	WWERAILR

Appendix 2.1. Plant species at stream-vegetation survey sites in the Barnegat Bay Watershed. Filled circles indicate a species was present at a site. Surveys were completed by Kim J. Laidig. Refer to Chapter 3 (Stream Vegetation) for sampling details. Refer to Appendix 2.0 for site descriptions and explanations of site codes. Plant common names are presented in Appendix 2.2.

Species	Sites																								
	CCEDOUBS	CCELACEY	CCEROUT9	CCHSANDR	CFALACEY	CLOBRYAN	CNOPOWER	COYRT532	CWAROUT9	CWERT539	MCEROUT9	MFOLIGHT	MFOOXYCO	MMI72LWR	MMI72UPR	MMIHAYRD	RDALACES	RDAMULER	RDART530	RJADOUBL	RSUMULER	RSUTOWNS	RTITR530	RWRCONGA	RWRMULER
<u>Herbaceous plants:</u>																									
Agrostis perennans	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agrostis sp.	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	!	-	!	-	-	-	-	-
Agrostis stolonifera	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon virg.. var. abbreviatus	!	-	-	-	-	-	!	!	-	!	-	-	-	-	-	!	-	!	-	-	-	-	-	-	!
Andropogon virg. var. virginicus	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-
Apios americana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asclepias incarnata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Aster nemoralis	!	-	-	-	-	!	!	!	-	!	-	!	-	-	!	!	-	-	-	-	-	!	-	-	-
Aster novi-belgii	!	!	-	!	-	!	!	!	-	!	-	!	-	-	!	!	-	!	-	!	-	!	!	-	!
Aster vimineus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bartonia paniculata	-	-	!	-	!	-	-	!	!	!	-	!	-	-	-	!	!	-	-	-	-	-	-	-	-
Bartonia virginica	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bidens sp.	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Boehmeria cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Brasenia schreberi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Cabomba caroliniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Callitriche heterophylla	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Cardamine rhomboidea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex albolutescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Carex atlantica	-	-	-	!	-	-	!	-	-	-	-	!	!	-	!	!	!	-	-	-	-	-	-	!	-
Carex atlantica var. capillacea	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-
Carex bullata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex collinsii	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Carex exilis	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Carex folliculata	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Carex intumescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex livida	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Carex lurida	-	-	-	!	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Carex sp.	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex striata	-	-	!	!	!	!	!	!	-	!	-	-	-	-	!	-	!	-	-	-	-	!	-	!	-
Carex stricta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex trisperma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Chasmanthium laxum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinna arundinacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cladium mariscoides	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cuscuta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	-	!	-	-	-	-

Species	CCEDOUBS	CCELACEY	CCEROUT9	CCHSANDR	CFALACEY	CLOBRYAN	CNOPOWER	COYRT532	CWAROUT9	CWERT539	MCEROUT9	MFOLIGHT	MFOOXYCO	MMI72LWR	MMI72UPR	MMIHAYRD	RDALACES	RDAMULER	RDART530	RJADOUBL	RSUMULER	RSUTOWNS	RTITR530	RWRCONGA	RWRMULER
Cyperus dentatus	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Cyperus strigosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-
Danthonia sericea var. epilis	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decodon verticillatus	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	!	!	!	!	-	-	!	!	-
Drosera filiformis	-	-	-	-	-	-	-	!	-	!	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drosera intermedia	!	-	!	!	!	-	!	!	-	!	!	!	-	-	!	-	!	!	!	-	!	!	-	-	-
Drosera rotundifolia	!	-	!	!	-	-	!	!	-	!	!	-	!	-	!	!	!	-	!	!	-	!	-	-	-
Dryopteris carthusiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Dulichium arundinaceum	!	!	-	!	!	!	-	-	!	!	!	!	!	-	-	-	!	-	!	-	-	!	!	!	-
Echinochloa muricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eleocharis acicularis	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Eleocharis flavescens var. olivacea	!	-	-	-	!	-	-	-	-	-	-	!	-	-	!	-	!	-	-	!	!	-	-	-	-
Eleocharis ovata	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	!	-	-	-	-
Eleocharis robbinsii	!	!	!	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-
Eleocharis tenuis	!	-	-	!	-	-	-	-	-	!	-	!	-	-	-	-	-	!	-	-	-	-	!	-	-
Eleocharis tuberculosa	!	-	!	-	-	-	-	!	-	!	-	!	-	-	!	-	-	!	-	-	-	-	-	-	-
Elodea nuttallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erechtites hieracifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriocaulon aquaticum	!	!	-	!	-	-	!	!	!	-	-	-	-	-	!	!	-	-	-	-	-	!	-	-	-
Eriocaulon compressum	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriophorum virginicum	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Eupatorium dubium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eupatorium perfoliatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eupatorium resinosum	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eupatorium rotundifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Euthamia tenuifolia	!	-	!	!	!	-	!	!	-	-	-	!	-	-	-	-	!	!	-	!	-	-	-	-	-
Galium tinctorium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Glyceria canadensis	-	!	-	!	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Glyceria obtusa	!	-	-	!	-	-	-	!	!	-	-	-	!	-	!	-	!	-	!	!	-	-	!	-	-
Grass sp.	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helonias bullata	-	-	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Hibiscus moscheutos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Hypericum canadense	-	-	!	!	-	-	!	!	-	!	-	!	!	-	!	-	-	!	!	-	!	-	-	-	-
Hypericum mutilum	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!
Impatiens capensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Iris versicolor	!	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	-	-	-	-
Juncus biflorus	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus canadensis	!	!	!	!	!	-	!	!	!	!	-	!	-	-	!	-	!	!	!	!	!	!	!	-	-
Juncus effusus	-	-	-	!	!	-	-	!	-	!	-	!	-	-	-	-	!	!	-	!	!	!	!	!	!

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Juncus militaris	!	-	!	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus pelocarpus	!	-	!	!	!	-	!	!	-	-	-	!	!	-	!	!	!	!	!	!	!	-	-	-	-
Juncus tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lachnanthes caroliniana	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-
Leersia oryzoides	-	!	-	-	-	-	-	-	-	-	-	!	!	!	!	-	!	!	!	!	!	!	!	-	-
Lindernia dubia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lobelia cardinalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lobelia nuttallii	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lophiola aurea	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ludwigia alternifolia	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-
Ludwigia palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Lycopodium alopecuroides	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium appressum	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopus uniflorus	-	-	-	!	-	-	-	-	-	-	-	!	!	-	-	-	-	!	-	!	!	-	!	-	-
Lycopus virginicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lysimachia terrestris	!	!	!	!	!	-	-	!	-	!	-	-	!	-	-	-	-	!	!	-	!	-	!	!	-
Lythrum salicaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Maianthemum canadense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microstegium vimineum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!
Mikania scandens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mitchella repens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muhlenbergia uniflora	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-
Myriophyllum humile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Nuphar variegata	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!	-
Nymphaea odorata	!	!	!	-	!	-	-	!	-	!	-	-	-	-	-	-	!	-	!	-	!	-	-	-	-
Onoclea sensibilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-
Orontium aquaticum	!	-	-	!	-	-	-	!	-	!	-	-	-	-	!	!	-	-	-	-	-	!	-	-	-
Osmunda cinnamomea	!	-	-	!	-	-	-	-	!	!	-	-	!	-	!	!	-	-	-	!	-	!	!	!	!
Osmunda regalis	-	!	!	!	-	-	!	!	-	-	!	-	!	-	!	!	-	-	-	-	-	-	-	-	-
Oxypolis rigidior	-	-	-	!	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum clandestinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Panicum dichotomum	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-
Panicum cf. dichotomum	!	-	-	-	-	-	-	!	!	-	-	-	-	!	-	-	-	!	-	!	-	-	-	-	!
Panicum longifolium	!	-	!	-	!	-	!	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Panicum verrucosum	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!	!	!	-	-	-	-	-	-
Panicum virgatum	-	!	-	!	!	-	!	!	-	!	-	-	-	-	-	-	!	!	-	!	!	-	-	-	-
Peltandra virginica	!	!	-	!	!	-	-	!	!	-	-	-	!	!	-	-	-	!	!	!	-	-	-	!	-
Phragmites australis	-	!	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonia ophioglossoides	-	-	-	-	-	-	-	!	!	!	-	-	-	-	!	!	-	-	-	-	-	!	-	-	-

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Polygala brevifolia	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala cruciata	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum hydropiperoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	!	-	-
Polygonum punctatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum sagittatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pontederia cordata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamogeton confervoides	!	!	!	-	-	-	-	-	-	-	-	!	-	-	-	-	!	!	-	-	-	-	-	-	!
Potamogeton diversifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	-	-	-	-
Potamogeton epihydrus	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Potamogeton pusillus	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Potamogeton sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proserpinaca pectinata	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pteridium aquilinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhexia virginica	!	-	-	!	-	-	-	!	-	-	!	!	-	-	-	-	!	!	!	!	!	-	-	-	!
Rhynchospora alba	!	-	-	-	!	-	-	!	-	-	-	-	!	-	-	-	!	-	!	-	-	-	-	-	-
Rhynchospora capitellata	!	-	!	!	-	-	!	!	-	-	-	!	-	-	-	-	-	-	-	!	!	-	-	-	-
Rhynchospora chalarocephala	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sabatia difformis	!	-	-	!	-	-	-	!	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Sagittaria engelmanniana	!	-	!	-	!	-	-	-	-	-	-	!	-	-	-	-	!	-	!	-	!	-	-	-	-
Sagittaria latifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sagittaria cf. latifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Sarracenia purpurea	!	-	-	!	-	-	!	!	-	!	!	-	-	-	!	!	-	-	-	-	-	!	-	-	-
Schizachyrium scoparium	-	-	-	-	!	-	!	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizaea pusilla	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Scirpus cyperinus	-	-	-	-	!	-	!	-	-	!	-	!	!	!	-	-	!	-	!	!	!	-	!	!	-
Scirpus pungens	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!	-	-
Scirpus subterminalis	!	!	!	!	!	-	!	!	!	-	!	!	-	!	-	-	!	!	-	!	-	-	-	!	-
Scutellaria lateriflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilax herbacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilax pseudochina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solidago altissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solidago sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Sparganium americanum	!	!	-	!	!	-	!	!	!	!	!	!	-	!	-	!	!	-	!	!	!	!	!	-	-
Thelypteris palustris	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thelypteris simulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Triadenum virginicum	!	!	!	!	!	-	-	!	!	-	!	!	!	!	-	-	!	!	!	!	!	!	!	!	!
Typha angustifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Utricularia cornuta	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	CCEDOUBS	CCELACEY	CCEROUT9	CCHSANDR	CFALACEY	CLOBRYAN	CNOPOWER	COYRT532	CWAROUT9	CWERT539	MCEROUT9	MFOLIGHT	MFOOXYCO	MMI72LWR	MMI72UPR	MMIHAYRD	RDALACES	RDAMULER	RDART530	RJADOUBL	RSUMULER	RSUTOWNS	RTITR530	RWRCONGA	RWRMULER
Utricularia fibrosa	-	-	-	-	-	!	-	-	-	!	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Utricularia cf. fibrosa	!	!	-	!	-	-	-	-	-	-	-	!	-	!	-	-	!	-	-	-	-	-	-	-	-
Utricularia geminiscapa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Utricularia purpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia subulata	-	-	!	-	-	-	!	-	-	!	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Vernonia noveboracensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viola lanceolata	-	!	-	-	-	-	-	-	-	-	-	!	!	-	!	-	-	-	-	-	-	-	-	-	-
Viola sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Woodwardia areolata	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!
Woodwardia virginica	!	-	-	!	-	!	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Xyris difformis	!	-	!	!	!	-	!	-	-	!	-	!	-	-	!	-	!	!	!	-	!	-	-	-	-
Zizania aquatica	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Woody plants:</u>																									
Acer platanoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acer rubrum	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	-	!	!	!	!	!	!	!	!	!
Acer saccharinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alnus serrulata	-	!	-	!	-	-	-	-	!	-	-	!	-	!	!	-	-	-	-	-	-	-	-	-	-
Amelanchier canadensis	-	!	-	!	-	!	-	-	!	!	-	-	-	-	!	!	!	-	-	-	-	-	-	!	-
Amorpha fruticosa	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aronia arbutifolia	-	-	-	!	-	!	-	!	-	-	-	-	!	-	-	!	!	-	!	-	-	!	-	-	-
Betula populifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	!	-	-	!	!	-
Betula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Campsis radicans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catalpa bignonioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cephalanthus occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamaecyparis thyoides	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	-	!	!	!	!
Chamaedaphne calyculata	-	-	-	!	!	-	!	!	-	!	!	-	-	-	!	!	!	!	!	!	-	!	!	!	-
Clethra alnifolia	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	-	!	!	!	!
Cornus amomum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Eubotrys racemosa	-	!	-	!	!	!	!	!	-	!	!	!	!	!	!	!	!	-	!	-	-	!	!	!	-
Gaylussacia dumosa	-	-	-	!	-	!	!	!	-	!	-	-	-	-	!	!	!	-	-	-	-	-	-	-	-
Gaylussacia frondosa	-	-	-	!	-	!	!	-	-	!	!	-	!	-	!	!	!	-	!	-	-	!	!	!	-
Hypericum densiflorum	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Ilex glabra	-	-	!	-	-	-	!	!	!	!	-	!	!	-	!	-	!	!	!	-	-	!	-	!	-
Ilex laevigata	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	!	!	-	!	-	-	-	-	-	-
Ilex opaca	-	-	-	-	-	-	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Ilex verticillata	-	!	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Itea virginica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	CCEDOUBS	CCELACEY	CCEROUT9	CCHSANDR	CFALACEY	CLOBRYAN	CNOPOWER	COYRT532	CWAROUT9	CWERT539	MCEROUT9	MFOLIGHT	MFOOXYCO	MMI72LWR	MMI72UPR	MMIHAYRD	RDALACES	RDAMULER	RDART530	RJADOUBL	RSUMULER	RSUTOWNS	RTITR530	RWRCONGA	RWRMULER
Kalmia angustifolia	!	-	-	!	-	!	!	!	-	!	-	-	-	-	!	!	-	-	-	-	-	!	-	!	!
Kalmia latifolia	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-
Ligustrum obtusifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liquidambar styraciflua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lonicera japonica	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Lyonia ligustrina	-	!	-	!	-	-	-	-	-	-	-	!	-	-	-	-	!	-	-	-	-	!	!	-	-
Magnolia virginiana	-	-	-	!	-	!	!	!	!	-	-	-	!	!	!	-	!	-	!	-	-	-	-	!	-
Myrica pensylvanica	-	-	-	!	!	!	!	!	-	!	-	-	-	-	!	!	!	-	-	!	-	!	-	-	-
Nyssa sylvatica	-	!	-	-	-	!	-	-	!	-	!	-	!	-	!	-	-	-	!	-	-	-	-	!	!
Parthenocissus quinquefolia	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinus rigida	-	-	-	-	-	!	!	-	-	!	!	!	-	-	!	!	-	!	-	-	-	-	-	-	-
Platanus occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prunus serotina	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus coccinea	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Quercus ilicifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	-	-
Quercus velutina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhododendron viscosum	!	!	-	!	-	!	!	!	-	!	!	-	!	-	!	!	!	-	!	-	-	!	-	!	!
Rhus copallina	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosa multiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Rubus hispidus	-	-	-	-	-	-	!	-	!	!	-	!	!	-	!	!	-	!	-	-	-	-	!	-	!
Salix sp.	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sambucus canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-
Sassafras albidum	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Smilax glauca	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Smilax laurifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Smilax rotundifolia	!	!	-	!	-	-	-	-	!	-	!	!	!	!	!	-	-	-	-	-	-	!	-	!	!
Spiraea tomentosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxicodendron radicans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxicodendron vernix	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium corymbosum	!	-	-	!	!	!	!	!	!	!	!	!	!	-	!	!	!	!	!	!	-	!	!	!	!
Vaccinium macrocarpon	!	!	!	-	!	!	!	!	!	!	-	-	-	-	-	-	!	!	-	!	-	-	-	!	-
Viburnum dentatum	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	!	-	-	-	-	-
Viburnum nudum var. nudum	-	!	-	!	-	!	-	-	-	-	-	-	-	-	!	-	-	-	!	-	-	!	-	!	-
Vitis labrusca	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	RWRSOUTH	RWRTOWNV	TBLCENTR	TBLRTE70	TCARAILR	TDOGRAWT	TMABOWMA	TMARTE70	TMIRT528	TOLBECKE	TOLRTE70	TRIHANGA	TRIHIGHB	TRIRIDGE	TSHTURNS	TTOBOWMA	TTORT528	TTORT547	TTOTR571	TUNCOLON	WMINUGEN	WMIPOORM	WTHPOLLY	WWEFORGS	WWERAILR
<u>Herbaceous plants:</u>																									
Agrostis perennans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agrostis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Agrostis stolonifera	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-
Andropogon virg. var. abbreviatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Andropogon virg. var. virginicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apios americana	!	-	-	!	-	-	-	-	!	-	-	-	-	-	!	!	!	-	-	!	-	-	-	-	-
Asclepias incarnata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aster nemoralis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	!
Aster novi-belgii	!	-	!	!	!	-	-	!	-	-	-	-	-	-	!	!	-	-	-	-	!	!	-	-	!
Aster vimineus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Bartonia paniculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bartonia virginica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bidens sp.	!	-	-	-	!	-	-	!	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Boehmeria cylindrica	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Brasenia schreberi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cabomba caroliniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Callitriche heterophylla	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-
Cardamine rhomboidea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-
Carex albolutescens	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex atlantica	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-
Carex atlantica var. capillacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Carex bullata	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex collinsii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex exilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex folliculata	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	!	-	-
Carex intumescens	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex livida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex lurida	-	-	-	-	!	!	-	-	!	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-	!
Carex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex striata	-	-	-	!	-	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	!	-	-	-	-
Carex stricta	-	-	-	-	-	-	-	!	-	-	-	-	!	!	-	-	-	!	-	!	-	-	-	-	-
Carex trisperma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Chasmanthium laxum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Cinna arundinacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Cladium mariscoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cuscuta sp.	!	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Cyperus dentatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	!	-	-	-	-
Cyperus strigosus	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-

Species	RWRSOUTH	RWRTOWNV	TBLCENTR	TBLRTE70	TCARAILR	TDOGRAWT	TMABOWMA	TMARTE70	TMIRT528	TOLBECKE	TOLRTE70	TRIHANGA	TRIHIGHB	TRIRIDGE	TSHTURNS	TTOBOWMA	TTORT528	TTORT547	TTOTR571	TUNCOLON	WMINUGEN	WMIPOORM	WTHPOLLY	WWEFORGS	WWERAILR
Danthonia sericea var. epilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decodon verticillatus	-	-	!	-	!	!	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Drosera filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Drosera intermedia	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Drosera rotundifolia	-	-	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-
Dryopteris carthusiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dulichium arundinaceum	-	!	-	!	-	-	-	!	-	-	!	!	-	-	!	-	-	-	-	!	-	-	!	-	-
Echinochloa muricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-
Eleocharis acicularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	!
Eleocharis flavescens var. olivacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eleocharis ovata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Eleocharis robbinsii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	!	!
Eleocharis tenuis	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Eleocharis tuberculosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elodea nuttallii	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erechtites hieracifolia	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriocaulon aquaticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	!
Eriocaulon compressum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriophorum virginicum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Eupatorium dubium	-	-	-	-	-	!	-	!	!	-	-	-	-	!	-	!	!	-	-	!	-	-	-	-	-
Eupatorium perfoliatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Eupatorium resinosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eupatorium rotundifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euthamia tenuifolia	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium tinctorium	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Glyceria canadensis	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Glyceria obtusa	-	!	-	!	-	-	-	!	-	-	!	-	!	-	-	-	-	-	-	-	-	-	!	-	-
Grass sp.	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-
Helonias bullata	-	-	-	!	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hibiscus moscheutos	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypericum canadense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Hypericum mutilum	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-
Impatiens capensis	!	-	-	-	-	-	-	!	!	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-
Iris versicolor	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Juncus biflorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-
Juncus canadensis	-	!	-	!	-	-	-	!	-	-	!	!	!	-	!	-	-	!	-	!	!	-	-	-	-
Juncus effusus	!	!	-	-	!	-	-	!	-	-	!	-	!	-	!	-	-	!	!	!	!	-	-	-	!
Juncus militaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!
Juncus pelocarpus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	!	-	-

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Juncus tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Lachnanthes caroliniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leersia oryzoides	!	!	!	!	!	!	-	!	!	-	-	!	!	!	!	!	-	!	!	!	-	-	-	!	-
Lindernia dubia	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-
Lobelia cardinalis	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	!	!	-	-	-	-	-	-	-
Lobelia nuttallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lophiola aurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ludwigia alternifolia	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!
Ludwigia palustris	!	-	-	-	-	!	-	!	!	-	-	-	-	-	-	!	!	!	-	!	-	-	-	-	-
Lycopodium alopecuroides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium appressum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopus uniflorus	!	-	-	-	!	!	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!
Lycopus virginicus	-	-	-	-	!	!	-	-	!	-	-	-	-	-	-	!	!	!	-	-	-	-	-	-	-
Lysimachia terrestris	-	-	-	-	!	-	-	-	-	-	!	!	!	!	-	-	-	!	-	!	-	-	-	!	-
Lythrum salicaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maianthemum canadense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Microstegium vimineum	!	-	-	-	-	-	-	!	!	-	-	-	-	-	!	!	!	-	!	-	-	-	-	-	-
Mikania scandens	-	-	-	-	!	-	-	!	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-
Mitchella repens	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muhlenbergia uniflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriophyllum humile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Nuphar variegata	!	-	!	!	-	-	!	-	-	-	!	-	-	-	!	-	-	-	-	!	!	-	-	!	-
Nymphaea odorata	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-	!	-	!	!	!
Onoclea sensibilis	!	-	-	-	-	!	-	-	!	-	-	-	!	-	-	!	!	-	-	!	-	-	-	-	-
Orontium aquaticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Osmunda cinnamomea	-	!	!	!	!	!	!	-	!	!	!	-	!	-	-	!	-	-	!	-	!	!	!	!	!
Osmunda regalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	!	-	!
Oxypolis rigidior	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum clandestinum	!	-	-	-	!	-	-	!	!	-	-	!	-	-	-	!	!	-	!	-	-	-	-	-	-
Panicum dichotomum	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Panicum cf. dichotomum	-	!	-	-	-	-	-	-	-	-	-	!	-	!	-	!	-	!	-	-	-	-	-	-	-
Panicum longifolium	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Panicum verrucosum	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Panicum virgatum	!	!	-	!	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Peltandra virginica	!	!	!	!	-	-	-	!	!	!	!	-	-	-	-	!	!	-	-	!	-	-	-	-	-
Phragmites australis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	!
Pogonia ophioglossoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala brevifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Polygala cruciata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Polygonum hydropiperoides	!	-	-	-	-	!	-	-	!	-	-	-	-	-	-	!	!	!	-	!	-	-	-	-	-
Polygonum punctatum	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum sagittatum	!	-	-	-	!	-	-	!	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Polygonum sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Pontederia cordata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-
Potamogeton confervoides	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!
Potamogeton diversifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamogeton epihydrus	-	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-
Potamogeton pusillus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamogeton sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Proserpinaca pectinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pteridium aquilinum	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhexia virginica	-	!	-	!	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	!
Rhynchospora alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Rhynchospora capitellata	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-
Rhynchospora chalarocephala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sabatia difformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sagittaria engelmanniana	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	!	-
Sagittaria latifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Sagittaria cf. latifolia	!	-	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Sarracenia purpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-
Schizachyrium scoparium	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizaea pusilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scirpus cyperinus	!	-	!	-	-	-	-	!	!	-	!	!	-	-	-	-	-	!	-	!	!	-	-	-	-
Scirpus pungens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-
Scirpus subterminalis	-	-	!	!	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	!	-	!	!	!
Scutellaria lateriflora	-	-	-	-	-	-	-	-	!	-	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-
Smilax herbacea	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-
Smilax pseudochina	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Solidago altissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Solidago sp.	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sparganium americanum	!	-	-	!	!	!	-	!	!	!	!	!	-	-	-	!	!	!	!	!	!	!	!	!	!
Thelypteris palustris	-	-	-	-	!	-	-	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	-
Thelypteris simulata	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triadenum virginicum	!	!	!	!	!	!	-	-	-	-	!	!	!	-	!	!	-	-	-	!	!	!	-	-	!
Typha angustifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia cornuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia fibrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Utricularia cf. fibrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	-	-	-	-

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Utricularia geminiscapa	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utricularia purpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Utricularia subulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-
Vernonia noveboracensis	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viola lanceolata	-	-	-	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	!	-	-	-	-	!
Viola sp.	-	-	-	-	!	-	-	-	!	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-
Woodwardia areolata	-	!	-	!	-	!	!	-	-	!	!	!	-	-	-	!	-	!	-	-	-	-	-	-	-
Woodwardia virginica	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	-	-	!	-	-	-	-
Xyris difformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Zizania aquatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Woody plants:</u>																									
Acer platanoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Acer rubrum	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	-	!	!	!	!	!	!
Acer saccharinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Alnus serrulata	-	-	-	!	-	-	-	!	-	-	!	-	-	-	!	-	-	!	-	-	!	-	!	!	!
Amelanchier canadensis	-	-	-	!	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-
Amorpha fruticosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aronia arbutifolia	-	-	-	!	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	!	!	!	-
Betula populifolia	-	-	!	-	-	-	!	-	-	!	!	-	!	-	-	!	-	-	-	-	-	-	-	-	-
Betula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-
Campsis radicans	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catalpa bignonioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!
Cephalanthus occidentalis	-	-	-	-	-	-	-	-	-	-	!	!	!	!	!	!	-	!	-	!	-	-	-	-	-
Chamaecyparis thyoides	-	-	!	!	!	-	!	!	-	!	!	-	!	-	-	-	-	-	-	-	!	!	!	!	!
Chamaedaphne calyculata	-	!	!	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	!	-
Clethra alnifolia	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!
Cornus amomum	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Eubotrys racemosa	-	!	!	!	!	-	!	!	-	!	!	!	!	!	-	-	-	!	-	-	!	-	!	!	!
Gaylussacia dumosa	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	!	-	-
Gaylussacia frondosa	-	-	!	!	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	-	!	!	-
Hypericum densiflorum	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilex glabra	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	!	-
Ilex laevigata	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-
Ilex opaca	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-
Ilex verticillata	-	-	-	!	-	!	!	-	!	-	-	-	-	-	-	!	!	!	-	!	-	-	-	-	!
Itea virginica	-	!	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-
Kalmia angustifolia	-	!	!	!	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	!	!	!	-	-
Kalmia latifolia	-	-	!	-	!	-	!	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-

Species	RWRSOUTH	RWRTOWNV	TBLCENTR	TBLRTE70	TCARAILR	TDOGRAWT	TMABOWMA	TMARTE70	TMIRT528	TOLBECKE	TOLRTE70	TRIHANGA	TRIHIGHB	TRIRIDGE	TSHTURNS	TTOBOWMA	TTORT528	TTORT547	TTOTR571	TUNCOLON	WMINUGEN	WMIPOORM	WTHPOLLY	WWEFORGS	WWERAILR
Ligustrum obtusifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Liquidambar styraciflua	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	!	!	-	-	-	-	-	-	-	-
Lonicera japonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Lyonia ligustrina	-	!	!	-	-	-	!	-	-	!	!	-	!	-	!	-	-	-	-	-	-	-	!	!	-
Magnolia virginiana	-	-	-	-	!	-	-	-	-	!	-	-	!	-	-	-	-	-	-	-	!	!	!	!	-
Myrica pensylvanica	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	!	!	!	-
Nyssa sylvatica	-	!	!	-	!	!	-	-	!	!	!	!	!	-	-	!	-	-	!	-	-	-	!	!	!
Parthenocissus quinquefolia	-	-	-	!	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Pinus rigida	-	!	-	!	-	-	!	-	!	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-
Platanus occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-
Prunus serotina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-
Quercus alba	-	-	-	-	-	-	!	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Quercus coccinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus ilicifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus velutina	-	-	-	-	-	-	-	-	!	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Rhododendron viscosum	-	!	!	!	!	!	!	!	-	!	!	-	!	!	!	!	!	-	-	-	!	-	!	!	!
Rhus copallina	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosa multiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	!
Rubus hispidus	!	!	!	-	!	-	-	!	!	-	-	!	-	-	-	-	-	-	-	!	-	-	!	!	!
Salix sp.	-	-	-	-	-	-	-	!	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-	-
Sambucus canadensis	!	-	-	-	-	!	-	-	!	-	-	-	-	-	-	!	-	-	!	-	-	-	-	-	-
Sassafras albidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilax glauca	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilax laurifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilax rotundifolia	-	!	!	!	!	-	!	!	!	!	!	!	!	!	-	!	!	!	-	!	!	!	!	!	!
Spiraea tomentosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-
Toxicodendron radicans	-	-	-	!	-	!	-	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	-	-
Toxicodendron vernix	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium corymbosum	-	!	!	!	!	!	!	-	!	!	!	!	!	!	-	!	!	!	-	-	!	-	!	!	!
Vaccinium macrocarpon	-	!	-	-	-	-	-	-	-	-	-	-	!	-	-	-	-	-	-	-	-	-	-	-	-
Viburnum dentatum	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	-	!	-	!	-	-	-	-	-	!
Viburnum nudum var. nudum	-	-	!	!	-	-	-	!	-	-	!	-	-	-	-	-	-	-	-	-	-	-	!	-	-
Vitis labrusca	-	-	-	-	-	-	-	!	!	-	-	-	-	-	-	!	!	-	!	-	-	-	-	-	-

Appendix 2.2. Scientific and common names of plants found at stream-vegetation survey sites in the Barnegat Bay Watershed. Taxonomic nomenclature follows Gleason and Cronquist (1991). Common names are taken from various sources.

Scientific/Common Name

Herbaceous plants:

Agrostis perennans
upland bent-grass
Agrostis sp.
upland bent-grass
Agrostis stolonifera
creeping bent-grass
Andropogon virg. var. abbreviatus
bushy beard-grass
Andropogon virg. var. virginicus
broomsedge
Apios americana
groundnut
Asclepias incarnata
swamp milkweed
Aster nemoralis
bog aster
Aster novi-belgii
New York aster
Aster vimineus
small white aster
Bartonia paniculata
twining bartonia
Bartonia virginica
yellow bartonia
Bidens sp.
beggar ticks
Boehmeria cylindrica
false nettle
Brasenia schreberi
water shield
Cabomba caroliniana
fanwort
Callitriche heterophylla
larger water starwort
Cardamine rhomboidea
spring cress
Carex albolutescens
greenish-white sedge
Carex atlantica
Atlantic sedge
Carex atlantica var. capillacea
Howe's sedge
Carex bullata
button sedge
Carex collinsii
Collins' sedge
Carex exilis
coast sedge
Carex folliculata
long sedge
Carex intumescens
bladder sedge
Carex livida
livid sedge
Carex lurida
sallow sedge
Carex sp.
sedge
Carex striata
Walter's sedge
Carex stricta
tussock sedge
Carex trisperma
three-fruited sedge
Chasmanthium laxum
slender spike-grass
Cinna arundinacea
wood-reed
Cladium mariscoides
twig-rush
Cuscuta sp.
dodder
Cyperus dentatus
toothed cyperus
Cyperus strigosus
straw-colored cyperus
Danthonia sericea var. epilis
silky wild oat-grass
Decodon verticillatus
swamp loosestrife
Drosera filiformis
thread-leaved sundew
Drosera intermedia
spatulate-leaved sundew
Drosera rotundifolia
round-leaved sundew
Dryopteris carthusiana
spinulose wood fern
Dulichium arundinaceum
three-way sedge
Echinochloa muricata
American barnyard grass
Eleocharis acicularis
needle spike-rush
Eleocharis flavescens var. olivacea
green spike-rush
Eleocharis ovata
blunt spike-rush
Eleocharis robbinsii
Robbin's spike-rush
Eleocharis tenuis
slender spike-rush
Eleocharis tuberculosa
tubercled spike-grass
Elodea nuttallii
Nuttall's water-weed
Erechtites hieracifolia
pilewort
Eriocaulon aquaticum
seven-angled pipewort
Eriocaulon compressum
flattened pipewort
Eriophorum virginicum
tawny cotton-grass
Eupatorium dubium
eastern joe-pye weed
Eupatorium perfoliatum
boneset
Eupatorium resinosum
pine barrens boneset
Eupatorium rotundifolium
round-leaved boneset
Euthamia tenuifolia
slender-leaved goldenrod
Galium tinctorium
stiff marsh bedstraw
Glyceria canadensis
rattlesnake grass
Glyceria obtusa
blunt manna-grass
Grass sp.
grass
Helonias bullata
swamp pink
Hibiscus moscheutos
swamp rose mallow
Hypericum canadense
Canada Saint John's-wort
Hypericum mutilum
dwarf Saint John's-wort
Impatiens capensis
spotted touch-me-not
Iris versicolor
larger blue flag

Scientific/Common Name
Juncus biflorus two-flowered rush
Juncus canadensis Canada rush
Juncus effusus common rush
Juncus militaris bayonet rush
Juncus pelocarpus brown-fruited rush
Juncus tenuis slender rush
Lachnanthes caroliniana redroot
Leersia oryzoides rice cut-grass
Lindernia dubia short-stalked false pimpernel
Lobelia cardinalis cardinal flower
Lobelia nuttallii Nuttall's lobelia
Lophiola aurea golden-crest
Ludwigia alternifolia seedbox
Ludwigia palustris water purslane
Lycopodium alopecuroides foxtail-clubmoss
Lycopodium appressum southern bog clubmoss
Lycopus uniflorus northern bugleweed
Lycopus virginicus Virginia bugleweed
Lysimachia terrestris swamp loosestrife
Lythrum salicaria purple loosestrife
Maianthemum canadense Canada mayflower
Microstegium vimineum stiltgrass
Mikania scandens climbing hempweed
Mitchella repens partridge berry
Muhlenbergia uniflora late-flowering dropseed
Myriophyllum humile low water milfoil
Nuphar variegata bullhead lily
Nymphaea odorata white water lily
Onoclea sensibilis sensitive fern
Orontium aquaticum golden club
Osmunda cinnamomea cinnamon fern
Osmunda regalis royal fern
Oxypolis rigidior cowbane
Panicum clandestinum deertongue grass
Panicum dichotomum forked panic-grass
Panicum cf. dichotomum forked panic-grass
Panicum longifolium long-leaved panic-grass
Panicum verrucosum warty panic-grass
Panicum virgatum switchgrass
Peltandra virginica arrow arum
Phragmites australis common reed
Pogonia ophioglossoides rose pogonia
Polygala brevifolia short-leaved milkwort
Polygala cruciata cross-leaved milkwort
Polygonum hydropiperoides mild water pepper
Polygonum punctatum dotted smartweed
Polygonum sagittatum arrow-leaved tearthumb
Polygonum sp. smartweed
Pontederia cordata pickerel-weed
Potamogeton confervoides alga-like pondweed
Potamogeton diversifolius hair-like pondweed
Potamogeton epihydrus Nuttall's pondweed
Potamogeton pusillus small pondweed
Potamogeton sp. pondweed
Proserpinaca pectinata cut-leaved mermaid-weed
Pteridium aquilinum bracken
Rhexia virginica Virginia meadow beauty
Rhynchospora alba white beaked-rush
Rhynchospora capitellata small-headed beaked-rush
Rhynchospora chalarocephala loose-headed beaked-rush
Sabatia difformis lance-leaved sabatia
Sagittaria engelmanniana Engelmann's arrowhead
Sagittaria latifolia broad-leaved arrowhead
Sagittaria cf. latifolia broad-leaved arrowhead
Sarracenia purpurea pitcher plant
Schizachyrium scoparium little bluestem
Schizaea pusilla curly-grass fern
Scirpus cyperinus wool-grass
Scirpus pungens three-square bulrush
Scirpus subterminalis water club-rush
Scutellaria lateriflora mad-dog skullcap
Smilax herbacea carrion flower
Smilax pseudochina halberd-leaved greenbrier
Solidago altissima tall goldenrod
Solidago sp. golden rod
Sparganium americanum slender bur-reed
Thelypteris palustris marsh fern
Thelypteris simulata bog fern

Scientific/Common Name

Triadenum virginicum
marsh Saint John's-wort

Typha angustifolia
narrow-leaved cat-tail

Utricularia cornuta
horned bladderwort

Utricularia fibrosa
fibrous bladderwort

Utricularia cf. fibrosa
fibrous bladderwort

Utricularia geminiscapa
hidden-fruited bladderwort

Utricularia gibba
creeping bladderwort

Utricularia purpurea
purple bladderwort

Utricularia subulata
zig-zag bladderwort

Vernonia noveboracensis
New York ironweed

Viola lanceolata
lance-leaved violet

Viola sp.
violet

Woodwardia areolata
netted chain fern

Woodwardia virginica
Virginia chain fern

Xyris difformis
yellow-eyed grass

Zizania aquatica
wild rice

Woody plants:

Acer platanoides
Norway maple

Acer rubrum
red maple

Acer saccharinum
silver maple

Alnus serrulata
smooth alder

Amelanchier canadensis
oblongleaf juneberry

Amorpha fruticosa
false indigo

Aronia arbutifolia
red chokeberry

Betula populifolia
gray birch

Betula sp.
birch

Campsis radicans
trumpet creeper

Catalpa bignonioides
common catalpa

Cephalanthus occidentalis
buttonbush

Chamaecyparis thyoides
Atlantic white cedar

Chamaedaphne calyculata
leatherleaf

Clethra alnifolia
sweet pepperbush

Cornus amomum
silky dogwood

Eubotrys racemosa
fetterbush

Gaylussacia dumosa
dwarf huckleberry

Gaylussacia frondosa
dangleberry

Hypericum densiflorum
bushy Saint John's-wort

Ilex glabra
inkberry

Ilex laevigata
smooth winterberry

Ilex opaca
American holly

Ilex verticillata
winterberry

Itea virginica
Virginia willow

Kalmia angustifolia
sheep laurel

Kalmia latifolia
mountain laurel

Ligustrum obtusifolium
privet

Liquidambar styraciflua
sweet gum

Lonicera japonica
Japanese honeysuckle

Lyonia ligustrina
maleberry

Magnolia virginiana
sweet bay

Myrica pensylvanica
bayberry

Nyssa sylvatica
black gum

Parthenocissus quinquefolia
Virginia creeper

Pinus rigida
pitch pine

Platanus occidentalis
sycamore

Prunus serotina
black cherry

Quercus alba
white oak

Quercus coccinea
scarlet oak

Quercus ilicifolia
scrub oak

Quercus velutina
black oak

Rhododendron viscosum
swamp azalea

Rhus copallina
winged sumac

Rosa multiflora
multiflora rose

Rubus hispidus
swamp dewberry

Salix sp.
willow

Sambucus canadensis
common elder

Sassafras albidum
sassafras

Smilax glauca
glaucous greenbrier

Smilax laurifolia
laurel-leaved greenbrier

Smilax rotundifolia
common greenbrier

Spiraea tomentosa
steeplebush

Toxicodendron radicans
poison ivy

Toxicodendron vernix
poison sumac

Vaccinium corymbosum
highbush blueberry

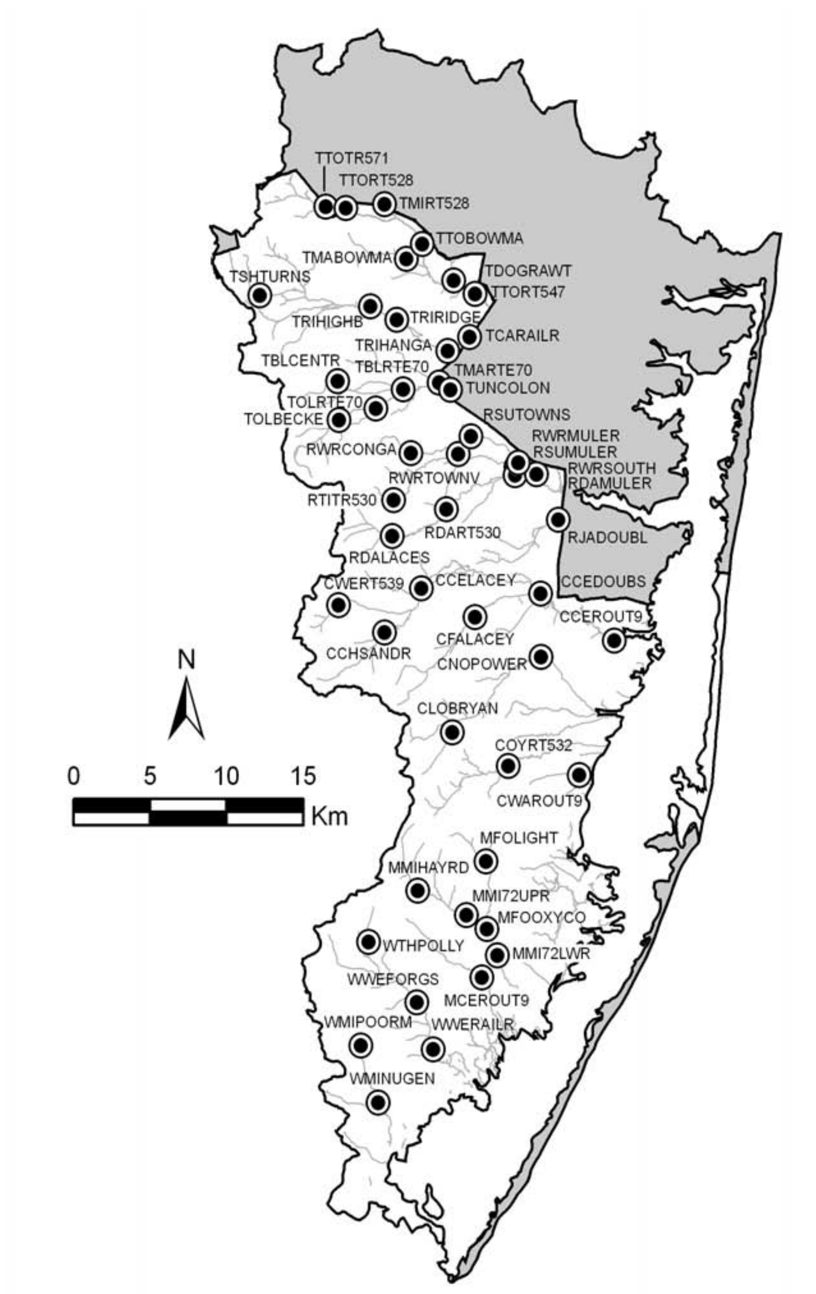
Vaccinium macrocarpon
large cranberry

Viburnum dentatum
southern arrowwood

Viburnum nudum var. nudum
naked withe-rod

Vitis labrusca
fox grape

APPENDIX 2.3. PLANT-DISTRIBUTION MAPS



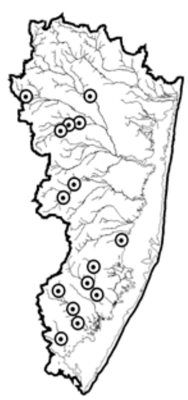
Location of 50 stream-vegetation survey sites in the Barnegat Bay Watershed. Shaded areas are outside the Pinelands National Reserve. Distribution maps for plants found at two or more sites are on the following pages. Refer to Appendix 2.0 for site descriptions and explanations of site codes.

Acer rubrum
red maple

Agrostis perennans
upland bent-grass

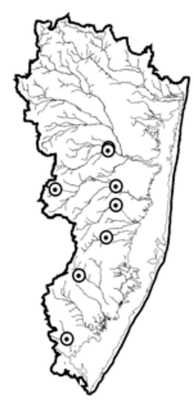
Agrostis stolonifera
creeping bent-grass

Agrostis sp.
upland bent-grass



Alnus serrulata
smooth alder

Amelanchier canadensis
oblongleaf juneberry

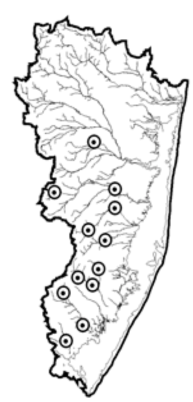


Andropogon virginicus var. abbreviatus
bushy beard-grass

Andropogon virginicus var. virginicus
broomsedge

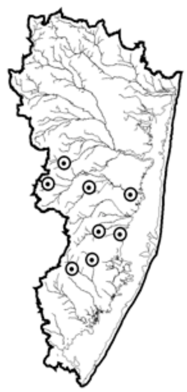
Apios americana
groundnut

Aronia arbutifolia
red chokeberry

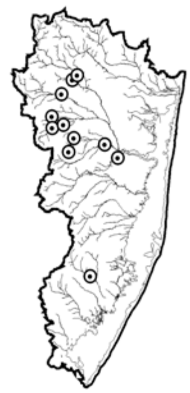


Aster nemoralis
bog aster

Aster novi-belgii
New York aster



Bartonia paniculata
twining bartonia



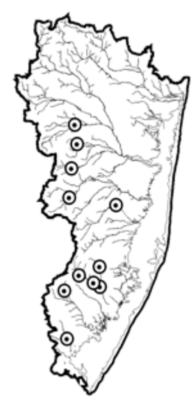
Betula populifolia
gray birch

Bidens sp.
begger ticks

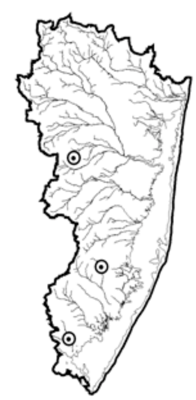
Boehmeria cylindrica
false nettle

Callitriche heterophylla
large water starwort

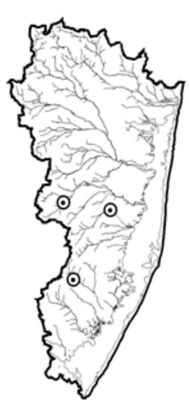
Carex albolutescens
greenish-white sedge



Carex atlantica
Atlantic sedge



Carex atlantica var. capillacea
Howe's sedge



Carex collinsii
Collin's sedge

Carex exilis
coast sedge

Carex folliculata
long sedge

Carex livida
livid sedge

Carex lurida
sallow sedge

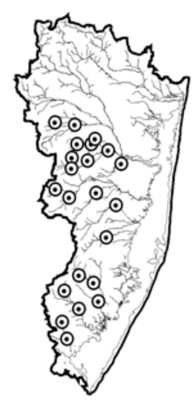
Carex striata
Walter's sedge

Carex stricta
tussock sedge

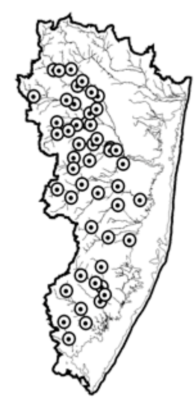
Carex trisperma
three-fruited sedge

Cephalanthus occidentalis
buttonbush

Chamaecyparis thyoides
Atlantic white cedar



Chamaedaphne calyculata
leatherleaf



Clethra alnifolia
sweet pepperbush

Cornus amomum
silky dogwood

Cuscuta sp.
dodder

Cyperus dentatus
toothed cyperus

Cyperus strigosus
straw-colored cyperus

Decodon verticillatus
swamp loosestrife

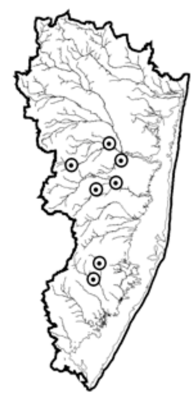
Drosera filiformis
thread-leaved sundew

Drosera intermedia
spatulate-leaved sundew

Drosera rotundifolia
round-leaved sundew

Dulichium arundinaceum
three-way sedge

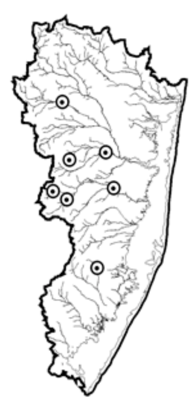
Eleocharis acicularis
needle spike-rush



Eleocharis flavescens var. olivacea
green spike-rush

Eleocharis ovata
blunt spike-rush

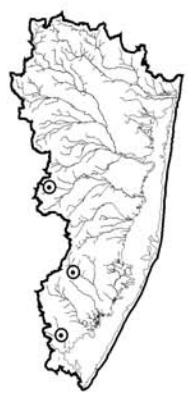
Eleocharis robbinsii
Robbin's spike-rush



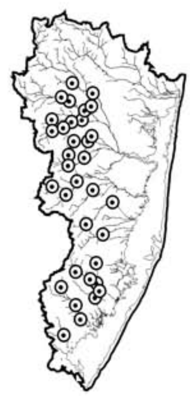
Eleocharis tenuis
slender spike-rush

Eleocharis tuberculosa
tubercled spike-grass

Eriocaulon aquaticum
seven-angled pipewort

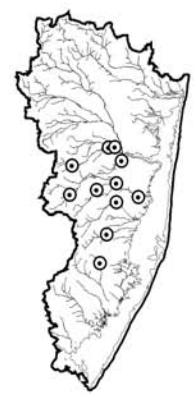


Eriophorum virginicum
tawny cotton-grass

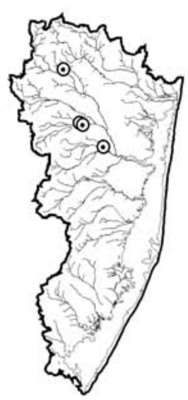


Eubotrys racemosa
fetterbush

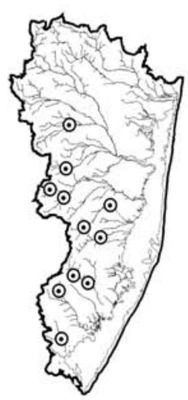
Eupatorium dubium
eastern joe-pye weed



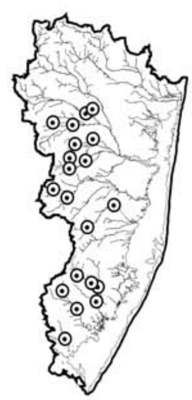
Euthamia tenuifolia
slender-leaved goldenrod



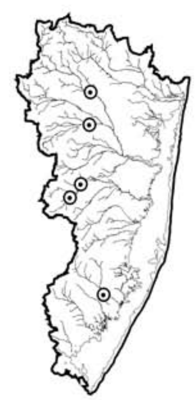
Galium tinctorium
stiff marsh bedstraw



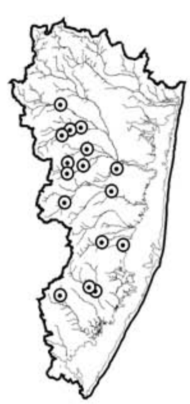
Gaylussacia dumosa
dwarf huckleberry



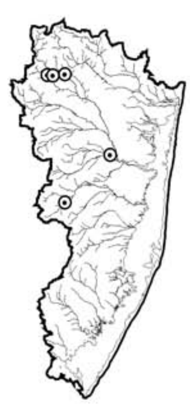
Gaylussacia frondosa
dangleberry



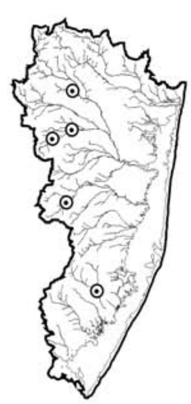
Glyceria canadensis
rattlesnake grass



Glyceria obtusa
blunt manna-grass



Grass sp.
grass



Helonias bullata
swamp pink

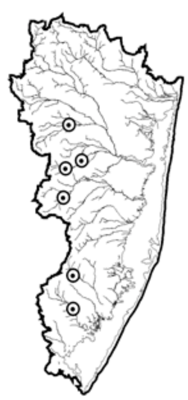
Hibiscus moscheutos
swamp rose mallow

Hypericum canadense
Canada St. Johnswort

Hypericum densiflorum
bushy St. Johnswort

Hypericum mutilum
dwarf St. Johnswort

Ilex glabra
inkberry



Ilex laevigata
smooth winterberry

Ilex opaca
American holly

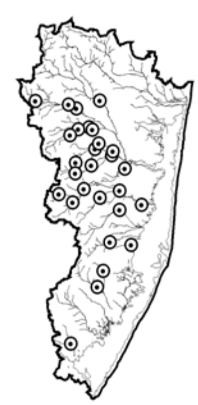
Ilex verticillata
winterberry

Impatiens capensis
spotted touch-me-not

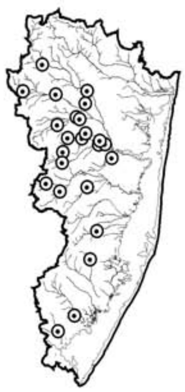
Iris versicolor
larger blue flag

Itea virginica
Virginia willow

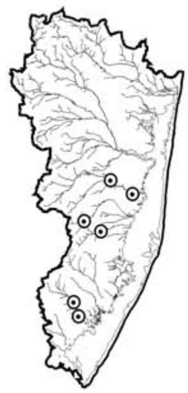
Juncus biflorus
two-flowered rush



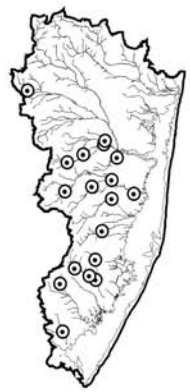
Juncus canadensis
Canada rush



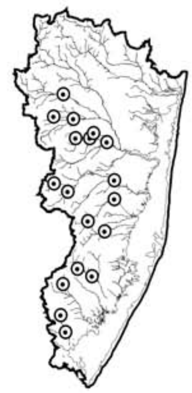
Juncus effusus
common rush



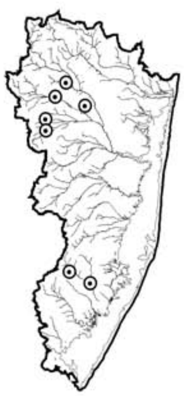
Juncus militaris
bayonet rush



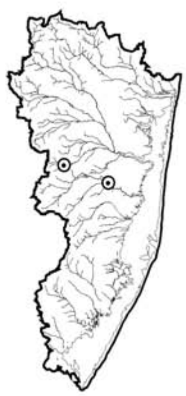
Juncus pelocarpus
brown-fruited rush



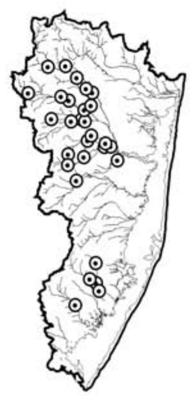
Kalmia angustifolia
sheep laurel



Kalmia latifolia
mountain laurel



Lachnanthes caroliniana
redroot

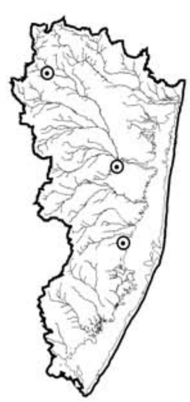


Leersia oryzoides
rice cut-grass

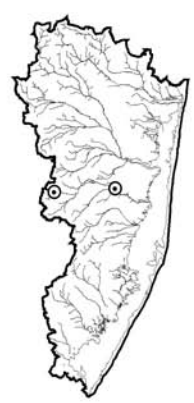
Lindernia dubia
short-stalked false pimpernel

Liquidambar styraciflua
sweet gum

Lobelia cardinalis
cardinal flower



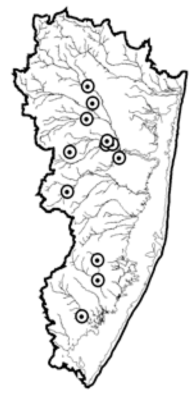
Lonicera japonica
Japanese honeysuckle



Lophiola aurea
golden-crest

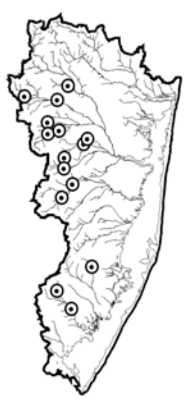
Ludwigia alternifolia
seedbox

Ludwigia palustris
water purslane

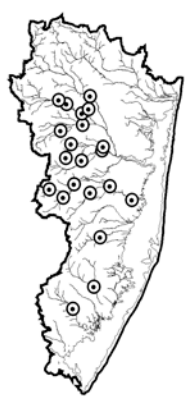


Lycopus uniflorus
northern bugleweed

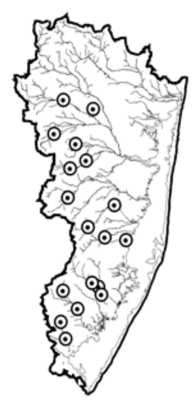
Lycopus virginicus
Virginia bugleweed



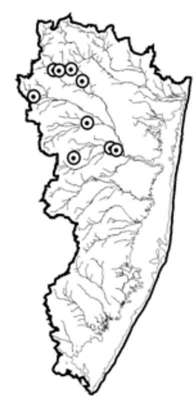
Lyonia ligustrina
maleberry



Lysimachia terrestris
swamp loosestrife



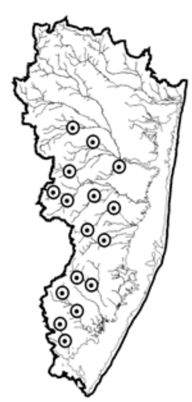
Magnolia virginiana
sweet bay



Microstegium vimineum
stiltgrass

Mikania scandens
climbing hempweed

Muhlenbergia uniflora
late-flowering dropseed

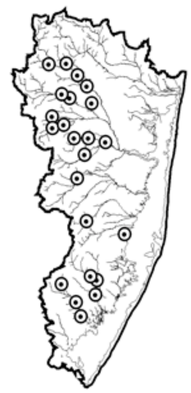


Myrica pensylvanica
bayberry

Myriophyllum humile
low water milfoil

Nuphar variegata
bullhead lily

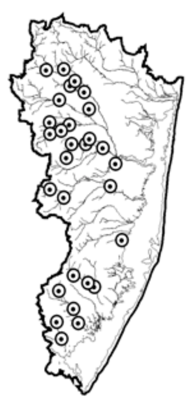
Nymphaea odorata
white water lily



Nyssa sylvatica
black gum

Onoclea sensibilis
sensitive fern

Orontium aquaticum
golden club



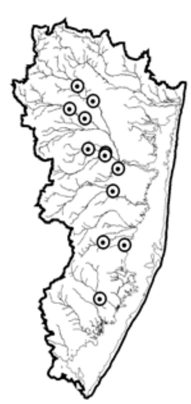
Osmunda cinnamomea
cinnamon fern

Osmunda regalis
royal fern

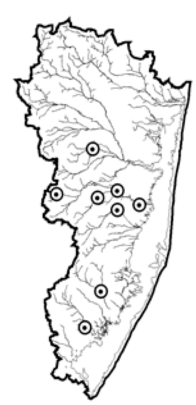
Oxypolis rigidior
cowbane

Panicum clandestinum
deertongue grass

Panicum dichotomum
forked panic-grass



Panicum cf. dichotomum
forked panic-grass



Panicum longifolium
long-leaved panic-grass

Panicum verrucosum
warty panic-grass

Panicum virgatum
switchgrass

Parthenocissus quinquefolia
Virginia creeper

Peltandra virginica
arrow arum

Phragmites australis
common reed

Pinus rigida
pitch pine

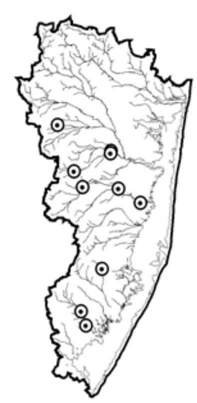
Pogonia ophioglossoides
rose pogonia

Polygala brevifolia
short-leaved milkwort

Polygonum hydropiperoides
mild water pepper

Polygonum sagittatum
arrow-leaved tearthumb

Pontederia cordata
pickerel-weed



Potamogeton confervoides
alga-like pondweed

Potamogeton diversifolius
hair-like pondweed

Potamogeton epihydrus
Nuttall's pondweed

Prunus serotina
black cherry

Quercus alba
white oak

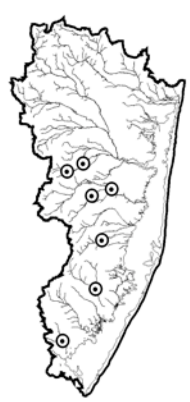
Quercus ilicifolia
scrub oak

Quercus velutina
black oak

Rhexia virginica
Virginia meadow beauty

Rhododendron viscosum
swamp azalea

Rhus copallina
winged sumac

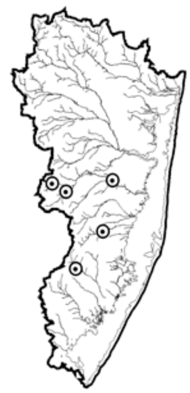


Rhynchospora alba
white beaked-rush

Rhynchospora capitellata
small-headed beaked-rush

Rosa multiflora
multiflora rose

Rubus hispidus
swamp dewberry



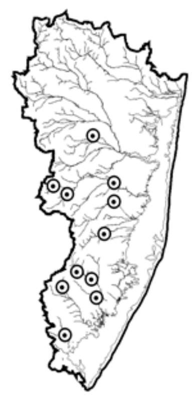
Sabatia difformis
lance-leaved sabatia

Sagittaria engelmanniana
Engelmann's arrowhead

Sagittaria cf. latifolia
broad-leaved arrowhead

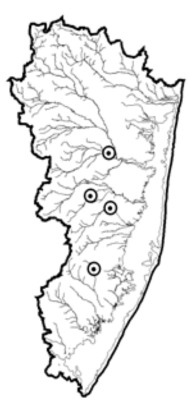
Salix sp.
willow

Sambucus canadensis
common elder



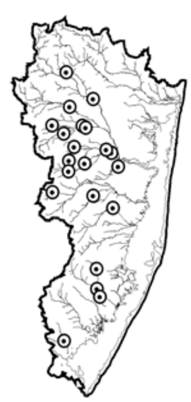
Sarracenia purpurea
pitcher plant

Sassafras albidum
sassafras



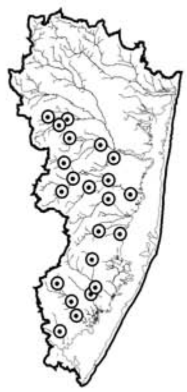
Schizachyrium scoparium
little bluestem

Schizaea pusilla
curly-grass fern



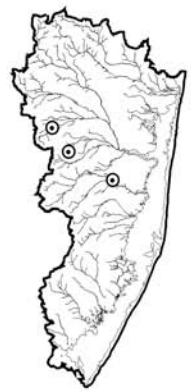
Scirpus cyperinus
wool-grass

Scirpus pungens
three-square bulrush



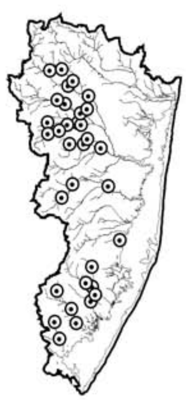
Scirpus subterminalis
water club-rush

Scutellaria lateriflora
mad-dog skullcap



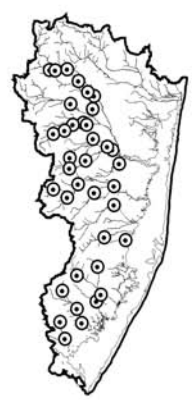
Smilax glauca
glaucous greenbrier

Smilax herbacea
carrion flower

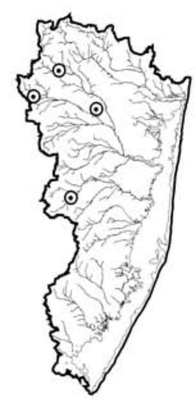


Smilax rotundifolia
common greenbrier

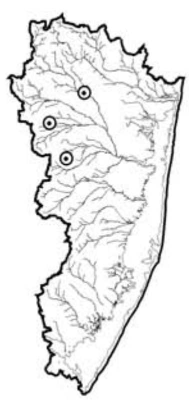
Solidago sp.
golden rod



Sparganium americanum
slender bur-reed

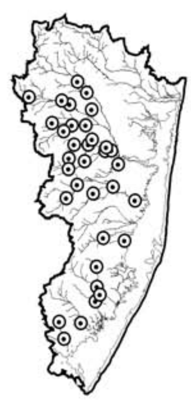


Thelypteris palustris
marsh fern

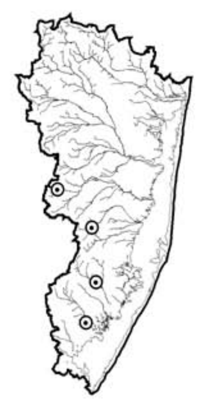


Thelypteris simulata
bog fern

Toxicodendron radicans
poison ivy



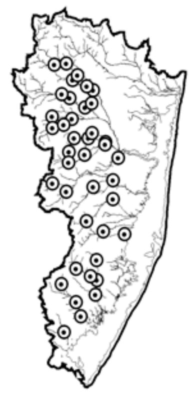
Triadenum virginicum
marsh St. Johnswort



Utricularia fibrosa
fibrous bladderwort

Utricularia cf. fibrosa
fibrous bladderwort

Utricularia subulata
zig-zag bladderwort



Vaccinium corymbosum
highbush blueberry

Vaccinium macrocarpon
large cranberry

Viburnum dentatum
southern arrowwood

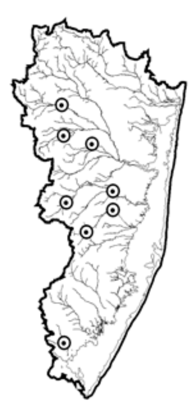
Viburnum nudum var. nudum
naked withe-rod

Viola lanceolata
lance-leaved violet

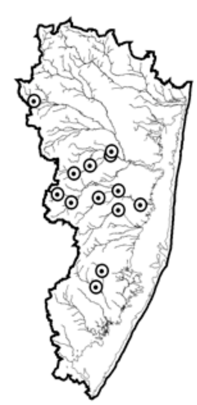
Viola sp.
violet

Vitis labrusca
fox grape

Woodwardia areolata
netted chain fern



Woodwardia virginica
Virginia chain fern



Xyris difformis
yellow-eyed grass

APPENDIX 3. FISH-ASSEMBLAGE DATA

Appendix 3.0. Fish-monitoring sites (streams and impoundments) in the Barnegat Bay Watershed. Two 10-m sections were sampled for each stream site. Sections were not assigned in impoundments. Latitude, longitude, and USGS 7.5 minute topographic quadrangle names are given in parentheses. Sites are ordered alphabetically by site code.

Site Name and Description	Site Code
Bamber Lake Lacey Twp., Ocean Co. (lat 39°53'41.93", long 74°19'00.48", Keswick Grove quad). Impoundment on Cedar Creek upstream from Route 614 (Whiting-Lacey Road).	CCEBAMBR
Cedar Creek impoundment at Double Trouble State Park Berkeley and Lacey Twps., Ocean Co. (lat 39°53'57.95", long 74°13'50.94", Toms River quad). Impoundment in Double Trouble State Park, upstream from confluence with Factory Branch.	CCEDOUBL
Cedar Creek at Double Trouble Road Berkeley and Lacey Twps., Ocean Co. (lat 39°53'38.64", long 74°13'30.75", Toms River quad). Sections located upstream from Double Trouble Road.	CCEDOUBS
Cedar Creek at Route 614 Lacey Twp., Ocean Co. (lat 39°53'50.25", long 74°18'58.63", Keswick Grove quad). Sections located upstream from Route 614 (Whiting-Lacey Road).	CCELACEY
Cedar Creek at Route 9 Berkeley and Lacey Twps., Ocean Co. (lat 39°52'03.70", long 74°10'08.08", Forked River quad). Sections located upstream from Route 9 at Dudley Park.	CCEROUT9
Chamberlain Branch at an unnamed road Lacey Twp., Ocean Co. (lat 39°52'22.11", long 74°20'40.06", Brookville quad). Sections located upstream and downstream from unnamed road.	CCHSANDR
Factory Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°52'52.18", long 74°16'30.65", Keswick Grove quad). Sections located downstream from Route 614 (Whiting-Lacey Road).	CFALACEY
Lower Lake Lacey Twp., Ocean Co. (lat 39°50'09.98", long 74°11'46.18", Forked River quad). Impoundment on North Branch Forked River upstream from Parker Avenue.	CNOLOWER
North Branch Forked River at a powerline right-of-way Lacey Twp., Ocean Co. (lat 39°51'31.38", long 74°13'29.85", Forked River quad). Sections located upstream from powerline right-of-way.	CNOPOWER
Oyster Creek at Route 532 Lacey and Ocean Twps., Ocean Co. (lat 39°47'53.91", long 74°15'00.33", Brookville quad). Sections located upstream and downstream from Route 532 (Waretown-Brookville Road).	COYRT532
Wells Mills Lake Ocean Twp., Ocean Co. (lat 39°47'35.67", long 74°16'34.11", Brookville quad). Impoundment on Oyster Creek in Wells Mills County Park.	COYWELLS
Waretown Creek at Route 9 Ocean Twp., Ocean Co. (lat 39°47'34.87", long 74°11'45.57", Forked River quad). Sections located upstream from Route 9.	CWAROUT9
Webbs Mill Branch at Route 539 Lacey Twp., Ocean Co. (lat 39°53'16.50", long 74°22'46.54", Whiting quad). Sections located downstream from Route 539.	CWERT539
Cedar Run at Route 9 Stafford Twp., Ocean Co. (lat 39°40'48.95", long 74°16'15.05", West Creek quad). Sections located upstream and downstream from Route 9.	MCEROUT9
Fourmile Branch at Lighthouse Drive Stafford Twp., Ocean Co. (lat 39°44'42.81", long 74°16'01.86", West Creek quad). Sections located downstream from Lighthouse Drive.	MFOLIGHT
Holiday Lake Stafford Twp., Ocean Co. (lat 39°43'56.58", long 74°15'56.97", West Creek quad). Impoundment on Four Mile Branch downstream from Lighthouse Drive at Ocean Acres Country Club.	MFOOCEAN
Mill Creek at Route 72 below Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°41'33.72", long 74°15'31.93", West Creek quad). Sections located downstream from Route 72 below Manahawkin Lake.	MMI72LWR

Site Name and Description	Site Code
Mill Creek at Route 72 above Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°42'54.39", long 74°16'56.30", West Creek quad). Sections located upstream from path near Route 72 above Manahawkin Lake.	MMI72UPR
Mill Creek at Hay Road Stafford Twp., Ocean Co. (lat 39°43'43.43", long 74°19'09.52", West Creek quad). Sections located upstream and downstream from path near Hay Road.	MMIHAYRD
Manahawkin Lake Stafford Twp., Ocean Co. (lat 39°41'46.39", long 74°15'34.75", West Creek quad). Impoundment on Mill Creek upstream from Route 9.	MMIMANAH
Harry Wright Lake Manchester Twp., Ocean Co. (lat 39°55'50.66", long 74°21'19.81", Keswick Grove quad). Impoundment on Davenport Branch upstream from Lake Road.	RDAHARRY
Davenport Branch impoundment at Route 614 Lacey Twp., Ocean Co. (lat 39°55'35.97", long 74°20'17.97", Keswick Grove quad). Impoundment on Davenport Branch upstream from Route 614 (Whiting-Lacey Road).	RDALACEL
Davenport Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°55'35.97", long 74°20'17.97", Keswick Grove quad). Sections located downstream from Route 614 (Lacey Road).	RDALACES
Davenport Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'37.78", long 74°14'40.17", Toms River quad). Sections located upstream from Mule Road.	RDAMULER
Davenport Branch at Route 530 Berkeley Twp., Ocean Co. (lat 39°56'29.25", long 74°17'48.60", Keswick Grove quad). Sections located upstream and downstream from Route 530 (Pinewald-Keswick Road).	RDART530
Jakes Branch at Double Trouble Road Beachwood and South Toms River Boros, Ocean Co. (lat 39°56'07.45", long 74°12'41.58", Toms River quad). Sections located downstream from Double Trouble Road.	RJADOUBL
Sunken Branch at Mule Road Berkeley Twp., Ocean Co. (lat 39°58'02.91", long 74°14'31.13", Toms River quad). Sections located upstream and downstream from Mule Road.	RSUMULER
Sunken Branch at Township Line Road Berkeley and Manchester Twps., Ocean Co. (lat 39°58'55.48", long 74°16'41.07", Keswick Grove quad). Sections located upstream and downstream from Township Line Road.	RSUTOWNS
Keswick Lake Manchester Twp., Ocean Co. (lat 39°56'57.40", long 74°20'42.72", Keswick Grove quad). Impoundment on Tice Van Horn Branch at Keswick Retreat Center.	RTIKESWI
Tice Van Horn Branch tributary at Route 530 Manchester Twp., Ocean Co. (lat 39°56'48.37", long 74°20'14.18", Keswick Grove quad). Sections located upstream and downstream from Route 530 (Pinewald-Keswick Road).	RTITR530
Wrangel Brook at Congasia Road Manchester Twp., Ocean Co. (lat 39°58'22.14", long 74°19'26.46", Keswick Grove quad). Sections located upstream from Congasia Road.	RWRCONGA
Wrangel Brook at Mule Road Berkeley Twp., Ocean Co. (lat 39°57'53.69", long 74°14'36.99", Toms River quad). Sections located upstream and downstream from Mule Road.	RWRMULER
Wrangel Brook at South Hampton Road Berkeley Twp., Ocean Co. (lat 39°57'39.48", long 74°13'41.26", Toms River quad). Sections located upstream from South Hampton Road.	RWRSOUTH
Wrangle Brook near Township Line Road Manchester Twp., Ocean Co. (lat 39°58'26.61", long 74°17'32.09", Keswick Grove quad). Sections located downstream from impoundment above Township Line Road.	RWRTOWNS
Blacks Branch at Route 70 Manchester Twp. and Lakehurst Boro, Ocean Co. (lat 40°00'30.66", long 74°19'47.86", Lakehurst quad). Sections located upstream and downstream from Route 70.	TBLRTE70

Site Name and Description	Site Code
Dove Mill Branch at Grawtown Road Jackson Twp., Ocean Co. (lat 40°04'08.82", long 74°17'28.18", Lakehurst quad). Sections located upstream from Grawtown Road.	TDOGRAWT
Dove Mill Branch impoundment at Route 528 Jackson Twp., Ocean Co. (lat 40°04'53.76", long 74°17'37.83", Lakehurst quad). Impoundment upstream from Route 528 (Van Hiseville-Lakewood Road).	TDOIM528
Manapaqua Brook at Route 70 Manchester Twp. and Lakehurst Boro, Ocean Co. (lat 40°00'44.35", long 74°18'08.89", Lakehurst quad). Sections located upstream from Route 70.	TMARTE70
Mirey Run at Route 528 Jackson Twp., Ocean Co. (lat 40°06'43.05", long 74°20'38.03", Lakehurst quad). Sections located downstream from Route 528.	TMIRT528
Old Hurricane Brook at Route 70 Manchester Twp., Ocean Co. (lat 39°59'51.78", long 74°21'03.30", Keswick Grove quad). Sections located downstream from Route 70.	TOLRTE70
Ridgeway Branch at Hangar Road Jackson Twp., Ocean Co. (lat 40°02'50.29", long 74°20'04.83", Lakehurst quad). Sections located downstream from Hangar Road.	TRIHANGA
Ridgeway Branch at High Bridge Road Jackson Twp., Ocean Co. (lat 40°03'17.51", long 74°21'17.16", Lakehurst quad). Sections located upstream from High Bridge Road.	TRIHIGHB
Ridgeway Branch at Ridgeway Boulevard Manchester Twp., Ocean Co. (lat 40°01'47.86", long 74°17'44.49", Lakehurst quad). Sections located upstream and downstream from Ridgeway Boulevard.	TRIRIDGE
Success Lake Jackson Twp., Ocean Co. (lat 40°03'31.48", long 74°23'29.58", Cassville quad). Impoundment on Shannae Brook upstream from Success Road.	TSHSUCCE
Turnmill Pond Jackson Twp., Ocean Co. (lat 40°03'40.41", long 74°26'22.54", Cassville quad). Impoundment on Shannae Brook tributary downstream from Success Road.	TSHTURNL
Shannae Brook tributary at Turn Mill Pond Jackson Twp., Ocean Co. (lat 40°03'40.41", long 74°26'22.54", Cassville quad). Sections located downstream from Turn Mill Pond.	TSHTURNS
Shannae Brook impoundment Jackson Twp., Ocean Co. (lat 40°04'56.37", long 74°25'30.03", Cassville quad). Impoundment at end of sand road upstream from Success Lake.	TSHUPPER
Toms River at Bowman Road Jackson Twp., Ocean Co. (lat 40°05'22.70", long 74°18'54.00", Lakehurst quad). Sections located upstream and downstream from Bowman Road.	TTOBOWMA
Toms River tributary impoundment at Route 571 Jackson Twp., Ocean Co. (lat 40°06'38.66", long 74°23'19.46", Cassville quad). Impoundment upstream from Route 571 (Cassville-Toms River Road).	TTOIM571
Toms River at Route 528 Jackson Twp., Ocean Co. (lat 40°06'35.24", long 74°22'25.32", Lakehurst quad). Sections located downstream from Route 528.	TTORT528
Toms River at Route 547 Jackson Twp., Ocean Co. (lat 40°03'42.06", long 74°16'28.46", Lakehurst quad). Sections located upstream from Route 547 (Lakehurst-Whitesville Road).	TTORT547
Toms River tributary at Route 571 Jackson Twp., Ocean Co. (lat 40°06'38.66", long 74°23'19.46", Cassville quad). Sections located downstream from Route 571 (Cassville-Toms River Road).	TTOTR571
Union Branch at Colonial Drive Manchester Twp., Ocean Co. (lat 40°00'29.38", long 74°17'37.40", Lakehurst quad). Sections located downstream from Colonial Drive.	TUNCOLON

Site Name and Description	Site Code
Horicon Lake Lakehurst Twp., Ocean Co. (lat 40°00'34.82", long 74°19'06.74", Lakehurst quad). Impoundment on Union Branch upstream from Lake Street.	TUNHORIC
Mill Branch at Nugentown Road Little Egg Harbor Twp. and Tuckerton Boro, Ocean Co. (lat 39°36'37.50", long 74°20'59.83", Tuckerton quad). Sections located upstream and downstream from Nugentown Road.	WMINUGEN
Pohatcong Lake Tuckerton Boro, Ocean Co. (lat 39°36'08.72", long 74°20'33.31", Tuckerton quad). Impoundment on Mill Branch upstream from Route 9.	WMIPOHAT
Westecunk Creek impoundment at Stafford Forge Eagleswood Twp., Ocean Co. (lat 39°40'26.01", long 74°19'41.12", West Creek quad). Third impoundment upstream from Forge Road.	WWEFORG3
Westecunk Creek at Forge Road Eagleswood Twp., Ocean Co. (lat 39°39'59.59", long 74°19'12.92", West Creek quad). Sections located downstream from Forge Road.	WWEFORGS
Westecunk Creek at Railroad Avenue Eagleswood Twp., Ocean Co. (lat 39°38'24.94", long 74°18'28.61", West Creek quad). Sections located upstream from Railroad Avenue.	WWERAILR

Appendix 3.1. Total number collected for each fish species at monitoring sites in the Barnegat Bay Watershed. A dash (-) indicates that a species was not collected at a site. Surveys were completed by John F. Bunnell, Robert A. Zampella, Nicholas A. Procopio, and Jim Rutherford. Refer to Chapter 4 (Fish Assemblages) for survey methodology. Refer to Appendix 3.0 for detailed site information and Appendix 3.2 for common names for each species.

Species	Site Code and Date														
	CCEBAMBR 10/02/03	CCEDOUBL 08/14/03	CCEDOUBS 08/14/03	CCELACEY 08/01/03	CCEROUT9 08/01/03	CCHSANDR 06/12/03	CFALACEY 08/01/03	CNOLOWER 08/14/03	CNOPOWER 08/14/03	COYRT532 07/23/03	COYWELLS 10/22/03	CWAROUT9 07/23/03	CWERT539 06/12/03	LBLRTE70 08/19/03	MCEROUT9 09/25/03
Acantharchus pomotis	3	-	-	1	2	-	-	-	1	-	-	1	-	1	-
Ameiurus natalis	3	-	5	3	7	-	-	-	-	-	5	-	-	-	7
Ameiurus nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anguilla rostrata	-	-	6	-	4	1	-	-	-	1	1	3	-	-	7
Aphredoderus sayanus	8	-	-	3	-	1	-	1	-	-	-	-	3	6	2
Enneacanthus chaetodon	23	24	2	15	3	-	-	-	-	-	-	-	4	34	-
Enneacanthus gloriosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enneacanthus obesus	67	49	6	5	11	2	3	30	5	2	36	-	3	4	-
Enneacanthus species	12	-	-	-	-	-	-	10	-	-	4	-	1	1	-
Erimyzon oblongus	2	3	1	2	1	-	-	-	-	2	6	-	-	-	-
Esox americanus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Esox niger	7	2	1	-	1	1	-	-	-	1	3	1	2	4	1
Esox species	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Etheostoma fusiforme	14	12	4	2	9	7	-	10	20	-	8	-	2	17	-
Etheostoma olmstedi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fundulus diaphanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gibbosus	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-
Lepomis macrochirus	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Lepomis species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropterus salmoides	-	-	-	-	-	-	-	34	-	-	-	-	-	-	-
Notemigonus crysoleucas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Noturus gyrinus	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Perca flavescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomoxis nigromaculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbra pygmaea	40	-	-	2	3	11	7	-	-	-	1	-	7	2	1

Species	Site Code and Date														
	MFOLIGHT 07/02/03	MFOOCEAN 09/25/03	MMI72LWR 07/09/03	MMI72UPR 07/09/03	MMIHAYRD 07/09/03	MMIMANAH 10/22/03	RDAHARRY 08/22/03	RDALACEL 10/22/03	RDALACES 08/01/03	RDAMULER 08/22/03	RDART530 08/22/03	RJADOUBL 08/01/03	RSUMULER 08/26/03	RSUTOWNS 08/22/03	RTIKESWI 10/15/03
Acantharchus pomotis	8	-	1	-	-	-	-	-	2	-	-	2	-	-	-
Ameiurus natalis	3	1	1	-	-	-	-	-	11	3	1	1	-	1	-
Ameiurus nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Anguilla rostrata	-	-	-	2	-	-	-	-	5	4	1	2	-	-	-
Aphredoderus sayanus	4	-	-	-	-	-	3	-	-	9	-	2	-	-	-
Enneacanthus chaetodon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26
Enneacanthus gloriosus	-	5	8	-	-	44	-	-	-	-	-	-	-	-	-
Enneacanthus obesus	1	2	-	-	-	5	10	21	3	3	2	1	3	1	18
Enneacanthus species	-	6	-	-	-	-	8	-	8	-	-	-	-	-	-
Erimyzon oblongus	-	-	-	-	-	-	-	3	11	-	-	-	-	-	-
Esox americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
Esox niger	2	-	4	2	-	-	1	3	3	-	-	-	5	-	-
Esox species	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Etheostoma fusiforme	-	2	-	-	-	6	-	2	1	-	5	4	-	-	3
Etheostoma olmstedi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fundulus diaphanus	-	32	3	-	-	41	-	-	-	-	-	-	-	-	1
Lepomis gibbosus	-	2	9	-	-	-	58	27	-	1	-	-	2	-	-
Lepomis macrochirus	-	61	10	3	-	8	71	55	-	-	-	-	6	-	24
Lepomis species	-	-	-	-	-	38	13	187	-	-	-	-	-	-	8
Micropterus salmoides	-	4	-	-	-	1	18	-	-	-	-	-	2	-	1
Notemigonus crysoleucas	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Noturus gyrinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perca flavescens	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomoxis nigromaculatus	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
Umbra pygmaea	6	9	1	-	-	-	1	-	-	8	-	18	-	-	-

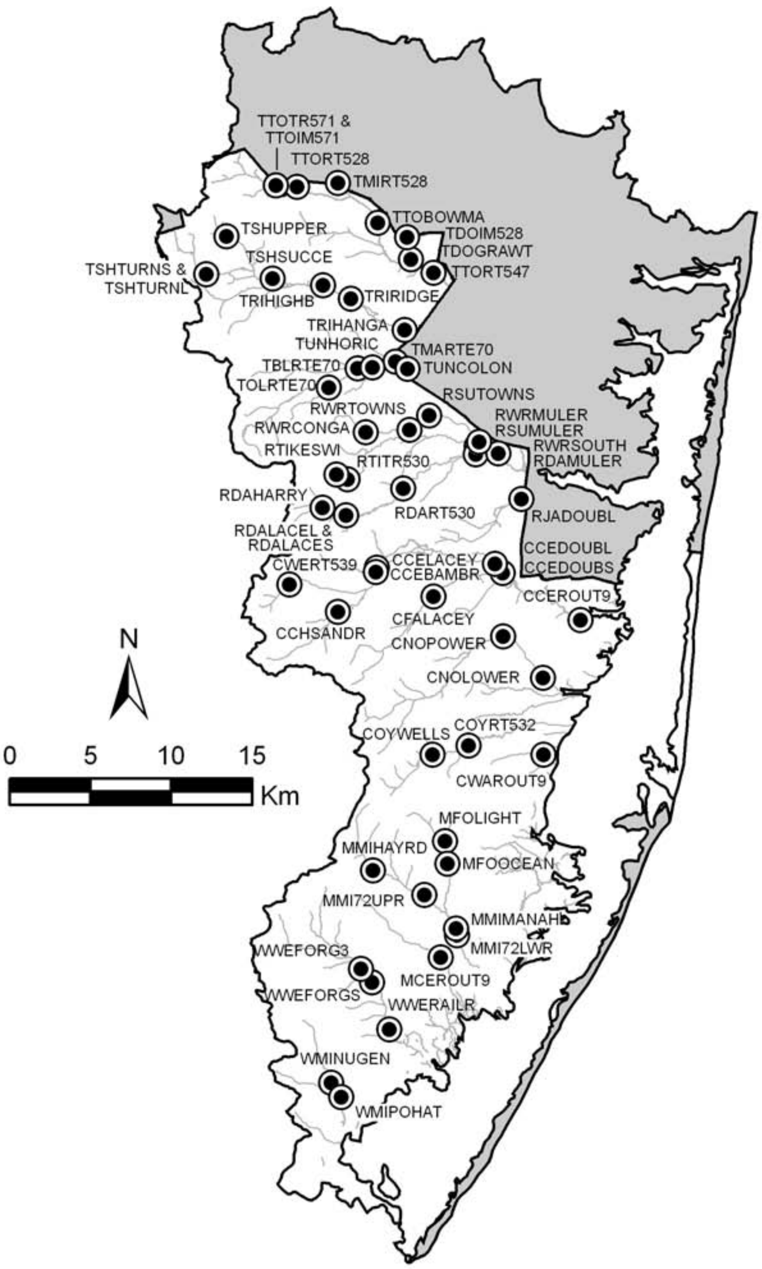
Species	Site Code and Date														
	RTITR530 07/23/03	RWRCONGA 07/23/03	RWRMULER 08/26/03	RWRSOUTH 08/22/03	RWRTOWNS 07/23/03	TDOGRAWT 09/12/03	TDOIM528 10/15/03	TMARTE70 08/19/03	TMIRT528 09/12/03	TOLRTE70 08/19/03	TRIHANGA 10/15/03	TRIHIGHB 08/19/03	TRIRIDGE 08/19/03	TSHSUCCE 09/05/03	TSHTURNL 09/11/03
Acantharchus pomotis	-	-	-	-	2	1	1	1	-	1	-	-	-	1	-
Ameiurus natalis	-	-	1	-	-	-	-	-	-	-	-	-	-	16	1
Ameiurus nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anguilla rostrata	2	-	5	8	-	2	-	1	8	-	-	1	-	-	-
Aphredoderus sayanus	-	-	4	13	-	1	2	1	8	2	7	6	1	20	-
Enneacanthus chaetodon	-	-	-	2	-	7	86	4	-	-	-	-	-	-	-
Enneacanthus gloriosus	-	-	-	7	-	4	-	-	-	-	-	3	-	59	7
Enneacanthus obesus	-	-	1	-	6	1	14	11	-	7	-	3	-	108	-
Enneacanthus species	-	-	-	1	2	1	5	1	-	-	-	5	-	63	18
Erimyzon oblongus	-	-	5	-	-	-	-	18	-	-	-	-	1	-	-
Esox americanus	-	-	-	1	6	2	-	-	1	-	-	1	-	-	-
Esox niger	-	-	1	1	-	5	3	3	1	2	1	-	5	5	4
Esox species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Etheostoma fusiforme	-	2	-	-	6	3	5	5	2	3	3	3	2	22	22
Etheostoma olmstedi	-	-	25	-	-	3	-	-	1	-	-	-	-	-	-
Fundulus diaphanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Lepomis gibbosus	1	-	2	2	-	-	1	2	3	-	-	-	-	-	-
Lepomis macrochirus	-	-	-	-	-	-	3	-	-	-	-	-	-	-	12
Lepomis species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	101
Micropterus salmoides	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8
Notemigonus crysoleucas	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Noturus gyrinus	-	-	1	-	-	1	-	1	1	-	-	-	-	-	2
Perca flavescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomoxis nigromaculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbra pygmaea	4	-	-	-	11	1	-	-	2	11	-	5	-	12	-

Species	Site Code and Date													
	TSHTURNS 08/26/03	TSHUPPER 08/26/03	TTOBOWMA 09/12/03	TTOIM571 10/15/03	TTORT528 09/12/03	TTORT547 10/15/03	TTOTR571 09/12/03	TUNCOLON 08/19/03	TUNHORIC 10/03/03	WMINUGEN 07/02/03	WMIPOHAT 09/24/03	WWEFORG3 09/24/03	WWEFORGS 07/02/03	WWERAILR 09/24/03
Acantharchus pomotis	1	-	-	-	-	1	-	-	1	-	-	-	-	1
Ameiurus natalis	1	1	-	-	-	-	1	3	3	-	2	1	2	11
Ameiurus nebulosus	-	-	-	1	-	-	-	1	-	-	-	-	-	-
Anguilla rostrata	-	-	2	-	5	1	1	1	-	2	3	-	5	2
Aphredoderus sayanus	10	2	-	6	-	15	-	1	20	1	-	-	-	8
Enneacanthus chaetodon	-	-	-	-	-	5	-	7	103	-	-	-	-	-
Enneacanthus gloriosus	32	26	-	25	1	-	5	-	1	-	26	-	-	-
Enneacanthus obesus	2	15	-	25	-	-	-	2	66	1	24	37	14	14
Enneacanthus species	-	4	-	4	1	-	8	-	12	-	16	14	-	-
Erimyzon oblongus	1	80	-	5	-	-	-	2	3	-	-	-	-	17
Esox americanus	-	-	-	-	-	1	-	1	-	-	-	-	-	-
Esox niger	7	3	1	1	1	1	2	2	4	2	2	2	1	1
Esox species	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Etheostoma fusiforme	3	5	-	8	1	2	20	3	26	-	-	6	5	9
Etheostoma olmstedi	-	-	23	-	4	4	1	-	-	-	-	-	-	-
Fundulus diaphanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepomis gibbosus	-	2	-	2	-	-	-	-	-	-	3	-	-	-
Lepomis macrochirus	6	-	-	-	-	-	1	-	-	-	4	7	-	-
Lepomis species	1	1	-	2	-	-	2	-	-	-	-	4	-	-
Micropterus salmoides	4	-	-	-	-	-	-	-	-	-	22	-	-	-
Notemigonus crysoleucas	-	-	-	-	-	-	2	-	-	-	-	-	-	15
Noturus gyrinus	3	-	-	-	1	-	-	2	-	-	-	-	-	-
Perca flavescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomoxis nigromaculatus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbra pygmaea	-	-	-	-	1	3	1	1	5	3	-	-	-	1

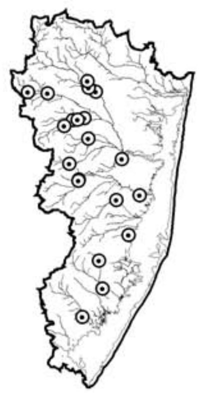
Appendix 3.2. Common and scientific names for 22 fish species collected in Barnegat Bay Watershed streams and impoundments. Nomenclature follows Page and Burr (1991).

Scientific Name	Common Name
Acantharchus pomotis	mud sunfish
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead
Anguilla rostrata	American eel
Aphredoderus sayanus	pirate perch
Enneacanthus chaetodon	blackbanded sunfish
Enneacanthus gloriosus	bluespotted sunfish
Enneacanthus obesus	banded sunfish
Erimyzon oblongus	creek chubsucker
Esox niger	chain pickerel
Esox americanus	redfin pickerel
Etheostoma fusiforme	swamp darter
Etheostoma olmstedi	tesselated darter
Fundulus diaphanus	banded killifish
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus	bluegill
Micropterus salmoides	largemouth bass
Notemigonus crysoleucas	golden shiner
Noturus gyrinus	tadpole madtom
Perca flavescens	yellow perch
Pomoxis nigromaculatus	black crappie
Umbra pygmaea	eastern mudminnow

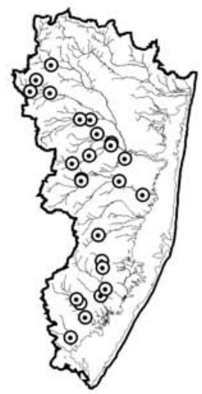
APPENDIX 3.3. FISH-DISTRIBUTION MAPS



Location of 59 fish-survey sites in the Barnegat Bay Watershed. Shaded areas are outside the Pinelands National Reserve. Distribution maps on the following pages show where each fish species was present.

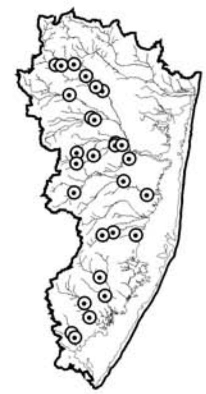


Acantharchus pomotis
mud sunfish

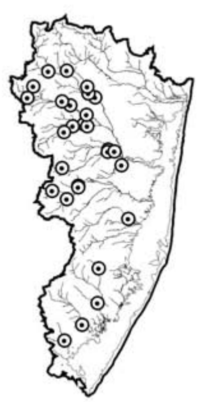


Ameiurus natalis
yellow bullhead

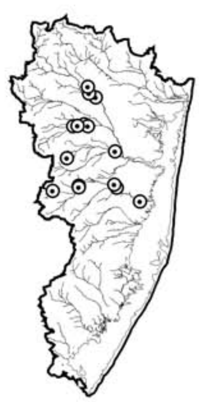
Ameiurus nebulosus
brown bullhead



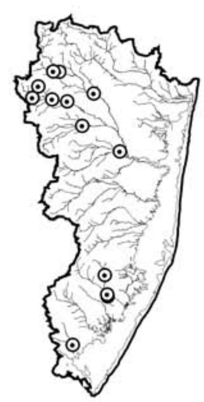
Anguilla rostrata
American eel



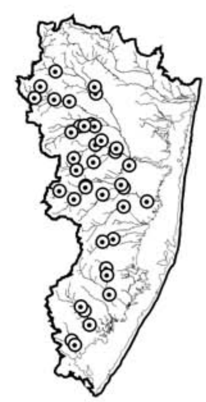
Aphredoderus sayanus
pirate perch



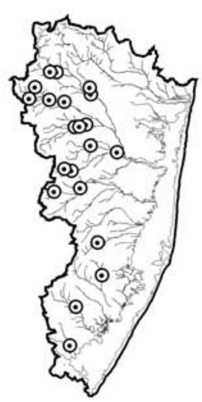
Enneacanthus chaetodon
blackbanded sunfish



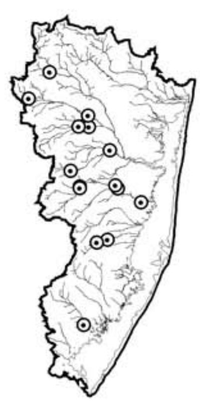
Enneacanthus gloriosus
bluespotted sunfish



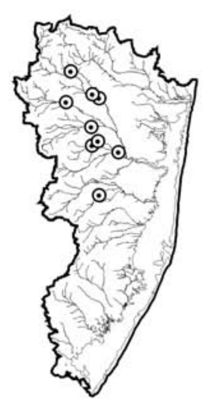
Enneacanthus obesus
banded sunfish



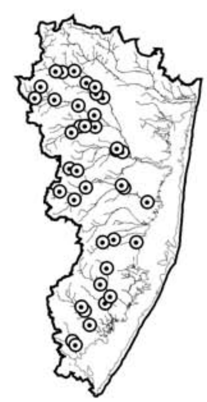
Enneacanthus species



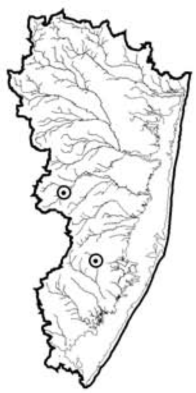
Erimyzon oblongus
creek chubsucker



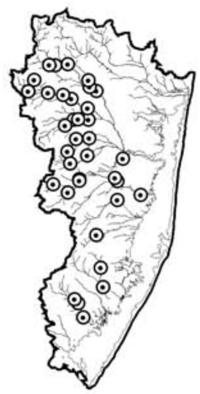
Esox americanus
redfin pickerel



Esox niger
chain pickerel

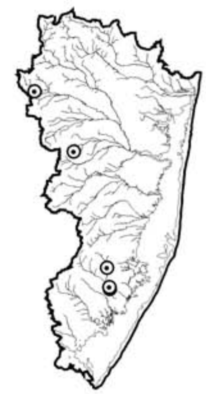


Esox species

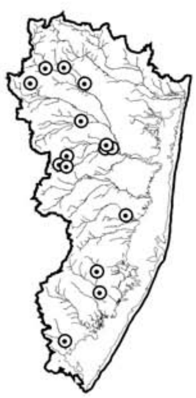


Etheostoma fusiforme
swamp darter

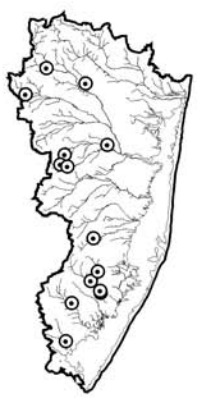
Etheostoma olmstedi
tessellated darter



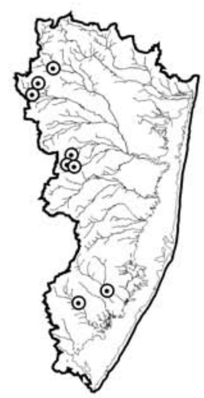
Fundulus diaphanus
banded killifish



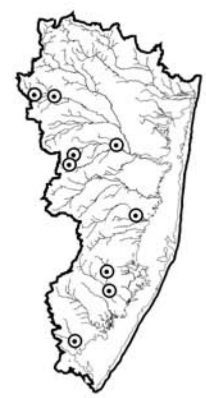
Lepomis gibbosus
pumpkinseed



Lepomis macrochirus
bluegill

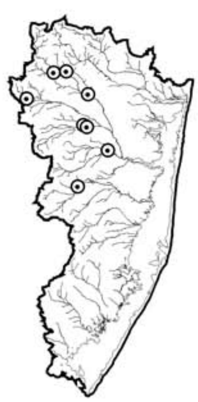


Lepomis species



Micropterus salmoides
largemouth bass

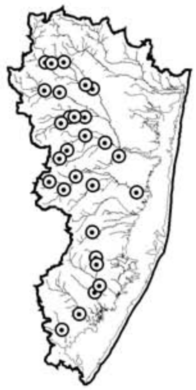
Notemigonus crysoleucas
golden shiner



Noturus gyrinus
tadpole madtom

Perca flavescens
yellow perch

Promoxis nigromaculatus
black crappie



Umbra pygmaea
eastern mudminnow

APPENDIX 4. ANURAN-ASSEMBLAGE DATA

Appendix 4.0. Anuran-monitoring sites in the Barnegat Bay Watershed. Latitude, longitude, and USGS 7.5 minute topographic quadrangle names are given in parentheses. The listening point is given in brackets after the site location. Sites are ordered alphabetically by site code.

Site Name and Description	Site Code
Bamber Lake Lacey Twp., Ocean Co. (lat 39°53'44.55", long 74°19'06.47", Keswick Grove quad). Impoundment on Cedar Creek, upstream from Route 614 (Whiting-Lacey Road) [northern shoreline near outflow].	CCEBAMBR
Cedar Creek impoundment at Double Trouble State Park Berkeley and Lacey Twps., Ocean Co. (lat 39°54'00.28", long 74°13'47.68", Toms River quad). Impoundment in Double Trouble State Park, upstream from confluence with Factory Branch [eastern shoreline near outflow].	CCEDOUBL
Factory Branch at Route 614 Lacey Twp., Ocean Co. (lat 39°52'51.58", long 74°16'28.84", Keswick Grove quad). Impoundment upstream from Route 614 (Whiting-Lacey Road) [Route 614].	CFALACEY
Lake Barnegat Lacey Twp., Ocean Co. (lat 39°50'41.07", long 74°12'24.37", Forked River quad). Impoundment on North Branch Forked River, between Deerhead Lake and Lower Lake [western shoreline].	CNOBARNE
Deer Head Lake Lacey Twp., Ocean Co. (lat 39°51'02.80", long 74°12'37.57", Forked River quad). Impoundment on North Branch Forked River, upstream from Deer Head Drive [southern shoreline near outflow].	CNODEERH
Lower Lake Lacey Twp., Ocean Co. (lat 39°50'05.10", long 74°11'52.75", Forked River quad). Impoundment on North Branch Forked River, upstream from Parker Avenue [southern corner near Parker Avenue].	CNOLOWER
Oyster Creek tributary impoundment at Brookville Road Berkeley Twp., Ocean Co. (lat 39°46'39.09", long 74°18'37.68", Keswick Grove quad). Impoundment upstream from Route 611 (Brookville Road) [Brookville Road].	COYTRBRO
Wells Mills Lake Ocean Twp., Ocean Co. (lat 39°47'38.21", long 74°16'38.02", Brookville quad). Impoundment on Oyster Creek in Wells Mills County Park [northern shoreline near outflow].	COYWELLS
Waretown Lake Lacey Twp., Ocean Co. (lat 39°47'37.69", long 74°12'40.83", Keswick Grove quad). Impoundment on Waretown Creek in Waretown Lake and Recreation Area [dike that bisects lakes].	CWAPARKL
Cedar Run at Route 9 Stafford Twp., Ocean Co. (lat 39°40'49.63", long 74°16'16.09", West Creek quad). Impoundment upstream from Route 9 [southern corner near outflow].	MCEROUT9
Eightmile Branch impoundment at Route 72 Stafford Twp., Ocean Co. (lat 39°44'41.86", long 74°18'17.96", West Creek quad). Impoundment upstream from Route 72 [southern shoreline near outflow].	MEIIMP72
Holiday Lake Stafford Twp., Ocean Co. (lat 39°44'13.83", long 74°15'54.01", West Creek quad). Impoundment on Four Mile Branch, downstream from Lighthouse Drive at Ocean Acres Country Club [western shoreline at beach].	MFOOCEAN
Manahawkin Lake Lacey Twp., Ocean Co. (lat 39°41'51.21", long 74°15'32.29", Forked River quad). Impoundment on Mill Creek, upstream from Route 9 [southeastern shoreline].	MMIMANAH
Davenport Branch bog at Route 530 Berkeley Twp., Ocean Co. (lat 39°56'26.93", long 74°17'52.15", Keswick Grove quad). Impoundment upstream from Route 530 (Pinewald-Keswick Road) [northeastern shoreline near outflow].	RDABG530
Harry Wright Lake Manchester Twp., Ocean Co. (lat 39°55'47.79", long 74°21'28.80", Keswick Grove quad). Impoundment on Davenport Branch, upstream from Lake Road [southcentral shoreline].	RDAHARRY
Davenport Branch impoundment at Route 614 Lacey Twp., Ocean Co. (lat 39°55'37.32", long 74°20'21.00", Keswick Grove quad). Impoundment on Davenport Branch, upstream from Route 614 (Whiting-Lacey Road) [northern shoreline near Route 614].	RDALACEL
Davenport Branch tributary impoundment at Lake Road Manchester Twp., Ocean Co. (lat 39°55'30.75", long 74°20'55.59", Keswick Grove quad). Impoundment on Davenport Branch tributary, upstream from Lake Road [Lake Road].	RDATRIMP

Site Name and Description	Site Code
Jakes Branch tributary bog near Route 530 Stafford Twp., Ocean Co. (lat 39°55'56.08", long 74°14'07.04", West Creek quad). Impoundment on Jakes Branch tributary, downstream from Route 530 (Dover Road) [Route 530].	RJATRBOG
Michaels Branch impoundment Manchester Twp., Ocean Co. (lat 39°57'42.49", long 74°19'58.28", Keswick Grove quad). Impoundment in Whiting Wildlife Management Area [northeastern corner of impoundment].	RMIWHWMA
Sunken Branch impoundment near Jamaica Road Berkeley Twp., Ocean Co. (lat 39°58'56.95", long 74°16'07.16", Keswick Grove quad). Impoundment upstream from Bimini Drive, near the end of Jamaica Road [northern shoreline].	RSUJAMAI
Keswick Lake Manchester Twp., Ocean Co. (lat 39°56'56.05", long 74°20'43.97", Keswick Grove quad). Impoundment on Tice Van Horn Branch at Keswick Retreat Center [southeastern shoreline].	RTIKESWI
Tice Van Horn Branch impoundment at Schoolhouse Road Manchester Twp., Ocean Co. (lat 39°57'11.60", long 74°21'26.51", Keswick Grove quad). Impoundment above Schoolhouse Road [Schoolhouse Road].	RTISCHOO
Tice Van Horn Branch tributary impoundment in Crestwood Village Manchester Twp., Ocean Co. (lat 39°56'27.96", long 74°20'52.83", Keswick Grove quad). Impoundment in Crestwood Village [western shoreline near parking area].	RTITRCRE
Wrangel Brook impoundment at Township Line Road Manchester Twp., Ocean Co. (lat 39°58'25.70", long 74°17'33.28", Keswick Grove quad). Impoundment upstream from Township Line Road, between confluence with Green Branch and Michaels Branch [southeastern corner near outflow].	RWRTOWNL
Bordens Mill Branch impoundment - lower Jackson Twp., Ocean Co. (lat 40°3'03.60", long 74°26'20.34", Cassville quad). Impoundment downstream from Hawkins Road [southern shoreline near outflow].	TBOHAWLW
Bordens Mill Branch impoundment - upper Jackson Twp., Ocean Co. (lat 40°3'22.79", long 74°26'47.36", Cassville quad). Impoundment upstream from Hawkins Road [Hawkins Road].	TBOHAWUP
Dove Mill Branch impoundment at Route 528 Jackson Twp., Ocean Co. (lat 40°4'56.81", long 74°17'32.14", Lakehurst quad). Impoundment upstream from Route 528 (Van Hiseville-Lakewood Road) [southeastern shoreline].	TDOIM528
Success Lake Jackson Twp., Ocean Co. (lat 40°3'33.51", long 74°23'29.65", Cassville quad). Impoundment on Shannae Brook, upstream from Success Road [eastern shoreline near outflow].	TSHSUCCE
Turnmill Pond Jackson and Plumsted Twps., Ocean Co. (lat 40°3'53.31", long 74°26'56.02", Cassville quad). Impoundment on Shannae Brook tributary, downstream from Success Road [northernmost boat access on western shoreline].	TSHTURNL
Shannae Brook impoundment Jackson Twp., Ocean Co. (lat 40°4'55.02", long 74°25'32.32", Cassville quad). Impoundment at end of sand road, upstream from Success Lake [southeastern corner of impoundment].	TSHUPPER
Toms River tributary impoundment at Route 527 Jackson Twp., Ocean Co. (lat 40°4'12.44", long 74°16'31.94", Lakehurst quad). Impoundment upstream from Route 527 (Whitesville Road) [Route 527].	TTOIM527
Toms River tributary impoundment at Route 571 Jackson Twp., Ocean Co. (lat 40°6'37.34", long 74°23'23.20", Cassville quad). Impoundment upstream from Route 571 (Cassville-Toms River Road) [northern shoreline].	TTOIM571
Horicon Lake Lakehurst Twp., Ocean Co. (lat 40°0'25.37", long 74°19'18.55", Lakehurst quad). Impoundment on Union Branch, upstream from Lake Street [southern shoreline at boat launch].	TUNHORIC
Gifford Mill Branch impoundment Little Egg Harbor Twp. and Tuckerton BoroOcean Co. (lat 39°36'24.21", long 74°21'18.30", Tuckerton quad). Impoundment upstream from Giffordtown Lane [eastern shoreline near outflow].	WGIGIFFL
Governors Branch at Watering Place Little Egg Harbor Twp., Ocean Co. (lat 39°42'08.03", long 74°23'11.01", Oswego Lake quad). Impoundment upstream from entrance road to Warren Grove Weapons Range [southeastern corner].	WGOWATER

Site Name and Description	Site Code
Log Swamp Branch impoundment at Munion Field Road Little Egg Harbor Twp., Ocean Co. (lat 39°40'31.89", long 74°20'53.87", West Creek quad). First impoundment upstream from Munion Field Road [eastern shoreline at dike].	WLOMUNIO
Pohatcong Lake Tuckerton Boro, Ocean Co. (lat 39°36'11.94", long 74°20'42.20", Tuckerton quad). Impoundment on Mill Branch, upstream from Route 9 [western shoreline at beach].	WMIPOHAT
Rail Branch impoundment at Munion Field Road Eagleswood Twp., Ocean Co. (lat 39°40'06.20", long 74°19'50.63", West Creek quad). Impoundment upstream from Munion Field Road [eastern shoreline at dike].	WRAMUNIO
Tuckerton Creek tributary impoundment at Great Bay Boulevard Tuckerton Boro, Ocean Co. (lat 39°35'14.35", long 74°20'46.29", Tuckerton quad). Impoundment upstream from Great Bay Boulevard [southeastern corner].	WTUTRBAY
Westecunk Creek impoundment at Stafford Forge Eagleswood Twp., Ocean Co. (lat 39°40'36.72", long 74°20'06.13", West Creek quad). Fourth impoundment upstream from Forge Road [southeastern shoreline at dike].	WWEFORG4

Appendix 4.1. Maximum-call ranks for eight anuran species at monitoring sites in the Barnegat Bay Watershed. Observer (s) are JFB = John F. Bunnell and RAZ = Robert A. Zampella. Weather codes are 0 = clear, 1 = cloudy, 2 = overcast, 3 = fog/haze, 4 = breezy, 5 = drizzle, 6 = constant rain, 7 = showers, 8 = thunder storm occurred within one hour, and 9 = thunderstorm. Maximum-call ranks are 1 = 1, 2 = 2-5, 3 = 6-10, and 4 > 10 individuals calling. The letter "V" refers to the visual observation of a species that was not calling. A dash (-) indicates that a species was not heard or observed at a site. Refer to the Methods section for survey methodology. Refer to Appendix 4.0 for detailed site information and Appendix 4.2 for full scientific and common names.

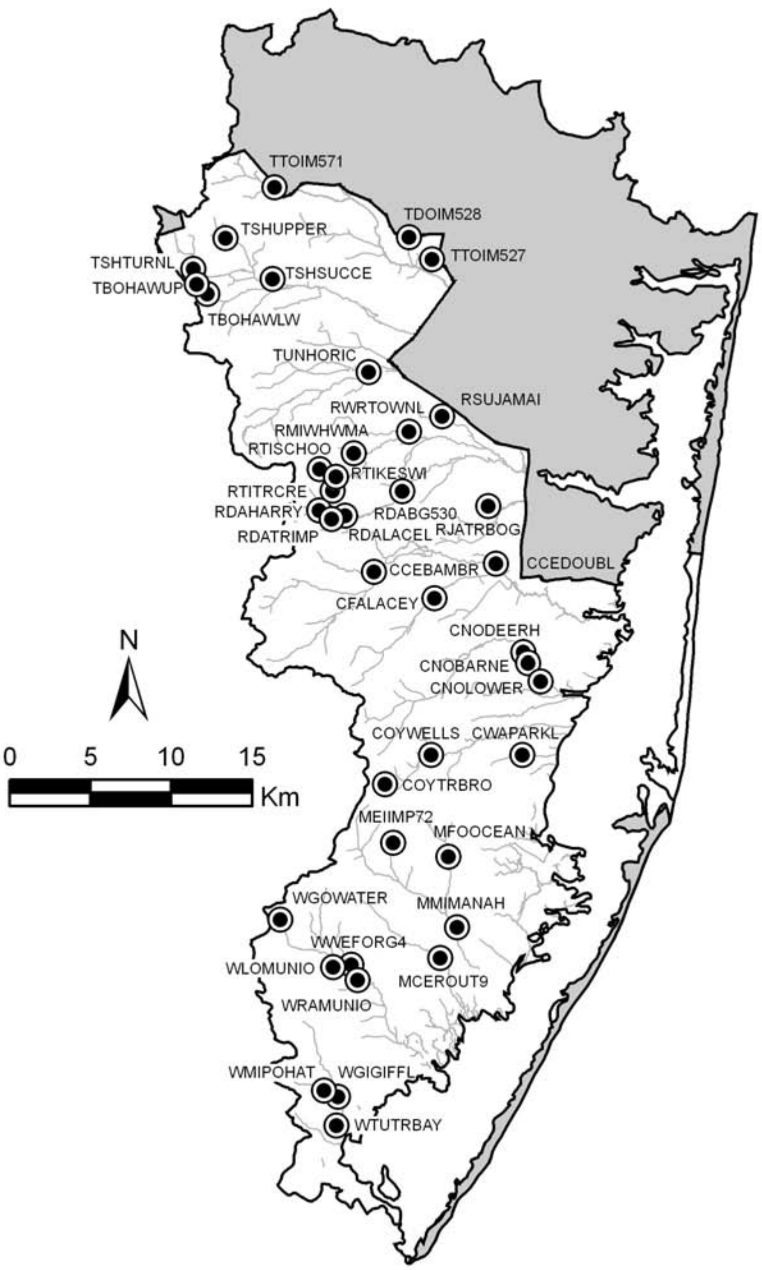
Site Code	Observer(s)	Date	Time	Weather Code	Air Temp. (°C)	Rel. Hum. (%)	*B. w. fowleri*	*H. andersonii*	*H. versicolor*	*P. c. crucifer*	*R. catesbeiana*	*R. c. clamitans*	*R. utricularia*	*R. virgatipes*
CCEBAMBR	JFB	06/18/03	11:20 PM	0	17.5	96	-	-	-	-	-	-	-	3
CCEBAMBR	JFB	06/30/03	10:00 PM	0	24.0	86	2	-	-	-	1	1	-	3
CCEDOUBL	JFB	06/10/03	11:50 PM	0	17.0	100	1	2	-	-	2	2	2	-
CCEDOUBL	JFB	06/30/03	9:35 PM	0	24.0	86	-	2	-	-	-	1	-	4
CFALACEY	JFB	06/18/03	11:28 PM	0	17.0	100	-	2	-	-	-	1	-	-
CFALACEY	JFB	06/30/03	10:15 PM	0	24.0	86	-	1	-	-	-	1	-	-
CNOBARNE	JFB	06/30/03	10:50 PM	0	23.0	92	2	-	-	-	-	2	-	2
CNODEERH	JFB	06/18/03	11:45 PM	0	17.0	100	-	-	-	-	2	1	-	-
CNOLOWER	JFB	06/30/03	10:56 PM	0	23.0	92	-	-	-	-	2	2	-	-
COYTRBRO	JFB/RAZ	06/25/03	12:05 AM	0	22.0	84	-	1	-	-	-	2	-	-
COYTRBRO	JFB	06/30/03	11:30 PM	0	21.0	92	-	1	-	-	-	2	-	-
COYWELLS	JFB/RAZ	06/25/03	12:25 AM	0	22.0	84	-	-	-	-	-	2	-	-
COYWELLS	JFB	07/09/03	11:20 PM	5	19.5	100	-	-	-	-	-	1	-	-
CWAPARKL	JFB	06/18/03	12:00 AM	0	17.0	100	-	-	-	-	-	2	-	-
CWAPARKL	JFB/RAZ	06/25/03	12:50 AM	0	22.0	84	-	-	-	-	-	2	-	-
CWAPARKL	JFB	06/30/03	11:05 PM	0	23.0	92	2	-	-	-	-	2	-	-
MCEROUT9	JFB/RAZ	06/25/03	10:05 PM	0	22.5	80	1	-	-	-	-	-	-	-
MCEROUT9	JFB	07/09/03	9:25 PM	2,4,5	20.5	92	-	-	-	-	-	-	-	-
MEIIMP72	JFB/RAZ	06/25/03	11:45 PM	0	22.0	84	1	-	-	-	1	-	-	-
MEIIMP72	JFB	07/09/03	9:57 PM	5	20.0	100	-	-	-	-	V	-	-	-
MFOOCEAN	JFB/RAZ	06/25/03	11:10 PM	0	24.0	76	2	-	-	-	2	-	-	-
MMIMANAH	JFB/RAZ	06/25/03	10:25 PM	0	22.5	80	-	-	-	-	-	2	-	-
MMIMANAH	JFB	07/09/03	9:35 PM	2,4,5	20.0	100	-	-	-	-	-	-	-	-
RDABG530	JFB	06/30/03	9:05 PM	0	24.0	86	1	4	-	-	1	2	-	-
RDAHARRY	JFB	06/10/03	12:10 AM	0	17.0	100	1	-	-	-	2	-	-	-
RDALACEL	JFB	06/10/03	12:42 AM	0,4	17.5	96	1	-	-	-	2	2	-	4
RDATRIMP	JFB	06/10/03	12:20 AM	0,4	17.5	96	1	2	-	-	1	4	1	4
RJATRBOG	JFB	06/18/03	10:20 PM	2	18.0	100	2	-	-	2	-	-	-	4
RMIWHWMA	JFB	06/10/03	11:00 PM	0,4	19.0	82	2	1	-	-	2	2	2	4
RSUJAMAI	JFB	06/10/03	10:02 PM	0	19.0	74	4	-	1	-	2	-	-	-
RTIKESWI	JFB	06/10/03	10:47 PM	1,4	19.0	82	-	-	-	-	-	-	-	-
RTIKESWI	JFB	06/30/03	8:50 PM	0	24.0	86	-	-	-	-	-	-	-	-
RTISCHOOL	JFB	06/10/03	10:40 PM	1,4	19.0	82	2	-	-	-	2	-	-	-
RTITRCRE	JFB	07/09/03	11:45 PM	5	19.5	100	-	-	-	-	1	-	-	-
RWRTOWNL	JFB	06/18/03	9:40 PM	2	18.0	100	-	-	-	1	-	-	-	3
TBOHAWLW	JFB	06/09/03	8:55 PM	0,4	21.0	76	2	-	4	1	2	-	1	-
TBOHAWUP	JFB	06/09/03	9:10 PM	0,4	19.0	86	2	-	2	-	2	4	1	4
TDOIM528	JFB	06/09/03	12:35 AM	0	19.0	82	2	-	-	-	2	-	2	-
TSHSUCCE	JFB	06/09/03	10:35 PM	0	19.5	82	2	-	-	-	-	2	2	4

Site Code	Observer(s)	Date	Time	Weather Code	Air Temp. (°C)	Rel. Hum. (%)	*B. w. fowleri*	*H. andersonii*	*H. versicolor*	*P. c. crucifer*	*R. catesbeiana*	*R. c. clamitans*	*R. utricularia*	*R. virgatipes*
TSHTURNL	JFB	06/09/03	9:25 PM	0	19.0	92	4	-	-	-	2	2	-	-
TSHUPPER	JFB	06/09/03	10:10 PM	0	19.0	86	4	-	-	-	-	-	-	3
TTOIM527	JFB	06/09/03	12:56 AM	0	19.0	82	-	-	-	-	2	4	-	-
TTOIM571	JFB	06/09/03	11:00 PM	0	19.0	92	3	-	2	-	2	-	-	-
TUNHORIC	JFB	06/10/03	9:30 PM	1,4	19.0	74	4	2	-	-	-	-	-	4
WGIGIFFL	JFB	06/23/03	9:55 PM	0	20.0	82	-	-	-	-	2	2	-	-
WGOWATER	JFB/RAZ	06/25/03	8:55 PM	0	23.0	80	2	2	-	-	-	1	-	-
WGOWATER	JFB	07/09/03	8:55 PM	2,4	20.5	92	-	2	-	-	-	-	-	-
WLOMUNIO	JFB	06/23/03	11:05 PM	0	17.5	96	3	2	-	-	-	-	-	-
WLOMUNIO	JFB/RAZ	06/25/03	9:05 PM	0	23.0	80	-	-	-	-	-	1	-	-
WMIPOHAT	JFB	06/23/03	10:30 PM	0	19.0	82	2	-	-	-	1	-	-	-
WRAMUNIO	JFB	06/23/03	11:20 PM	0	17.5	96	-	2	-	-	-	4	2	-
WRAMUNIO	JFB/RAZ	06/25/03	9:25 PM	0	22.5	80	-	2	-	-	-	2	-	-
WTUTRBAY	JFB	06/23/03	10:20 PM	0	20.0	82	2	-	-	-	-	2	-	-
WTUTRBAY	JFB	07/09/03	8:35 PM	2,4	20.5	96	1	-	-	-	-	1	-	-
WWEFORG4	JFB	06/23/03	12:15 AM	0	18.0	100	-	1	-	-	-	4	2	-
WWEFORG4	JFB/RAZ	06/25/03	9:35 PM	0	22.5	80	1	2	-	-	-	2	-	-

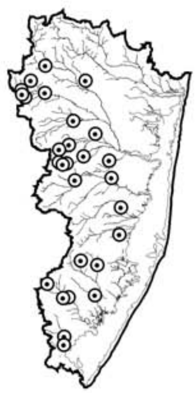
Appendix 4.2. Common and scientific names for eight anuran species heard during vocalization surveys in the Barnegat Bay Watershed. Nomenclature follows Conant and Collins (1998).

Scientific Name	Common Name
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Hyla versicolor	northern gray treefrog
Pseudacris c. crucifer	northern spring peeper
Rana virgatipes	carpenter frog
Rana clamitans melanota	green frog
Rana utricularia	southern leopard frog
Rana catesbeiana	bullfrog

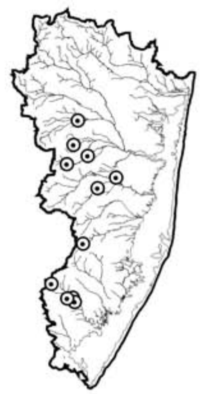
APPENDIX 4.3. ANURAN-DISTRIBUTION MAPS



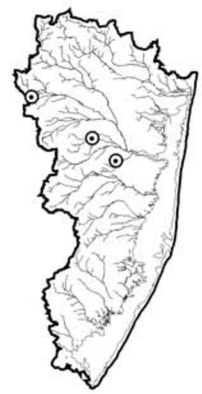
Location of 40 anuran-survey sites in the Barnegat Bay Watershed. Shaded areas are outside the Pinelands National Reserve. Distribution maps on the following pages show where each anuran species was present.



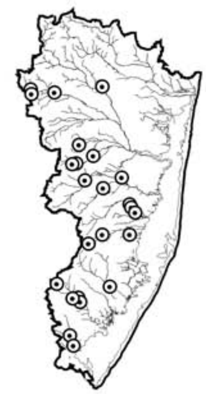
Bufo woodhousii fowleri
Fowler's toad



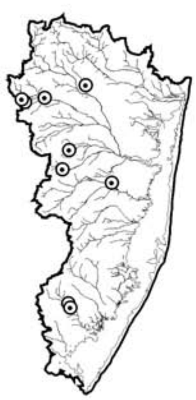
Hyla andersonii
Pine Barrens treefrog



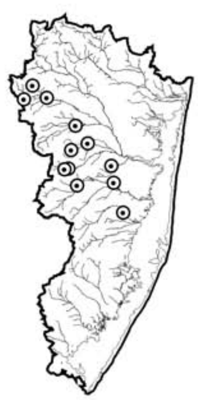
Pseudacris c. crucifer
northern spring peeper



Rana clamitans melanota
green frog

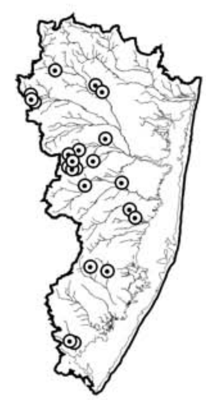


Rana utricularia
southern leopard frog



Rana virgatipes
carpenter frog

Hyla versicolor
northern gray treefrog



Rana catesbeiana
bullfrog