DELAWARE NATIONAL ESTUARINE RESEARCH RESERVE

ESTUARINE PROFILE

Prepared by

Delaware Department of Natural Resources and Environmental Control
Delaware National Estuarine Research Reserve
818 Kitts Hummock Rd.
Dover, DE 19901

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PREFACE

The Delaware National Estuarine Research Reserve (DNERR) is pleased to have developed the DNERR Site Profile. This technical document characterizes the environmental features and natural resources of the DNERR's two component sites, the Upper Blackbird Creek Reserve and the Lower St. Jones River Reserve. The Site Profile is intended to highlight or summarize the geography, environmental setting, ecology and biology, living resources, historical and cultural resources, and environmental stressors of the DNERR.

This document should be of interest to estuarine scientists and researchers (either agency-based or academic-affiliated) stationed on-site or visiting the Reserve; to natural resource or land managers; to environmental educators and undergraduate or graduate students; to coastal policy decision makers; and to technically-oriented members of the public who enjoy studying natural history or helping wisely manage our coastal resources. The information contained herein should be of value in developing further scientific studies and applied management investigations.

The DNERR was formed in 1993 from private lands and very little site-specific information existed for either DNERR component site at that time. As such, in our charge to review the existing state of environmental and ecological knowledge about the DNERR, it was first necessary to generate such knowledge. This was done in a series of on-site characterization studies performed from 1993 to 1997, and then supplemented with pertinent information about environmental conditions or natural resources generic to the lower Delaware Estuary.

The Site Profile is divided into two principal parts: 1) a Site Profile Overview of 19 text pages that should provide the reader, after about a 30-minute investment, with a thorough synopsis of the Reserve's natural features; and 2) the Comprehensive Site Profile, which with aid of expanded text, references, maps, figures and tables provides more technical detail about each subject. For those readers interested in further pursuing any topic, additional technical information can be found in the Literature Cited section.

Primary support for developing and preparing the DNERR Site Profile came from dedicating each year to site characterization work (over a 5-year period) a portion of the annual DNERR site operations grant, which has been awarded every year since 1993 by the National Oceanic and Atmospheric Administration. Completion of the Site Profile fulfills an important regulatory requirement of Section 315 (National Estuarine Research Reserve System) of the Coastal Zone Management Act of 1972 (as amended by the Coastal Zone Protection Act of 1996).

SITE PROFILE OVERVIEW

Introduction

The Delaware National Estuarine Research Reserve (DNERR) has been established as described in:

> 1) *Delaware National Estuarine Research Reserve – Final Environmental Impact Statement/Draft Management Plan* (DNREC, 1992)
>
> 2) *Delaware National Estuarine Research Reserve – Final Management Plan* (DNREC, 1993a)

The DNERR was designated by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) in 1993 as the 22nd Reserve in the National Estuarine Research Reserve System (NERRS). The DNERR is managed by the Delaware Department of Natural Resources and Environmental Control (DNREC). The primary administrative and many program functions are performed by the Delaware Coastal Programs Section (DCPS) in DNREC's Division of Soil and Water Conservation, which also administers the Delaware Coastal Management Program (DCMP). Additionally, DNREC's Division of Parks and Recreation directly participates in the DNERR for many environmental education functions, as does DNREC's Division of Fish and Wildlife for estuarine research and resource management functions.

The goals and objectives of the DNERR program focus on resource protection and conservation, estuarine research, and environmental education. Resource protection and conservation are achieved through acquiring key properties that include marshland and upland buffers, entering cooperative agreements with property owners, and utilizing conservation-oriented land management practices. Estuarine research and environmental education activities associated with the DNERR will help to better protect, conserve and manage the DNERR sites. More importantly, they will provide better land and natural resource stewardship within the DNERR's two watersheds and throughout Delaware's coastal zone, as well as on regional and national scales in association with the nationwide NERRS program. A key to making both the DNERR and NERRS work is providing, in a timely manner, pertinent estuarine research information to coastal management decision-makers.

The DNERR Site Profile provides characteristic descriptions of abiotic and biotic environmental features for the DNERR sites. Since all DNERR lands were private property without any history of environmental monitoring or research, very little site-specific information existed prior to site designation in 1993. As such, it was first necessary to conduct a series of field studies and inventories to characterize basic environmental features important in any coastal area. Starting in 1993 and continuing through 1997, field studies were conducted on DNERR lands to examine for the first time features such as wetlands vegetation cover, aquatic macroinvertebrate communities, finfish populations, waterbird populations, phytoplankton and zooplankton assemblages, tidal hydrography, and water quality. In preparing the DNERR Site Profile, this original information was then combined with more generic information from the existing literature concerning Delaware's coastal zone and the Delaware Estuary (Delaware River and Bay). To perform much of the field characterization work and to help develop the Site Profile, the DNERR contracted with two environmental consulting companies, Wetlands Research Services (Newark, DE) and Environmental Consulting Services, Inc. (Middletown, DE).

Geographic Setting

Two component sites compose the DNERR, with both sites managed under identical auspices – the Upper Blackbird Creek Reserve (southern New Castle County, between Odessa and Smyrna), and the Lower St. Jones River Reserve (east-central Kent County, southeast of Dover)(see Figure 1 in Comprehensive Site Profile). The DNERR sites are subestuaries of the Delaware River/Bay estuary, with both sites characterized by tidal rivers or creeks traversing extensive tidal wetlands. The two sites provide good representation of tide-marsh-dominated estuaries in NOAA's Middle Atlantic subregion of the Virginian biogeographic region.

Upper Blackbird Creek DNERR Reserve

The more landward Upper Blackbird Creek Reserve is 477 ha (1180 ac) in designated size, distributed along 9.2 km (5.7 mi) of low-salinity brackish or freshwater tidal creek, starting about 9.3 km (5.8 mi) upstream from where Blackbird Creek empties into the lower Delaware River (see Figure 2 in Comprehensive Site Profile). The Blackbird Reserve contains 50 parcels of land held by 46 private landowners, plus the DNERR and one other state agency. Within the Blackbird Reserve's designated boundaries, about 85.8 ha (212 ac) of tidal marshes, upland fields, woodlots, and croplands were purchased by the DNERR in 1990, but the remaining majority of the Reserve is still in private ownership. An additional 74.1 ha (183 ac) of tidal marsh, woodlands, and croplands, across Blackbird Creek from the DNERR property and within the Reserve's designated boundaries, was purchased in 1996 by DNREC's Division of Fish and Wildlife (as part of the Division's Cedar Swamp Wildlife Area), and is available for use in DNERR activities. Much of the expansive tidal marshes and upland borders along Lower Blackbird Creek, downstream of the Upper Blackbird Creek Reserve's designated boundaries, are owned and managed by the Division of Fish and Wildlife. This area primarily consists of a large parcel known as The Rocks (which is also part of the Cedar Swamp State Wildlife Area). Upstream of the Reserve, in non-tidal areas west of Rt. 13, are extensive areas of forested wetlands containing unique coastal plain ponds, much of it within Blackbird State Forest, which is owned and managed by the Delaware Department of Agriculture's Forestry Section. Blackbird Creek's watershed is still primarily agricultural or forested, although low-density residential development is increasing.

Lower St. Jones River DNERR Reserve

The more seaward Lower St. Jones River Reserve is about 1518 ha (3750 ac) in designated size, distributed along 8.8 km (5.5 mi) of medium-salinity tidal river situated at the lower end of the St. Jones River watershed, with the river discharging into mid-Delaware Bay (see Figure 3 in Comprehensive Site Profile). The St. Jones Reserve contains 35 parcels of land held by 23 private landowners, plus the DNERR and one other state agency. Within the St. Jones Reserve's designated boundaries, about 282.8 ha (698.5 ac) of tidal marshes, upland fields, woodlots, and croplands were purchased or protected by the DNERR in 1991-92 [with 174.7 ha (431.3 ac) purchased through fee-simple acquisition, and 108.1 ha (267.2 ac) protected through conservation easement], but the remaining majority of the Reserve is still in private ownership. The Lower St. Jones River Reserve will house on the DNERR property the new DNERR education/research facility (containing a small but well equipped laboratory for DNERR researchers), scheduled for completion in mid-1999; a marsh boardwalk for interpretive and research activities has already been constructed on the DNERR property. Adjacent to the Lower St. Jones River Reserve on its eastern side is the Ted Harvey Conservation Area, owned and managed by DNREC's Division of Fish and Wildlife, consisting of 817 ha (2019 ac) of woodlands, upland fields, croplands, freshwater ponds and wetlands, coastal wetland impoundments, and Delaware Bay shoreline. While the Ted Harvey Conservation Area is not within the DNERR's designated boundaries, it is nonetheless available through cooperative arrangements with the Division of Fish and Wildlife for use in DNERR research and educational activities. The Division of Fish and Wildlife's Roberts Tract, a 71.2 ha (176 ac) parcel of the Little Creek State Wildlife Area, borders the St. Jones Reserve at its western end; in conjunction with the Division's Ted Harvey Conservation Area, the Roberts Tract provides conservation-oriented land ownership on both upstream and downstream ends of the St. Jones Reserve. The John Dickinson Plantation and Mansion, owned and managed by the Delaware Division of Historical and Cultural Affairs, provides another 106.4 ha (262.8 ac) of protected area within the Reserve's designated boundaries, adjacent to the DNERR property's western border. A small-boat ramp and fishing pier at Scotton Landing, owned and managed by the Division of Fish and Wildlife, provides good boat and water access to the main channel of the St. Jones River towards the Reserve's western end. On its far eastern end, the Lower St. Jones River Reserve also contains about 1036 ha (2560 ac) of Delaware Bay bottom and nearshore waters, running for 3.2 km (2.0 mi) along the Ted Harvey Conservation Area's bay shoreline and extending outward 3.2 km (2.0 mi) into the open bay. The St. Jones River watershed has significant development in upstream non-tidal areas, where urbanized Dover (Delaware's state capital) dominates the middle and upper watershed. However, downstream portions of the St. Jones River watershed, where the Lower St. Jones River Reserve is located, are still primarily agricultural, with the Dover Air Force Base nearby. The two DNERR component sites are about 32 km (20 mi) apart.

Human Population

The Blackbird Creek watershed encompasses 80 sq. km (31 sq. mi) inhabited by 4200 people (1990 census), for a population density of 52.5/sq. km (135.5/sq. mi). The St. Jones River watershed encompasses 233 sq. km (90 sq. mi) inhabited by 56,000 people (1990 census), for a population density of 240.3/sq. km (622.2/sq. mi).

Environmental Setting

Geology, topography, soils, climate

Both DNERR sites are in the gently-sloping Atlantic Coastal Plain, characterized by thick layers of unconsolidated sediments or semi-consolidated sedimentary rocks. The DNERR is on the Delmarva Peninsula, a region of drastic changes in relative sea-level over geological time. At many locations in coastal Delaware, a Holocene marine transgression of tidal wetlands into upland areas is now occurring, associated with an ongoing relative sea-level rise estimated to be from 12.5-40 cm/100 yrs (4.9-15.7 in/100 yrs). A graduate study is nearing completion by a DNERR Graduate Research Fellow who is trying to determine the extent and magnitude of any localized anthropogenic effects on relative sea-level rise in the DNERR and other Delaware Bay subestuaries. Discussions are currently underway with the U.S. Geological Survey to establish Sediment Elevation Tables (SETs) at the DNERR, to measure changes in marsh surface elevations and sediment accretion rates.

Topographic relief in the Upper Blackbird Creek Reserve ranges from sea-level up to 25 m (82 ft), and in the Lower St. Jones River Reserve is from sea-level to 22 m (72 ft). The DNERR sites contain broad tidal wetlands behind narrow washover dune barriers, or are landward of broad bayside tidal flats. Most DNERR tidal wetlands are regularly flooded and range from salty to brackish in salinity, and contain tide marsh soils characterized by thick, mucky peats containing variously stratified layers of sand or clay. Upland soils in the DNERR range from well- or moderately-drained sandy loams to poorly-drained sandy clay loams rich in organic matter. Unconfined and confined aquifers underlay DNERR lands, all part of several regional aquifers important for providing groundwater for drinking and irrigation; there is great concern for keeping contaminants out of these aquifers.

The DNERR's temperate climate is typical of mid-Atlantic coastal areas, having well-defined seasons that are humid, warm/hot in the summer (average maximum July temperature = 31.7 ^{o}C or 89^{o}F) and cool/cold in winter (average minimum January temperature = 4.4^{o}C or 24^{o}F). Annual precipitation is about 117 cm/yr (46 in/yr), and is fairly uniformly distributed throughout the year. Average seasonal snowfall is 40 cm/yr (16 in/yr). Prevailing winds are from the west/northwest throughout most of the year, but become south/southwest in summer. Hurricanes affecting Delaware occur about once per year from August to October, but usually do not involve direct hits, and hence usually do not do great damage. However, winter coastal storms ("nor'easters") occur more frequently, often accompanied by significant coastal flooding and shoreline erosion. The DNERR has established a Campbell weather station to NOAA specifications at the Lower St. Jones River Reserve. The station is operated by DCPS staff, and continuously measures air temperature, relative humidity, wind speed and direction, precipitation, barometric pressure, and photosynthetically active radiation (PAR). Additionally, an atmospheric deposition sampler has been deployed to monitor pH, nitrogen and other contaminants in rainwater.

Tidal hydrography (main channels)

Similar to other areas along the Atlantic Coast, both DNERR sites are subject to semi-diurnal tides, with about 12.4 hours between two consecutive high tides or two consecutive low tides. Mean tide range in Lower Blackbird Creek is about 1.7m (5.65 ft), with spring tide range averaging 1.92 m (6.3 ft). Mean tide range in Lower St. Jones River is about 1.5 m (4.8 ft), with spring tide range averaging 1.7 m (5.7 ft). Tide ranges in both systems are attenuated proceeding upstream, ranging from 50-80% decreases in tidal amplitudes dependent upon distance upstream and lunar cycle stage (i.e. spring vs. neap tides). Tide wave progression from the mouth of Blackbird Creek or St. Jones River to upstream stations near head of tide in either system takes about two to three hours, dependent upon lunar cycle stage. Time lags between peak tide stands (high or low) and slack currents (high or low) at stations in seaward ends of either system are about one hour apart, again dependent upon lunar cycle stage.

Channel (creek) widths along the main stem of Blackbird Creek from seaward to landward ends typically range from 75-110 m (246-361 ft), without a very noticeable decrease in channel widths as one proceeds landward. Channel (river) widths along the main stem of St. Jones River typically range from 40-90 m (131-295 ft), with wide widths often occurring far upstream. Expansive mudflats at low tides are often associated with the main channels in upstream areas of both systems. Low tide mid-channel depths in Blackbird Creek decrease proceeding landward, ranging from 5.7 m (18.7 ft) in lower reaches to only 0.5 m (1.6 ft) in upper reaches. Low tide mid-channel depths in St. Jones River are similarly deep in lower reaches (5.5 m or 18.0 ft deep), but in many places are still relatively deep far upstream (2.7 m or 8.9 ft deep at the St. Jones River's "upper station").

Mid-channel, mid-depth maximum current velocities in both Blackbird Creek and St. Jones River occur around mid-flood (low slack water + three hrs) or mid-ebb (high slack water + three hrs) tides, with velocity dependent in part upon lunar cycle stage. For Blackbird Creek's lower (seaward) station these maximum current velocities range from 50-70 cm/sec (1.6-2.3 ft/sec), while for the St. Jones River's lower station these maximum velocities range from 20-40 cm/sec (0.7-1.3 ft/sec). There were no observations of estuarine bi-layered flow in either system, and it is probable that these relatively narrow, shallow systems have unidirectional channelized flow from top to bottom at almost all times during any given tide cycle. However, some bi-layered flow might occur during short periods of time near peak stand/slack water periods, especially near each system's seaward end.

Water quality (main channel tidal waters)

Water quality parameters in Blackbird Creek and St. Jones River are being measured at an upper-reach station in Blackbird Creek (Blackbird Landing) and a middle-reach station in St. Jones River (Scotton Landing), using continuously recording water quality monitors (YSI Model 6000 data loggers). Parameters currently being measured include water depth, water temperature, salinity, pH, dissolved oxygen (DO), and turbidity. Many of these data are currently available over the Internet at NERRS Central Data Management Office, at the following address – HTTP:// INLET.GEOL.SC.EDU/CDMOHOME. HTML. Depending upon technological development and operational refinement of monitoring sensors, chlorophyll-a and ammonia may be measured in the future. The water quality data loggers are being operated by DCPS staff and DNERR Graduate Research Fellows.

Maximum average daily water temperature at both Reserve sites occurs in August at 26°C (78.8°F), and discrete summertime water temperatures can be as high as 30°C (86°F). During late winter months, water temperatures sometimes go below freezing, and during severe winters both systems' main channels can ice over. Water temperatures can vary from 2-4°C over any given tide cycle, dependent upon tide stage, passing weather systems, and stormwater runoff events.

Water turbidity at the Upper Blackbird Creek and middle St. Jones River water quality monitoring stations typically ranges from 50-100 ntu, making for generally murky waters. Occasional turbidity values as high as 1000 ntu have been observed, usually associated with storm events and heavy runoff.

Dissolved oxygen (DO) concentrations at the Upper Blackbird Creek and middle St. Jones River water quality monitoring stations are clearly affected by time of year, time of day, and stage of tide cycle. Colder waters during winter months hold higher amounts of DO, and during times of high phytoplankton productivity (e.g. daytime during late spring), oxygen supersaturation (>100%) can occur. On any given tide cycle, lowest DO values usually occur near low tide. DO percent saturation usually ranges from 30 to 100% or above, but there are occasional hypoxic events down to almost 0% saturation, particularly in the St. Jones River during mid- to late summer. Annual mean DO concentration for Blackbird Creek's upper-reach was 8.7 mg/l, with the average DO concentration declining to 6.0 mg/l in summer months. Annual mean DO concentration for St. Jones River's middle-reach was 6.5 mg/l, with some summer DO concentrations dropping below 4.0 mg/l, a point where fish survival starts to become impaired.

Annual pH values at Upper Blackbird Creek and middle St. Jones River water quality monitoring stations are approximately neutral for both sites, with Blackbird Creek being slightly more acidic. pH values for St. Jones River had an annual mean of 7.02, with ranges from 6.01-8.87. Values of pH for Blackbird Creek had an annual mean of 6.76, with ranges from 5.70-8.67. pH values are highly influenced by tide stage (high vs. low) and lunar stage (spring vs. neap), as well as temporary runoff events.

Salinity at the Upper Blackbird Creek and middle St. Jones River water quality monitoring stations are highly influenced by tide stage (high vs. low) and lunar stage (spring vs. neap), as well as recent rainfall and runoff events. Typical salinities in Upper Blackbird Creek range from 0.1-3.5 ppt, and as such most of the Upper Blackbird Creek Reserve can be classified as a combined limnetic (<0.5 ppt) and oligohaline (0.5-5.0 ppt) system. Typical salinities in the middle-reach of the St. Jones River ranged from as low as 1.0 ppt up to over 20 ppt, but for the most part the Lower St. Jones River Reserve can be classified as a mesohaline (5-18 ppt) system.

Preliminary analyses of dissolved nutrient concentrations and BOD loads for stations in lower, middle and upper tidal reaches of Blackbird Creek and St. Jones River showed little differences between Reserve sites for annual concentration ranges of dissolved phosphorus, total phosphorus, ammonia nitrogen, total Kjeldahl nitrogen, and BOD loads. However, the annual range of chlorophyll-a/pheophytin-a concentrations was higher in the St. Jones River than Blackbird Creek, perhaps reflecting differential productivity potentials of phytoplankton assemblages that dominate the higher-salinity St. Jones River versus lower-salinity Blackbird Creek.

Watershed land-use cover

The Blackbird Creek watershed is still largely rural, having land-use cover that is about 39% agriculture, 22% forestland, 25% wetlands, and 4% open water, with only about 10% of the watershed converted to development (impervious surfaces). The St. Jones River watershed is also still somewhat rural, but the Dover area (in the watershed's middle and upper non-tidal reaches) has been extensively and intensively developed. The St. Jones River watershed has land-use cover that is about 48% agriculture, 10% forestland, 14% wetlands, and 3% open water, with the remaining 25% converted to development.

Ecological/Biological Setting

Tidal datums and coastal marsh vegetation zonation

Typical of most tidal wetlands, the types, locations and patterns of coastal marsh vegetation in the DNERR are highly influenced by hydroperiod (frequency, height and duration of tidal inundations) and salinity. Emergent marsh grasses do not grow below mean tide level (MTL), and habitat in the DNERR between MTL and mean low water (MLW) primarily tends to be non-vegetated, muddy tidal channel slopes or tidal mudflats. Going below MLW, especially below the lowest low tides that occur during a lunar cycle, essentially leaves the intertidal zone descending into permanently inundated subtidal habitats where benthic macroalgae or submerged aquatic vegetation might grow. Going above MTL, the intertidal zone from MTL up to mean high water (MHW) is considered to be emergent "low marsh," and in more saline areas of the DNERR is dominated by saltmarsh cordgrass (*Spartina alterniflora*). The "low marsh" is completely inundated by high tides at a frequency of at least once per day. "High marsh" emergent vegetation consists of more diverse plant assemblages growing in more elevated intertidal areas of the marsh, from above MHW up to the highest extremes of spring tide mean high water (MHHW), which occur around times of full or new moons. The approximate location of MHW level is often observable in the field, since this is the elevation where saltmarsh cordgrass (*S. alterniflora*) starts to become non-dominant surface cover, being replaced by other marsh plant assemblages. The mixed-vegetation "high marsh" is inundated at a frequency of less than once per day, and more elevated areas of the "high marsh" are flooded only a few times per month, at times of spring tides. Upland terrestrial vegetation starts above the MHHW level. Upland marsh borders can occasionally still be flooded by estuarine tidal waters during coastal storms, especially if the storms occur during spring tides. If storm-induced flooding of saline waters in upland areas lasts long enough, terrestrial vegetation is often killed.

Tidal wetlands emergent vegetation communities

Vegetation cover in both DNERR sites is dominated by expansive areas of emergent tidal wetlands species. In the Lower St. Jones River Reserve, saltmarsh cordgrass (*Spartina alterniflora*) occupies about 62% of the

Reserve, primarily occurring in its short-form, with tall-form plants found along channel edges. Other important associations include common reed (*Phragmites australis*) along marsh upland borders; marsh shrubs (marsh elder, *Iva frutescens* and groundselbush, *Baccharis halimifolia*) in higher areas of the marsh; scattered stands of salt hay (saltmeadow cordgrass, *Spartina patens* and saltgrass, *Distichlis spicata*) above MHW; and big cordgrass (*Spartina cynosuroides*) along channel edges. Open water habitat in the St. Jones Reserve in the form of marsh pools/pannes occupies about 7% of the marsh surface, although the nearby Logan Lane Impoundment in the Ted Harvey Conservation Area creates several hundred hectares/acres of open water managed habitat.

Emergent tidal wetlands in Upper Blackbird Creek Reserve are also dominated by saltmarsh cordgrass but to a much lesser extent, covering only about 29% of the Blackbird Reserve. Wetlands vegetation in Upper Blackbird Creek tends to be more diverse than in the Lower St. Jones River, reflecting the Blackbird's lower salinities. Common reed is abundant, especially toward the more seaward end of the Reserve, where it grows across the marsh plain. Marsh shrubs are found in higher areas of the marsh, often mixed with swamp rose mallow (*Hibiscus palustris*) and buttonbush (*Cephalanthus occidentalis*). A low-marsh mixed association of deep water emergents is found along channel edges, consisting of pickerelweed (*Pontederia cordata*), arrow arum (*Peltandra virginica*), yellow pondweed (*Nuphar lutea*), and marshpepper smartweed (*Polygonum hydropiper*). Tidal swamp forest is common along Upper Blackbird Creek, dominated by red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), sweet gum (*Liquidambar styraciflua*), and green ash (*Fraxinus pennsylvaticus*). The Upper Blackbird Creek Reserve is characterized by more open water areas than the Lower St. Jones River Reserve, with open water habitat occupying about 14% of the marsh, plus having expansive tidal mudflats at low tides that cover about 26% of the marsh plain.

The DNERR has three minor emergent wetland communities that have important wildlife values, particularly in Upper Blackbird Creek. Cattails (*Typha* spp.) are desirable habitats for muskrats and other marsh animals, and often contain other valuable plants such as saltmarsh waterhemp (*Acnida cannabina*) and rice cutgrass (*Leersia oryzoides*). American threesquare (*Scirpus americanus*) is a rush found in brackish marshes that is also preferred muskrat habitat. Wild rice (*Zizania aquatica*) stands are important food sources for birds.

Upland vegetation assemblages

Upland areas of the DNERR that are not in agricultural cropland or old fields are covered by mixed deciduous hardwood forests that have been cut several times since European settlement. Remaining upland forest cover is not very contiguous in extent, essentially being fragmented woodlots scattered among agricultural fields, or along drier slopes and tops of riparian corridors. Dominant upland trees include tulip poplar (*Liriodendron tulpifera*), American beech (*Fagus grandifolia*), white oak (*Quercus alba*), southern red oak (*Q. falcata*), various hickories (*Carya* spp.), black cherry (*Prunus serotina*), American holly (*Ilex opaca*), and sassafras (*Sassafras albidum*).

Plant species of special concern

Upper Blackbird Creek marshes were found to have 113 plant species, while the more saline St. Jones River marshes had 66 plant species. Four plant species of special concern (due to their statewide rarity) were found in the Upper Blackbird Creek Reserve – marsh marigold (*Caltha palustris*), rough avens (*Geum virginiana*), Canada lily (*Lilium canadense*), and nodding bur-marigold (*Bidens cernua*). A fifth plant species of special concern, swamp milkweed (*Asclepias incarnata*), is historically known to occur in Upper Blackbird Creek, but has not been found for an extended period.

Many more aquatic or wetland plant species of special concern are found nearby in non-tidal coastal plain ponds ("Delmarva Bays") west of the Blackbird Reserve, in the forested wetlands of Blackbird State Forest.

Expansion/incursion of common reed (Phragmites) and its control

Expansion of common reed (*Phragmites australis*) over the past 50 years in Delaware and other areas the mid-Atlantic and southern New England has become a serious problem, with extensive monotypic stands seriously degrading coastal wetlands for wildlife habitat values, and possibly adversely affecting estuarine detrital food webs. It is still not well understood why *Phragmites* has undergone such aggressive expansions and incursions, although several hypotheses have been advanced, including anthropogenic marsh disturbances involving wetlands dewatering or marsh surface spoil deposition, increased nutrient loading of tidal waters, and possible introduction of a more aggressive European strain of this species. The most practicable control technique developed to date involves application of glyphosate herbicide followed by prescribed burning.

Expansion of *Phragmites* cover within the DNERR's tidal wetlands is a serious management concern, especially in the lower salinity Upper Blackbird Creek Reserve. Within Lower Blackbird Creek marshes, immediately downstream from the Upper Blackbird Creek Reserve, the Delaware Division of Fish and Wildlife has treated over 390 ha (963 acres) of *Phragmites*-infested marsh on The Rocks parcel (part of Cedar Swamp State Wildlife Area). Private landowners have treated an additional several hundred hectares (acres) in the Lower Blackbird Creek basin, in concert with the Division's cost-share *Phragmites* control program for private landowners.

Other vegetation assemblages (edaphic algae and SAV)

Edaphic microalgae on marsh surfaces play important roles in tidal wetlands for primary production, nutrient cycling, and marsh food web energetics, particularly in winter and early spring when emergent marsh grass production is greatly reduced.

The role of submerged aquatic vegetation (SAV) is much less in the DNERR, due to the lack of shallow lagoon habitats that favor SAV growth, and also to the turbid, murky waters of both sites' tidal channels. While SAV is or has been important in many coastal areas, including Delaware's Inland Bays in Sussex County, SAV has probably never been a major component of estuarine habitat in the lower Delaware Estuary, possibly due to lack of suitable bathymetry or bottom sediments for its widespread establishment, and in part due to high wave-energy environments along Delaware Bay shorelines. There is also some debate that perhaps Delaware Bay waters have always naturally been too turbid to allow widespread SAV establishment. The most important SAV species found in Delaware Bay's tidal wetlands is widgeongrass (*Ruppia maritima*), which when encountered is usually confined to small salt marsh ponds that have permanent water, or to larger man-made coastal impoundments.

Phytoplankton assemblages

Phytoplankton in Blackbird Creek are represented by 42 taxa, with the diatoms *Skeletonema, Melosira,* and *Nitzchia* being the most abundant taxa, followed by blue-green algae *Anabaena* and *Microcystis*. Green algae include *Actinastrum, Scenedesmus, Ankistrodesmus, Volvox, Chlamydomonas, Hydrodicton,* and *Tetraedron.* Phytoplankton in Blackbird Creek are most abundant and diverse in summer, least abundant in winter, and least diverse in fall.

Phytoplankton in St. Jones River are represented by 44 taxa, with the diatoms *Melosira* and *Guinardia* being most abundant, followed by the dinoflagellate *Ceratium* and the diatom *Biddulphia.* Dominant blue-green algae include *Anabaena, Microcystis,* and *Oscillatoria*, while dominant green algae include *Volvox, Ankistrodesmus, Scenedesmus, Chlamydomonas, Chlorella,* and *Hydrodictyon.* Phytoplankton in St. Jones River are most abundant in spring and most diverse in summer, least abundant in winter, and least diverse in fall.

Zooplankton assemblages

Microzooplankton (<64 um) in Blackbird Creek consist of 36 taxa dominated by copepod nauplii and rotifers *Filinia* and *Notholca.* Other common microzooplankters are other rotifers and larvae of gastropods, bivalves, and polychaetes. Blackbird Creek's 44 taxa of mesozooplankton (64-250 um) are dominated by cladoceran *Diaphanosoma* and copepod *Acartia hudsonia.* Other common mesozooplankters include various copepods (*Acartia tonsa, Eurytemora affinis, Halicyclops fosteri, Ectinosoma*, *Scottolana, Cyclops*, and *Oithona*); fiddler crab (*Uca* spp.) zoeae; hydrozoan medusae; rotifers; cladocerans; and larvae of gastropods, bivalves, polychaetes, and cirripeds. For both size groups, diversity is highest in summer and lowest in winter.

Microzooplankton in St. Jones River consist of 39 taxa dominated by copepod nauplii and rotifers *Keratella* and *Notholca.* Other common microzooplankters are cladoceran *Daphnia*; rotifers *Brachionus* and *Filinia*; larvae of polychaetes, gastropods, bivalves, and ascidians; and various protozoans. The greatest diversity occurs in the summer, least in the fall. The St. Jones River's 53 taxa of mesozooplankton are dominated by polychaete larvae and a rich assemblage of copepods (*Acartia tonsa, Eurytemora affinis, Halicyclops fosteri, Pseudodiaptomus pelagicus, Oithona, Ectinosoma, Leptastacus,* and *Cyclops*). Other common mesozooplankters include various cladocerans (*Diaphanosoma, Bosmina,* and *Daphnia*); fiddler crab (*Uca* spp.) and mud crab (*Rhithropanopeus harissi*) zoeae; rotifers *Brachionus* and *Notholca*; cnidarian medusae; nematodes; larvae of gastropods, bivalves, cirripeds, and ascidians; and mysid shrimp (*Neomysis americana).* Polychaete larvae are the most abundant mesoplankton in spring and summer, copepod *Eurytemora affinis* dominate in fall, while nematodes are the most abundant mesozooplankters in winter.

Subtidal benthic macroinvertebrates

Benthic macroinvertebrates in Upper Blackbird Creek consist of 21 taxa dominated by oligochaetes, chironomid larvae, amphipods *Corophium* and *Gammarus*, and isopod *Cyathura polita.* Blue crab (*Callinectes sapidus*) and xanthid mud crabs are also commonly encountered. Densities of total macroinvertebrates range from a minimum 2040/m^2 in summer to a maximum of 4289/m^2 in spring. Dominant parabenthos in Upper Blackbird Creek are grass shrimp (*Palaemonetes* spp.), amphipods *Corophium* and *Gammarus,* and mysid shrimp (*Neomysis americana).*

Benthic macroinvertebrates in the Lower St. Jones River consist of 33 taxa dominated by oligochaetes, chironomid larvae, polychaetes including clamworm (*Streblospio benedicti),* amphipods *Corophium* and *Gammarus,* isopod *Edotea triloba,* mysid shrimp (*Neomysis americana*), mud snail (*Ilyanassa*), and turbellarians. Densities of total macroinvertebrates range from a minimum of 3850/m^2 in summer to a maximum of 4573/m^2 in spring. Parabenthos of Lower St. Jones River was dominated by mysid shrimp (*Neomysis americana*), a species having a peak density of 20,460/m^2 in fall. Other benthic or parabenthic macroinvertebrates known to inhabit the Lower St. Jones River are eastern oyster (*Crassostrea virginica),* in that there is a large live oyster bed just inside the river's mouth; blue crab (*Callinectes sapidus),* for which numerous crab pots are set in the lower river and adjacent Delaware Bay for its harvest; and horseshoe crab (*Limulus polyphemus*), which is particularly abundant during its spring spawning season along nearby Delaware Bay shorelines.

Emergent marsh benthic macroinvertebrates

Common aquatic macroinvertebrates of emergent salt marsh habitats in the Lower St. Jones River Reserve include saltmarsh snail (*Melampus bidentatus*), red-jointed fiddler crab (*Uca minax*), marsh fiddler crab (*Uca pugnax),* marsh crab (*Sesarma reticulatum),* saltmarsh amphipod (*Orchestia grillus),* Atlantic ribbed mussel (*Geukensia demissa),* grass shrimps (*Palaemonetes* spp.), mud snail (*Ilyanassa obsoleta),* and blue crab (*Callinectes sapidus).* Emergent marsh surface habitats having the highest macroinvertebrate densities are tall-form or short-form saltmarsh cordgrass (*Spartina alterniflora),* followed in decreasing order by big cordgrass (*S. cynosuroides*), salt hay (*S. patens/Distichlis spicata*), common reed (*Phragmites australis*), and marsh shrubs (*Iva frutescens/Baccharis halimifolia*). Saltmarsh snails are the most abundant macroinvertebrate in emergent marsh habitats, followed in decreasing abundance by red-jointed fiddler crab, saltmarsh amphipod, marsh fiddler crab, Atlantic ribbed mussel, and marsh crab. Grass shrimps (*Palaemonetes* spp.) are common in intertidal and subtidal channels within the marsh, as well as in marsh surface ponds. Mud snails and blue crabs will also be found in these aquatic habitats.

Horseshoe crabs

Horseshoe crabs (*Limulus polyphemus*) are important marine organisms in the mid-Atlantic region and particularly in Delaware Bay, where they are known for prolific egg production along bayfront beaches during their mid-May to early June peak spawning period. Horseshoe crab eggs provide an important food source for many migratory shorebirds enroute in spring to their Arctic nesting grounds. Bayfront shoreline in the Ted Harvey Conservation Area is an important site for both horseshoe crab spawning and shorebird feeding. The DCPS is supporting studies of how to best enumerate horseshoe crab egg abundance, and for the role that horseshoe crab eggs play in shorebird feeding energetics, with special attention to the red knot.

Saltmarsh mosquitoes and their control

Wetlands in both DNERR sites can produce abundant populations of biting flies, including aedine and culicine mosquitoes, tabanids such as greenheads and deer flies, and biting gnats (ceratopogonids). The saltmarsh mosquito (*Aedes sollicitans*) is a particular concern because of its ability to fly several miles away from breeding marshes and cause nuisance and economic problems to surrounding communities. It can also potentially transmit Eastern Equine Encephalitis, a viral disease that when contracted is often fatal to horses and humans. Various chemical insecticide practices (larvicides and adulticides applied by airplane, helicopter, truck or hand) are used by the Delaware Mosquito Control Section to control saltmarsh mosquitoes. Selected wetlands of the Lower St. Jones River Reserve are occasionally sprayed with mosquito control insecticides as warranted. Source reduction methods may also be used. The mosquito control practice of parallel-grid-ditching has now been discontinued because excessively removing marsh surface waters degrades marsh habitats. The modern source reduction practice of Open Marsh Water Management (OMWM) employs selective ponding and ditching that avoids this adverse impact. Because of the nature of tidal marshes in the Lower St. Jones River Reserve, and because of the proximity of this Reserve to Dover, future installation of OMWM systems are planned for some of the Lower St. Jones River's wetlands, which should reduce or eliminate the need for insecticides and restore dewatered habitats in a previously parallel-grid-ditched marsh. At present, mosquito production problems in the Upper Blackbird Creek Reserve do not warrant insecticide control nor OMWM treatment.

Finfishes

Finfishes in both Reserves are representative of the more common estuarine fishes found in the lower Delaware Estuary. Finfishes are found in a variety of Reserve habitats, including tidal river and creek channels, marsh ditches, and marsh surface ponds or pools, as well as along the open shoreline of Delaware Bay. A survey of Upper Blackbird Creek found 21 finfish species, with the most abundant species being spot (*Leiostomus xanthurus*), Atlantic menhaden (*Brevoortia tyrannus*), white perch (*Morone americana*), and mummichog (*Fundulus heteroclitus*). Finfish species that prefer brackish or fresh waters were more often found in Upper Blackbird Creek and included brown bullhead, silvery minnow, gizzard shad, yellow perch, black crappie, bluegill, and pumpkinseed sunfish. A similar survey conducted in the Lower St. Jones River and adjacent inshore waters of Delaware Bay found 25 finfish species, with the most abundant being Atlantic silverside (*Menidia menidia*), mummichog, sheepshead minnow (*Cyprinodon variegatus*), and bay anchovy (*Anchoa mitchilli*). Finfishes that prefer more saline waters than found in Upper Blackbird Creek, and which were collected only in the Lower St. Jones River, include spotted hake, Atlantic herring, Atlantic croaker, striped mullet, striped killifish, black sea bass, bluefish, northern searobin, oyster toadfish, and summer flounder. Finfishes that were found at both sites included five of the dominant species (spot, white perch, mummichog, Atlantic silverside, and bay anchovy), plus lesser numbers of hogchoker, weakfish, striped bass, American eel, black drum, and channel catfish. The lack of recording any Atlantic menhaden in the Lower St. Jones River during this survey was clearly a sampling artifact, since Atlantic menhaden are well known in the St. Jones River by their unfortunate past involvement in massive fishkills. The primary recreational species sought by anglers in DNERR waters, particularly in the Lower St. Jones River and nearby inshore waters of Delaware Bay, are weakfish, striped bass, white perch, summer flounder, and bluefish.

Reptiles and amphibians

Several species of reptiles and amphibians occur in the DNERR. Frequently observed aquatic turtles include northern diamondback terrapin (*Malacleys terrapin*) and snapping turtle (*Chelydra serpentina*), with eastern mud turtle (*Kinosternon subrubrum*) and red-bellied turtle (*Pseudemys rubriventris)* also present. Among sea turtles, all which are listed on the federal endangered species list, the loggerhead turtle (*Caretta caretta*) is most often seen in Delaware Bay and most frequently washes ashore along bay beaches. Other sea turtles known to occasion Delaware Bay include Kemp's Ridley (*Lepidochelys kempii*) and green sea turtle (*Chelonia mydas*). Common snakes in the DNERR include northern water snake (*Nerodia sipedon*) and black rat snake (*Elaphe obsoleta*). Amphibians characteristic of the DNERR include bullfrog (*Rana catesbeiana*), green frog (*R. melanota*), wood frog (*R. sylvatica*), southern leopard frog (*R. sphenocephala*), and northern spring peeper (*Hyla crucifer*), as well as red-backed salamander (*Plethodon cinereus*) and two-lined salamander (*Eurycea bislineata*). Amphibians are more common in the Upper Blackbird Creek Reserve as opposed to the Lower St. Jones River Reserve, because of its abundance and diversity of freshwater wetland habitats. Additionally, freshwater coastal plain ponds ("Delmarva Bays") in forested wetlands of Blackbird State Forest, just west of Upper Blackbird Creek Reserve, provide valuable habitat for several amphibian species of special concern.

Waterbirds (wading birds, waterfowl, shorebirds, gulls and terns)

Both DNERR sites have diverse habitats supporting a variety of waterbirds (wading birds, waterfowl, shorebirds), raptors, and passerine species. The two DNERR sites are located close to the Bombay Hook National Wildlife Refuge/Little Creek-Ted Harvey State Wildlife Area complex, famous in mid-Atlantic birding circles for its diversity of habitats and an abundance of birds within a relatively small geographic area.

Wading birds commonly found at either DNERR site include great blue heron, great egret, snowy egret, cattle egret, black-crowned night heron, green-backed heron, and glossy ibis, with the little blue heron and tricolored heron only occasionally seen. Dabbling ducks including American black duck, gadwall, mallard, common pintail, American wigeon, northern shoveler, and green-winged and blue-winged teals are common during migratory seasons in open water habitats of the DNERR. The expansive open waters of Logan Lane Impoundment in the Ted Harvey Conservation Area provide excellent feeding and resting areas for these marsh ducks, along with good habitat for diving ducks such as canvasback, redhead, and ring-necked ducks. [A study of the impoundment's benthic community, which is a primary food source for waterbirds foraging in the impoundment, was recently completed under auspices of a NERRS nationwide competitive research grant, and found high abundance of oligochaetes (*Paranais littoralis, Tubificidae* sp.), burrowing anemones, and chironomid larvae.] Other waterbirds frequenting the impoundment include pied-billed grebe, ruddy duck, and American coot. Canada and snow geese are also commonly observed in the Ted Harvey Conservation Area. The Logan Lane Impoundment has also been the location of unusual bird sightings, such as whiskered and white-winged terns of Eurasian origins, bringing hundreds of birders from all over the country to this managed wetlands. Wood ducks are frequently found along the forested corridor of Upper Blackbird Creek, as are kingfishers.

Migratory shorebirds are periodically abundant in or near the Lower St. Jones River Reserve, particularly during spring migration when many shorebird species stop to feed on horseshoe crab eggs deposited along Delaware Bay beachfronts (such as the Ted Harvey Conservation Area), or to forage in mudflats within managed impoundments (such as the Logan Lane Impoundment) when water levels are low. The most common migratory shorebirds seen are semipalmated sandpiper, ruddy turnstone, red knot, and sanderling, with lesser but still significant numbers of dunlin, short-billed dowitcher, semipalmated plover, black-bellied plover, and greater yellowlegs. Along Upper Blackbird Creek there is less attractive shorebird habitat, but greater yellowlegs, killdeer, and spotted sandpipers have been observed there.

Waterbirds commonly seen in nearshore Delaware Bay waters off bayfront beaches include common and red-throated loons, horned grebe, double-crested cormorant, northern gannet, snow goose, common and red-breasted mergansers, surf and black scoters, bufflehead, oldsquaw, and lesser scaup. The most commonly observed gulls are herring, ring-billed, greater black-backed, and laughing gulls. The most commonly observed terns are common, Forster's, and little (least) terns, with occasional sightings of royal and Caspian terns. Black skimmers are frequently seen throughout the summer at the mouth of the St. Jones River, and not surprisingly are often observed skimming over open shallow waters of the Logan Lane Impoundment.

In addition to wading birds, waterfowl, and shorebirds, other waterbirds frequently seen in tidal wetlands of both DNERR sites include clapper, king and Virginia rails, willet, laughing gull, and Forster's tern.

Raptors and passerine birds

Red-tailed hawks are frequently seen in both DNERR sites, and less frequently sharp-shinned hawks are observed. Turkey vultures are common. Raptors occasionally observed over the DNERR's tidal wetlands include northern harrier, and in winter short-eared owl and rough-legged hawk. A breeding pair of bald eagles is found along Upper Blackbird Creek. Ospreys are only infrequently seen at either DNERR site, possibly reflecting less than ideal foraging habitats (relative to other coastal areas), perhaps caused by a shortage of lagoonal habitats containing clear waters.

Osprey eggs and osprey prey fish along the lower Delaware River and upper Delaware Bay have also been found (in comparison to other regional areas) to still have relatively high levels of DDE and DDD (metabolites of the discontinued organochlorine insecticide DDT) and other contaminants, manifested in relatively thinner osprey egg shells, which might also help explain the relatively low occurrence of ospreys in the Delaware Estuary. Habitat in the forested bottomlands along Upper Blackbird Creek is probably excellent for barred owls and red-shouldered hawks. Great horned and screech owls will occur in the DNERR's woodlands.

Passerine species frequently seen in the DNERR's tidal wetlands include marsh wren, red-winged blackbird, boat-tailed grackle, common yellowthroat, and seaside and sharp-tailed sparrows. Passerine species that would find the forested bottomlands of Upper Blackbird Creek good habitat include northern parula warbler, prothonotary warbler, and swamp sparrow.

Both DNERR sites have diverse habitats for many upland species. By known geographic ranges, characteristic birds of open fields, wet meadows, brushy hedgerows, roadsides and other open or semi-open habitats in the DNERR would include: northern bobwhite, ring-necked pheasant, mourning dove, northern flicker, eastern phoebe, eastern kingbird, house wren, barn and tree swallows, American crow, brown thrasher, northern mockingbird, eastern bluebird, American robin, eastern meadowlark, common grackle, European starling, brown-headed cowbird, northern oriole, American goldfinch, bobolink, cedar waxwing, northern cardinal, indigo bunting, yellow warbler, prairie warbler, yellow-breasted chat, blue grosbeak, northern junco, and song, field, savannah, chipping and house sparrows. By known geographic ranges, characteristic birds of shrubby thickets, woodlots or woodlands in the DNERR would include: downy and red-bellied woodpeckers, eastern pewee, blue jay, Carolina chickadee, tufted titmouse, nuthatches, brown creeper, kinglets, blue-gray gnatcatcher, gray catbird, wood thrush, red-eyed and white-eyed vireos, yellow-rumped warbler, black-throated blue warbler, Kentucky warbler, American redstart, ovenbird, scarlet tanager, rufous-sided towhee, and fox and white-throated sparrows.

Mammals (terrestrial, aquatic and marine)

Almost all mammals commonly found in Delaware will occur in one or both of the DNERR sites. Aquatic mammals of wetland areas are muskrat and rice rats, and in lesser abundance beaver, river otter, and mink. By known geographic ranges or on-site sightings, other mammals found in varying abundances include short-tail, masked and least shrews, meadow and pine voles, meadow jumping mouse, white-footed mouse, woodchuck, gray squirrel, opossum, raccoon, striped skunk, longtail weasel, cottontail rabbit, red and gray foxes, and white-tailed deer. Bat species would include little brown myotis, eastern pipistrel, and big brown bat, and the more highly migratory silver-haired, hoary, and red bats.

Marine mammals occur very infrequently within the DNERR, and are mainly associated with open waters of Delaware Bay. A few species of large whales occasionally are spotted in Delaware Bay, primarily in lower bay waters, including humpback, northern right, and finback whales. The most common marine cetacean near or within DNERR waters and throughout Delaware Bay is bottlenose dolphin (*Tursiops truncata*), which occasionally strands or washes up on bay shorelines. Harbor porpoises (*Phocoena phocoena*) are somewhat common in open waters of the lower bay. The most common pinniped is harbor seal (*Phoca vitulina*), which appears in Delaware Bay during winter months.

Nearshore Delaware Bay habitat

The DNERR's small portion (1086 ha/2560 ac) of open Delaware Bay waters and subtidal bay bottom adjacent to the Ted Harvey Conservation Area provides representation of estuarine habitat much different than the two DNERR landward sites that are dominated by tidal wetlands. The bay shoreline itself provides representation of washover barrier dune and sandy beachfront habitats. Inshore bay bottom substrates in this area are primarily mucky fine silts and clays (70-100% silt/clay) having high organic content, grading into fine sands as one progresses offshore. Delaware Bay supports three important shellfisheries, composed of species that also play important ecological roles in estuarine systems. The eastern oyster (*Crassostrea virginica*) is commercially harvested, and its characteristic “beds” form substrates that support a diverse, abundant benthic community. Through filtering water when feeding, oysters also play an important role in maintaining estuarine water quality. The blue crab (*Callinectes sapidus*) is the bay’s most important commercial fishery, and blue crabs are also important components of the estuarine food web, transferring energy from lower trophic levels to top order consumers like striped bass, weakfish, or wading birds. The horseshoe crab (*Limulus polyphemus*) is commercially harvested as an important bait for use in other marine fisheries, as well as for medical uses of its blood. Horseshoe crab eggs provide critical nourishment for migratory shorebirds. Encompassing representative habitat of open Delaware Bay gives the DNERR opportunity to examine many important and interesting natural features of the bay.

Living Resources – Consumptive Uses

With exception of waterfowl hunting or muskrat trapping that occurs in the DNERR’s tidal wetlands or other nearby marshes, most human uses of living resources are centered on Delaware Bay commercial or recreational fisheries, with some of these fisheries extending landward into the DNERR subestuaries.

Furbearer trapping and waterfowl hunting

Muskrats are the most important furbearers trapped in or near DNERR tidal wetlands and elsewhere in Delaware, both for their pelts and meat, with much lower numbers of mink and river otter also taken. Waterfowl hunting is an important recreational and economic activity in or near DNERR tidal wetlands and throughout coastal areas of Delaware. Hunting is popular in coastal marshes and impoundments for several species of puddle and diving ducks, as well as on a much more limited scale in open waters of Delaware Bay for sea ducks. Because of concerns about population levels for black duck, northern pintail and canvasback along the Atlantic Flyway, special restrictions apply to these species’ harvests. Decreasing populations of migratory Canada geese, and expanding populations of resident Canada geese and migratory snow geese, have also created various management problems requiring special harvest considerations. Upland hunting also occurs in or near DNERR sites for white-tailed deer and wild turkey, as well as small game hunting for rabbit, squirrel, pheasant, quail, woodcock and dove.

Eastern oyster

The eastern oyster (*Crassostrea virginica*) has been commercially harvested in Delaware Bay since the late 1600’s, and reached impressive peak harvests in the early 1900’s. However, in the late 1950’s the oyster harvest plummeted by over 95%, primarily due to MSX, a disease caused by the protozoan parasite *Haplospridium nelsoni.* Declines in the oyster industry were also accelerated by oyster drill (*Urosalpinx* spp.) predation, and were later maintained by the appearance of Dermo (*Perkinsus marinus*), another oyster parasite. Today, what is left of the Delaware oyster industry primarily depends upon about 1000 acres of state-owned seed beds, from which oysters are then transplanted to harvest grounds. Recent Delaware oyster harvests peaked in 1991 at 846,000 pounds, but both disease and overharvesting problems prompted harvest closure of natural beds in 1996 and 1997. A hope for recovery of the Delaware Bay oyster fishery lies in development of disease-resistant oyster strains, with obvious preference for native species stocks to avoid any potential problems with stocking non-indigenous species. However, even if someday more disease-resistant oysters are established, there will still probably remain problems with harvest in many inshore locations, due to bacterial contamination from upland runoff or seepage.

Blue crab

The blue crab (*Callinectes sapidus*) is economically the most important commercial fishery in Delaware Bay, as well as an important inshore recreational fishery. Record Delaware landings of 6.3 million pounds occurred in 1995. The blue crab is harvested year-round, by a crab pot fishery from late April through October, and by a winter dredge fishery from December through March. Annual harvests can be quite variable, dependent upon factors like nearshore ocean currents affecting larval dispersion and recruitment patterns, or excessively cold water temperatures killing overwintering buried adults. A bi-state Blue Crab Fishery Management Plan is currently under development by Delaware and New Jersey.

A limited amount of hard clams (*Mercenaria mercenaria*) are incidentally harvested in lower Delaware Bay, as bycatch of the blue crab winter dredge fishery. Conch (*Busycon* spp.) are also harvested in Delaware Bay, both as incidental bycatch of the blue crab winter dredge fishery, and as directed pot and dredge fisheries.

Horseshoe crab

Horseshoe crabs (*Limulus polyphemus*) have been harvested in Delaware since the 1800's for animal feed and use as fertilizer, with periods of high harvests followed by relative scarcities. Over the past decade in Delaware their harvest has again increased dramatically, with an estimated 422,000 adults (2.1 million pounds) collected in 1996. About 80% of the harvest comes from a shore-based hand-collection fishery, and the rest from a bottom dredge fishery. The primary use for horseshoe crabs is as bait for eel and conch fisheries, and secondarily for medical applications of its unique blood. There is a serious concern that overharvesting of horseshoe crabs along Delaware Bay could have detrimental effects on migratory shorebirds during spring migration. These shorebirds consume many horseshoe crab eggs as part of their energy needs to complete northbound migration and breed on their Arctic nesting grounds. This situation has lead to calls for better protection and conservation of horseshoe crabs and their eggs. The Atlantic States Marine Fisheries Commission (ASMFC) approved in October 1998 a coastwide Fishery Management Plan that should help deal with this concern.

Finfisheries

Commercial finfisheries in Delaware Bay waters are centered on a relatively small inshore gillnet fishery, involving both anchored and drift gillnets, concentrating in the spring on white perch, weakfish, American shad and striped bass. The once abundant Atlantic menhaden harvest from Delaware Bay waters is now a thing of the past primarily due to overharvesting. This resulted in the 1992 banning of all menhaden purse seine fishing in Delaware's tidal waters. American eels are caught in Delaware Bay and tidal tributaries with eel pots and small fyke nets, but in recent years concern with overharvesting of immature eels (elvers) for Japanese export has risen in mid-Atlantic and New England states. The principal recreational fisheries in Delaware Bay center on weakfish (Delaware's official "state fish"), bluefish, and summer flounder, with the recent addition of striped bass following this species' coastwide stock recovery. Bottom angling for black sea bass, tautog, scup, black drum and other structure-oriented fishes, as well as shark fishing, are also important activities.

On a small-scale basis, snapping turtles and diamondback terrapins are locally trapped and used for food.

Historic and Cultural Resources

A total of 32 prehistoric archaeological sites have been found in upland areas fringing the Lower St. Jones River marshes. These sites span a period of more than 8000 years, covering Archaic and Woodland I and II periods of Native American habitation. Historic period sites include the oldest settlements in Kent County (Kingston-Upon-Hull, Town Point), and the John Dickinson Plantation and Mansion ("Penman of the Revolution") from colonial times.

A total of 73 prehistoric archaeological sites have been found in upland areas fringing the Blackbird Creek marshes, with evidence of intensive prehistoric habitation from 3000 B.C. to 1000 A.D. The oldest historic dwelling is the Huguenot House built in the early 1700's. Historic period sites are not as common as along the Lower St. Jones River.

Environmental Stressors (past, present and future)

Water quality

Many factors intertwine to adversely affect water quality in both Blackbird Creek and St. Jones River. Among the more important are chemical toxins (e.g. heavy metals, pesticides, PCBs, hydrocarbons), dissolved nutrients (nitrogen, phosphorus), suspended sediments and other particulates, and bacteria and other pathogens, interacting in various manners to directly produce lethal or sub-lethal impacts on organisms, or to harm organisms through habitat perturbations, such as creating hypoxic dissolved oxygen conditions. Both point-source and nonpoint-source pollution contribute to these problems.

Point-source pollution discharges

Of the two Reserve sites, the Lower St. Jones River has more contamination problems, primarily due to Dover's extensive and intensive urbanization in the St. Jones River's middle and upper watersheds. Because of polychlorinated biphenyls (PCBs) in aquatic sediments and the food web, all tidal and several non-tidal reaches of the St. Jones River watershed have a health advisory recommending only very limited consumption of catfishes, white perch, carp or largemouth bass. It is not well understood where the PCBs in the St. Jones River watershed originated (but they might well have been from now discontinued point-source discharges), nor is there much effort underway to remediate what has accumulated throughout the watershed, but the situation does not seem to be getting worse. Dover's central sewer system (which eventually feeds into Kent County's sewage treatment plant on the Murderkill River near Frederica) has occasional problems with combined sewage overflows during heavy rainfalls, as well as occasional breakdowns of sewage pump stations. Both periodically contribute untreated wastewaters to the St. Jones River at specific (point-source) locations. There are also four sites within the St. Jones River watershed that are under auspices of DNREC's National Pollution Discharge Elimination System (NPDES), constituting permitted point-source discharges of industrial wastewaters. There are no NPDES-sites in the Blackbird Creek watershed. Overall, as in many other areas of the state and country, problems with point-source discharges of contaminants are now relatively well understood, identified, and for the most part under control.

Nonpoint-source pollution sources

Nonpoint-source (NPS) pollution is now the more serious concern in both DNERR watersheds, arising from both urban and rural land-uses in the St. Jones River watershed, and primarily from rural land-uses in the Blackbird Creek watershed. Many federal, state and local programs are currently being developed or implemented to combat NPS pollution, but more resources are needed if substantial reductions in NPS problems are to be achieved. Of particular concern in both Reserve watersheds is the contribution of dissolved and particulate nutrients (mainly nitrogen and phosphorus) and suspended sediments from agricultural runoff, associated primarily with corn and soybean production or animal feedlot operations. However, in the St. Jones River watershed significant contributions of NPS pollution also occur from developed areas with impervious surfaces or residential landscapes, and in the upper reaches of the Blackbird Creek watershed from silviculture activities. A NERRS-supported study done in the southeastern United States has shown that detrimental impacts can occur to estuarine organisms from abnormally-fluctuating salinity levels associated with "flash event" stormwater runoff in watersheds that are heavily developed with impervious surfaces. Leaching of nutrients or bacteria from septic fields into surface or ground waters, and atmospheric deposition of nutrients and toxic chemicals to surface waters, also contribute to NPS pollution problems. A DCPS study is currently underway in the St. Jones River watershed to model total nitrogen loading into surface waters coming from six different land-use types during storm runoff events. A major concern with excessive NPS nutrient runoff in Delaware and elsewhere is its contribution to creating or exacerbating eutrophication of coastal waters, which in some areas might manifest itself in nuisance or harmful algal blooms.

Land-use conversions and corollary impacts

Changes in land-use can often cause water pollution problems. How localized or dispersed these land-use changes are will then determine if they are point or nonpoint-sources of pollution, although most pollution attributed to land-use conversions is considered NPS pollution. Land-use conversions of concern for the DNERR include the ongoing construction of a new superhighway (the Rt. 1 relief route or bypass for old Rt. 13) in tidal headwaters of Blackbird Creek, very near the western end of Upper Blackbird Creek Reserve. Highway construction over Blackbird Creek's riparian corridor has potential for water quality degradation from sediment runoff and other contaminants, as well as loss of wildlife habitats. Completion of Rt. 1 will undoubtedly spur further land conversions along or near Blackbird Creek. Since the new highway will make it significantly quicker and easier for commuting to New Castle County, "bedroom" residential developments, schools, roadside shopping centers, and golf courses will emerge. This in turn may eventually lead to increases in septic system problems. Land-use regulations currently in place in New Castle County might not be effective for the Blackbird Creek Reserve in preventing substantial water quality or habitat degradation from overdevelopment.

As just mentioned, land-use conversions to residential development along certain watercourses can create septic system problems that eventually lead to bacterial contamination of inshore shellfish beds. The oyster bar at the mouth of the St. Jones River is closed to harvest. Prohibitions against harvesting shellfish on a year-round or seasonal basis are now in effect for 109 sq. km (42 sq. mi) of Delaware Bay.

Borrow pits associated with sand-and-gravel mining are land-use conversions that have the potential to create water quality problems in both Reserves, especially for groundwater contamination in cases where abandoned borrow pits become illegal dump sites. The proposed development and operation of a sand-and-gravel pit along the St. Jones River presented some controversy during the DNERR's site nomination phase, and borrow pits are numerous in both Reserve watersheds.

From the 1930's through the 1960's, a form of land-use conversion, or more accurately a type of land-cover alteration, was done in the name of mosquito control to a majority of Delaware's coastal marshes. This alteration involved dewatering ("draining") marsh surfaces by excavating shallow parallel-grid-ditches about 46 m (150 ft) apart, installed over vast expanses of marsh (even in areas where saltmarsh mosquitoes didn't breed). This resulted in loss of valuable fish and wildlife habitat, particularly wherever larger, more permanent pools and pannes were drained. Today, this problem is no longer increasing, since the old parallel-grid-ditches are not being routinely recleaned, but instead are being allowed to slowly fill with tidally-borne sediments. In place of parallel-grid-ditching, and as a desirable alternative to chemical insecticide control, the modern mosquito control source reduction technique of Open Marsh Water Management (OMWM) is being used. Through selective ponding and ditching, this method avoids marsh surface dewatering, and in many locations helps restore lost surface waters.

A unique environmental problem occurs at the Lower St. Jones River Reserve, due to the past land-use conversion of creating a major airfield. Aircraft noise from large planes using Dover Air Force Base can frequently be quite loud (>70-80 db) over many areas of the Reserve. Fortunately, the location for the new DNERR facility is in an area where overhead aircraft noise is tolerable, and measures are being taken in the facility's design and construction to minimize noise impacts to DNERR educational and research activities. However, the extent of aircraft noise impacts to the Reserve's wildlife is unknown. Aircraft passing overhead have been observed to put resting waterfowl or feeding shorebirds into temporary alarm flights, performed at some energetic cost to the birds.

Dredging and channel maintenance

Dredging of the Delaware River has been a necessary operation for ship passage to Wilmington, Philadelphia and Camden ports ever since the late 1800's. It has created several environmental problems – e.g. how and where to dispose dredge spoil (resulting in many acres of tidal wetlands along the Delaware River being filled as spoil disposal areas); changes in upriver tidal amplitudes; salinity intrusions occurring further upriver than normal; etc. The current proposal by the U.S. Army Corps of Engineers to deepen the main shipping channel of Delaware Bay and River by an additional 1.5 m (5 ft) has created new environmental concerns. How such a deepening might affect the DNERR lands cannot be said with certainty, but most effects will probably be minor, since both DNERR sites are not in close proximity to dredging areas. The most substantial effect might involve the potential for using some main channel dredge material to nourish Delaware Bay shorelines, in areas where erosion has caused problems to beachfront developments, such as at Bowers Beach or Kitts Hummock near the Lower St. Jones River Reserve. It is even possible that some of this main channel dredge material might be used to replenish the bay shoreline at the Ted Harvey Conservation Area in order to protect the Logan Lane Impoundment levee, and to maintain good habitats for horseshoe crab spawning and migratory shorebird feeding. However, before any beachfront placement of main channel dredge spoil occurs, any concerns about the dredged material's suitability would first have to be fully resolved (e.g. issues regarding appropriate grain size and composition, or presence of toxic contaminants).

Shoreline erosion problems and relative sea-level rise

Shoreline erosion and loss are problems in many areas of the Delaware Estuary. In the past, these problems were often addressed by structural measures involving bulkheads, seawalls and other "hardened" structures. These efforts had varying degrees of success in addressing property protection, and almost always had some unintended adverse environmental impacts. One of these structural measures involved installing a nearshore breakwater to protect shoreline development at Kitts Hummock (near the Lower St. Jones River Reserve), through reducing wave height and energy hitting the Kitts Hummock beach. Today the preferred method to stabilize and protect shorelines, wherever practicable and effective to do, is with non-structural methods, such as constructing gentle slopes and planting saltmarsh cordgrass.

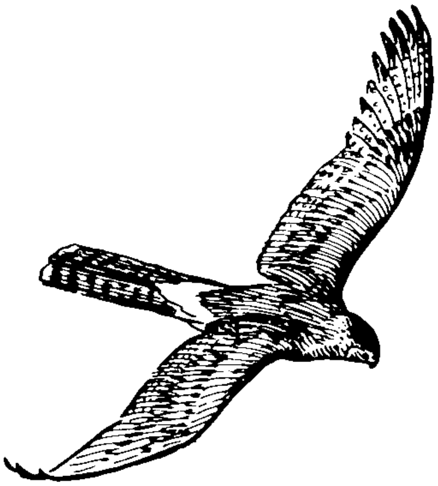
Ongoing relative sea-level rise is undoubtedly responsible for much of the shoreline erosion observed around the Delaware Estuary. This ongoing rise will eventually present severe problems for human and natural communities along Delaware Bay and River shorelines. At a minimum at both Reserve sites, it will involve a landward transgression of emergent wetlands into areas that are currently uplands, and a seaward loss of tidal marsh caused by increasing inundation. How well Reserve lands (and other areas) handle this inevitable change, especially in terms of maintaining tidal wetlands quantity, will depend in large measure upon land-use policies along the wetlands' upland borders, and perhaps upon how well engineered remedies (e.g. thin-layer spoil disposal, levee construction with managed tidal flows) are used or not used.

Landfills/industrial waste sites

Landfills or industrial plants constructed and operated during eras of less restrictive or non-existent environmental regulations can present serious on-site toxic contamination problems to wildlife, and cause both on-site and off-site degradation of surface or ground water quality arising from site leachates. As such, depending upon types of contaminants involved and areal extents of problem sites, landfills or industrial operations can contribute to both point and nonpoint-source pollution.

The St. Jones River watershed has three federal Superfund sites, which are locations of serious contamination listed on the EPA's National Priority List (i.e. NPL-sites). The Wildcat Landfill is an NPL-site located along the banks of the St. Jones River upstream of the Lower St. Jones River Reserve but downstream of Dover, only about 3.7 km (2 miles) away from the Reserve's western boundary. Wildcat Landfill was a privately-operated industrial/municipal waste disposal facility which leached PCBs and other contaminants into surface and ground waters and sediments along the St. Jones River corridor. The landfill was closed in 1973 due to permit violations. On-site contaminant remediation of Wildcat Landfill began in 1991 and is now satisfactorily completed. Another NPL-site in the St. Jones River watershed is Dover Gas Light Co. located in downtown Dover, whose operation caused contamination of soils and groundwater by coal tar. The location of this NPL-site is not as problematic for the Reserve, and contaminant remediation is currently underway. The third NPL-site is at the Dover Air Force Base. Groundwater contamination with volatile organic compounds (solvents, gasoline) resulting from over 50 years of aircraft operations is a problem, currently being remediated by several measures. A few contaminated groundwater plumes from the base might have reached small tributaries of the St. Jones River, but based upon ecological screenings to date, impacts to the river appear to be negligible. There are also some possible impacts to surface waters from heavy metals associated with stormwater runoff and from the base's industrial wastewater treatment plant that are currently being evaluated. No federal NPL-sites are in the Blackbird Creek watershed.

In addition to federal Superfund NPL-sites, there are also many locations where lesser but still problematic contamination problems have occurred. In Delaware the identification and remediation of these contaminated sites, which primarily involve abandoned landfills or industrial plants, is handled by DNREC's Division of Air and Waste Management under Delaware's Hazardous Substance Control Act, essentially involving state-level "superfund" sites (HSCA-sites). Within the St. Jones River watershed there are 33 state HSCA-sites, while none occur in the Blackbird Creek watershed.



COMPREHENSIVE SITE PROFILE

INTRODUCTION TO THE RESERVE

The Delaware National Estuarine Research Reserve (DNERR) has been established as described in:

> 1) *Delaware National Estuarine Research Reserve - Final Environmental Impact Statement/Draft Management Plan* (DNREC, 1992).
>
> 2) *Delaware National Estuarine Research Reserve - Final Management Plan* (DNREC, 1993a).

The DNERR was designated by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) in July 1993 as the 22nd site in the National Estuarine Research Reserve System (NERRS). Federal program support from NOAA comes through the Estuarine Reserves Division of the Office of Ocean and Coastal Resource Management. The DNERR is managed by the Delaware Department of Natural Resources and Environmental Control (DNREC). The primary administrative and many program functions are performed by the Delaware Coastal Programs Section (DCPS) in DNREC's Division of Soil and Water Conservation, which also administers the Delaware Coastal Management Program (DCMP). Additionally, DNREC's Division of Parks and Recreation directly participates in the DNERR for many environmental education functions, as does DNREC's Division of Fish and Wildlife for estuarine research and resource management functions.

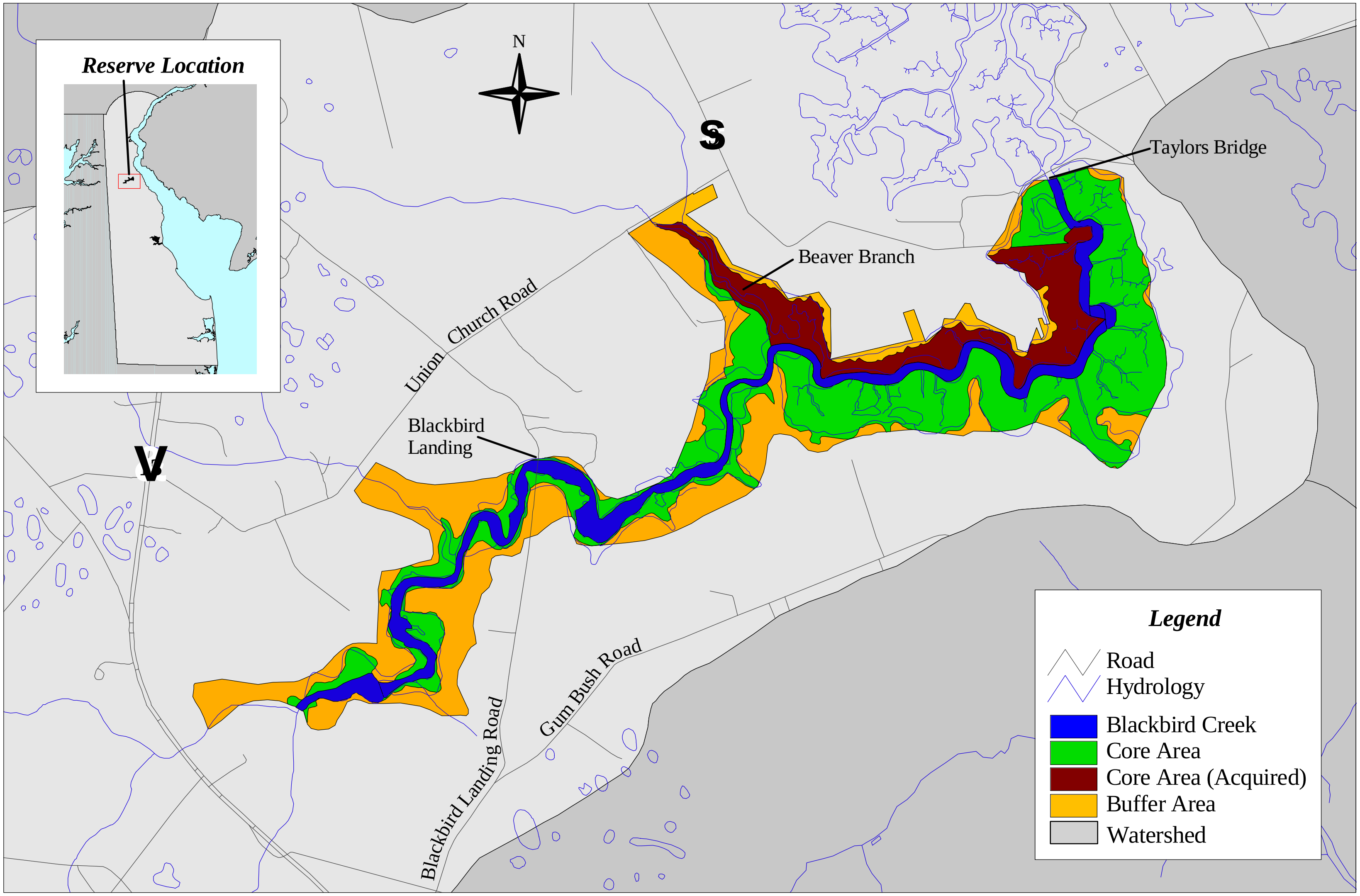
Two estuarine reserve components have been designated: Upper Blackbird Creek Reserve located in southern New Castle County (between Odessa and Smyrna), and Lower St. Jones River Reserve located in east-central Kent County (southeast of Dover) (Figure 1). These two sites provide good representation of tide-marsh-dominated estuaries in NOAA's Middle Atlantic sub-region of the Virginian biogeographic region. Figures 2-5 show the maximum proposed size and boundaries of each component. Participation by landowners within each site is on a voluntary and cooperative basis.

The goals and objectives of the DNERR program focus on resource protection and conservation, estuarine research, and environmental education. Resource protection and conservation are achieved through acquisition of key properties that include marshland and upland buffers, cooperative agreements with property owners, and conservation-oriented land management practices. Estuarine research and environmental education activities associated with the DNERR will help to better protect, conserve and manage the DNERR sites. More importantly, these activities will provide better land and natural resource stewardship within the DNERR's two watersheds and throughout Delaware's coastal zone, as well as on regional and national scales in association with the nationwide NERRS program. A key to making both the DNERR and NERRS work is providing, in a timely manner, pertinent estuarine research information to coastal management decision-makers.

The DNERR Site Profile provides characteristic descriptions of abiotic and biotic environmental features for the DNERR sites.

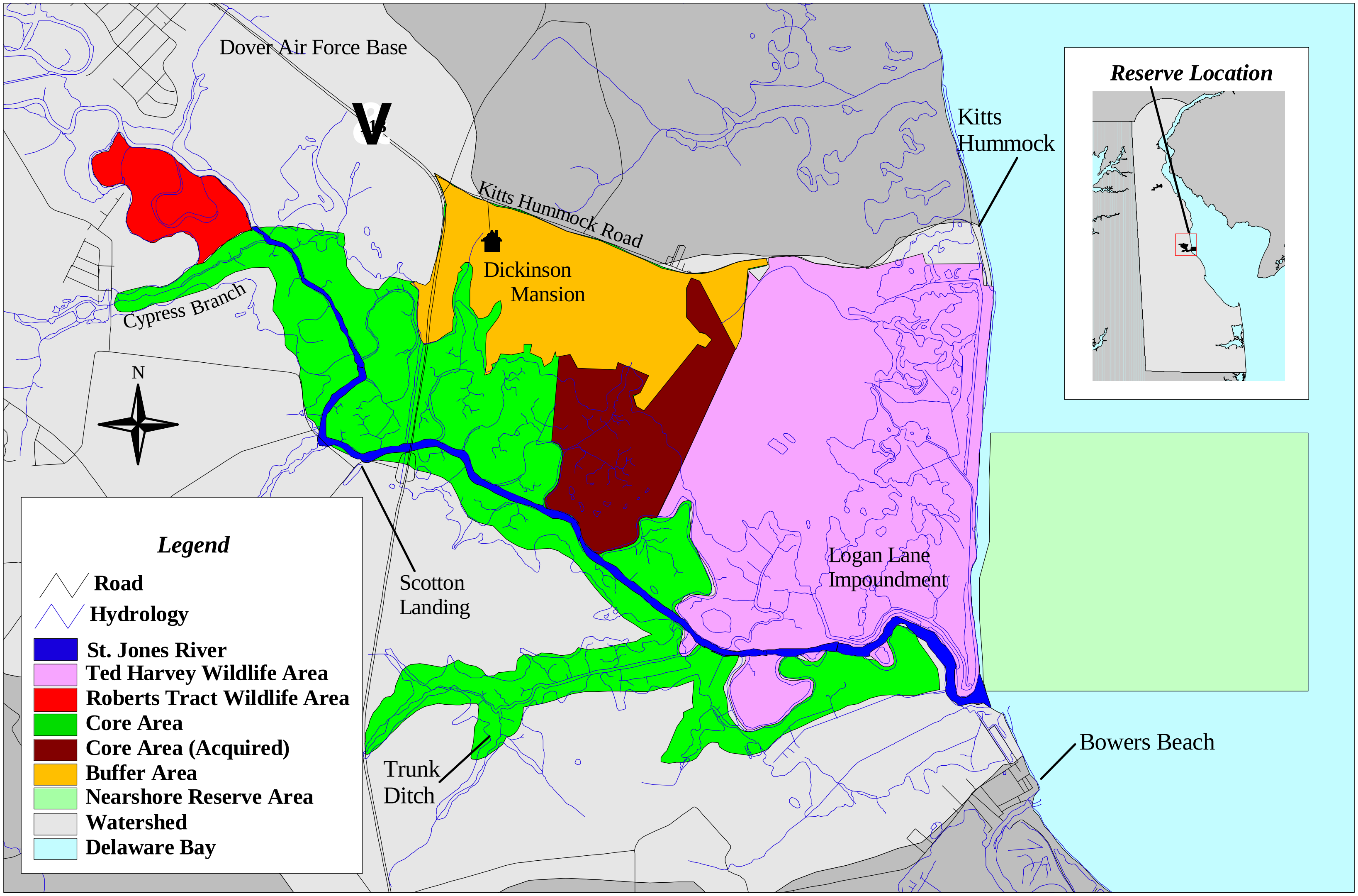
This map was prepared by the Delaware Coastal Managemen Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 1. Delaware National Estuarine Research Reserve Locations



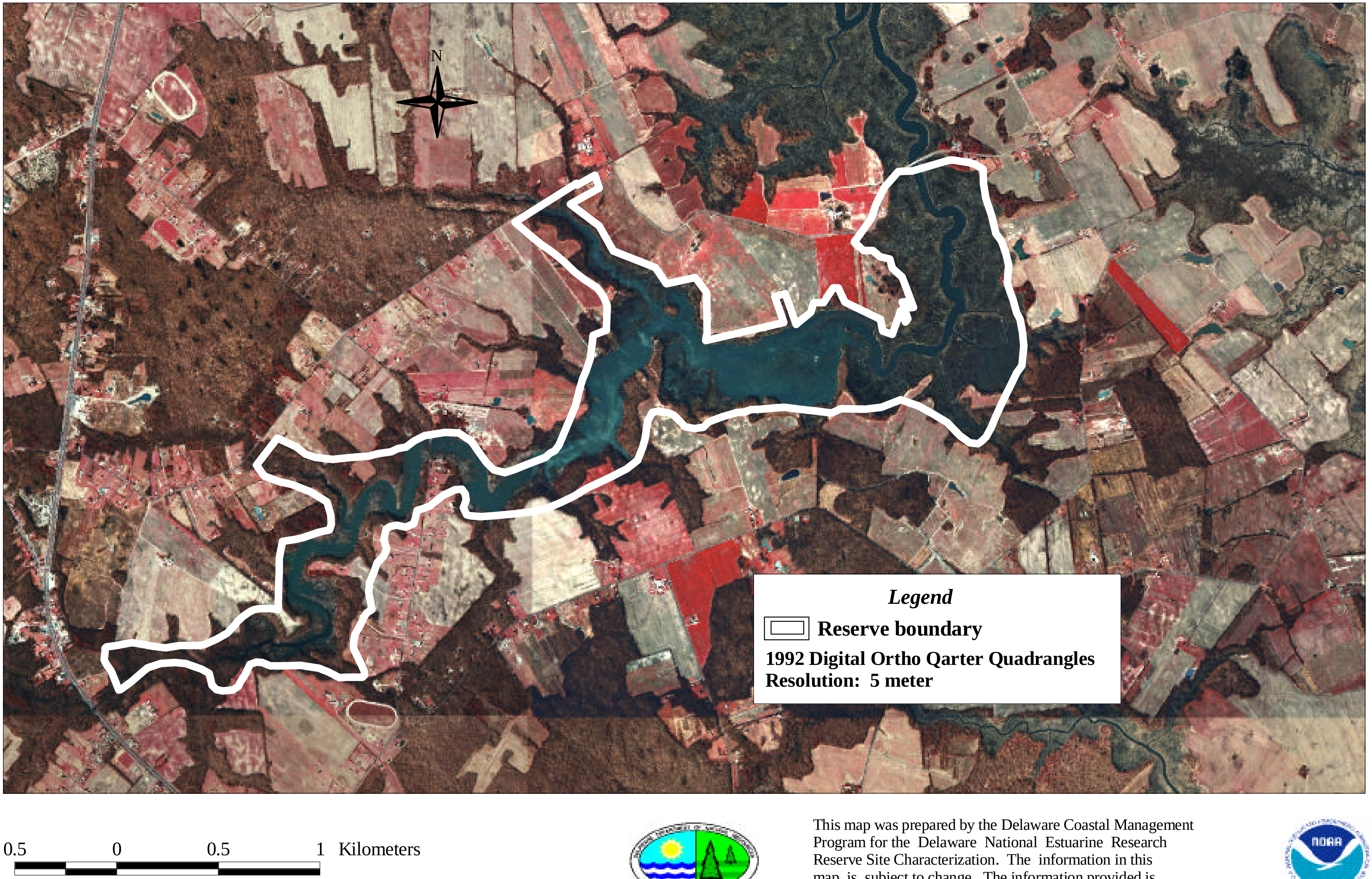
This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 2. Upper Blackbird Creek Reserve: General Features



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 3. Lower St. Jones River Reserve: General Features



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 4. Upper Blackbird Creek Reserve: Digital Ortho Quarter Quadrangles

This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 5. Lower St. Jones River Reserve: Digital Ortho Quarter Quadrangles

Since all DNERR lands were formerly private property without any history of environmental monitoring or research, very little site-specific information existed prior to site designation in 1993. As such, it was first necessary to conduct a series of field studies and inventories to characterize basic environmental features important in any coastal area. In order to characterize the Reserve and generate original environmental descriptions of plant and animal communities, a three-phase field study was initiated, starting in 1993 and running into 1997. The three phases were:

- Phase I - *Description/Analysis of Dominant Vegetation/Cover Types*, begun in 1993. A vegetation survey of each Reserve site was conducted, along with some water quality studies. Color-coded maps were developed of dominant vegetation along each waterway.

- Phase II - *Characterization of Finfish and Aquatic Macroinvertebrate Communities and Waterbird Populations*. Conducted in 1994, this primarily involved characterization of finfishes, aquatic macroinvertebrates, and avian communities within areas of the Upper Blackbird Creek and Lower St. Jones River Reserve sites.

- Phase III - *Characterization of Phytoplankton and Zooplankton Communities* was conducted in 1994-95, and included supplemental hydrography and water quality data in 1996 and 1997.

Following completion of the three-phase characterization studies, Phase IV of the Site Profile project involved the actual preparation of the Site Profile document. This involved drawing upon the original environmental information generated in the three-phase characterization study, plus incorporating additional information about water quality (provided by the Delaware Coastal Management Program) and other existing information about hydrology, geology, climate, soils, land use, etc. from existing literature concerning Delaware's coastal zone or the Delaware Estuary (River/Bay). To perform much of the field characterization work and help develop the Site Profile, the DNERR contracted with two environmental consulting companies, Wetlands Research Services (Newark, DE), and Environmental Consulting Services, Inc. (Middletown, DE).

Additional information on the general characteristics, development and management of the DNERR can be found in the *Delaware National Estuarine Research Reserve, Final Environmental Impact Statement/Draft Management Plan* (DNREC, 1992) and the *Delaware National Estuarine Research Reserve, Final Management Plan* (DNREC, 1993a).

GEOGRAPHIC SETTING

Geography and Biogeography

The DNERR sites are centrally located within the coastal plain of Delaware on the west side of the Delaware Estuary (Figure 1), about 32 km. (20 mi) apart. The Blackbird Creek component lies in southeastern New Castle County, between Odessa and Smyrna (Figure 2). The St. Jones River component is located southeast of Dover in east-central Kent County (Figure 3). Both sites are in the Middle Atlantic sub-region of the Virginian biogeographic region.

Boundaries and Ownership of Reserve Sites

Upper Blackbird Creek Reserve

The more landward Upper Blackbird Creek Reserve is 477 ha (1180 ac) in designated size, situated along 9.2 km (5.7 mi) of low-salinity brackish or freshwater tidal creek, starting about 9.3 km (5.8 mi) upstream from where Blackbird Creek empties into the lower Delaware River (Fig. 2). The total length of tidal Blackbird Creek is about 18.5 km (11.5 mi).

The Upper Blackbird Reserve contains 50 parcels of land held by 46 private landowners, plus the DNERR and one other state agency. Within the Blackbird Reserve's designated boundaries, about 85.8 ha (212 ac) of tidal marshes, upland fields, woodlots, and croplands were purchased by the DNERR in 1990, but the remaining majority of the Reserve is still in private ownership. An additional 74.1 ha (183 ac) of tidal marsh, woodlands, and croplands, across Blackbird Creek from the DNERR property and within the Reserve's designated boundaries, were purchased in 1996 by DNREC's Division of Fish and Wildlife (as part of the Division's Cedar Swamp Wildlife Area), and is available for use in DNERR activities.

The largest tributary of the upper creek segment is Beaver Branch, entering on the north side of Blackbird Creek about midway within the Reserve. Downstream of the seaward end of the Reserve, from Taylors Bridge to Delaware Bay, Lower Blackbird Creek passes by Red Bank and Stave Landing before reaching the bay. Much of the expansive tidal marshes and upland borders along Lower Blackbird Creek, downstream of the Upper Blackbird Creek Reserve's designated boundaries, primarily consisting of a large parcel known as The Rocks (which is also part of the Cedar Swamp State Wildlife Area), are owned and managed by the DNREC Division of Fish and Wildlife. Upstream of the Reserve in non-tidal areas west of Rt. 13 are extensive areas of forested wetlands containing unique coastal plain ponds ("Delmarva Bays"), much within Blackbird State Forest, which is owned and managed by the Delaware Department of Agriculture's Forestry Section.

Blackbird Creek's watershed is still primarily agricultural or forested, although low-density residential development is increasing.

Lower St. Jones River Reserve

The more seaward Lower St. Jones River Reserve is about 1518 ha (3750 ac) in designated size, situated along 8.8 km (5.5 mi) of medium-salinity tidal river at the lower end of the St. Jones River watershed, with the river discharging into mid-Delaware Bay (Fig. 3). The river continues upstream another 8 km (5 mi), flowing out of Silver Lake near downtown Dover. The total length of tidal St. Jones River is approximately 16.8 km. (10.5 mi).

The Lower St. Jones Reserve contains 35 parcels of land held by 23 private landowners, plus the DNERR and one other state agency. Within the St. Jones Reserve's designated boundaries, about 282.8 ha (698.5 ac) of tidal marshes, upland fields, woodlots, and croplands were purchased or protected by the DNERR in 1991-92 [with 174.7 ha (431.3 ac) purchased through fee-simple acquisition, and 108.1 ha (267.2 ac) protected through conservation easement], but the remaining majority of the Reserve is still in private ownership. The Lower St. Jones River Reserve will house on the DNERR property the new DNERR education/research facility (containing a small but well equipped laboratory for DNERR researchers), scheduled for completion in mid-1999. A marsh boardwalk for interpretive and research activities has already been constructed on the DNERR property.

Adjacent to the Lower St. Jones River Reserve on its eastern side is the Ted Harvey Conservation Area, owned and managed by DNREC's Division of Fish and Wildlife, consisting of 817 ha (2019 ac) of woodlands, upland fields, croplands, freshwater ponds and wetlands, coastal wetland impoundments, and Delaware Bay shoreline. While the Ted Harvey Conservation Area is not within the DNERR's designated boundaries, it is nonetheless available through cooperative arrangements with the Division of Fish and Wildlife for use in DNERR research and educational activities. The Division of Fish and Wildlife's Roberts Tract, a 71.2 ha (176 ac) parcel of the Little Creek State Wildlife Area, borders the St. Jones Reserve at its western end. In conjunction with the Division's Ted Harvey Conservation Area, the

Roberts Tract provides conservation-oriented land ownership on both upstream and downstream ends of the St. Jones Reserve.

A small-boat ramp and fishing pier at Scotton Landing, owned and managed by the Division of Fish and Wildlife, provides good boat and water access to the main channel of the St. Jones River towards the Reserve's western end.

On its far eastern end, the Lower St. Jones River Reserve also contains about 1036 ha (2560 ac) of Delaware Bay subtidal bottom and nearshore waters, running for 3.2 km (2.0 mi) along the Ted Harvey Conservation Area's bay shoreline and extending outward 3.2 km (2.0 mi) into the open bay.

The John Dickinson Plantation and Mansion, owned and managed by the Delaware Division of Historical and Cultural Affairs, provides another 106.4 ha (262.8 ac) of protected area within the Reserve's designated boundaries, adjacent to the DNERR property's western border. Dover Air Force Base is a considerable presence on the north/northwestern sides of the Reserve.

The largest tributaries of the Lower St. Jones River Reserve are Trunk Ditch, Beaver Gut Ditch, and Cypress Branch, all entering on the south side of the St. Jones River.

The St. Jones River watershed has significant development in upstream non-tidal areas, where urbanized Dover (Delaware's state capital) dominates the middle and upper watershed. However, downstream portions of the St. Jones River watershed, where the Lower St. Jones River Reserve is located, are still primarily agricultural, although Dover Air Force Base is nearby. The two DNERR sites are about 32 km (20 mi) apart.

Human population

The Blackbird Creek watershed encompasses 80 sq. km (31 sq. mi) inhabited by 4200 people (1990 census), for a population density of 52.5/sq. km (135.5/sq. mi). The St. Jones River watershed encompasses 233 sq. km (90 sq. mi) inhabited by 56,000 people (1990 census), for a population density of 240.3/sq. km (622.2/sq. mi).

ENVIRONMENTAL SETTING

Geology

Both the St. Jones and Blackbird Creek Reserves lie within the Atlantic Coastal Plain Province, south of the Appalachian Piedmont Fall Zone. Bedrock consists of Piedmont type rocks which are overlain by a thick wedge of unconsolidated and semi-consolidated sedimentary rocks. The oldest and most extensive layer of these sediments is at the base of the Cretaceous age Potomac Formation and is approximately 120 million years old. The Potomac Formation consists of clays and sands, fluvial sediments which originated from the early Appalachian Mountains. On top of this formation lies the Magothy Formation containing distinct white sands and black lignite, which suggests a transitional environment from stream deposits to a marine environment, much like that found in a delta. Marine formations of the Cretaceous and Eocene age can be found layered on top of the Magothy Formation, with the Piney Point Formation being the youngest. Above the Piney Point Formation is an unconformity or gap in the sedimentary record for which no sediments have been preserved (Oligocene age). Later, during the Miocene age, the sea again covered most of Delaware and deposited what is known as the Chesapeake Group, which consists of silts and sands reaching a thickness of approximately 122 meters (400 feet) near the St. Jones.

The repeated advance and retreat of continental glaciers during the past one to two million years (Pleistocene age) caused drastic changes in relative sea level and the configuration of streams draining the glaciers. The resultant Columbia Group and Formation consists of channel deposits from meltwater runoff. These layers of silt and sand are known important sources of groundwater, used today for both municipal and industrial purposes in the greater Dover area. The Columbia Group and Formation also supplies most of the sands and gravel that make up the largest mineral resource in Delaware (DNREC 1992).

Hydrogeology

Principal water-bearing units in the Reserve area are: 1) the unconfined aquifer, chiefly sand units of the Columbia Group; 2) the Cheswold and Frederica aquifers of the Chesapeake Group; and 3) the sand units of the Magothy and Piney Point Formations. The unconfined aquifer provides water for residences and farms in the area. Elevated concentrations of iron and nitrate in this aquifer have limited its use for water supply. The Piney Point and Cheswold aquifer supply most of the groundwater for the region. The Piney Point Aquifer is the larger of the two and supplies most of Dover. It can supply approximately 30 thousand cubic meters (8 million gallons) per day, yielding 2300 to 3800 liters per minute (600 to 1000 gallons per minute). The Cheswold Aquifer, which is the principal source of water for Dover Air Force Base and surrounding vicinity, can supply up to 21 thousand cubic meters (5.5 million gallons) per day. Because of groundwater use for drinking and irrigation, there is great concern for keeping contaminants out of these aquifers.

The principal minerals that can be found within the ground water depend on the parent material of the aquifer and the water source. The Columbia Formation is particularly vulnerable to surface contamination. This water table aquifer has the highest levels of nitrates, iron, sulfate and chloride. The Chesapeake Group and Piney Point Formation have higher levels of sodium, silica carbonate, bicarbonate and total dissolved solids. Calcium, magnesium and potassium are present in all aquifers, and to a lesser extent manganese, fluoride, and boron. The pH of the ground water tends to be slightly acidic (6.1) in the Columbia Formation, becoming alkaline (8.1) as depth increases to the Piney Point Aquifer.

Estuarine Geomorphology

The dominant factor in the Delaware Estuary’s development has been marine transgression. During the late Pleistocene glaciation, a deeply incised topography including the origins of the Delaware River and drainage system evolved. The residence of the ice sheet and subsequent sea level rise caused a coastal migration landward across the submerging continental shelf. The topography of the region allowed tidal water to intrude 100-200 km (60-120 mi) since the end of the Holocene transgression. The sea was 30 meters (100 feet) below its present level 12,000 years ago, and rose an average of 29.6 cm (11.65 inches)/100 year until 5000 years ago. Then, coastal erosion became a more important factor in coastal migration, along with subsidence of the continental shelf. During this time, sea level rise slowed from 20.7 cm (8.15 inches)/100 years (5000-2000 years ago) to 12.5 cm (4.92 inches)/100 year (2000 years ago to present). Estimates based upon recent historical data indicate an increase in relative sea level rise in the region to 40 cm (15.74 inches)/100 year.

A graduate study is nearing completion by a DNERR Graduate Research Fellow, who is trying to determine the extent and magnitude of any localized anthropogenic effects on relative sea-level rise in the DNERR and other Delaware Bay subestuaries. Discussions are currently underway with the U.S. Geological Survey to establish Sediment Elevation Tables (SETs) at the DNERR, for measuring changes in marsh surface elevations and sediment accretion rates.

The DNERR components are classified as Washover Barrier Marsh Systems, typical of the lower and middle western Delaware Bay. These systems include broad coastal salt marshes with relatively narrow washover barriers and broad tidal flats. Erosion of pre-Holocene sediments, from local, low-lying highlands of the coastal plain, provided sediment to the system. The deposition of muds in tidal salt marshes is a dominant process at the leading edge of the transgression.

Topography

Both component sites of the DNERR are located in the gently sloping coastal plain region of Delmarva Peninsula. The western-most boundaries of Blackbird Creek and St. Jones watersheds both lie on the divide between the Delaware Bay drainage basin to the east and the Chesapeake Bay drainage basin to the west.

The Blackbird Creek watershed contains gently rolling hills throughout, and reaches a maximum elevation of 25 meters (82 feet) at the western boundary of the watershed. Within the Reserve the elevation ranges from sea level to 17 meters (57 feet) in as little as 400 meters (0.25 mi).

The St. Jones River watershed rises gently away from the Delaware Bay at a gradient of 0.75 m/km (4 ft/mi) to a maximum height northwest of Dover of 22 meters (72 ft). The St. Jones River Reserve’s elevation ranges from sea level to 6 meters (20 feet) on gradually sloping surfaces.

Climate

The DNERR components have a climate of well-defined seasons, typical of the Middle Atlantic States region. The surrounding water bodies of Delaware Bay, Chesapeake Bay, and the Atlantic Ocean considerably modify climate on the Delmarva Peninsula. Easterly winds tend to raise winter temperatures and lower normal summer temperatures, while maintaining a humid environment. The warmest period of the year is towards the end of July, when maximum afternoon temperatures average 31.7 °C (89 °F) (Figure 6). Temperatures over 32.2 °C (90°F) occur on average 31 days a year, with one year having over 50 such days. Extremes of 37.8°C (100 °F) or higher can be expected in one year out of four. The coldest period is the end of January and the beginning of February, when the early morning temperature averages 4.4 °C (24 °F). On average the minimum temperature is below freezing 90 days of the year. Temperatures of 17.8 °C (0 °F) or lower can be expected one year in six.

The annual precipitation for central Delaware averages 117 cm (46 in.) (Figure 7). The monthly distribution is fairly uniform during the year, with monthly ranges from a minimum of 7.6 cm (3 in.) to a maximum of 12.7 cm (5 in.). Due to the predominance of convective storms during the summer months, rainfall amounts can vary widely across the region. The remainder of the year synoptic scale events dominate and produce a more even precipitation distribution. The average seasonal snowfall (October through April) is 40 cm (16 in.), with annual totals ranging from a trace to more than 114 cm (45 in.). A drought may occur in any season, but a serious drought is most likely in the summer.

The prevailing winds are from the west to northwest most of the year, but tend to be more southerly or southwestern in the summer. The average annual windspeed is approximately 4 meters/second (9 mph), but winds of 22 meter/second (50 mph) or more may accompany severe thunderstorms, hurricanes, and winter storms (nor’easters).

Thunderstorms occur on average 30 days a year with the majority occurring between May and August. Tornadoes average only one a year throughout Delaware, causing little damage. Typically, central Delaware can expect a hurricane or its remnants once a year, usually between August and October, usually causing little damage. However, winter coastal storms (“nor’easters”) occur more frequently, often accompanied by significant coastal flooding and shoreline erosion.

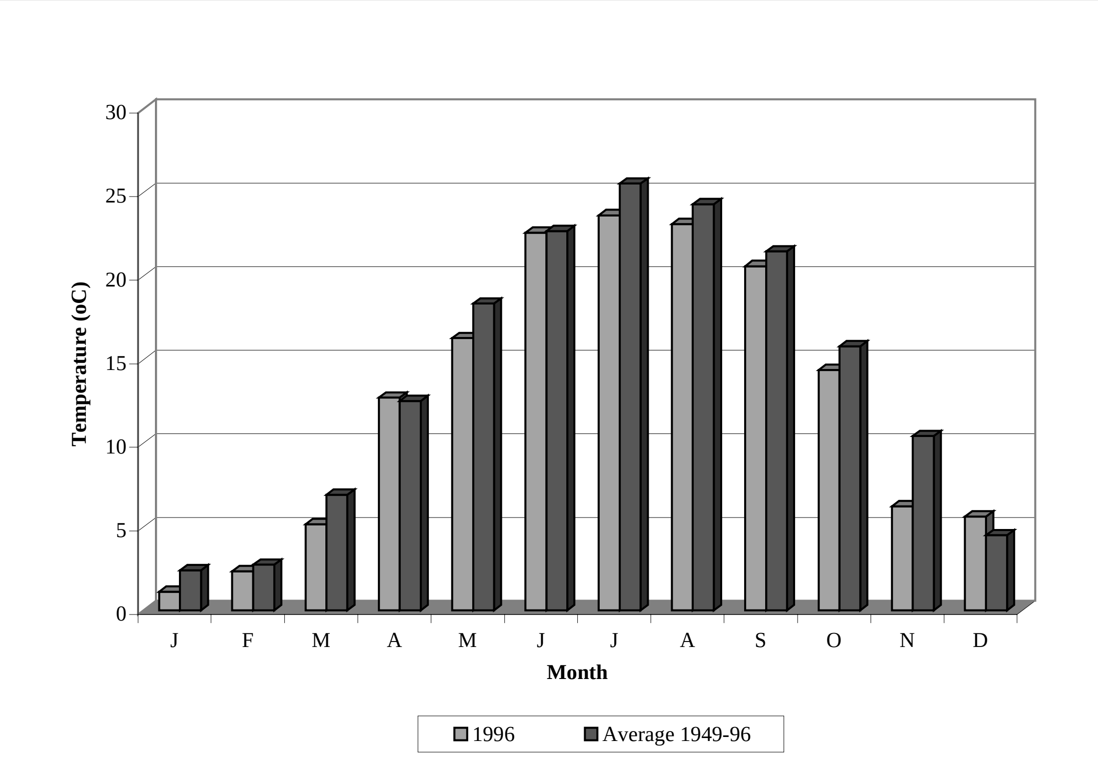


Figure 6. Temperature - Dover, Delaware. 1996 Monthly and 1949-1996 Monthly Averages.

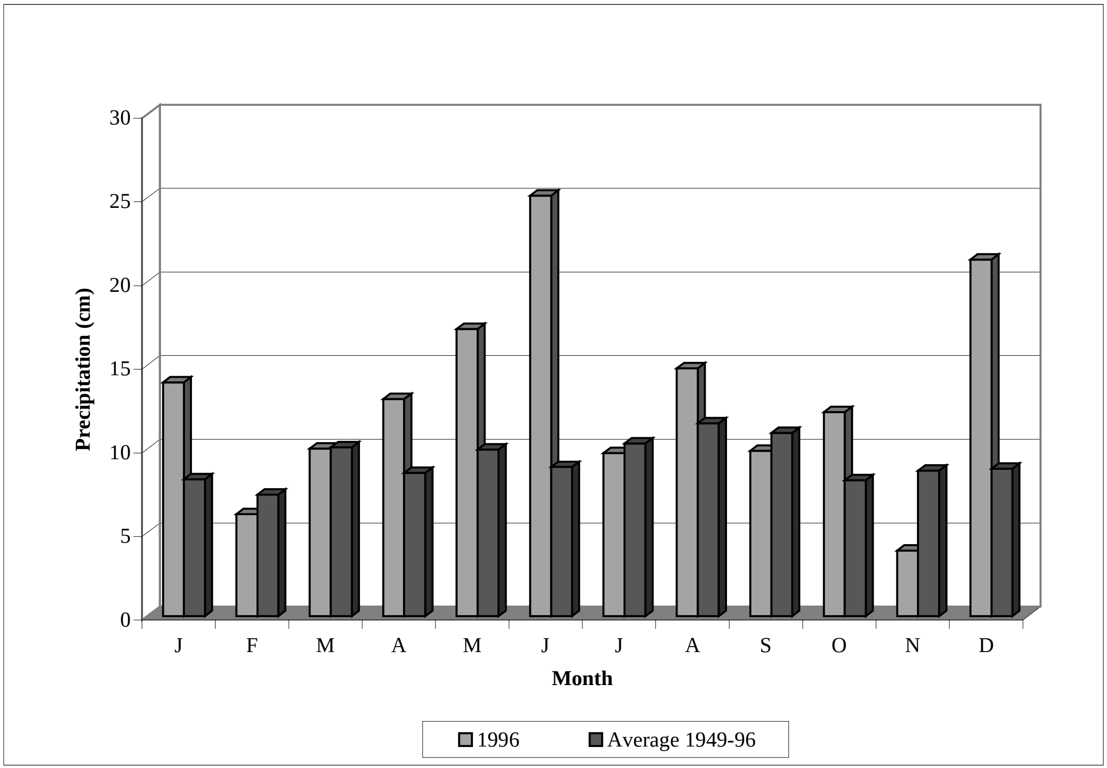


Figure 7. Precipitation - Dover, Delaware. 1996 Monthly and 1949-1996 Monthly Averages.

The DNERR has established, to NOAA specifications, a Campbell weather station at the Lower St. Jones River Reserve. Here DCPS staff continuously measure air temperature, relative humidity, wind speed and direction, precipitation, barometric pressure, and photosynthetically active radiation (PAR). Additionally, an atmospheric deposition sampler has been deployed to monitor pH, nitrogen and other contaminants in rainwater.

Soils

The majority of the soils of the two Reserve components are classified as Tidal Marsh. Tidal marsh soils are regularly flooded and range from salty to brackish. They consist of variously stratified sand and clay layers, with many places having thick peaty or mucky remains of vegetation. Some of the areas with significant layers of clay may contain large amounts of sulfur compounds.

The thickness of the St. Jones River marsh ranges from less than 1 meter (3 feet) up to 27.5 meters (90 feet) in depth at the mouth of the St. Jones River. The majority of the upland soils of the St. Jones component are Sassafras sandy loams. There are small areas of Matapeake, Johnston and Othello silt loams and a few pockets of Woodstown sandy loam. The Sassafras series consist of deep, well-drained soils on the uplands. The Woodstown series of soils are similar to the Sassafras, but only moderately well drained. The silt loam soils series contain a mantle of silty material over older sandy sediments. The Mattapeake soils are well drained, while the Othello and Johnston are poorly and very poorly drained, respectively. In a few areas prone to flooding along the river there are mixed alluvial soils, which are a mixture of recently deposited silty or sandy material eroded from adjacent uplands.

The upland soils of the Blackbird Creek component are similar to the St. Jones, with the exception of the Matapeake series being the dominant soil group. There are large sections of Sassafras and Johnston series along the upper reaches. The minor soil groups of the Blackbird component include Othello, Mattapex and Keyport. The Mattapex and Keyport soils are both deep, moderately well drained silt loams, but are slowly permeable.

Soil series commonly found in the transition between the tidal marsh and upland soils at both Reserve sites include Fallsington, Pocomoke, Elkton, and Mixed Alluvial soils. Fallsington, Pocomoke, and Elkton soils are poorly to very poorly drained soils characteristic of the Coastal Plain. The native vegetation supported by these soils includes mixed wetland hardwoods. Mixed Alluvial soils are commonly found on floodplains of rivers and streams. These soils are poorly drained and often flood at various times of the year.

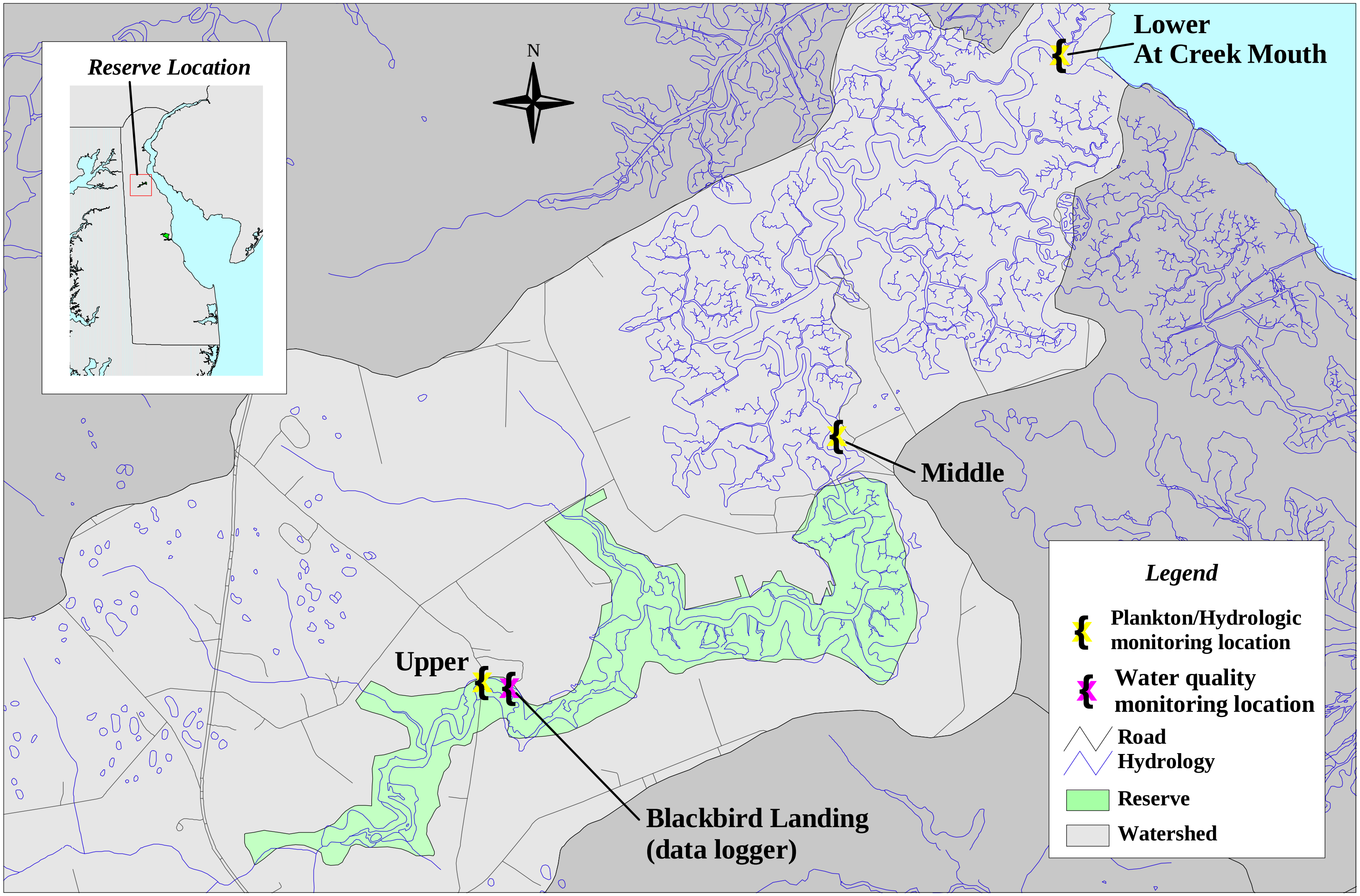
Detailed information on the soil classification of the DNERR is available in the Soil Surveys of New Castle and Kent Counties (SCS, 1970; SCS, 1971), distributed by the Natural Resources Conservation Services of each county.

Tidal Hydrography (main channels)

Environmental Consulting Services, Inc. (ECSI) collected data on general tidal characteristics on both Reserve sites in April and May of 1997. To date these data remain the only information about surface tidal hydrography for the DNERR. These data are supplemented by predicted tide ranges from the NOAA tidal current tables (tidal datum reference stations are Reedy Point at the entrance to the C&D Canal from the Delaware River, and Breakwater Harbor at Cape Henlopen). Table 1 presents a summary of tide data. Station locations refer to tide monitoring points in the lower, middle and upper reaches of Blackbird Creek and the St. Jones River. These generally match sampling stations used by ECSI in the 1995-96 plankton study (Figures 8 and 9). Extreme spring and neap values refer to the most extreme tidal ranges from NOAA predicted tidal elevations for each Reserve site (creek or river mouth). Observed

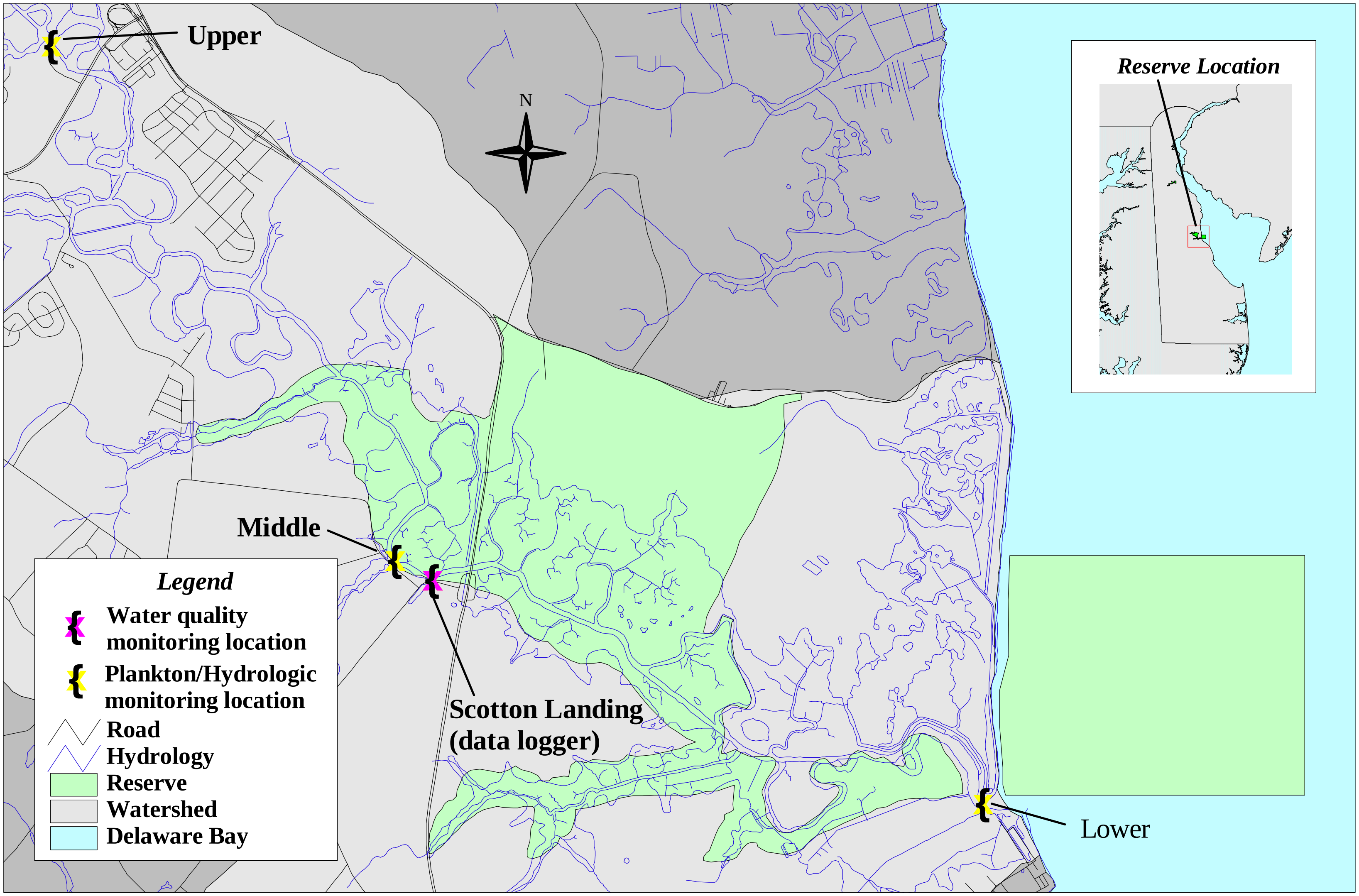
Location	Reedy Point	Blackbird Creek			Break water	St. Jones River		
Parameter	Lower	Lower	Middle	Upper	Lower	Lower	Middle	Upper
Main channel Distance to mouth (m)		690	9420	15720		1110	6770	14420
Width (m)		90	75	110		90	40	75
Observed Depth - High (m)		7.4	3.3	1.8		6.7	3.2	3.5
Observed Depth - Low (m)		5.7	2.3	0.5		5.5	2.4	2.7
Predicted Tidal Range								
Mean (m)	1.65				1.28			
Spring (m)	1.95				1.49			
Extreme Spring (m)		2.4				1.3		
Extreme Neap (m)		1.2				0.7		
Observed Tidal Range								
Spring Mean (m)		2.02	1.11	1.12		1.58	1.26	0.77
Neap Mean (m)		1.44	1.23	1.13		1.34	1.13	0.80
Tidal Wave Progression time - Spring (hrs:min)								
Low tide		00:00	01:56	02:52		00:00	00:35	02:09
High tide		00:00	01:14	02:53		00:00	00:15	02:15
Low tide		00:00	01:19	01:58		00:00	00:30	01:57
Tidal Wave Progression time - Neap (hrs:min)								
Low tide		00:00	NA	NA		00:00	00:46	02:15
High tide		00:00	01:54	02:33		00:00	00:46	02:12
Low tide		00:00	01:04	01:40		00:00	00:34	02:25
Tidal Stand/Slack (hrs:min)								
Spring Low tide/slack		01:35	00:38	00:12		01:10	01:21	00:24
Spring High tide/slack		01:12	01:01	00:16		00:49	01:16	00:07
Spring Low tide/slack		01:04	00:21	00:08		01:17	01:14	00:11
Neap Low tide/slack		NA	00:25	00:07		00:43	01:21	00:19
Neap High tide/slack		01:08	00:26	00:13		00:43	00:38	00:29
Neap Low tide/slack		00:56	00:27	00:07		00:43	00:46	00:08

Table 1. Tide Data



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 8. Upper Blackbird Creek Reserve: Plankton Community/Hydrologic and Water Quality Monitoring Locations



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 9. Lower St. Jones River Reserve: Plankton Community/Hydrologic and Water Quality Monitoring Locations

water depths were derived from ECSI channel cross section and elevation data.

Tide ranges

Similar to other areas along the Atlantic Coast, both DNERR sites are subject to semi-diurnal tides, with tides about 12.4 hours between two consecutive high tides or two consecutive low.

Mean tide range (i.e. difference between low and high tide heights, or a station's tidal amplitude) in Lower Blackbird Creek (where the creek empties into the lower Delaware River) is predicted by NOAA Tide Tables to be about 1.7 meters (5.65 ft), with spring tide range averaging about 1.92 meters (6.3 ft). Mean tide range in the Lower St. Jones River (where the river empties into Delaware Bay) as predicted by NOAA Tide Tables is not as large, averaging about 1.5 meters (4.8 ft) with spring tide range averaging about 1.7 meters (5.7 ft).

Observed percent differences for tide ranges during spring versus neap tides at the mouth of Blackbird Creek showed about a 29% decrease for neap tides, while similar observation comparisons for the mouth of the St. Jones River showed about a 15% decrease for neap tides. It is probable that the differences in tide ranges between spring tides and neap tides for both systems can be as large as 50% during extreme conditions.

Observed differences in tide ranges decreased in both systems as one progresses upstream. During spring tides in Blackbird Creek, observed tide ranges at both the middle and upper stations were only about 55% of the tide range at the lower station. During neap tides, Blackbird Creek's middle station's observed tide range was about 85% of the lower station, while the upper station was about 78% of the lower station's range. Thus, when the mouth of Blackbird Creek near the lower station has a tide range 1.7 meters (5.6 ft) for example, this being a tide cycle when the mean tide range is demonstrated, the middle station might have a tide range of about 1.2 meters (3.9 ft), while the upper station has a tide range of about 1.1 meters (3.7 ft). During spring tides in the St. Jones River, observed tide range at the middle station was about 80% of the lower station's range, and at the upper station it was only about 49% of the lower station. During neap tides, the St. Jones River's middle station's tide range was about 84% of the lower station, while the upper station was only about 60% of the lower station's range. Thus, when the mouth of the St. Jones River near the lower station has tide range of 1.5 meters (4.8 ft) for example, this being a tide cycle when the mean tide range is demonstrated, the middle station might have a tide range of about 1.2 meters (3.9 ft), while the upper station has a tide range of about 0.8 meters (2.6 ft). This attenuation of tide range as one progresses landward in smaller estuarine channels is typical of coastal rivers and creeks, with greater differences in landward tide range attenuations occurring during spring tides (as compared to neap tides).

Tide wave progression

Tide wave progression times (i.e. lag times of peak tidal stands, for low or high tides, as one proceeds landward from a river or creek mouth) were observed during spring tides in Blackbird Creek to be from 1.2-1.9 hours at the middle station after peak stand times at the lower station, and from 2.0-2.9 hours at the upper station in comparison to the lower station. During neap tides in Blackbird Creek, the tide wave progression times were observed to be from 1.1-1.9 hours at the middle station and from 1.7-2.6 hours at the upper station. Tide wave progression times were observed during spring tides in the St. Jones River to be from only 0.25-0.6 hours at the middle station after peak stand times at the lower station, and from 2.0-2.25 hours at the upper station in comparison to the lower station. During neap tides in the St. Jones River, the tide wave progression times were observed to be from only 0.6-0.8 hours at the middle station and from 2.2-2.4 hours at the upper station. The lag time for peak tide stands between lower and upper stations of over 2 hours (sometimes approaching 3 hours) in both systems is typical of many of Delaware's coastal tidal rivers and creeks. The relatively short time difference for peak tide stands of only 15-50 minutes between the lower and middle St. Jones River stations (versus 1-2 hours for similar comparisons for Lower Blackbird Creek) is probably reflective of the Lower St. Jones River's past channelization, whereby wave-slowing (and wave-dampening) channel meanders were eliminated.

Tide wave lags

Time lags between peak tide stand (high or low tide) and slack current (low slack water or high slack water) are common in estuarine channels, caused by factors of both progressive and standing waves interacting as a tide wave progresses landward. At the lower station in Blackbird Creek, during spring tides the difference between times of peak high tide and a following high slack water, or between times of peak low tide and a following low slack water, were observed to range from 1.1-1.6 hours. The middle station the lag time during spring tides was reduced to 0.3-1.0 hours, while at the upper station the lag was only 0.1- 0.3 hours. During neap tides in Blackbird Creek, the observed time difference at the lower station was 0.9-1.1 hours, at the middle station was about 0.4 hours, and at the upper station only 0.1-0.2 hours. At the lower station in the St. Jones River, during spring tides the observed difference between peak tide stands and slack water ranged from 0.8-1.3 hours. At the middle station, the lag time during spring tides ranged from 1.2-1.3 hours, while at the upper station it was reduced to 0.1-0.4 hours. During neap tides in the St. Jones River, the observed difference at the lower station was about 0.7 hours, at the middle station was from 0.6-1.3 hours, and at the upper station only 0.1-0.5 hours. The lag times of about 1 hour between peak tide stands and slack waters at the mouths of these two estuarine systems are fairly characteristic for coastal rivers and creeks around Delaware Bay. In Blackbird Creek, there was a shortening of this lag time as one progresses landward, but in the St. Jones River there wasn't a noticeable shortening of the lag time going from the lower station to the middle station, which once again may be due to past channelization of the Lower St. Jones River.

Channel widths and depths

Tidal elevation profile data are shown in Table 2 (Blackbird Creek), Table 3 (St. Jones River) and in Figures 10 (Blackbird Creek) and 11 (St. Jones River). Channel bottom cross section profiles (Figures 12 and 13) and channel widths illustrate decreasing channel depth with little channel narrowing between lower and upper stations. Channel width at Blackbird Creek's lower station is about 90 meters (295 ft), at the middle station about 75 meters (246 ft), and at the upper station about 110 meters (361 ft), in an upstream area of extensive shallow mudflats adjacent to the channel edges. Channel width at the St. Jones River's lower station is about 90 meters (295 ft), at the middle station about 40 meters (131 ft), and at the upper station about 75 meters (246 ft), also in an upstream area with extensive shallow mudflats adjacent to the main channel. At most locations mid-channel depths are the deepest depths (Figs. 12 and 13). Mid-channel depth at low tide at Blackbird Creek's lower station is about 5.7 meters (18.7 ft), at the middle station about 2.3 meters (7.5 ft), and at the upper station about 0.5 meters (1.6 ft). Mid-channel depth at low tide at the St. Jones River's lower station is about 5.5 meters (18.0 ft), at the middle station about 2.4 meters (7.9 ft), and at the upper station about 2.7 meters (8.9 ft). Mid-channel depths at high tide at all these stations would be deeper by an amount equal to the tide range at a station on any given cycle.

Tide elevation graphs (Figures 10 and 11) display broadening tidal curves moving upstream on either site, indicating that the rate of change in water depths decreases as one proceeds landward. Spring versus neap tide pattern differences for the tidal curves are noted, but are not very different for the upper stations.

Spring

Lower station

	Mid channel (cm/sec)			Tidal Elev. (cm.)	Salinity	
	Upper	Lower	Time	(bank crest)	Upper	Lower
LSW			07:00	-100	2.2	2.2
LSW + 1	44	36	08:00	-51	2.6	2.8
LSW + 2	59	57	09:00	-7	2.6	2.7
LSW + 3	62	75	10:00	22	2.7	2.7
LSW + 4	57	54	11:00	47	3.0	3.2
LSW + 5	10	26	12:00	38	3.1	3.1
HSW			12:20	25	3.1	3.1
HSW + 1	77	67	13:56	-41	2.9	2.8
HSW + 2	75	80	14:20	-60	2.7	2.9
HSW + 3	85	77	15:20	-85	2.8	3.0
HSW + 4	75	77	16:20	-119	2.7	2.7
HSW + 5	77	57	17:20	-144	2.6	2.6
LSW			19:19	-120	2.5	2.5

Middle station

	Mid channel (cm/sec)			Tidal	Salinity	
	Upper	Lower	Time	Elevation	Upper	Lower
LSW			07:59	-93	1.4	1.4
LSW + 1	31	36	08:59	-70	1.8	1.8
LSW + 2	44	41	09:59	-48	1.8	1.8
LSW + 3	62	67	10:59	-32	2.0	2.1
LSW + 4	39	33	11:59	#N/A	2.2	2.4
LSW + 5	26	15	12:59	-20	2.5	2.6
HSW			13:23	-21	2.5	2.6
HSW + 1	36	39	14:23	-24	2.4	2.3
HSW + 2	44	39	15:24	-40	2.2	2.4
HSW + 3	80	72	16:24	-68	2.0	2.0
HSW + 4	62	75	17:24	-94	1.4	1.4
HSW + 5	46	36	18:24	-118	1.3	1.3
LSW			19:55	-123	1.2	1.2

Upper station

	Mid channel (cm/sec)			Tidal	Salinity	
	Upper	Lower	Time	Elevation	Upper	Lower
LSW			08:29	-102	0.1	0.1
LSW + 1	30	21	09:29	-78	0.1	0.1
LSW + 2	26	21	10:29	-57	0.1	0.1
LSW + 3	24	27	11:29	-41	0.1	0.1
LSW + 4	15	24	12:29	-29	0.1	0.1
LSW + 5	#N/A	#N/A	13:30	-22	#N/A	#N/A
HSW			14:17	-20	1.0	1.0
HSW + 1	27	23	15:17	-30	0.5	0.5
HSW + 2	26	27	16:17	-43	0.2	0.2
HSW + 3	34	30	17:17	-63	0.1	0.1
HSW + 4	46	38	18:17	-86	0.1	0.1
HSW + 5	43	37	19:17	-125	0.1	0.1
LSW			20:21	-149	0.1	0.1

Blackbird Spring 5/6/97

Neap

Lower station

	Mid channel (cm/sec)			Tidal Elev. (cm.)	Salinity	
	Upper	Lower	Time	(bank crest)	Upper	Lower
LSW			13:24	-159	0	0
LSW + 1	46	39	14:24	-118	2	2
LSW + 2	41	54	15:24	#N/A	2	2
LSW + 3	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LSW + 4	33	57	17:24	-33	2	2
LSW + 5	51	51	18:24	-28	2	2
HSW			19:28	-39	2	2
HSW + 1	26	23	20:28	-69	2	2
HSW + 2	57	46	21:28	-99	2	2
HSW + 3	69	64	22:28	-136	2	2
HSW + 4	69	64	23:28	-154	2	2
HSW + 5	57	51	00:28	-166	2	2
LSW			02:01	-150	2	2

Middle station

	Mid channel (cm/sec)			Tidal	Salinity	
	Upper	Lower	Time	Elevation	Upper	Lower
LSW			13:58	-122	0.0	0.0
LSW + 1	41	33	14:58	-88	0.0	0.0
LSW + 2	51	36	15:58	-59	1.0	1.0
LSW + 3	57	36	16:58	-39	1.0	1.0
LSW + 4	51	41	17:58	#N/A	1.0	1.0
LSW + 5	36	28	18:58	-12	2.0	2.0
HSW			20:40	-13	2.0	2.0
HSW + 1	51	41	21:40	-24	2.0	2.0
HSW + 2	80	72	22:40	-41	1.0	1.0
HSW + 3	87	82	23:40	-96	1.0	1.0
HSW + 4	82	67	00:40	-94	1.0	1.0
HSW + 5	62	46	01:40	-112	0.0	0.0
LSW			02:36	-116	0.0	0.0

Upper station

	Mid channel (cm/sec)			Tidal	Salinity	
	Upper	Lower	Time	Elevation	Upper	Lower
LSW			14:23	-108	0	0
LSW + 1	27	27	15:23	-73	0	0
LSW + 2	27	27	16:23	-50	0	0
LSW + 3	27	26	17:23	-31	0	0
LSW + 4	26	24	18:23	-12	0	0
LSW + 5	17	12	19:23	-1	0	0
HSW			21:06	7	0	0
HSW + 1	27	21	22:06	-2	0	0
HSW + 2	26	24	23:06	-15	0	0
HSW + 3	30	26	00:06	-31	0	0
HSW + 4	40	35	01:06	-55	0	0
HSW + 5	34	34	02:06	-88	0	0
LSW			02:52	-101	0	0

Table 2. Channel Current Velocity, Tide Elevation, and Salinity – Blackbird Creek

Spring

Lower station
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elev. (cm.) (bank crest)	Salinity Upper	Lower
LSW			07:39	-111	13	13
LSW + 1	5	15	08:39	-76	13	13
LSW + 2	8	31	09:39	-35	15	15
LSW + 3	33	31	10:39	1	18	18
LSW + 4	31	26	11:39	10	21	22
LSW + 5	3	10	12:39	-9	21	21
HSW			12:29	-3	22	22
HSW + 1	33	21	13:29	-32	21	21
HSW + 2	62	21	14:29	-71	17	17
HSW + 3	39	39	15:29	-106	17	17
HSW + 4	49	31	16:29	-130	15	15
HSW + 5	31	33	17:29	-145	13	13
LSW			19:21	-111	11	12

Middle station
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elevation	Salinity Upper	Lower
LSW			08:25	-109	4	4
LSW + 1	41	46	09:25	-64	7	7
LSW + 2	62	51	10:25	-34	13	14
LSW + 3	62	67	11:25	-17	16	16
LSW + 4	54	44	12:25	#N/A	18	18
LSW + 5	15	18	13:25	-32	18	19
HSW			13:11	-30	18	19
HSW + 1	46	33	14:11	-53	15	15
HSW + 2	67	54	15:11	-78	15	16
HSW + 3	57	57	16:11	-104	13	13
HSW + 4	67	46	17:11	-127	11	11
HSW + 5	57	46	18:11	-141	5	5
LSW			19:48	-114	4	4

Upper station
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elevation	Salinity Upper	Lower
LSW			09:02	-61	0	0
LSW + 1	30	12	10:02	-43	0	0
LSW + 2	34	21	11:02	-27	0	0
LSW + 3	34	32	12:02	-14	1	1
LSW + 4	21	27	13:02	-4	1	1
LSW + 5	0	0	14:02	0	1	1
HSW			14:02	0	1	1
HSW + 1	9	21	15:02	-6	1	1
HSW + 2	18	18	16:02	-17	0	0
HSW + 3	37	34	17:02	-30	0	0
HSW + 4	40	38	18:02	-47	0	0
HSW + 5	35	37	19:02	-69	0	0
LSW			20:12	-84	0	0

St. Jones Spring 5/8/97

Neap

Lower station : data converted
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elev. (cm.) (bank crest)	Salinity Upper
LSW			13:55	-130	6
LSW + 1	10	15	14:55	-108	8
LSW + 2	13	21	15:55	-75	12
LSW + 3	15	21	16:55	-42	18
LSW + 4	15	26	17:55	-23	18
LSW + 5	11	23	18:55	-8	20
HSW			19:50	-18	20
HSW + 1	28	10	20:50	-36	18
HSW + 2	41	28	21:50	-57	12
HSW + 3	59	44	22:50	-96	12
HSW + 4	41	36	23:50	-118	12
HSW + 5	31	36	00:50	-139	8
LSW			02:20	-130	6

Middle station : data converted
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elevation	Salinity Upper
LSW			15:19	-145	0
LSW + 1	44	36	16:19	-118	1
LSW + 2	55	46	17:19	-63	2
LSW + 3	51	51	18:19	-32	3
LSW + 4	51	36	19:19	#N/A	5
LSW + 5	21	8	20:19	-39	6
HSW	0	10	20:31	-49	7
HSW + 1	57	41	21:31	-63	9
HSW + 2	69	51	22:31	-72	7
HSW + 3	77	67	23:31	-102	5
HSW + 4	46	51	00:31	-111	2
HSW + 5	57	36	01:31	-140	1
LSW			02:57	-133	0

Upper station : data converted
Mid channel (cm/sec)

	Upper	Lower	Time	Tidal Elevation	Salinity Upper
LSW			15:46	-84	0
LSW + 1	34	21	16:46	-65	0
LSW + 2	43	37	17:46	-47	0
LSW + 3	37	32	18:46	-33	0
LSW + 4	27	18	19:46	-21	0
LSW + 5	9	15	20:46	-13	0
HSW	0	0	21:48	-12	0
HSW + 1	3	2	22:48	-19	0
HSW + 2	34	30	23:48	-29	0
HSW + 3	37	35	00:48	-41	0
HSW + 4	41	37	01:48	-59	0
HSW + 5	32	32	02:48	-79	0
LSW			04:10	-92	0

Table 3. Channel Current Velocity, Tide Elevation, and Salinity – St. Jones River

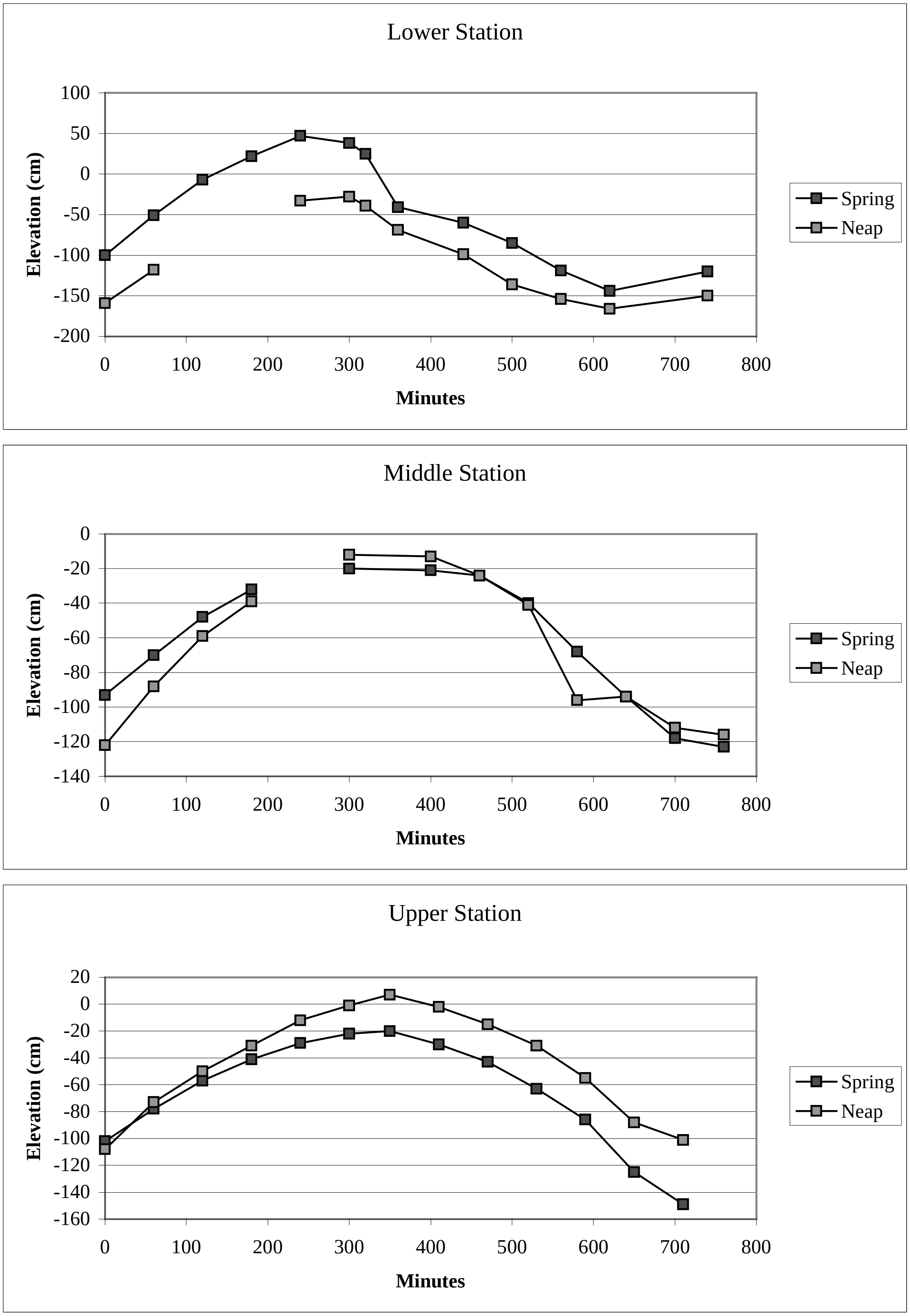


Figure 10. Representative Blackbird Creek Tidal Elevation Data, April-May 1997.

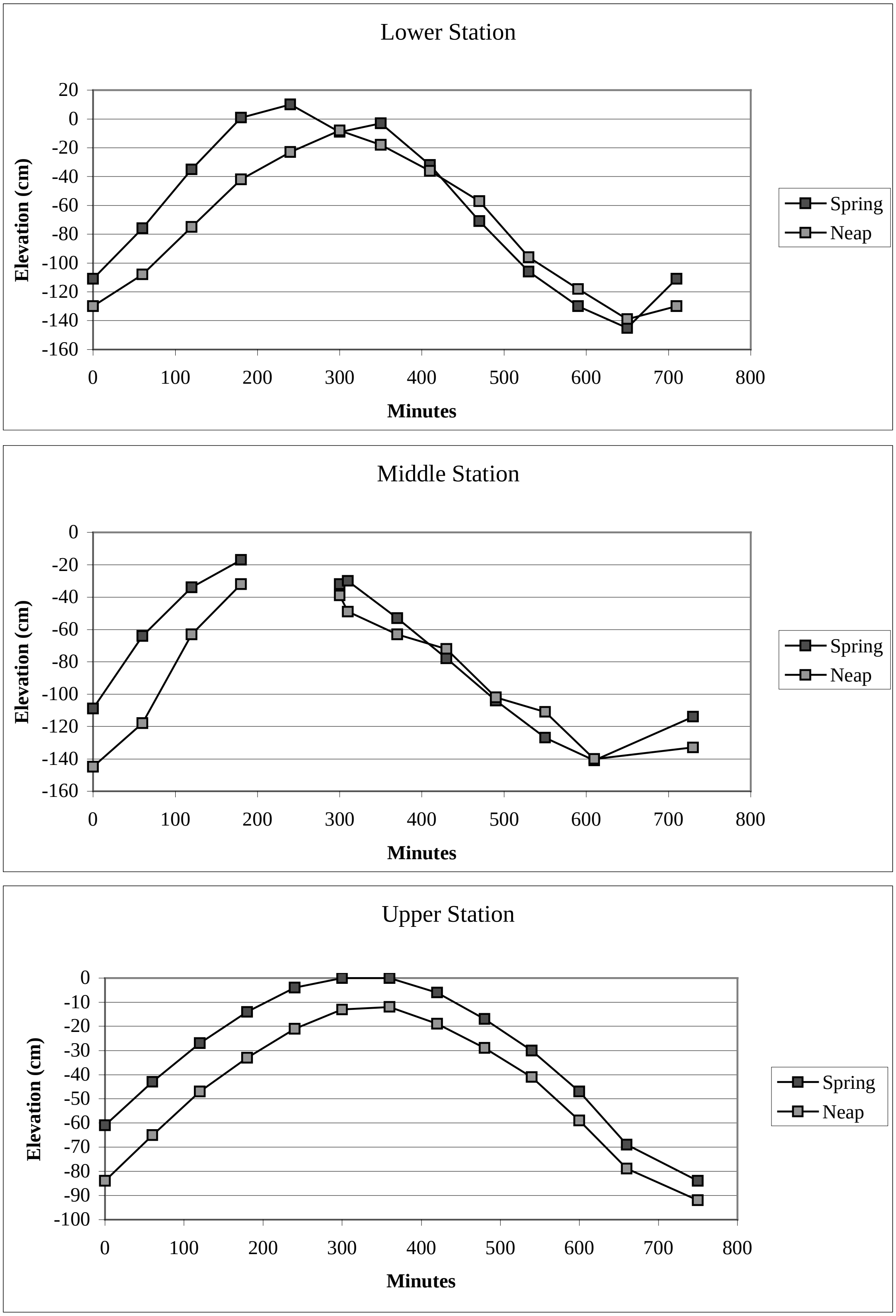


Figure 11. Representative St. Jones River Tidal Elevation Data, April-May 1997.

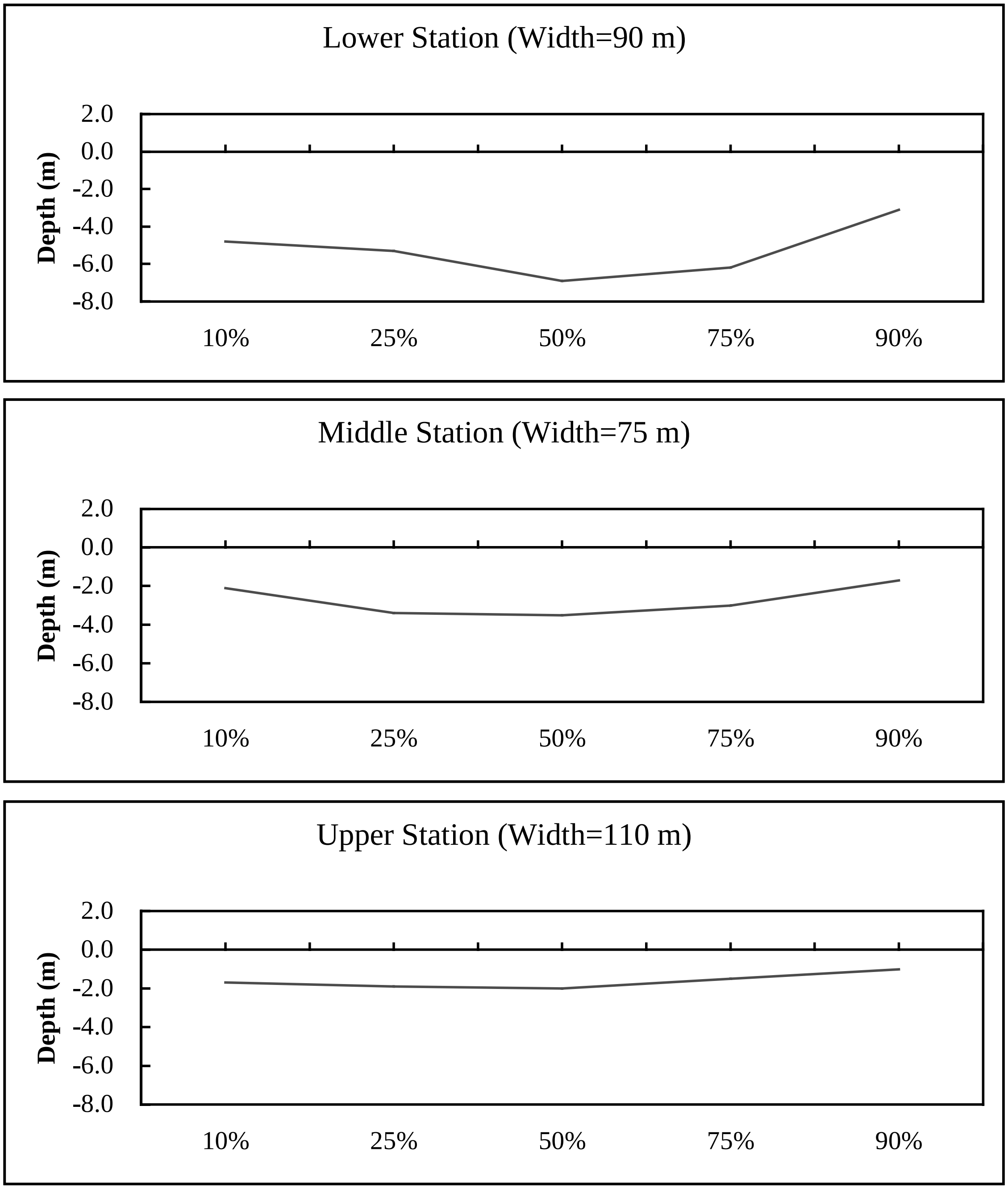


Figure 12. Blackbird Creek Channel Cross Section Profiles.
0% and 100% are channel edge tops at 0 m depth.

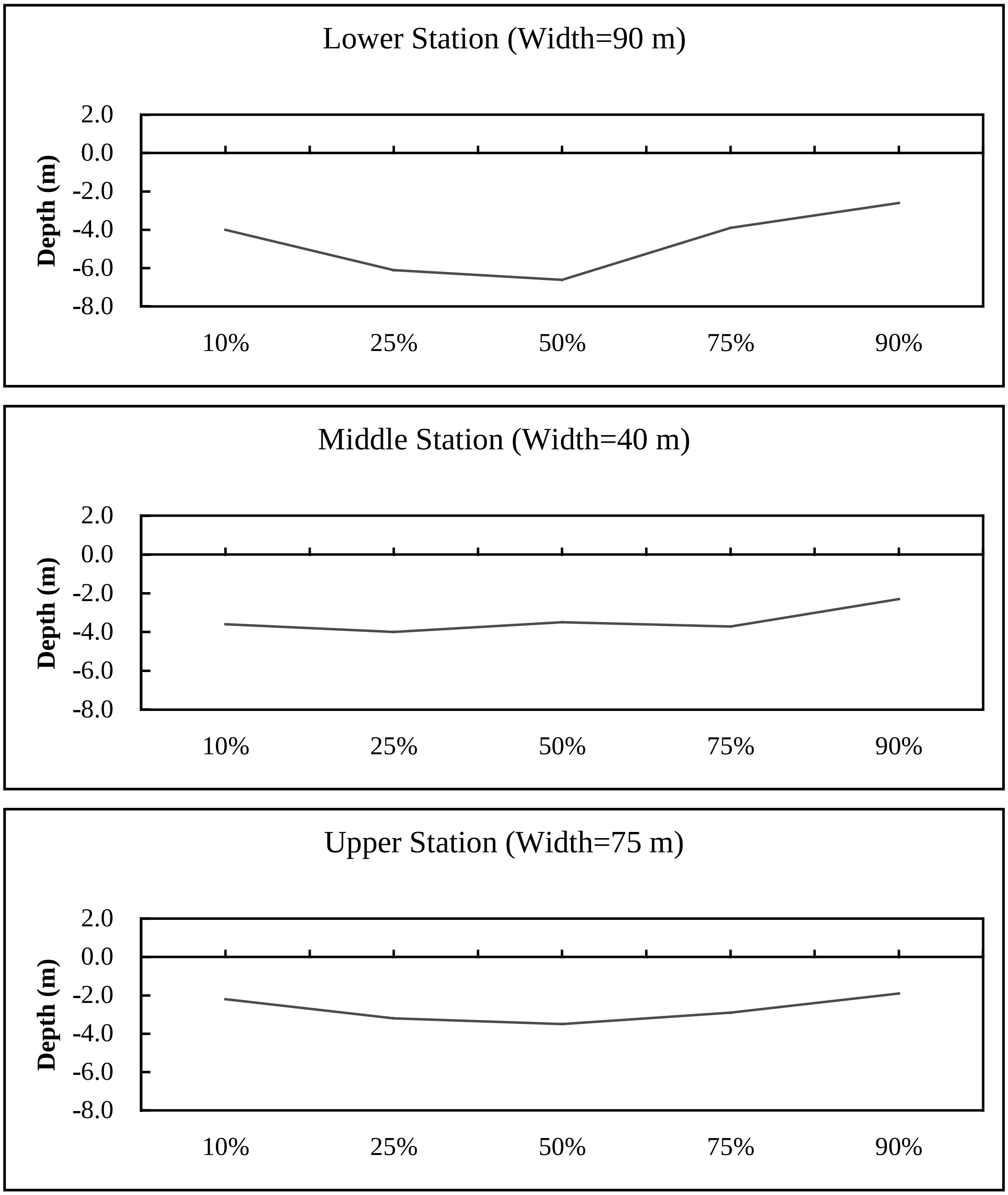


Figure 13. St. Jones River Channel Cross Section Profiles.
0% and 100% are channel edge tops at 0 m depth.

Tide range and water depth values determined by YSI Model 6000 data loggers for both Blackbird Landing and Scotton Landing (Figure 14) generally agree with tidal range data collected by ECSI (Table 1). Both monitoring stations have maximum depths of around 2.0 meters (6.6 ft), and minimum depths rarely were below 0.5 meters (1.6 ft). Mid-April 1996 data indicate occasional cycle periods of lower tidal elevations, possibly a result of large offshore storm systems or offshore winds. The Blackbird Landing depth frequency distribution data (Figure 15) display the dominance of higher tide elevations for this sampling point.

Tidal current velocities

Tables 2 and 3, current velocity data refer to center channel location (50%) and 25% (upper) and 75% (lower) depths. Tidal current velocity profiles are provided from the ECSI study in Table 4 (Blackbird Creek) and Table 5 (St. Jones River). These data cover mid-tide periods for both spring and neap tide conditions.

Observed mid-channel current velocities in both Blackbird Creek and the St. Jones River appear to have maximum speeds on either flood or ebb tides around times of mid-flood (e.g. LSW+3 hrs) and mid-ebb (e.g. HSW+3 hrs) (Tables 2 and 3). Mid-channel current velocities are usually faster than those at locations to either side of mid-channel (with measurements taken at points in mid-channel, halfway between mid-channel and channel edge, and at points no further away from shore than 10% of the channel's total width). This is most noticeable when one approaches within a few meters of the channel's bank edge, where friction effects can significantly reduce speeds, but in some locations the bend and orientation of a channel segment can cause fastest velocities to occur somewhat away from mid-channel (Tables 4 and 5).

Maximum current velocities at Blackbird Creek at the mid-channel lower station at mid-depth during spring tides were observed in the 60-70 cm/sec range, whereas during neap tides similar maximum velocities fell into the 50-60 cm/sec range (note: one nautical mile per hour, or one "naut" = 51.4 cm/sec). Maximum current velocities in the St. Jones River at the mid-channel lower station at mid-depth during spring tides were somewhat lower, in the 30-40 cm/sec range, and during neap tides dropped into the 20-30 cm/sec range. There is some indication that ebb tide currents are somewhat faster than flood tide currents in these systems, but more data need to be gathered before this could be definitively stated. Slight differences (10-20%) in current velocities occur depending upon vertical position in water column (with measurements taken at locations 10%, 25%, 50%, 75%, and 90% of the water column's total depth), but there is no clear pattern of upper levels being faster than lower levels or vice versa (Tables 4 and 5). There were no observations of estuarine bi-layered flow in either system (Tables 2 and 3), but this in part might be caused by current direction and velocity readings that were taken at times no closer than one hour to times of slack water. However, it is probable that flow in these relatively small subestuary channels is primarily uni-directional from top to bottom at almost all times. Current velocities were similar between lower and middle stations for both systems, but in both systems upper station maximum current velocities were often reduced by half in comparison to downstream stations (Tables 2 and 3).

Future Tidal Hydrography Information

Further characterization of DNERR site hydrology will result from the current studies described above, and additional projects that are already underway, but have not yet been analyzed or released. The Delaware Coastal Programs Section (DCPS) will be developing hydrologic loading factors and simple hydraulic models for program objectives on water quality issues. This task should include estimates of Reserve site tidal prism volumes, additional channel cross sections, and related sub-site analysis of hydrology. A graduate

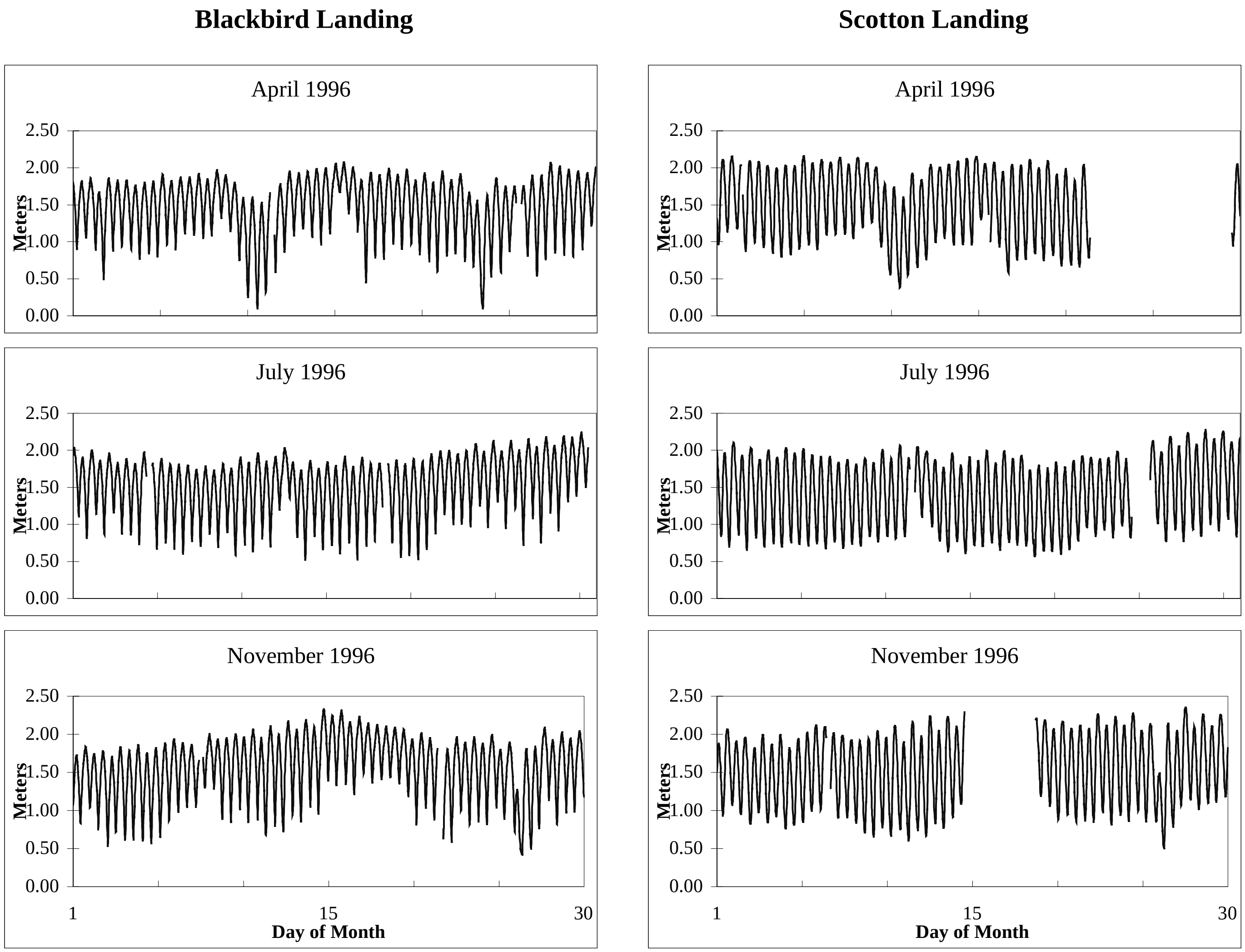


Figure 14. Representative Monthly Water Depth Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

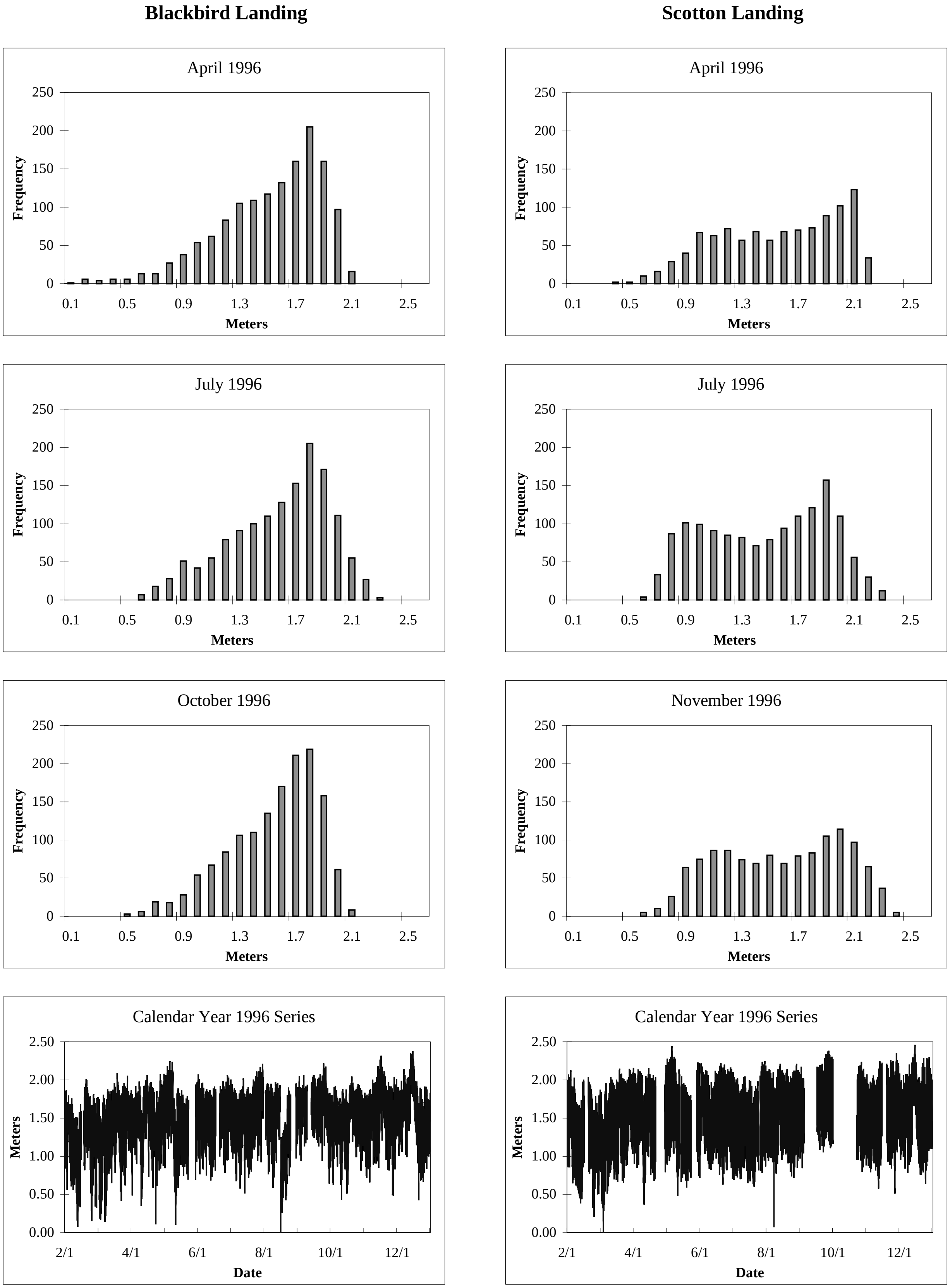


Figure 15. Representative Monthly Depth Frequency Distribution and Annual Depth Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

Spring

Lower station LSW + 4: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			49		
25%	5	10	62	93	93
50%			62		
75%	10	21	75	77	95
90%			67		

Lower station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			87		
25%	10	77	85	82	67
50%			77		
75%	8	51	77	77	69
90%			77		

Middle station LSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			57		
25%	21	26	62	41	15
50%			67		
75%	15	21	67	31	15
90%			51		

Middle station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			77		
25%	36	77	80	80	51
50%			72		
75%	31	85	72	67	41
90%			72		

Upper station LSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			21		
25%	3	21	24	15	3
50%			21		
75%	3	18	27	14	3
90%			24		

Upper station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			37		
25%	27	34	34	27	24
50%			30		
75%	24	24	30	32	21
90%			37		

Neap

Lower station LSW + 4: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			39		
25%	69	67	33	11	8
50%			54		
75%	64	64	57	8	8
90%			59		

Lower station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			64		
25%	67	67	69	85	69
50%			67		
75%	68	62	64	62	72
90%			64		

Middle station LSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			51		
25%	26	46	57	41	41
50%			51		
75%	10	51	36	41	15
90%			46		

Middle station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			87		
25%	21	67	87	62	62
50%			85		
75%	15	77	82	67	36
90%			77		

Upper station LSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			30		
25%	21	30	27	24	21
50%			26		
75%	21	27	26	23	23
90%			27		

Upper station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			34		
25%	26	29	30	27	27
50%			26		
75%	18	21	26	27	27
90%			27		

Table 4. Channel Cross Section Current Velocities – Blackbird Creek

Spring

Lower station LSW + 4: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			26		
25%	8	18	33	28	26
50%			10		
75%	5	21	31	49	21
90%			26		

Lower station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			41		
25%	13	41	39	36	26
50%			41		
75%	5	39	39	41	28
90%			36		

Middle station LSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			67		
25%	46	51	62	57	31
50%			69		
75%	31	41	67	49	21
90%			57		

Middle station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			41		
25%	31	46	57	41	36
50%			62		
75%	26	51	57	41	21
90%			36		

Upper station LSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			32		
25%	14	21	34	27	9
50%			35		
75%	9	17	32	24	24
90%			30		

Upper station HSW + 3: (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			27		
25%	30	40	37	20	15
50%			27		
75%	27	37	34	30	27
90%			34		

Neap

Lower station LSW + 4: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			13		
25%	39	13	15	33	26
50%			23		
75%	36	6	26	31	15
90%			28		

Lower station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			41		
25%	41	59	59	49	36
50%			57		
75%	41	59	44	41	41
90%			26		

Middle station LSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			67		
25%	21	51	51	62	26
50%			62		
75%	21	36	51	46	15
90%			57		

Middle station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			72		
25%	51	67	77	77	46
50%			77		
75%	46	62	67	67	51
90%			62		

Upper station LSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			35		
25%	9	30	37	34	21
50%			34		
75%	11	21	32	29	2
90%			30		

Upper station HSW + 3: data converted (cm/sec)

Depth of water column	Percent of river width looking upstream				
	10%	25%	50%	75%	90%
10%			34		
25%	40	40	37	37	37
50%			35		
75%	37	37	35	30	37
90%			34		

Table 5. Channel Cross Section Current Velocities – St. Jones River

student research project at the University of Delaware, College of Marine Studies (CMS) involves analysis of tidal creek geomorphology, including stream density, channel sinuosity, and channel morphology (Vinton Valentine, pers. comm.).

Surface water quality (main channel tidal waters)

Surface water quality of Delaware River and Bay is well characterized in reports of the Delaware Estuary Program, especially in the summary document (Sutton *et al*, 1996). Other information can be found in the Comprehensive Conservation and Management Plan for Delaware's Tidal Wetlands (DNREC, 1993a) and various DNREC Section 305 nonpoint management/monitoring program reports. USGS stream flow and water quality data are collected in the non-tidal portions of the Reserve watersheds, above Reserve boundaries.

A cooperative program between the DNERR and DCMP has established a water quality monitoring program, addressing base water quality and stormwater target compound parameters. Although the program began data collection in 1995, continuous monitoring of base water quality parameters was not in full operation until 1996. As part of the DNERR's contribution, water quality parameters in tidal portions of Blackbird Creek and St. Jones River are being measured every 30 minutes at an upper-reach station in Blackbird Creek (Blackbird Landing) and at a middle-reach station in St. Jones River (Scotton Landing), using continuously recording water quality monitors (YSI Model 6000 data loggers) (Figures 8 and 9). Parameters currently being measured include water depth, water temperature, salinity, pH, dissolved oxygen (DO), and turbidity. Many of these data are currently available over the Internet at the NERRS Central Data Management Office, at the following address – HTTP:// INLET.GEOL.SC.EDU/CDMOHOME. HTML. Depending upon technological development and operational refinement of monitoring sensors, future parameters to measure with the data loggers, might include chlorophyll-a and ammonia. The water quality data loggers are being operated by DCPS staff and DNERR Graduate Research Fellows.

Data excerpts of base water quality parameters provided from this monitoring program by the DCPS and University of Delaware/CMS staff are presented for the DNERR sites. Water depth data for representative sampling periods are provided in Figure 14. Water quality data, summarized by DCPS staff, are presented in the discussion for five monitored water quality parameters. These data provide an example of the type of data potentially available to future DNERR research studies.

Data summaries are provided for long-term monitoring locations in each Reserve (Blackbird Landing and Scotton Landing - Figures 8 and 9). For descriptive representation of the Reserves' water quality, monthly averages for the year 1996 are presented. To describe tidal influences on the hydrological characteristics, a spring (May 3-4) and neap (May 22-24) tide are evaluated. Both evaluations were during periods of little rainfall, however the neap tide had significant rainfall preceding the tidal cycle.

Water temperature

As shown on Figure 16, monthly water temperatures for both Reserve components show similar trends corresponding with seasonal temperature changes. The maximum monthly average temperatures for the sampling locations were 25.5 °C (78 °F) for the St. Jones River site and 26.3 °C (79 °F) for the Blackbird Creek site, both which occur in August. During late winter months the water temperature can go below freezing. The seasonal trend of water temperature is evident in the 1996 summaries for Blackbird Landing and Scotton Landing shown in Figures 17 and

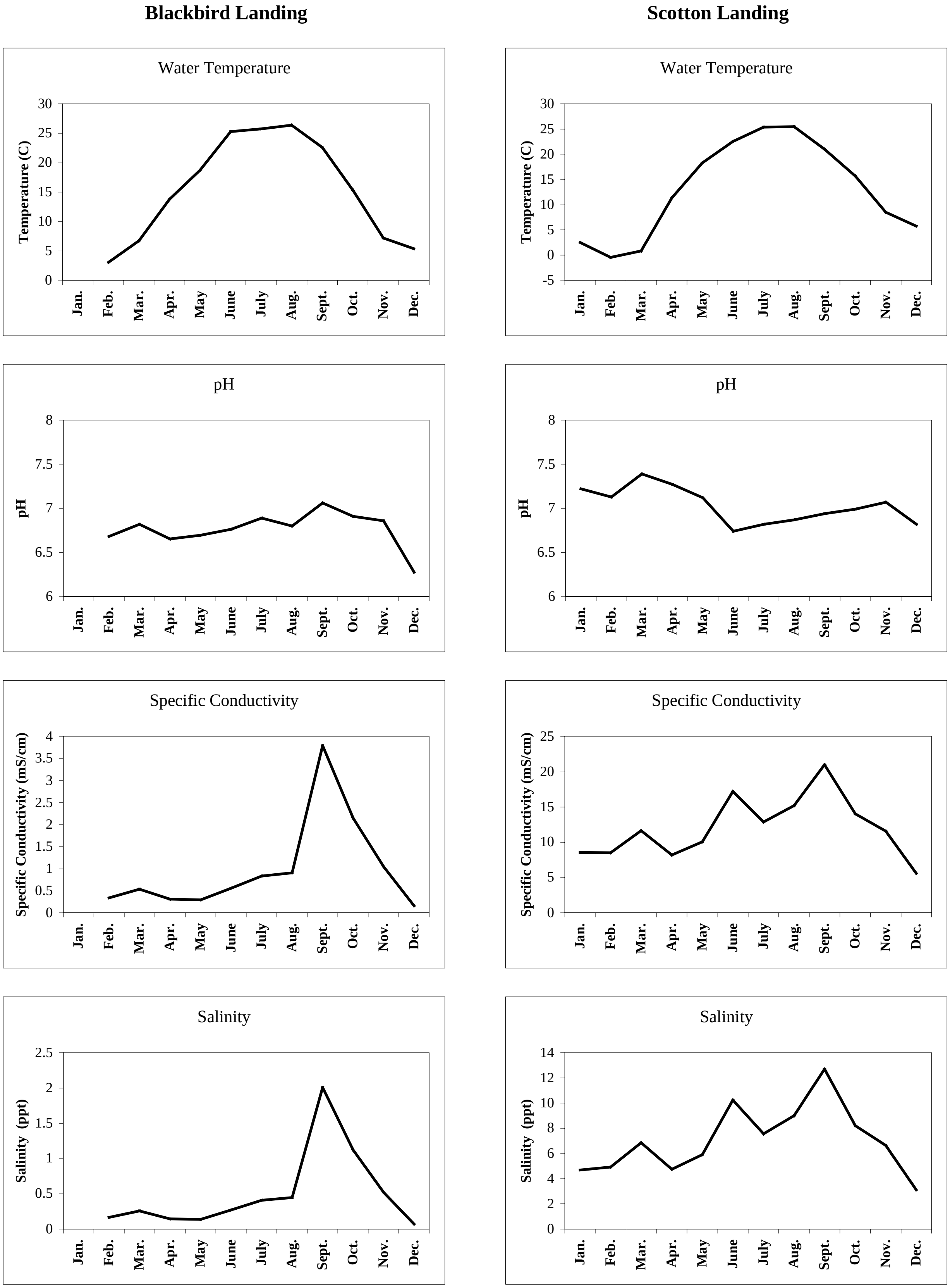


Figure 16. Monthly Mean Water Temperature, pH, Specific Conductivity, and Salinity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 1996.

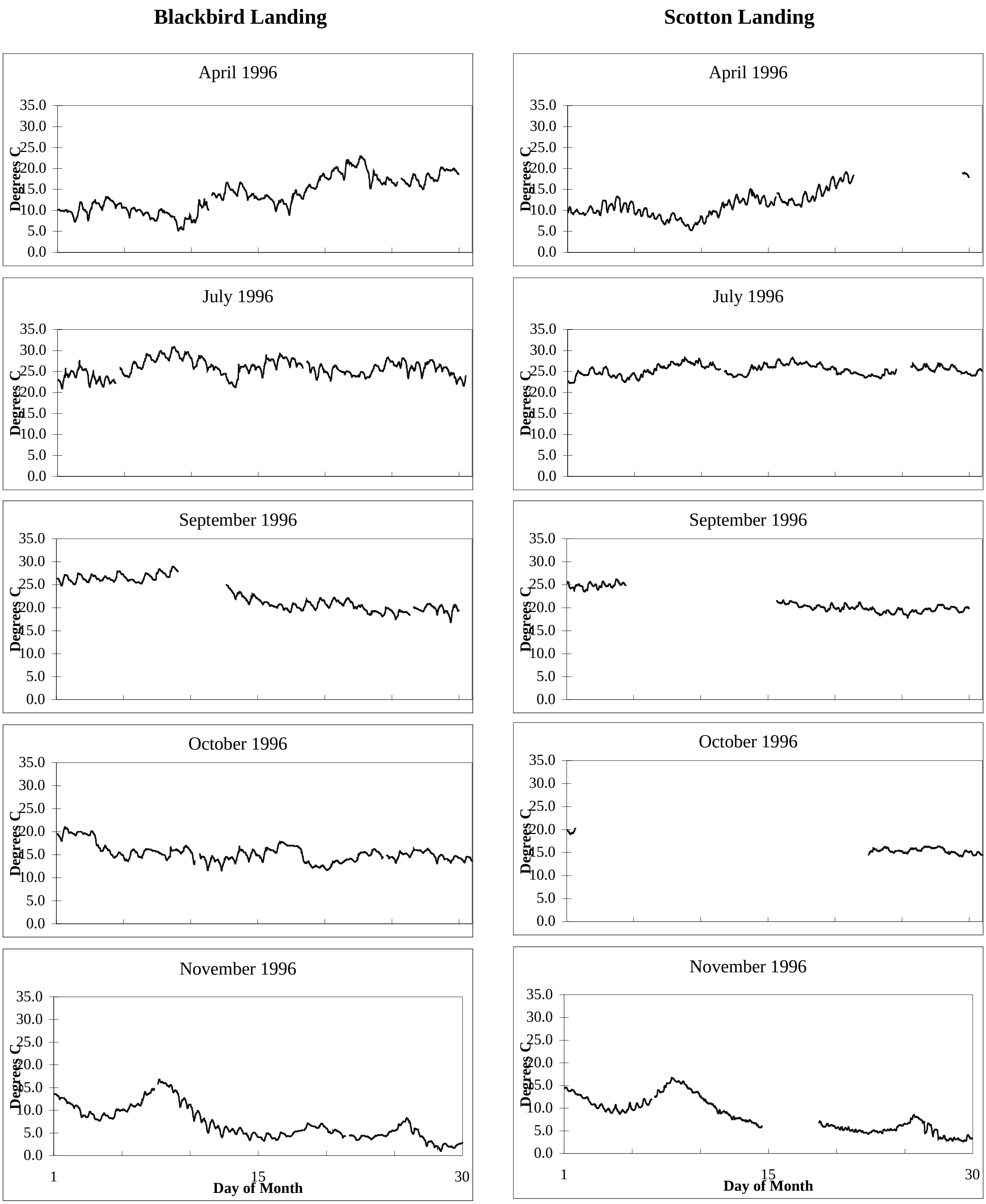


Figure 17. Representative Monthly Water Temperature Readings for Blackbird Landing (Left) and Scotton Landing (Right).

18. The annual temperature range at both sites is from about 0^o C to 30^o C.

The graphs of spring (Figure 19) and neap tides (Figure 20) clearly show not only tidal influence, but that of local climatic factors. The temperature of the Blackbird Creek component closely follows the tidal cycle. The water temperature pattern of the St. Jones River component is the opposite of the Blackbird temperature pattern, with an approximate 2-hour delay. The possible effects of solar heating and runoff from previous storm events are evident in the graphical outputs.

Turbidity

Water turbidity values (Figure 21) based on monthly averages normally ranged between 50 and 100 nephelometry turbidity units (ntu) for both Reserve components. Both sites show a spike in September, with Blackbird Creek being much more elevated. There is a small correlation with tidal cycles on the Blackbird component, however the St. Jones component has very little correlation (Figures 22-25). The St. Jones and Blackbird Reserve components irregularly have high values that commonly exceed 1000 ntu throughout the year.

pH

The annual pH is relatively neutral at both sites, with Blackbird Creek being slightly more acidic and having a steep decline in December (Figures 16 and 26). The pH for the St. Jones River component ranges from 6.01 to 8.87 with a mean of 7.02. The Blackbird component has a range of 5.70 to 8.67 with a mean of 6.76 (Figure 27). Data on Blackbird Creek seem to indicate the influence of stream runoff to a greater extent than the St. Jones data. The pH is highly influenced by tidal flow, as indicated in the graphs of spring and neap tides (Figures 19 and 20), along with reaction from other environmental factors. As a note of reference for 1996, average pH of local rainfall was 4.4, as estimated for the region by the National Atmospheric Deposition Program.

Dissolved Oxygen

Dissolved oxygen concentrations (Figures 23, 24 and 28) are clearly highly influenced by tide stage. Water (and atmospheric) temperature also influences DO, with generally higher temperatures associated with higher variance in both DO concentrations and percent saturation. The occasional tide cycle periods of lower tidal elevations seem associated with lower variation in DO. Greatest daily fluctuations in DO occur during the warmer months, when biological activity is greatest (Figure 29). At all times of the year, DO percent saturation usually ranges from above 30% to over 100% (supersaturated conditions). However, occasional hypoxic events down to almost 0% DO saturation were also observed (e.g. Figure 28, Scotton Landing during July, 1996).

The dissolved oxygen concentrations for Blackbird Creek are consistently higher than the St. Jones River on a monthly comparison. Blackbird Creek has an annual mean of 83% saturation with 8.7 mg/l of dissolved oxygen. The actual amount of DO drops to slightly above 6 mg/l for the summer months due to warmer water temperatures. The St. Jones River demonstrates more critical dissolved oxygen deprivation in summer months, going below the minimal levels for fish survival of 4.0 mg/l. This is due to factors other than temperature and salinity, as indicated by the percentage of dissolved oxygen going below 50% for those months. The range of DO values for the St. Jones River varies from 0 to 14.9 mg/l with an annual mean of 6.45 mg/l. The tidal graphical analysis of DO indicates tidal influence, and possibly higher correlation with time of day.

Salinity

Salinity is highly influenced by tide stage (Figures 19, 20 and 30). The observed St. Jones River annual salinity range (1 to 45 ppt) is much higher than Blackbird Creek’s range (0.1 to 3.5 ppt). The Blackbird Creek data reflect greater influence of storm runoff and possibly lower base flows. The occasional tide

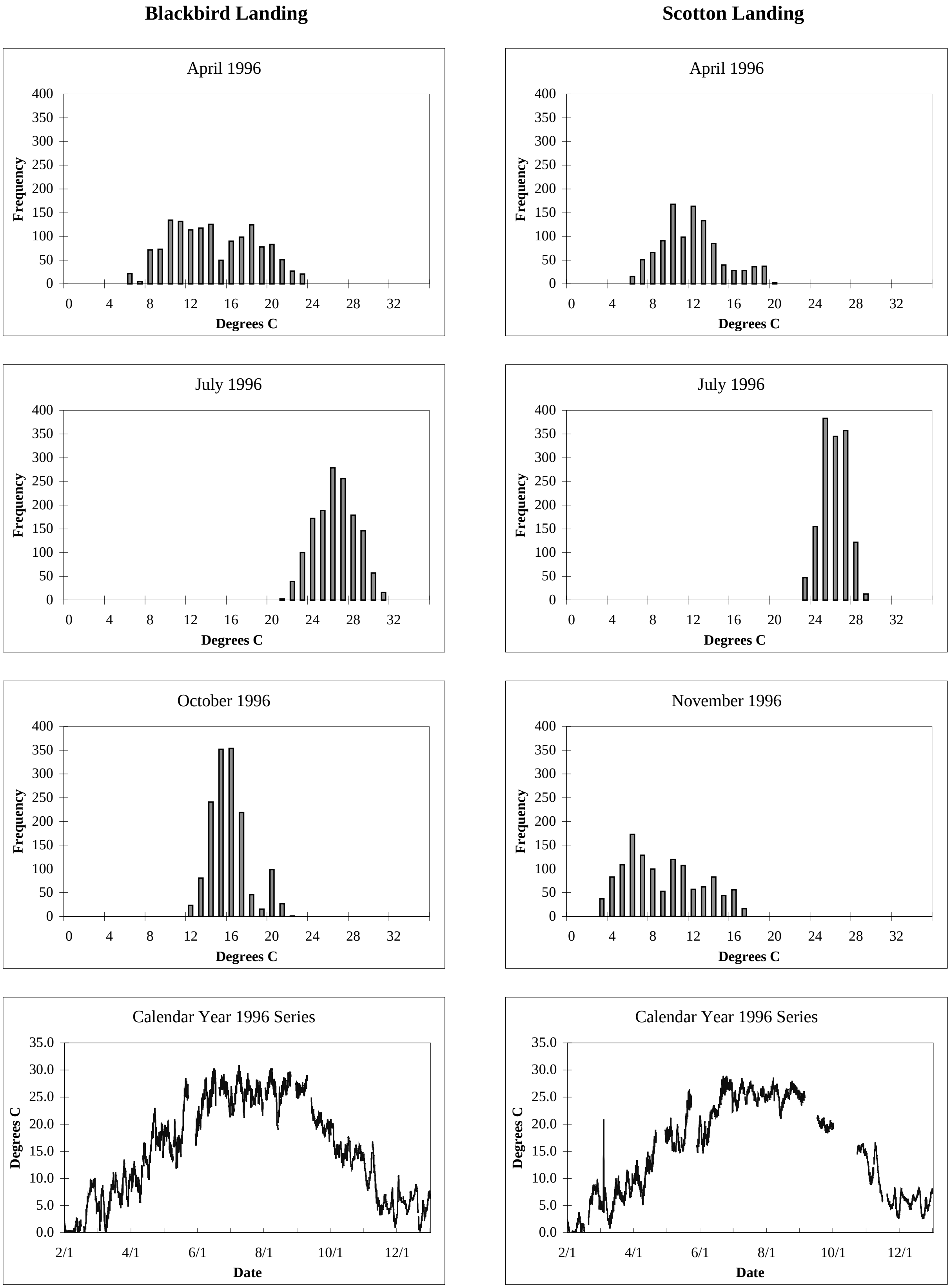
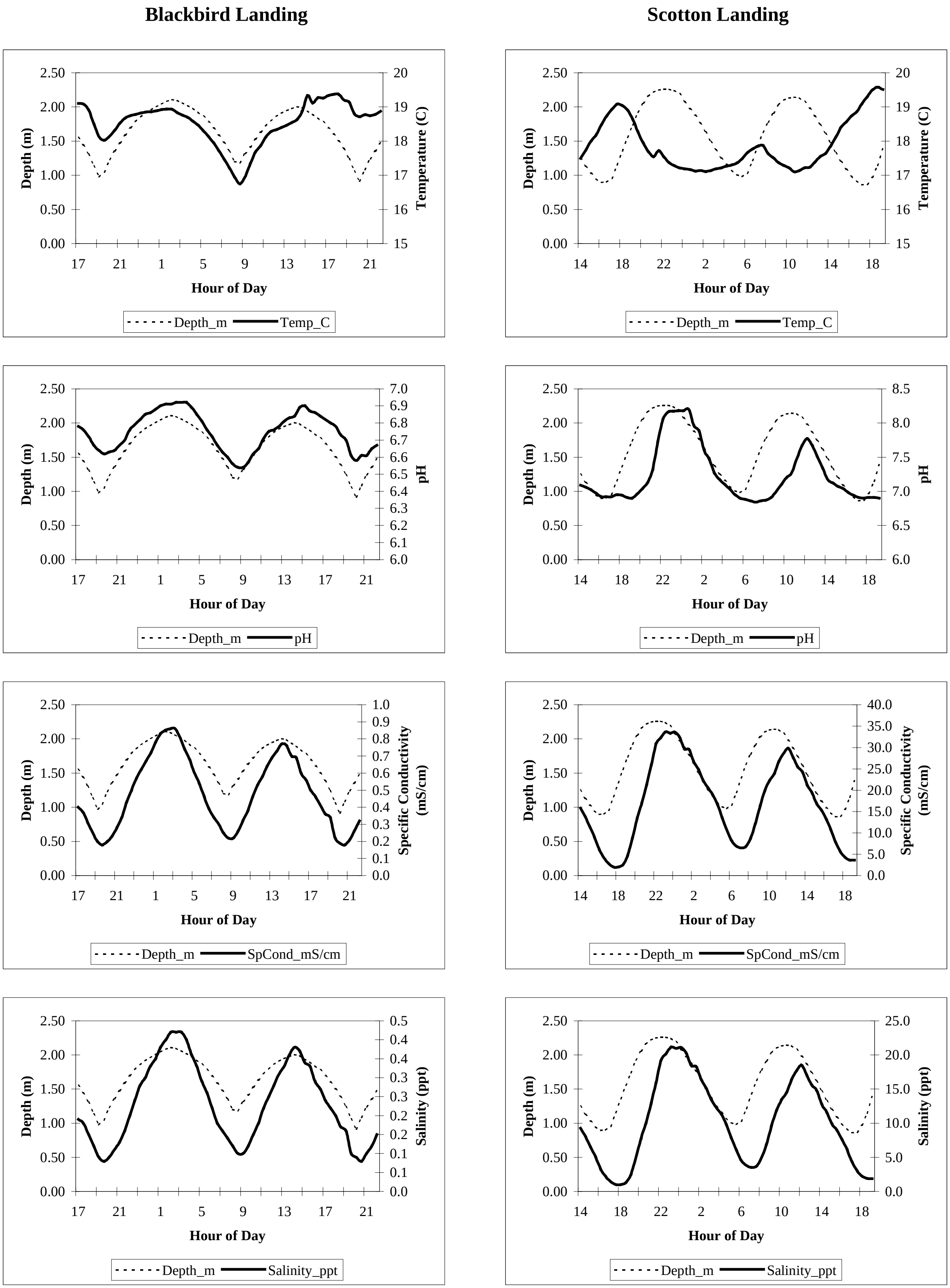


Figure 18. Representative Monthly Water Temperature Frequency Distribution and Annual Temperature Ranges for Blackbird Landing (Left) and Scotton Landing (Right).



Blackbird Landing

Scotton Landing

Figure 19. Representative Spring Tide Water Temperature, pH, Specific Conductivity, and Salinity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 5/3/96, 5/4/96.

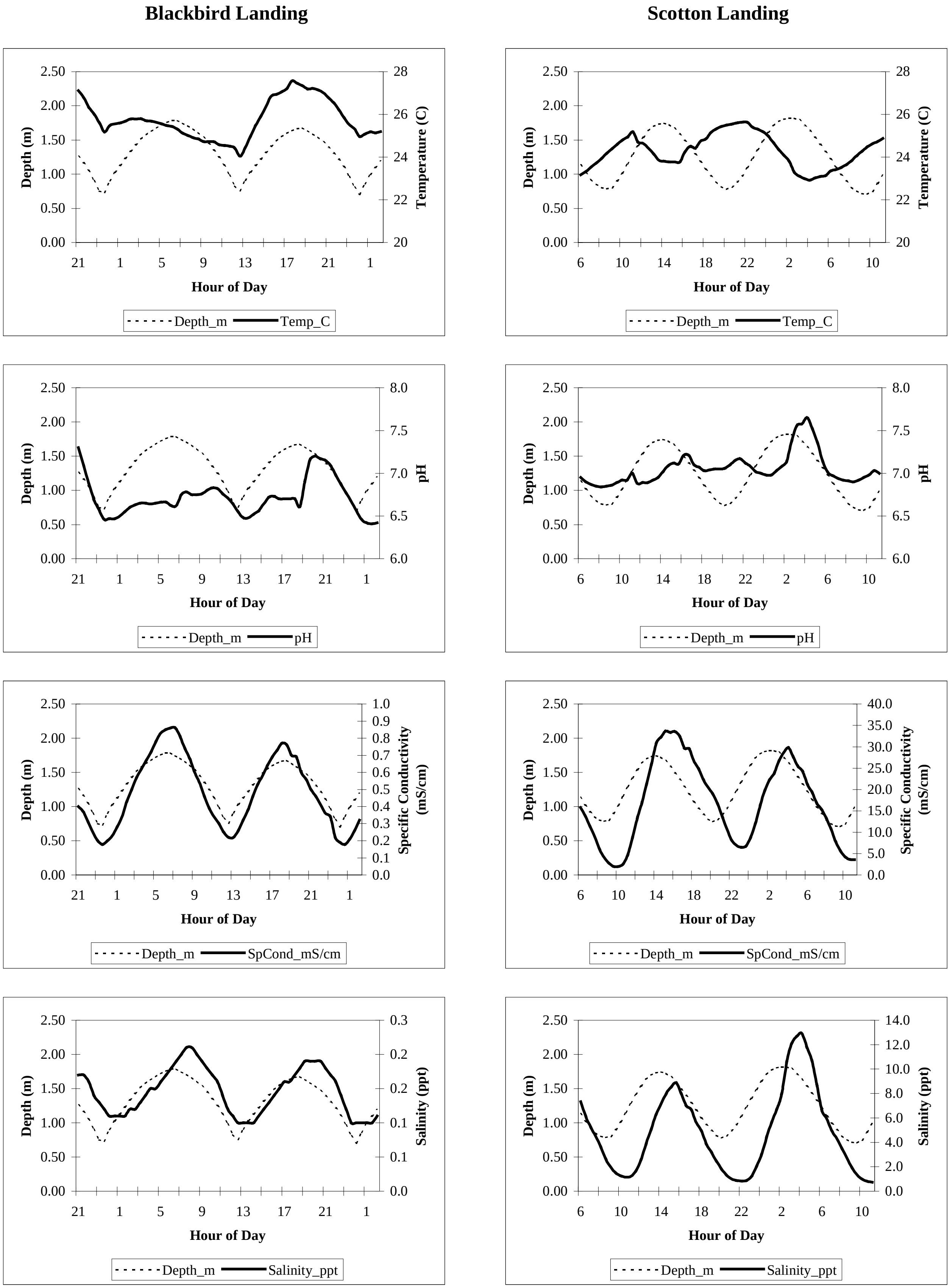


Figure 20. Representative Neap Tide Water Temperature, pH, Specific Conductivity, and Salinity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 5/22/96, 5/24/96.

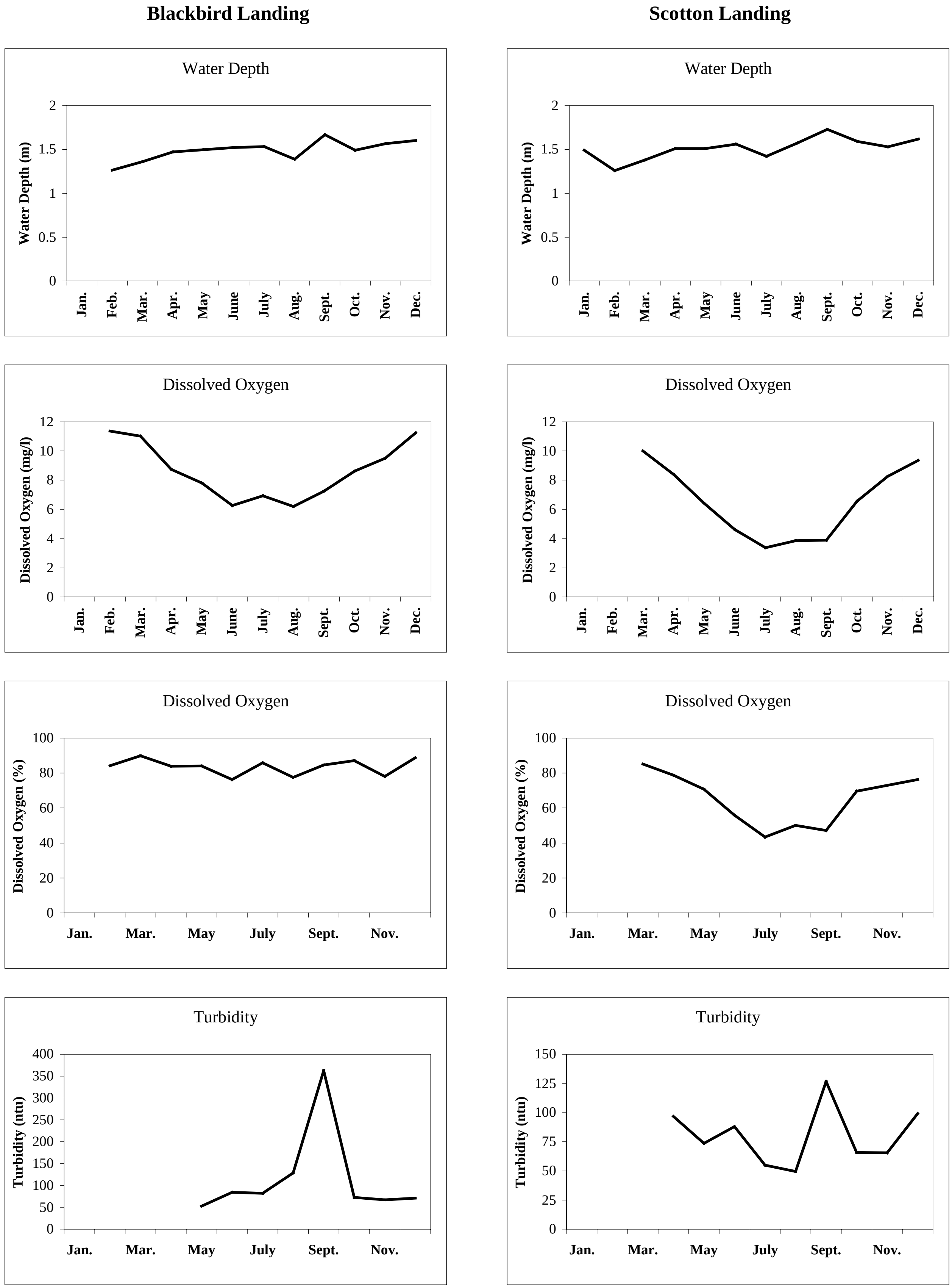


Figure 21. Monthly Mean Water Depth, Dissolved Oxygen, and Turbidity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 1996.

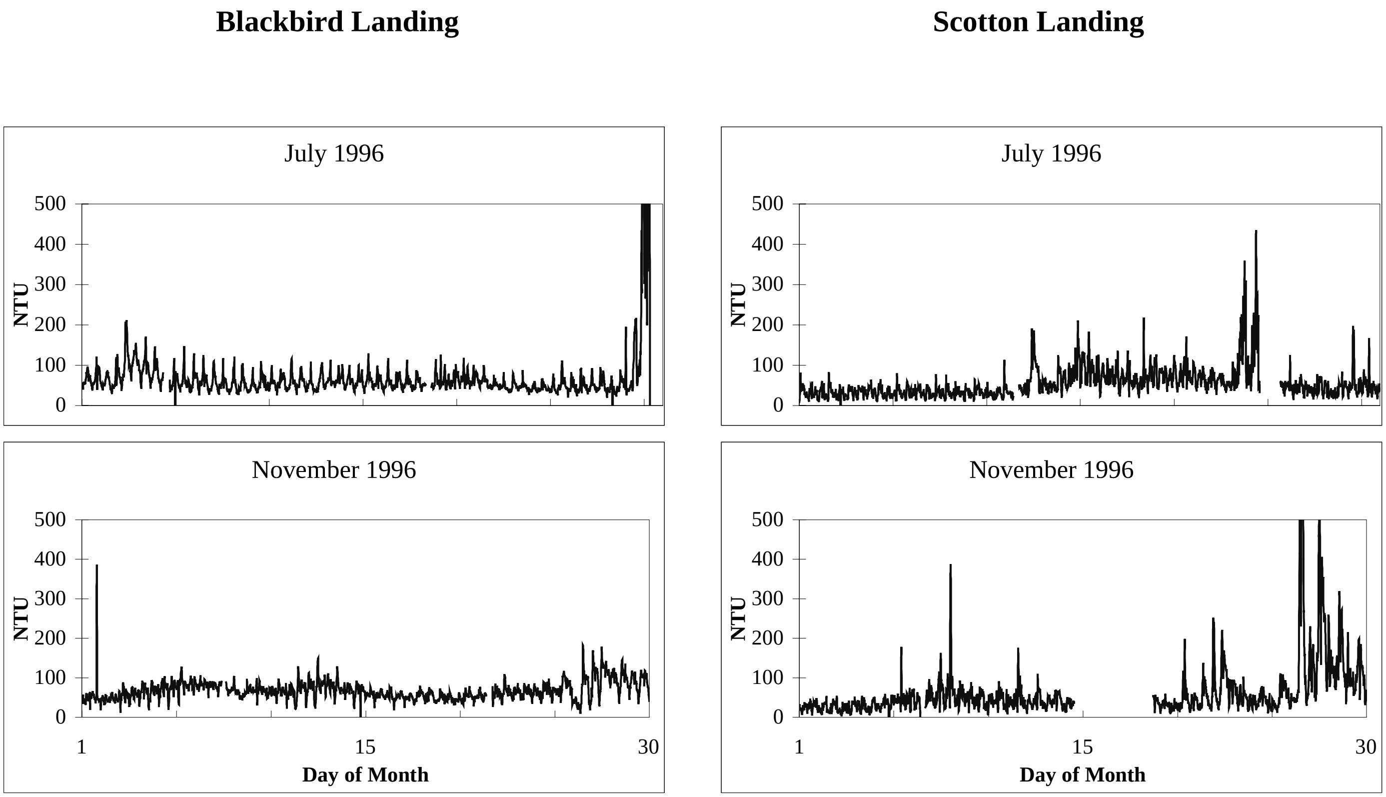


Figure 22. Representative Monthly Turbidity Readings for Blackbird Landing (Left) and Scotton Landing (Right).

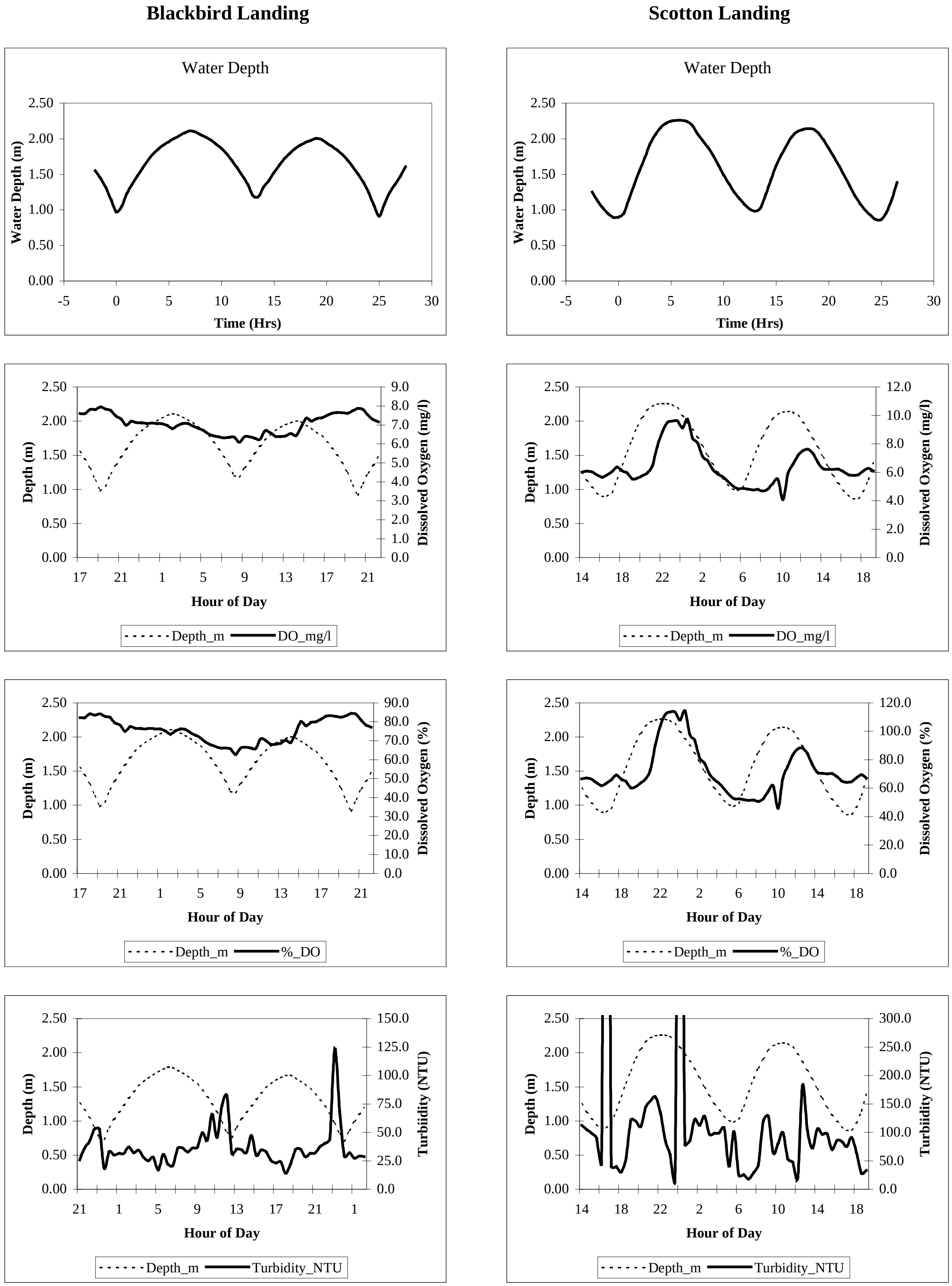
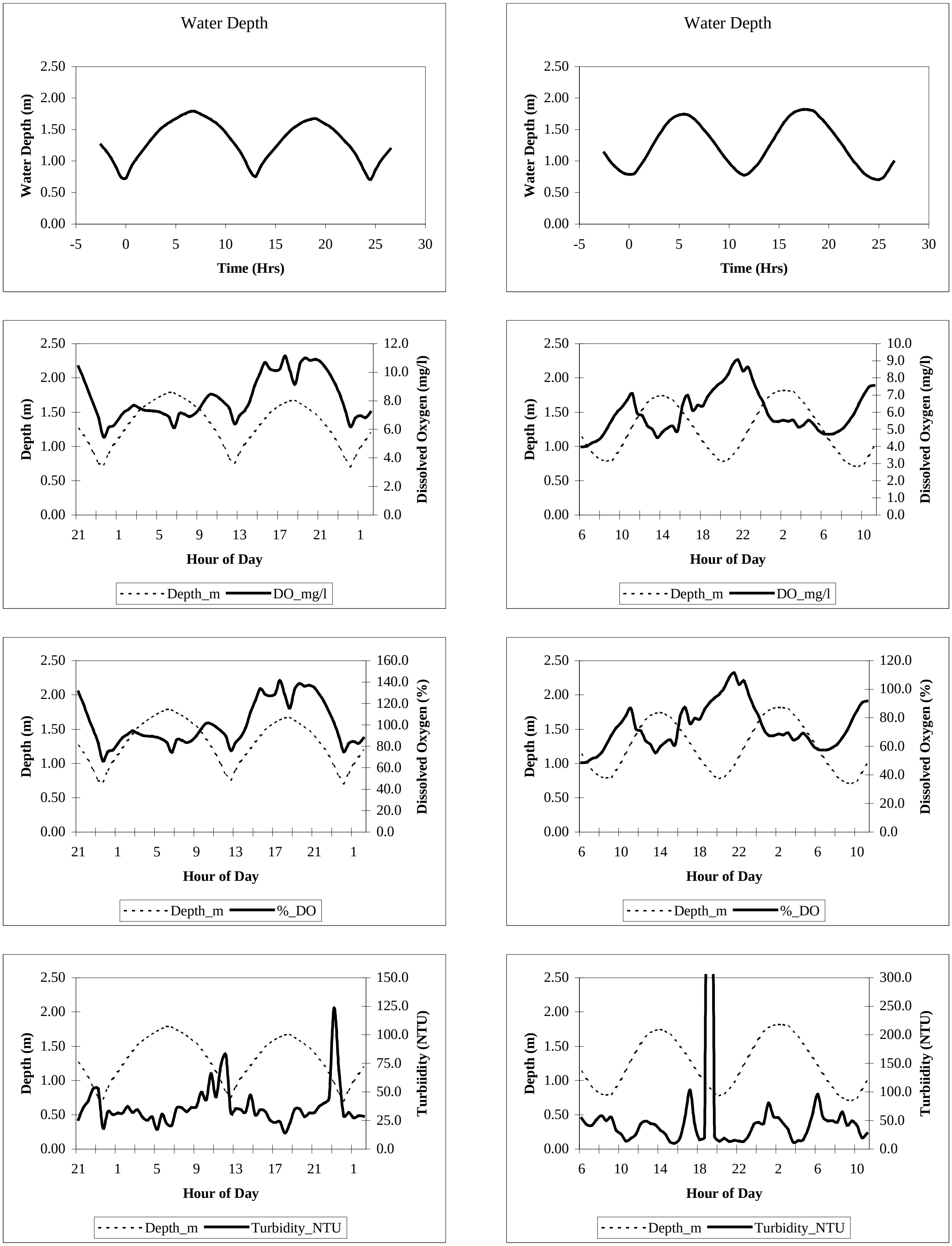


Figure 23. Representative Spring Tide Water Depth, Dissolved Oxygen, and Turbidity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 5/3/96, 5/4/96.



Blackbird Landing

Scotton Landing

Figure 24. Representative Neap Tide Water Depth, Dissolved Oxygen, and Turbidity Comparisons for Blackbird Landing (Left) and Scotton Landing (Right), 5/22/96, 5/24/96.

Blackbird Landing

Scotton Landing

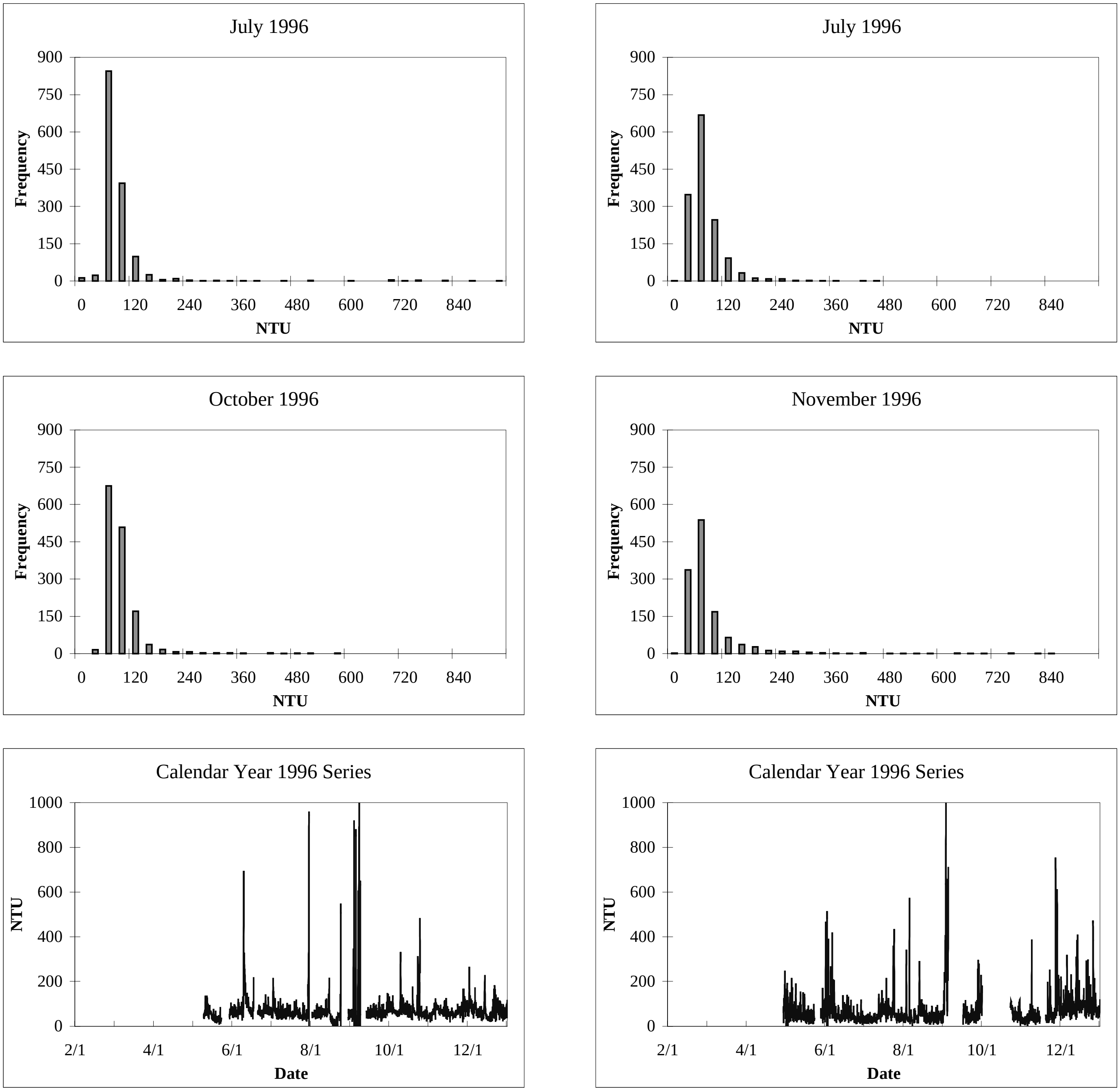


Figure 25. Representative Monthly Turbidity Frequency Distribution and Annual Turbidity Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

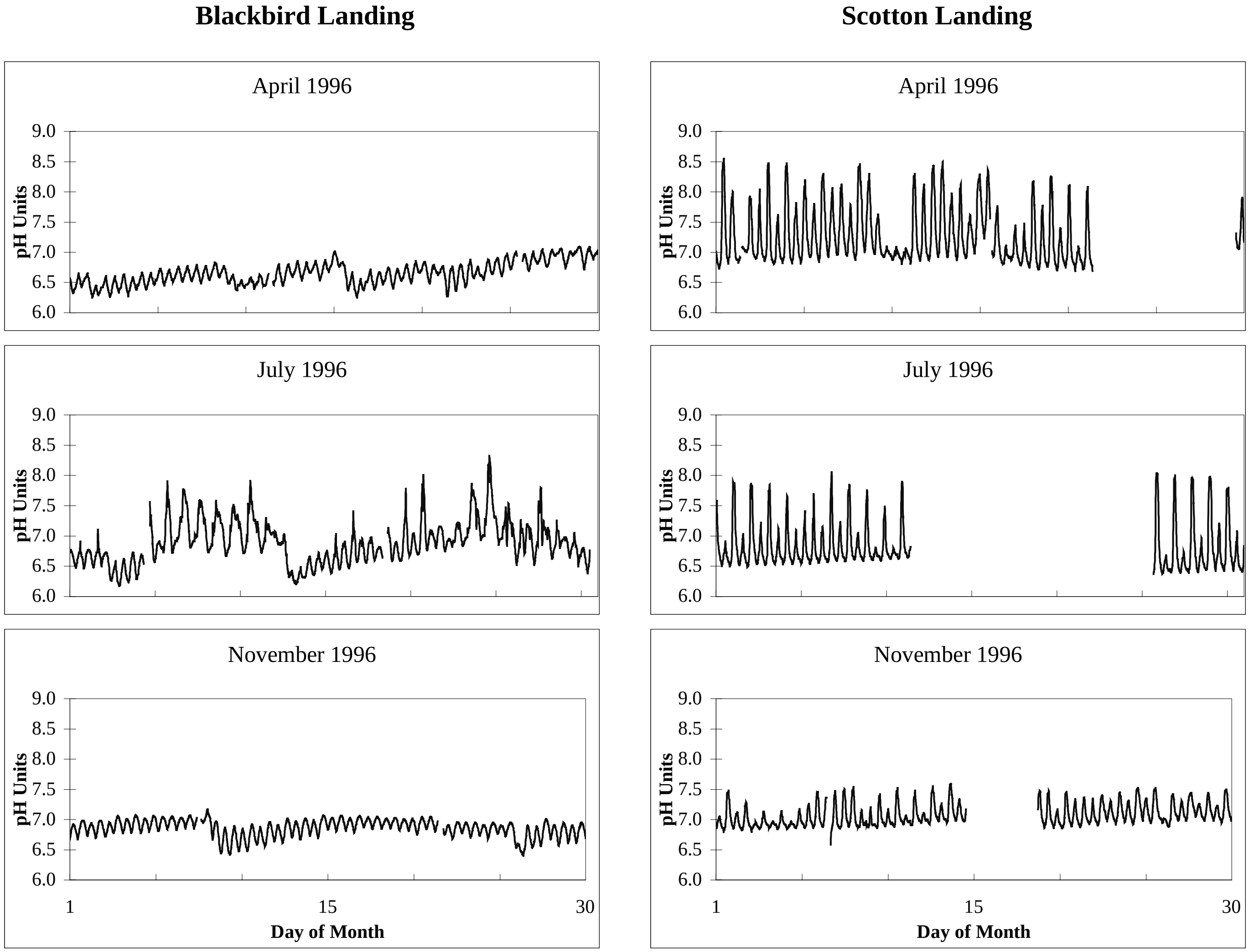


Figure 26. Representative Monthly Water pH Readings for Blackbird Landing (Left) and Scotton Landing (Right).

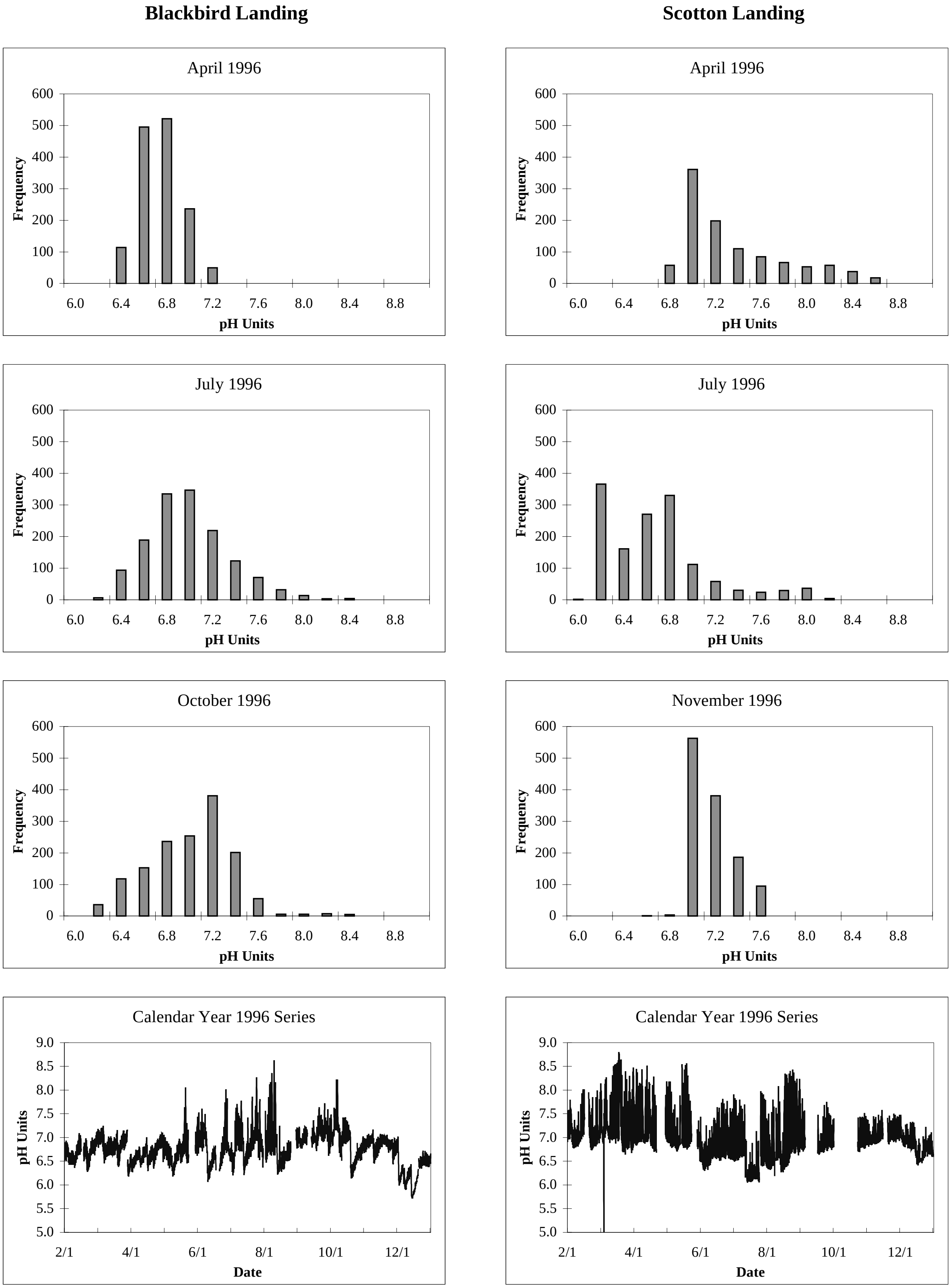


Figure 27. Representative Monthly pH Frequency Distribution and Annual pH Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

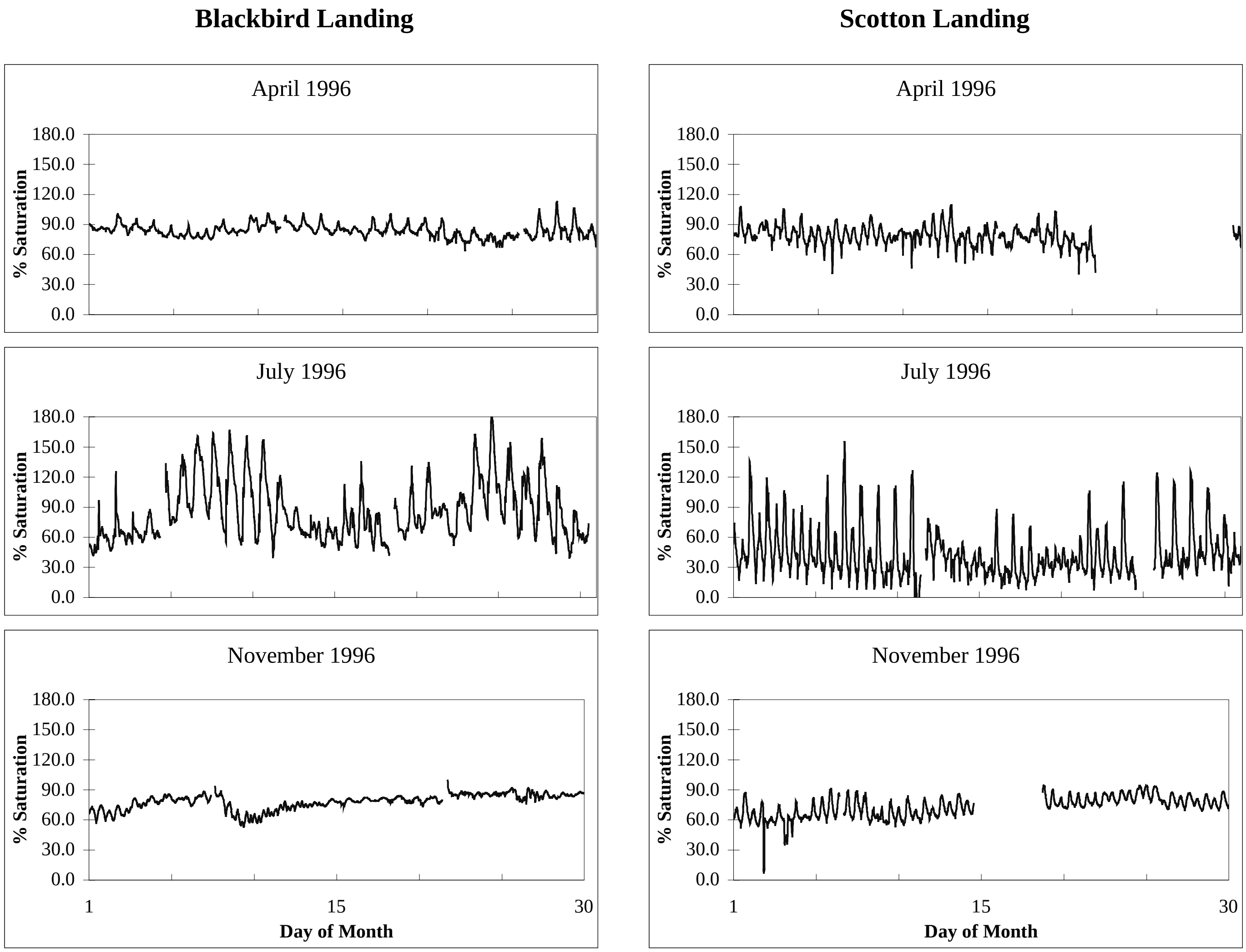


Figure 28. Representative Monthly Dissolved Oxygen Readings for Blackbird Landing (Left) and Scotton Landing (Right).

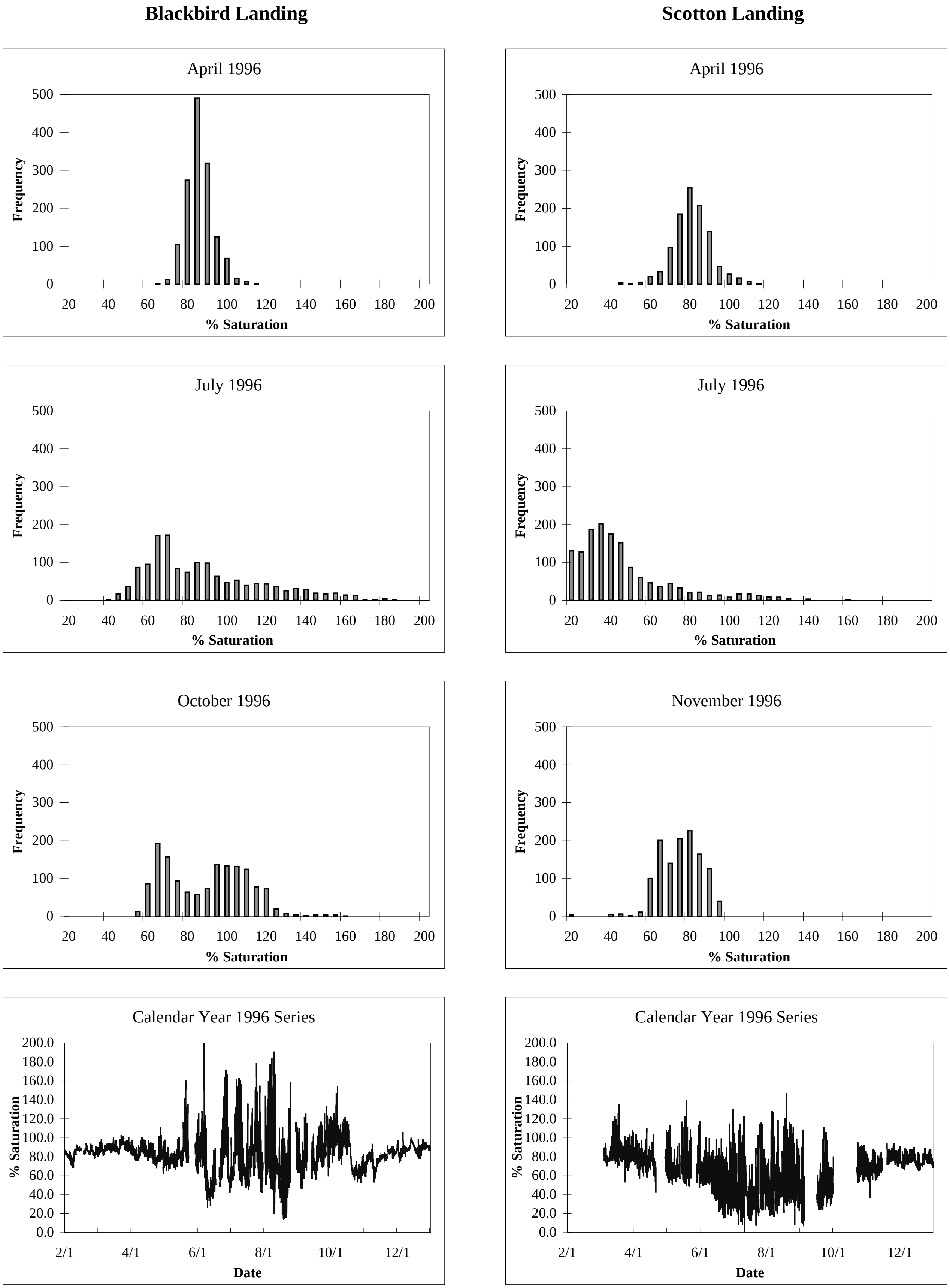


Figure 29. Representative Monthly Dissolved Oxygen Frequency Distribution and Annual Dissolved Oxygen Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

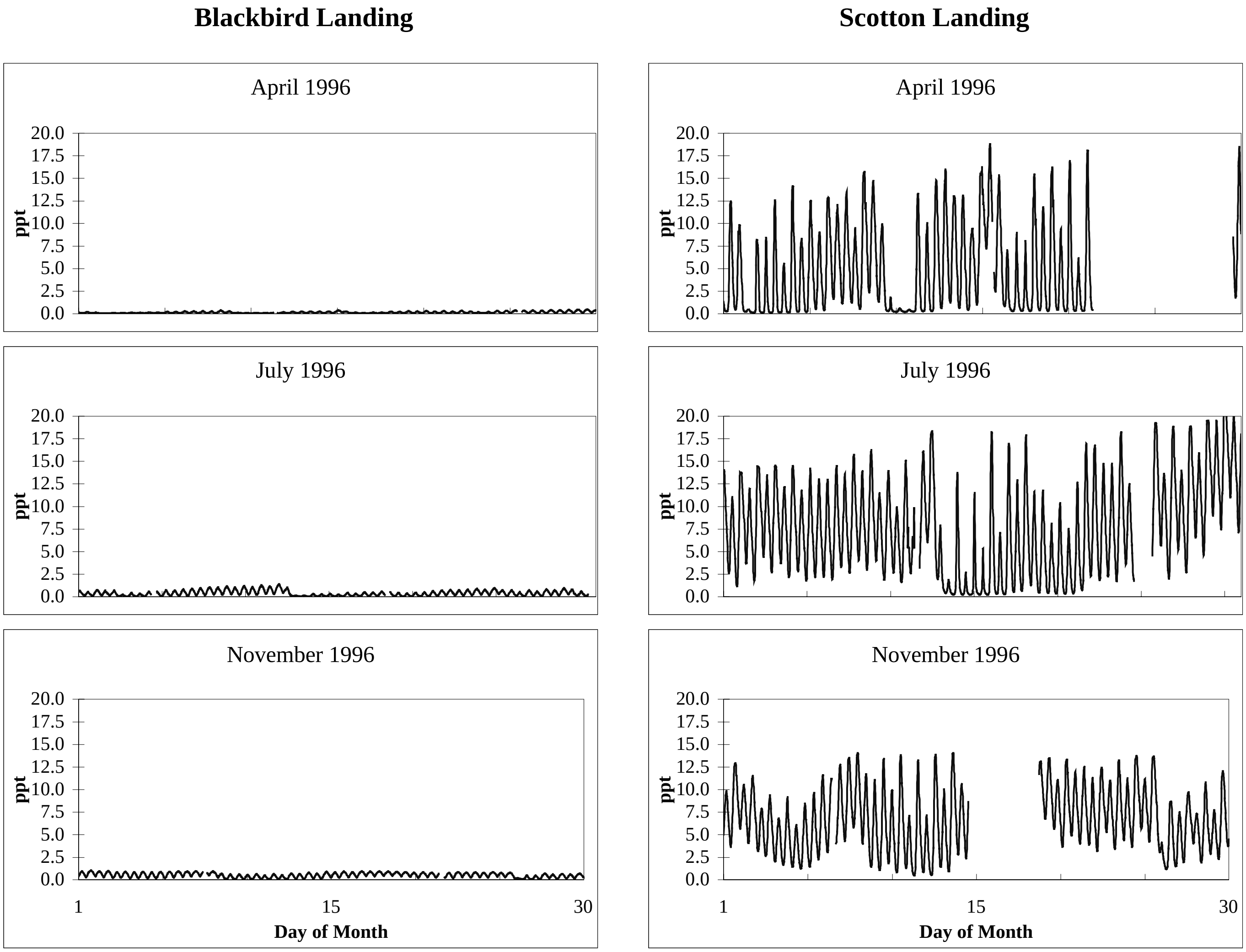


Figure 30. Representative Monthly Salinity Readings for Blackbird Landing (Left) and Scotton Landing (Right).

cycle periods of lower tidal elevations also seem associated with lower concentrations and variation in salinity. Despite a few salinity recordings of up to 45 ppt in the St. Jones River (which are probably due to instrument recording or calibration problems), typical salinities in the St. Jones River's middle reach range from just a few ppt up to 20 ppt. In general, the Lower St. Jones River marsh can be classified as mesohaline (5-18 ppt), while the Upper Blackbird Creek marsh is best classified a limnetic (<0.5 ppt) and oligohaline (0.5 - 5.0 ppt) system (Figure 31).

Dissolved Nutrients, BOD and Chlorophyll-a/Pheophytin-a

Grab and automated composite samples were collected on an approximately monthly basis to examine nutrient concentrations, BOD loads and chlorophyll-a/pheophytin-a levels for a 13-month period from November, 1995 to November, 1996. These samples were collected as part of a DCPS water quality/stormwater monitoring program. Samples were collected at lower, middle and upper reach tidal stations in both Blackbird Creek and the St. Jones River.

Preliminary results for these data are now available to show annual ranges of concentrations found within each DNERR river system, but temporal or within-system spatial analyses have not yet been performed. In both Blackbird Creek and St. Jones River, BOD 5-day loads had similar annual ranges from 2-11 mg/l. Dissolved phosphorus annual ranges were also similar in both systems, with annual concentrations varying from 0.02-0.14 mg/l in Blackbird Creek and 0.01-0.12 mg/l in St. Jones River. Total phosphorus for Blackbird Creek had an annual range from 0.12-0.43 mg/l, with an annual total phosphorus range in St. Jones River from 0.10-0.61 mg/l. Annual ranges in ammonia nitrogen concentrations were almost identical for both DNERR systems, ranging from 0.02-0.50 mg/l. Total Kjeldahl nitrogen concentration in Blackbird Creek had an annual range from 0.5-2.5 mg/l, while the annual range for the St. Jones River was 0.6-3.3 mg/l.

In contrast to nutrients and BOD, concentrations for chlorophyll-a and pheophytin-a had much higher annual ranges in the St. Jones River than Blackbird Creek. Chlorophyll-a annual range in St. Jones River was from 4-135 mg/l, while Blackbird Creek's annual range was only 2-58 mg/l. Pheophytin-a annual range in the St. Jones River was from 5-275 mg/l, while Blackbird Creek's annual range was only from 8-48 mg/l. Preliminary analyses do not seem to indicate substantial differences in nitrogen or phosphorus nutrient concentrations between tidal areas of the St. Jones River versus Blackbird Creek, and neither does preliminary analysis of turbidity data. As such, some of the higher chlorophyll-a/pheophytin-a concentrations observed in the St. Jones River might be attributable to different productivity potentials in phytoplankton species that dominate phytoplankton assemblages in the higher-salinity St. Jones River system, versus the productivities of those species that dominate phytoplankton communities in lower-salinity Blackbird Creek (for differences in phytoplankton community compositions, see phytoplankton discussion in Site Profile).

Watershed Land Use Cover

Figures 32 and 33 present land-use cover by basin for the both the Blackbird Creek and St. Jones River Reserve sites (DNREC, 1992). Both basins are dominated by agriculture (St. Jones = 48%, Blackbird = 39%) plus forests in the Blackbird (= 22%). However, the St. Jones watershed has significant area within the Dover urban complex, as evidenced by the high percentage (almost 25%) of impervious surface shown in Figure 34, versus only 10% impervious cover in the Blackbird watershed. Although the St. Jones River watershed has a slightly higher percentage of agricultural land use than the Blackbird Creek watershed, it has less than half the forested cover. Blackbird Creek watershed has a higher percentage of natural areas than does the St. Jones River

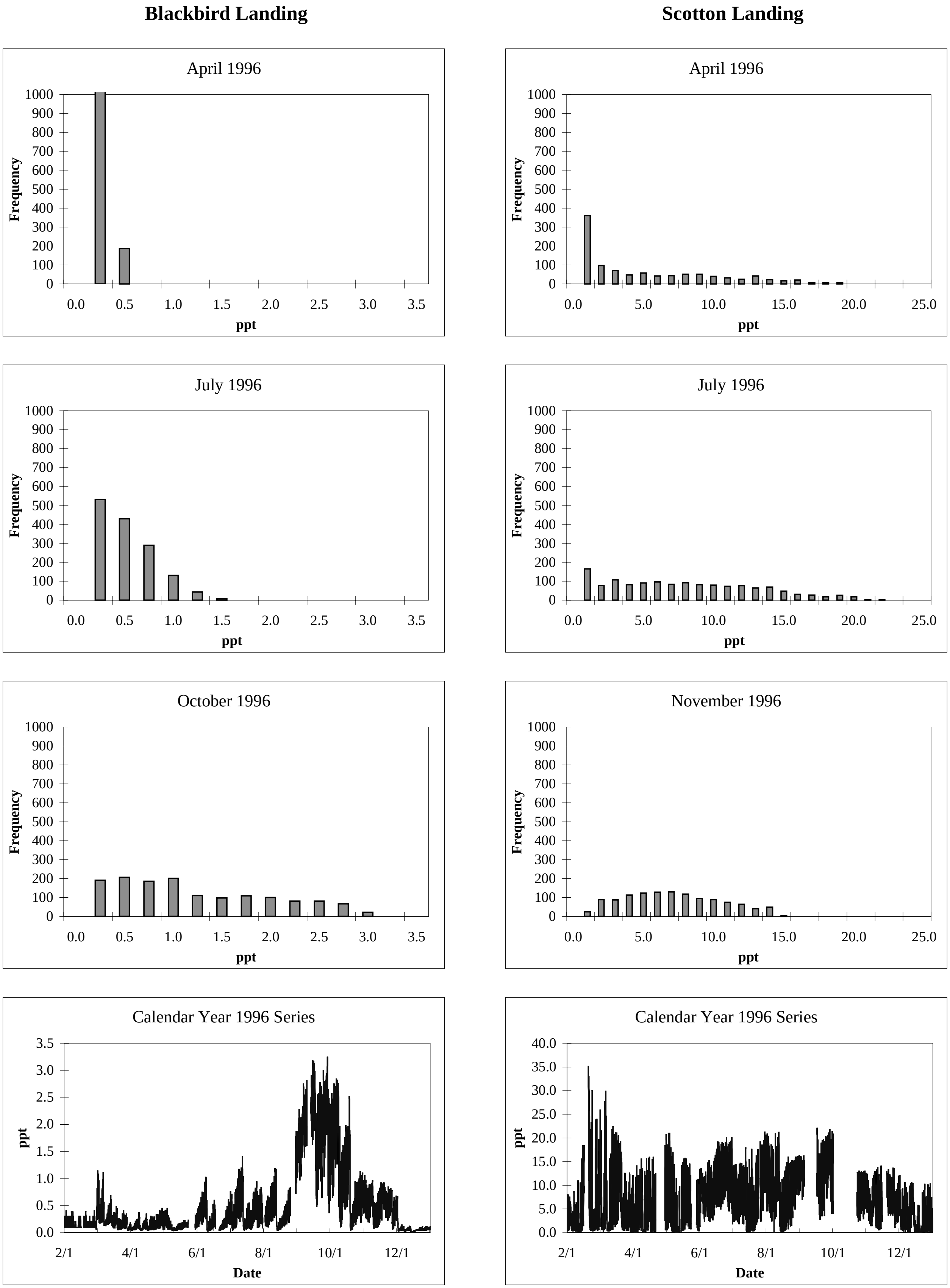


Figure 31. Representative Monthly Salinity Frequency Distribution and Annual Salinity Ranges for Blackbird Landing (Left) and Scotton Landing (Right).

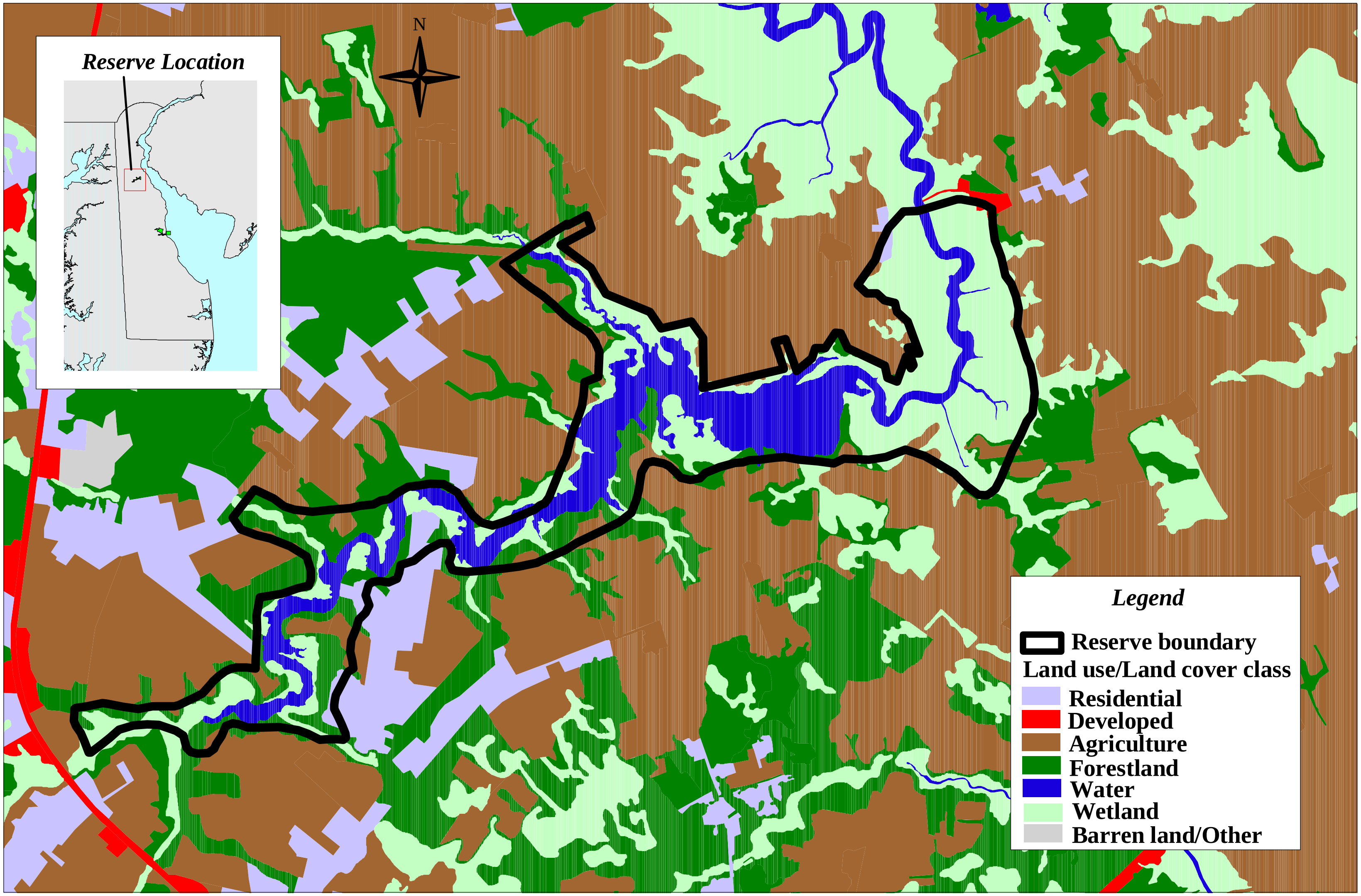


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Figure 32. Upper Blackbird Creek Reserve: 1992 Land Use/Land Cover Classification

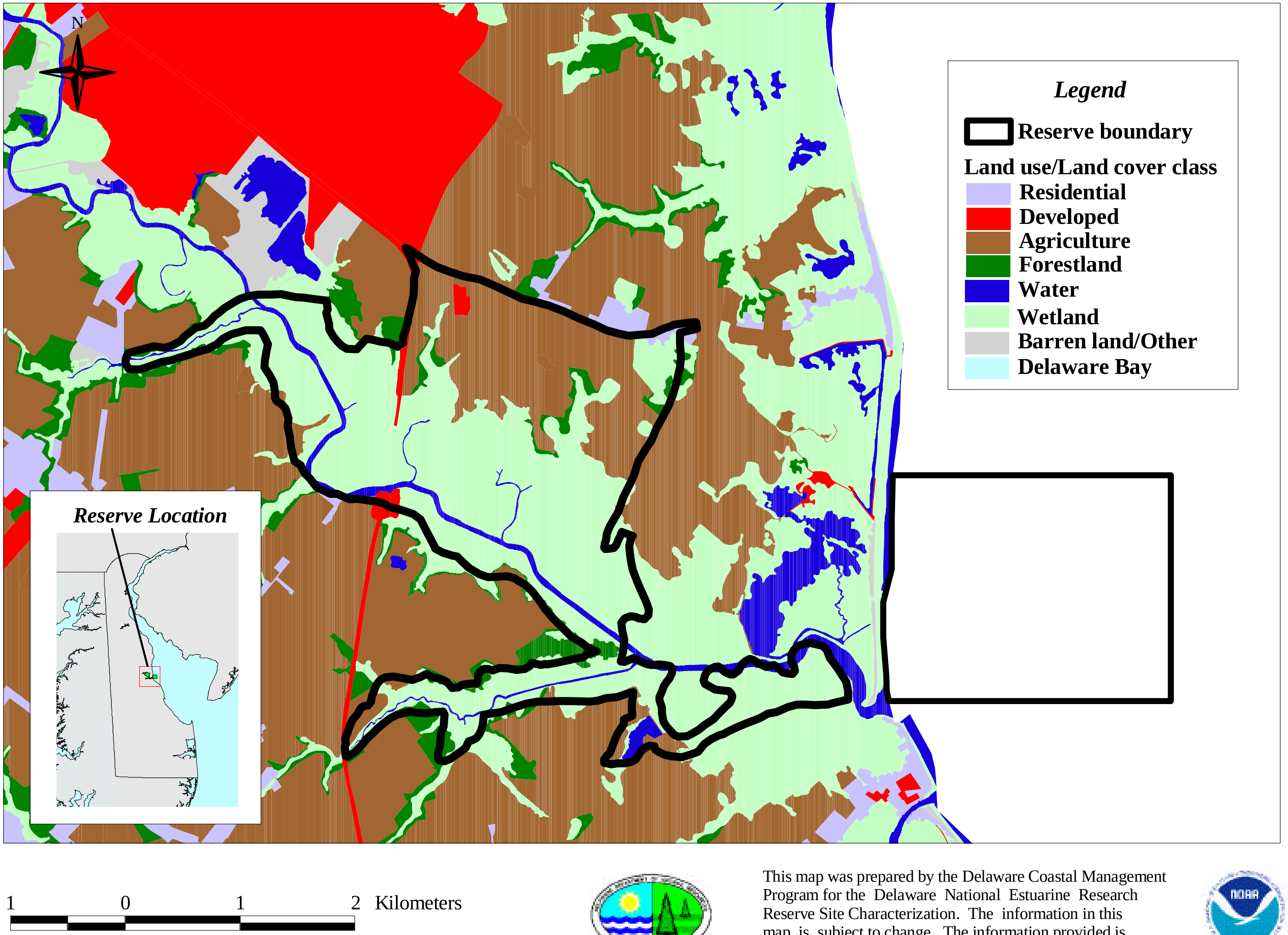

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Figure 33. Lower St. Jones River Reserve: 1992 Land Use/Land Cover Classification

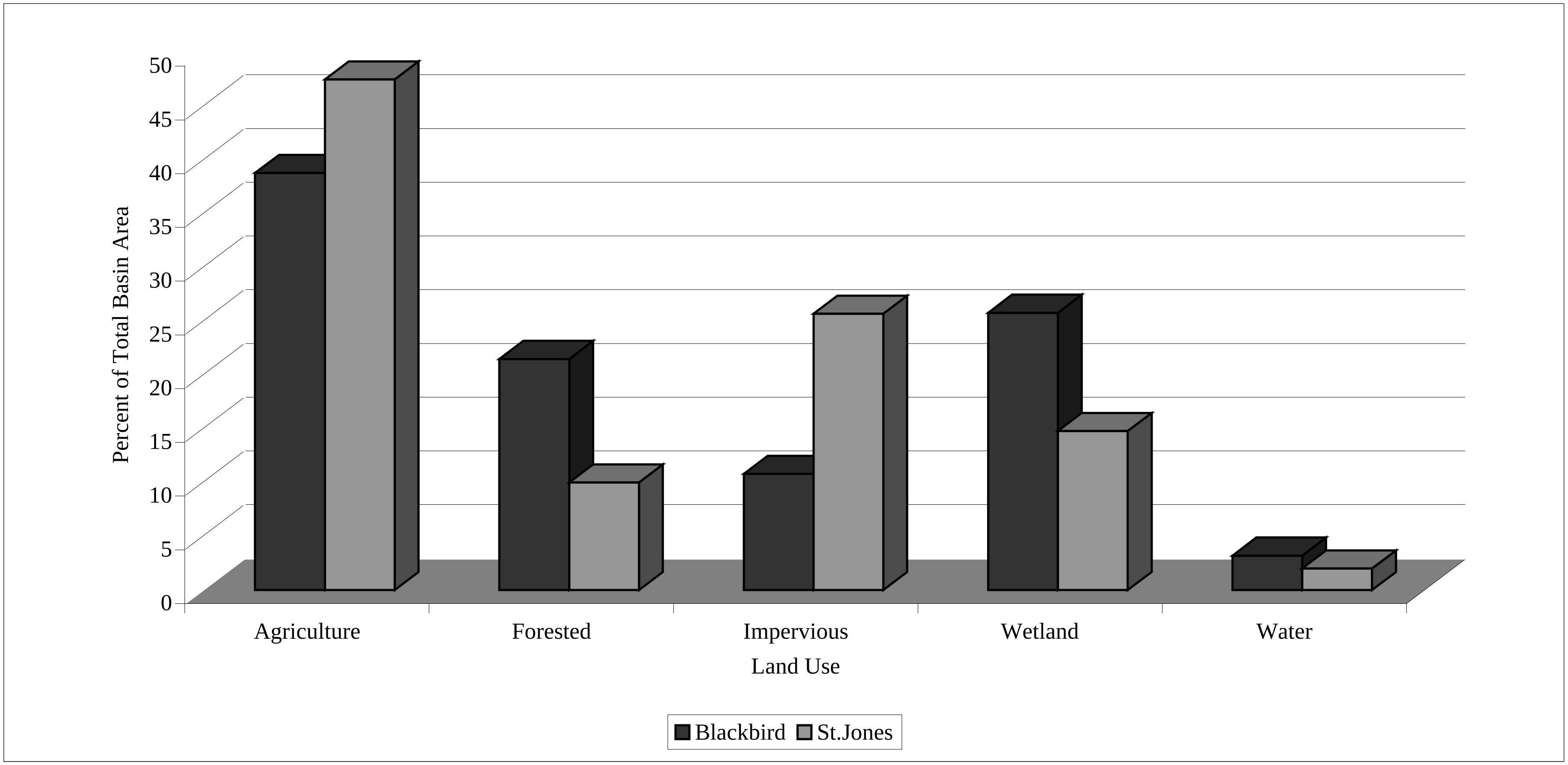

Figure 34. Land Use Categories for Blackbird Creek and St. Jones River Watersheds, 1992.

watershed, as evidenced by the percent of each watershed shown to be forested (22% vs. 10% respectively), wetlands (25% vs. 14% respectively), or open water (4% vs. 3% respectively). In total, about 51% of the Blackbird watershed can be considered undeveloped (i.e. not agricultural lands, nor urbanized), while only 27% of the St. Jones watershed is of similar undeveloped status.

Trends in land-use conversion discussed by Mackenzie (1989) included the conversion of both forests and wetlands to agriculture (1974 to 1984), and then from agriculture to urban or residential land use. A net loss of such natural forest watershed areas can have significant adverse influence on estuarine habitats and water quality.

A current evaluation of recent land-use trends and patterns is nearing completion by researchers at the University of Delaware, College of Marine Studies (Oliver Weatherbee, pers. comm. 1998). Using remote sensing techniques, a basin-wide land use classification should be completed for the Delaware River Basin by late 1998. Examples of similar land use classification study are provided in Figures 32 and 33, covering the Blackbird and St. Jones River watersheds.

ECOLOGICAL/BIOLOGICAL SETTING

Reserve Vegetation

Tidal datums and coastal marsh vegetation zonation

Typical of most tidal wetlands, the types, locations and patterns of coastal marsh vegetation in the DNERR are highly influenced by hydroperiod (frequency, height and duration of tidal inundations) and salinity. Emergent marsh grasses do not grow below mean tide level (MTL). Habitat in the DNERR between MTL and mean low water (MLW) primarily tends to be non-vegetated, muddy tidal channel slopes or tidal mudflats. Going below MLW, especially below the lowest low tides that occur during a lunar cycle, essentially leaves the intertidal zone, descending into permanently inundated subtidal habitats where benthic macroalgae or submerged aquatic vegetation might grow. Going above MTL, the intertidal zone from MTL up to mean high water (MHW) is considered to be emergent "low marsh," and in more saline areas of the DNERR is dominated by saltmarsh cordgrass (*Spartina alterniflora*). The "low marsh" is completely inundated by high tides at a frequency of at least once per day. "High marsh" emergent vegetation consists of more diverse plant assemblages growing in more elevated intertidal areas of the marsh, from above MHW up to the highest extremes of spring tide mean high water (MHHW), which occur around times of full or new moons. The approximate location of MHW level is often observable in the field, since this is the elevation where saltmarsh cordgrass (*S. alterniflora*) starts to become non-dominant surface cover, being replaced by other marsh plant assemblages. The mixed-vegetation "high marsh" is inundated at a frequency of less than once per day, and more elevated areas of the "high marsh" are flooded only a few times per month, at times of spring tides. Upland terrestrial vegetation starts above the MHHW level. Upland marsh borders can occasionally still be flooded by estuarine tidal waters during coastal storms, especially if the storms occur during spring tides. If storm-induced flooding of saline waters in upland areas lasts long enough, terrestrial vegetation is often killed.

Dominant vegetation cover

Wetland community types mapped for the Upper Blackbird Creek (Figure 35) and Lower St. Jones River (Figure 36) are generally as described in the *Atlas of Delaware's Wetlands and Estuarine Resources* (Daiber et al, 1976). The Reserve portions of the Blackbird Creek and St. Jones River marshes are characterized by forested tidal wetlands, scrub/forest, and scrub/marsh mixes, with a dominant mixed emergent marsh most prevalent on the expansive marshplain and along creek and tributary open waters. The percent of wetlands

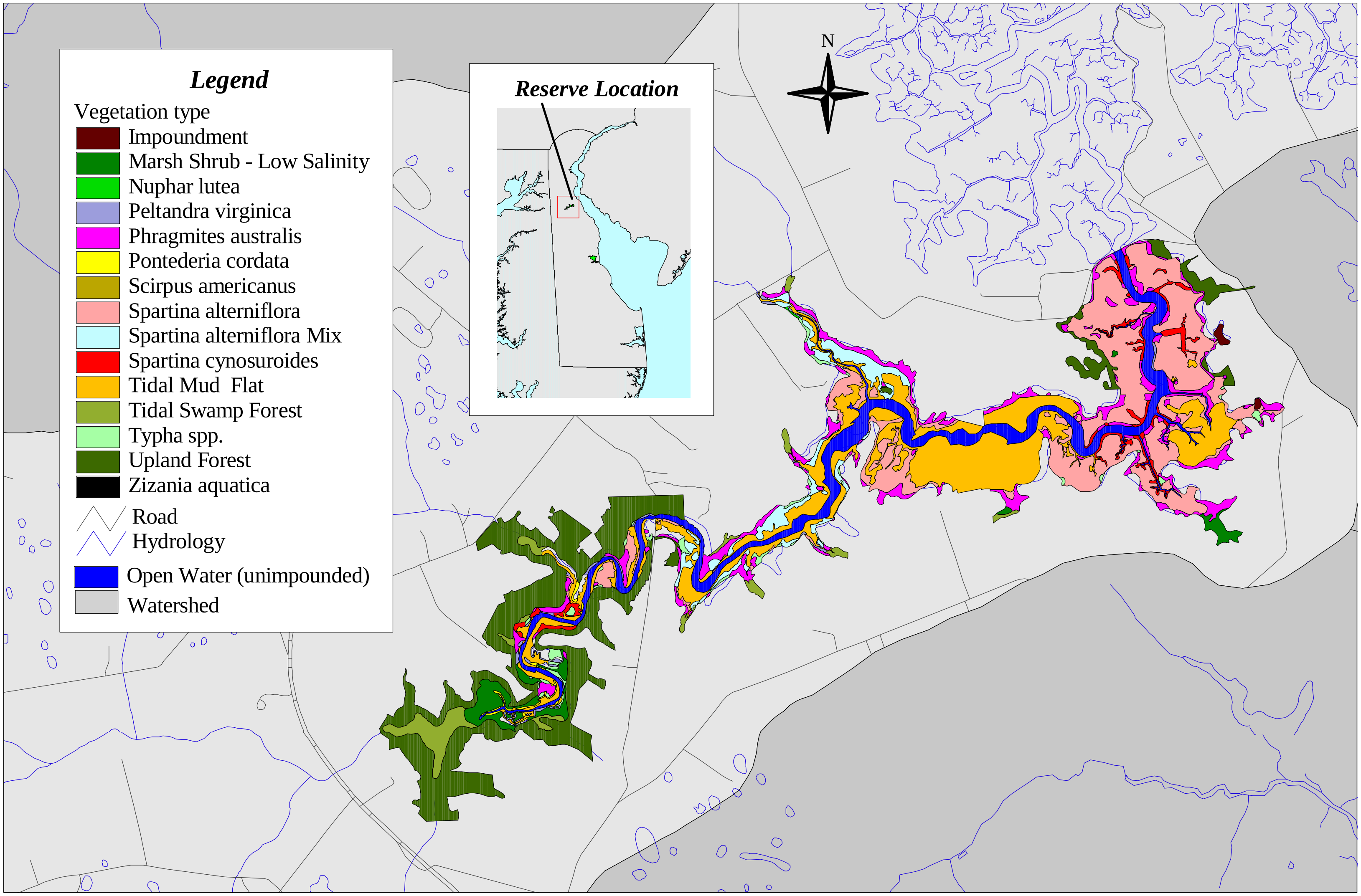

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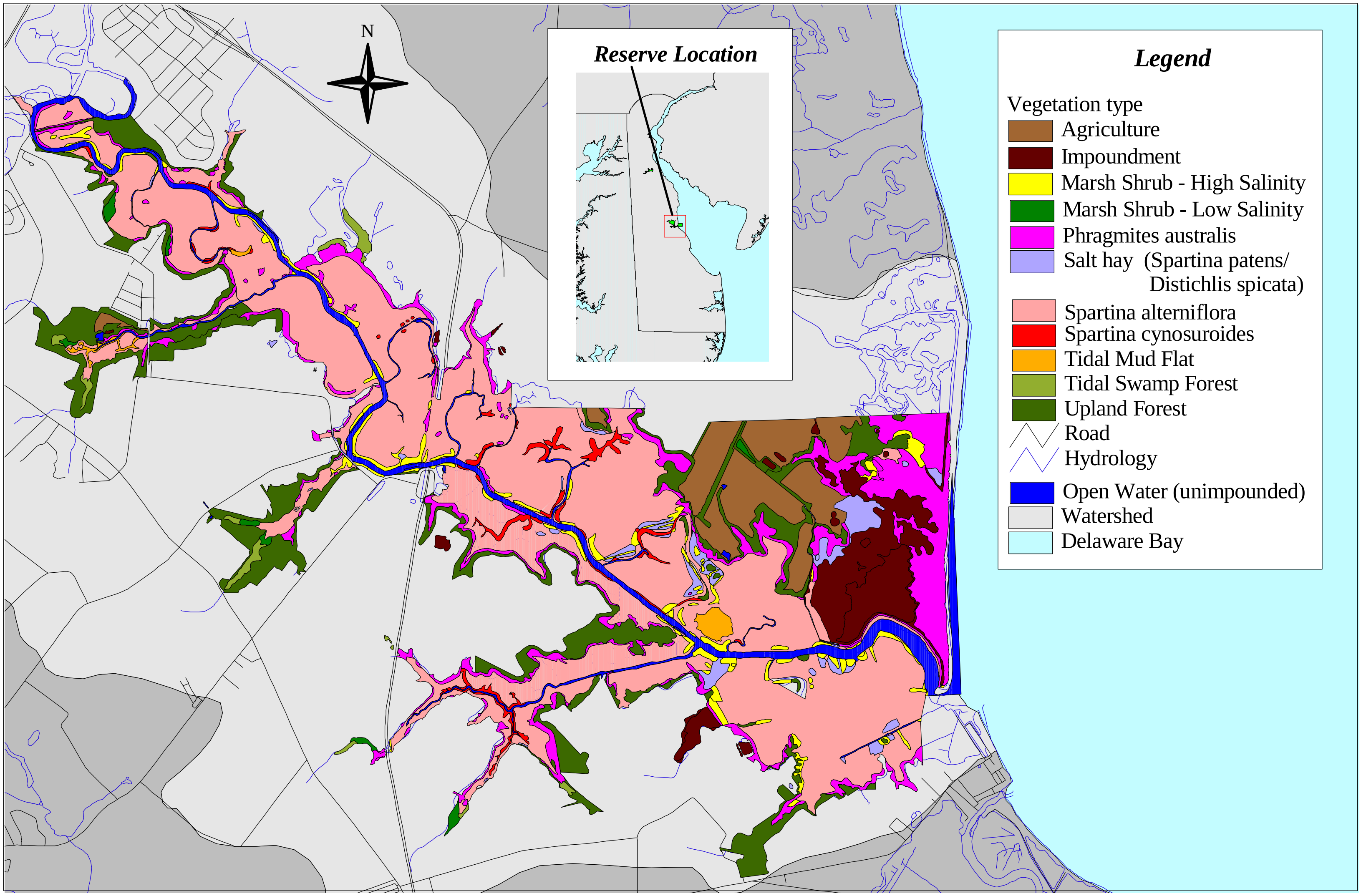
Figure 35. Upper Blackbird Creek Reserve: Vegetation



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 36. Lower St. Jones River Reserve: Vegetation

within each Reserve is shown in Table 6. Comparison of data shows that *Spartina alterniflora* marsh is the most abundant vegetation type in both Reserves. It is, however, much more dominant in the Lower St. Jones River Reserve than in the Upper Blackbird Creek Reserve. In total, the Blackbird Creek marshes contained 113 species of plants (Table 7), while the St. Jones River marshes contained 66 species (Table 8) (Wetlands Research Associates, Inc. 1995).

Emergent wetlands vegetation

Saltmarsh cordgrass (*Spartina alterniflora*) communities are dominant at both Reserve sites (62% in Lower St. Jones River and 29% in Upper Blackbird Creek), with expansive intertidal areas of this species' short-form present, while its tall-form is distributed along channel banks. This perennial saltmarsh cordgrass commonly grows in brackish to salty marshes. Subdominants found growing within lower salinity saltmarsh cordgrass communities include swamp rose mallow (*Hibiscus palustris*), marshpepper smartweed (*Polygonum hydropiper*), and pickerelweed (*Pontederia cordata*). Also found in select areas along channel banks is big cordgrass (*Spartina cynosuroides*). Patches of salt hay composed of salt grass (*Distichlis spicata*) and saltmeadow cordgrass (*Spartina patens*) occur throughout, particularly just below upper marsh borders. The marsh shrub communities found within the Reserve can also be broken down into two distinct categories: fresher, tidally influenced communities with low salinities, and brackish tidal communities with higher salinities. The fresher, lower salinity areas are dominated by woody plants such as buttonbush (*Cephalanthus occidentalis),* dogwoods (*Cornus spp.),* smooth alder (*Alnus serrulata),* sweet pepperbush (*Clethra alnifolia),* and winterberry (*Ilex verticillata).* The brackish, higher salinity tidal communities are dominated by groundselbush (*Baccharis halimifolia),* marsh elder (*Iva frutescens),* and red cedar (*Juniperus virginiana).*

Throughout the Reserve, communities of yellow pondweed (*Nuphar lutea*) and arrow arum (*Peltandra virginica*) can be found, particularly in the upper Blackbird. The yellow pondweed community is found in fresh to brackish creeks and ponds. It can form dense monospecific stands in one to three feet of water. The arrow arum community is an emergent community found along shores of fresh to moderately brackish creeks and ponds. This community also includes some small skunk cabbage in upper portions of the Blackbird Creek watershed.

Other wetlands communities that are found within the Reserve include *Typha*, *Scirpus americanus,* and *Zizania aquatica.* The *Typha* community is composed of one or both cattail species (broad-leaf *T. latifolia,* and narrow-leaf *T. angustifolia*), and may be monospecific or include other species. It can be codominant with nodding bur-marigold (*Bidens cernua),* saltmarsh waterhemp (*Acnida cannabina*), rice cutgrass (*Leersia oryzoides),* or saltmarsh cordgrass (*S. alterniflora*). The *Scirpus* community is an emergent community found along brackish shorelines that generally forms monospecific stands interspersed with other emergents. Occasionally, these communities co-dominate with saltmeadow cordgrass (*S. patens*). Subdominants here include salt marsh cordgrass (*S. alterniflora*) and salt grass (*D. spicata*). The *Zizania aquatica* community is made up of wild rice and often forms extensive monospecific stands in fresh to slightly brackish waters. All three of these relatively minor communities in the Reserve have high value as wildlife habitat or use as wildlife foods.

Common reed *(Phragmites australis*), found in fresh to brackish marshes, is densely distributed throughout the Lower Blackbird Creek watershed. Although common reed communities often form dense monospecific stands, they can also be associated with salt marsh cordgrass *(S. alterniflora),* big cordgrass *(S. cynosuroides*), red cedar *(Juniperus virginiana),* salt grass *(D. spicata),*

Upper Blackbird Creek		**Lower St. Jones River**	
Map Unit	% Cover	Map Unit	% Cover
Spartina alterniflora	28.64	*Spartina alterniflora*	62.23
Tidal Flat	26.44	*Phragmites australis*	13.38
Open Water (Not	14.21	Impoundment - Logan Lane	7.54
Phragmites australis	11.05	Open Water (Not impounded)	7.03
Spartina alterniflora Mix	4.74	Marsh Shrub - High Salinity	3.63
Tidal Swamp Forest	4.2	Salt hay (*Spartina*	2.37
Marsh Shrub - Low Salinity	3.64	*Spartina cynosuroides*	1.68
Spartina cynosuroides	2.72	Tidal Swamp Forest	0.92
Typha	1.53	Tidal Flat	0.72
Zizania aquatica	1.09	Marsh Shrub - Low Salinity	0.43
Peltandra virginica	0.96	*Typha* (*latifolia/angustifolia*)	0.04
Pontederia cordata	0.44	*Scirpus americanus*	0.02
Impoundment	0.30	*Atriplex triangularis*	0.01
Nuphar lutea	0.04	*Peltandra virginica*	0.01
Scirpus americanus	0.01		
Total	100%		100%

Table 6. Percent composition of cover types found in DNERR wetlands.

Species Name	**Common Name**	**Species Name**	**Common Name**
Acer rubrum	red maple	*Cornus racemosa*	gray dogwood
Acnida cannabina	saltmarsh water hemp	*Cyperus strigosus*	umbrella sedge
Acorus calamus	sweet flag	*Decodon verticillatus*	water willow
Alnus serrulata	smooth alder	*Echinochloa walteri*	water millet
Apios americana	groundnut	*Eleocharis ambigens*	a spike-rush
Arisaema triphyllum	jack-in-the-pulpit	*Eleocharis palustris*	marsh spike-rush
Aronia arbutifolia	chokeberry	*Elymus virginicus*	Virginia wild-rye
Asclepias incarnata	swamp milkweed	*Eupatorium fistulosum*	joe-pye-weed
Aster vimineus	white aster	*Fagus grandifolia*	American beech
Athryium filix-femina	lady fern	*Fragaria virginia*	wild strawberry
Bidens cernua	nodding bur-marigold	*Fraxinus pennsylvanica*	green ash
Boehmeria cylindrica	false nettle	*Galium tinctorium*	common madder
Calamagrostis canadensis	bluejoint	*Geum virginiana*	rough avens
Cartha palusrtis	marsh marigold	*Hamamelis virginiana*	witch hazel
Campsis radicans	trumpet creeper	*Hibiscus palustris*	swamp rose mallow
Carex comosa	bearded carex	*Hydrocotyl sibthorpioides*	a water penny-wort
Carex gigantia	large sedge	*Ilex opaca*	American holly
Carex lurida	lurid carex	*Ilex verticillata*	winterberry
Carex straminea	straw carex	*Impatiens capensis*	jewelweed
Carex stricta	uptight sedge	*Iris pseudacorus*	yellow flag
Carex vinata	a sedge	*Iris versicolor*	blue flag
Carpinus caroliniana	ironweed	*Itea virginica*	Virginia willow
Carya tomentosa	mockernut hickory	*Juglans nigra*	black walnut
Cephalanthus occidentalis	buttonbush	*Juniperus virginiana*	red cedar
Cicuta maculata	water hemlock	*Kosteletzya virginica*	seashore mallow
Clematis virginiana	virgin's bower	*Leersia oryzoides*	rice cutgrass
Clethra alnifolia	sweet pepperbush	*Lilium canadense*	Canada lily
Cornus amomum	silky dogwood	*Lindera benzoin*	spicebush
Cornus florida	flowering dogwood	*Liquidambar styraciflua*	sweet gum

Table 7. Plant Species List – Upper Blackbird Creek.

Species Name	Common Name	Species Name	Common Name
Liriodendron tulipifera	tulip tree	*Rumex verticillatus*	swamp dock
Lobelia cardinalis	cardinal flower	*Sagittaria australis*	long-beaked arrowhead
Mikania scandens	climbing hempweed	*Sassafras albidum*	sassafras
Nuphar luteum	yellow pond lily	*Saururus cernuus*	lizard's tail
Onoclea sensibilis	sensitive fern	*Scirpus americanus*	American three-square
Osmunda regalis	royal fern	*Scirpus polyphyllus*	leafy bulrush
Panicum laniterinum	a panic grass	*Scirpus robustus*	saltmarsh bulrush
Parthenocissus quinquefolia	Virginia creeper	*Scirpus validus*	giant bulrush
Peltandra virginica	arrow arum	*Sisyrinchium graminoides*	blue-eyed grass
Phragmites australis	common reed	*Sium suave*	water parsnip
Phytolacca americana	pokeweed	*Smilax glauca*	sawbriar
Podophyllum peltatum	mayapple	*Smilax rotundifolia*	common greenbriar
Polygonum arifolium	halberd-leaved tearthumb	*Spartina alterniflora*	saltmarsh cordgrass
Polygonum hydropiper	marshpepper smartweed	*Spartina cynosuroides*	big cordgrass
Polygonum sagittatum	arrow-leaved tearthumb	*Spartina patens*	saltmeadow cordgrass
Ponderia cordata	pickerelweed	*Stachys hispidus*	smooth hedge nettle
Prunus cf. Avium	mazzard	*Symplocarpus foetidus*	skunk cabbage
Prunus serotina	black cherry	*Thalictrum pubescens*	tall meadow-rue
Ptilimnium capillaceum	mock bishopweed	*Toxicodendron radicans*	poison ivy
Quercus alba	white oak	*Typha angustifolia*	narrow-leaf cattail
Quercus falcata	southern red oak	*Typha latifolia*	broad-leaf cattail
Quercus rubra	red oak	*Ulmus rubra*	slippery elm
Ranunculus longirostris	white water-crowfoot	*Vaccinium corymbosum*	highbush blueberry
Rhododendron viscosum	swamp honeysuckle	*Viburnum prunifolium*	black haw
Rhus copallina	winged sumac	*Viburnum recognitum*	northern arrowwood
Rorippa palustris	marsh yellow cress	*Viburnum rufidulum*	rusty black haw
Rosa palustris	swamp rose	*Xanthium strumarium*	common cocklebur
Rubus phoenicolasius	wineberry	*Zizania aquatica*	wild rice
Rubus sp.	blackberry		

Table 7. (Cont.) Plant Species List – Upper Blackbird Creek.

Species Name	Common Name	Species Name	Common Name
Acer rubrum	red maple	*Ilex opaca*	American holly
Apios americana	ground nut	*Ilex verticillatus*	winterberry
Atriplex patula	orach	*Impatiens capensis*	jewelweed
Baccharis halimifolia	groundsel bush	*Iva frutescens*	marsh elder
Calystegia sepium	hedge bindweed	*Juglans nigra*	black walnut
Carex alata	winged sedge	*Juniperus virginiana*	red cedar
Carex albolutescens	greenish-white sedge	*Leersia oryzoides*	rice cutgrass
Carex lonchocarpa	long sedge	*Liquidambar styraciflua*	sweet gum
Carex lurida	lurid sedge	*Lonicera japonica*	Japanese honeysuckle
Carex stricta	uptight sedge	*Magnolia virginiana*	sweet bay magnolia
Carya cordiformis	bitternut hickory	*Nuphar luteum*	yellow pond lily
Cephalanthus occidentalis	buttonbush	*Nyssa sylvatica*	black or sour gum
Cicuta maculata	water hemlock or spotted cowbane	*Osmunda cinnamomea*	cinnamon fern
Clethra alnifolia	sweet pepperbush	*Osmunda regalis*	royal fern
Coptis trifolia	canker root	*Peltandra virginica*	arrow arum
Diospyros virginiana	persimmon tree	*Phragmites australis*	common reed
Distichlis spicata	salt grass	*Polygonum convolvulus*	black bindweed
Eleocharis ambigens	a spikerush	*Prunus serotina*	black cherry
Fagus grandifolia	American beech	*Ptilimnium capillaceum*	mock bishopweed
Fraxinus pennsylvanica	green ash	*Quercus phellos*	willow oak
Galium tinctorium	common madder	*Rhododron viscosum*	swamp honeysuckle
Glyceria stricta	manna grass	*Rosa multiflora*	multiflora rose
Hibiscus palustris	swamp rose mallow	*Rosa palustris*	swamp rose
Hydrocotyle umbellata	many-flowered pennywort	*Rumex verticillatus*	swampdock
Ilex glabra	inkberry	*Salsola kali*	saltwort

Table 8. Plant Species List – Lower St. Jones River.

Species Name	Common Name	Species Name	Common Name
Sambucus canadensis	common elderberry	*Symplocarpus foetides*	skunk cabbage
Scirpus americanus	American three-square	*Thalictrum pubescens*	tall meadow-rue
Scirpus robustus	saltmarsh bulrush	*Toxicodendron radicans*	poison ivy
Scirpus validus	giant bulrush	*Typha angustifolia*	narrow-leaf cattail
Smilax glauca	sawbriar	*Typha latifolia*	broad-leaf cattail
Spartina alterniflora	saltmarsh cordgrass	*Vaccinium corumbosum*	highbush blueberry
Spartina cynosuroides	big cordgrass	*Viburnum recognitum*	northern arrowwood
Spartina patens	saltmeadow cordgrass	*Viburnum prunifloium*	black haw

Table 8. (Cont.) Plant Species List – Lower St. Jones River.

arrow arum *(Peltandra virginica)*, pickerelweed *(P. cordata)*, American three-square *(Scirpus americanus)*, and marsh elder *(Iva frutescens)*. The current distribution of *Phragmites* clusters suggests their radiation and colonization from creek bank, upland boundary, and occasional internal marsh locations. *Phragmites* distribution is more restricted in the St. Jones River portion of the Reserve, found only along the upland edge and major river banks, probably due to higher salinity.

Forest vegetation

The forested areas of the Reserve, particularly at Upper Blackbird Creek, are made up of two types of communities: tidal swamp forest and upland forest. The tidal swamp forest community consists of forested areas with tidally influenced hydrology. Species found in this community include willows (*Salix* spp.), red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanicus*), red cedar (*Juniperus virginiana*), black or sour gum (*Nyssa sylvatica*), and sweet gum (*Liquidambar styraciflua*). The upland forested community includes tulip tree (*Liriodendron tulipifera*), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), white oak (*Quercus alba*), southern red oak (*Quercus falcata*), hickory (*Carya* sp.), American holly (*Ilex opaca*), sassafras (*Sassafras albidum*), and black haw (*Viburnum prunifolium*).

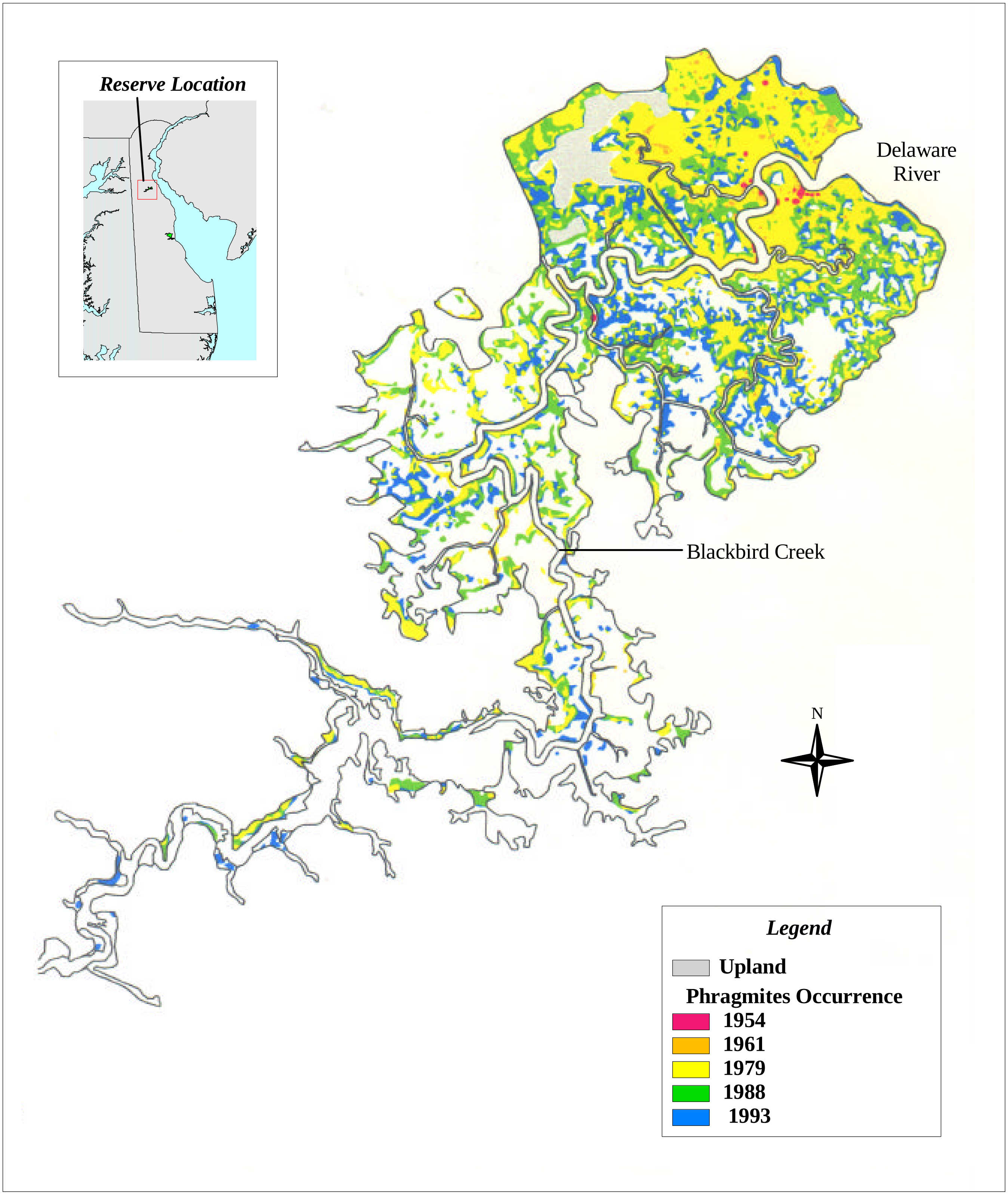
Expansion of Phragmites and its control

Expansion of common reed (*Phragmites australis*) over the past 50 years in Delaware and other areas of the mid-Atlantic and southern New England has become a serious problem. Extensive monotypic stands seriously degrade coastal wetlands for wildlife habitat values, and possibly adversely affect estuarine detrital food webs. It is still not well understood why *Phragmites* has undergone such aggressive expansions and incursions. Several hypotheses have been advanced including anthropogenic marsh disturbances involving wetlands dewatering or marsh surface spoil deposition, increased nutrient loading of tidal waters, and possible introduction of a more aggressive European strain of this species.

The historical invasion of *Phragmites* in St. Jones River and Blackbird Creek has been investigated through remote sensing techniques (Bailey, 1997). The spread of *Phragmites* appears to be primarily by vegetative growth, and initial establishment occurs from creek bank and upland edge (Figure 37). Although salinity seems to limit distribution in the St. Jones River, *Phragmites* could expand throughout the Blackbird Creek tidal wetlands.

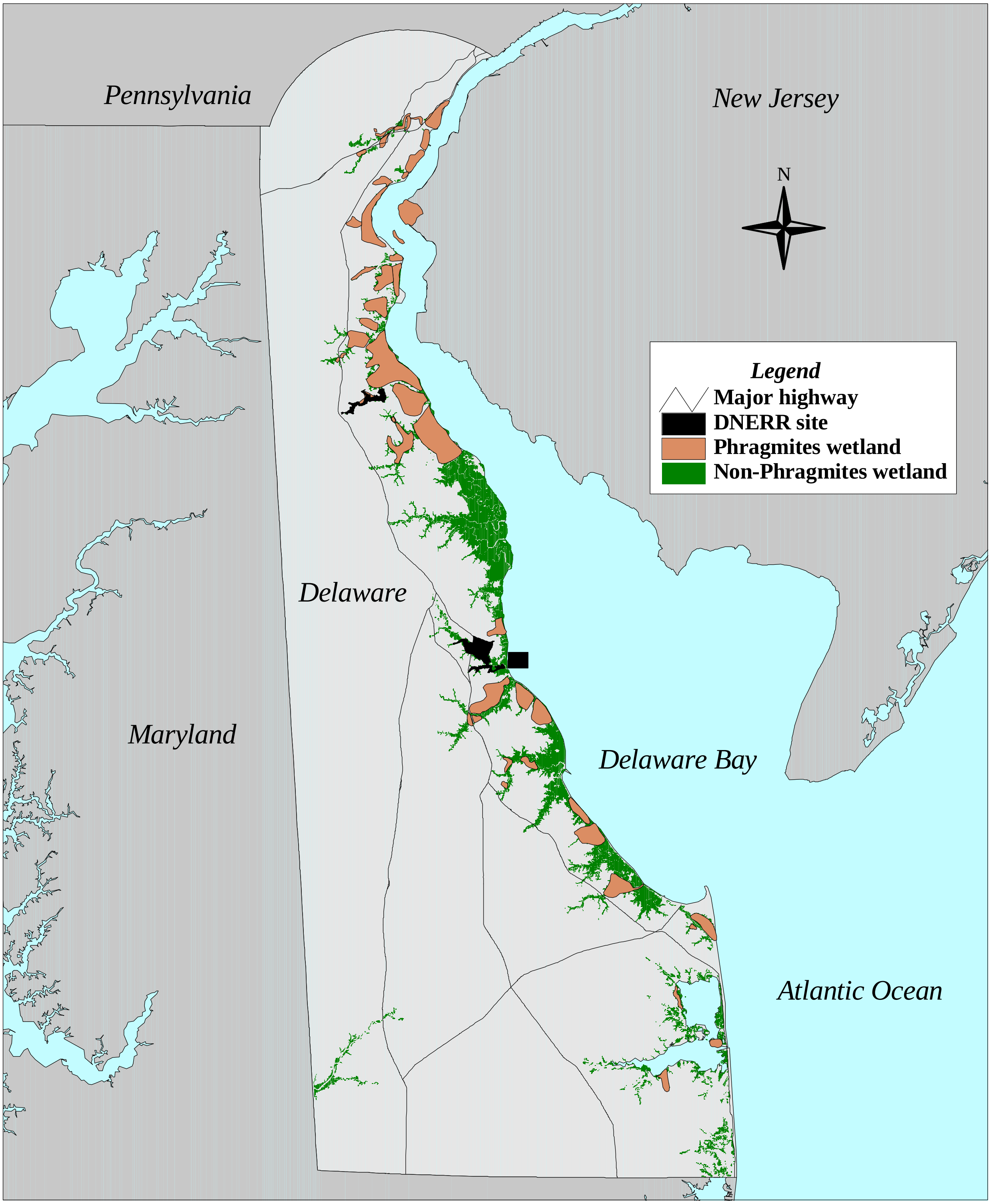
Over the past 50 years, *Phragmites* has spread to create thick monotypic stands in about 10-15% of Delaware's tidal wetlands, with lesser densities of *Phragmites* present in up to 1/3 of the state's coastal wetlands (Figure 38) (DNREC 1993). Several methods of control have been tested and the most practicable control method to date is aerial application of a herbicide followed by prescribed burning. The first step in *Phragmites* control operations performed by the DNREC Division of Fish and Wildlife involves aerial spraying of the herbicide glyphosate (Rodeo), applied in late summer over two consecutive years. After the first spraying, the dead stalks are burned wherever possible, usually in the following late winter or early spring. Burning is done again after the second spraying if the first burn was incomplete. This method is approximately 70-90% effective for several years, if the sprayings and burns are done properly (DNREC 1993). After the *Phragmites* is burned, original wetland vegetation is allowed to grow, replenishing the area with important resources necessary for a productive estuarine ecosystem. However, in order to maintain the desired vegetation, it is often necessary to continue long-term spot treatments of herbicides wherever *Phragmites* reestablishes itself.

Within Lower Blackbird Creek marshes, immediately downstream from the Upper



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information provided is only an approximate graphical representation, based on data provided by Allison Bailey.

Figure 37. Upper Blackbird Creek Reserve: Occurrence and Expansion of Phragmites Cover, 1954-1993 (Bailey, 1997)



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 38: Phragmites-Dominated Coastal Wetlands

Blackbird Creek Reserve, the Division of Fish and Wildlife has treated over 390 ha (963 acres) of *Phragmites*-infested marsh on The Rocks parcel (part of Cedar Swamp State Wildlife Area). Private landowners have treated an additional several hundred hectares (acres) in the Lower Blackbird Creek basin, under the Division’s cost-share *Phragmites* control program for private landowners.

Marsh edaphic algae

Edaphic diatoms, microscopic flora found within the top few millimeters of muddy marsh surface, play a very crucial ecological role in salt marshes. Acting as the base of the entire food web, edaphic diatoms serve as an important food source for many organisms, including small fish species such as *Fundulus heteroclitus* (mummichog). These smaller fish then act as a food source for larger fish and wading birds. According to Sullivan (1971), the diversity and abundance of edaphic algae in tall-form *Spartina alterniflora* and *Distichlis spicata* marshes during winter and early spring may be crucial in sustaining the salt marsh ecosystem, by providing a primary food source during a time when all other productivity is low. Because of this seasonal dependence on diatoms by the rest of the marsh, it is very important that edaphic algae survive all environmental stresses, including lack of water, temperature changes, and other extremes that may arise. Based on early studies done by Faure'-Fremiet (1951), the edaphic algae community also plays an important role for the survival of soil microfauna, in that the mucus secreted by the diatoms helps stabilize soil sediments. This stability helps prevent or reduce erosion and consequent loss of soil from the marsh. Without this stabilization, soil microfauna would come and go with the tides.

Submerged aquatic vegetation

Submerged aquatic vegetation (SAV) also plays an important ecological role in many salt marsh ecosystems, but is almost entirely lacking in the DNERR. SAV consists of rooted, flowering plants (e.g. eelgrass, widgeongrass) that colonize soft sediment habitats of coastal, estuarine, and freshwater environments. SAV is known to be a primary factor in the relatively high productivities of many estuarine ecosystems, including the Chesapeake Bay estuary (Kemp et al 1984). SAV has many functions, some of which include providing a main food source for many species of waterfowl, providing oxygen to surrounding organisms, and providing needed habitat for shellfish and finfish.

SAV can also serve as a good indicator of water clarity and of the amount of nutrients found within estuarine waters. In the late 1960's and early 1970's, there was a serious decrease in the amount of SAV found within Chesapeake Bay which continues today. Studies revealed that there was a probable connection with both agricultural runoff and increased development in surrounding communities. This caused increases in nutrients and sediments within the estuary, contributing to decreases in SAV (Orth and Moore 1983). It is possible that a lack of SAV within Upper Blackbird Creek and Lower St. Jones River is partially due to the poor water clarity and high nutrient levels, which might occur naturally, while an unknown contribution is also undoubtedly anthropogenic. Other causes for lack of much SAV around Delaware Bay might be inappropriate bathymetry or unsuitable subtidal substrates. The lack of shallow lagoon habitats within the DNERR (with exception of the nearby Logan Lane Impoundment), and the turbid, murky waters of both sites’ tidal channels, do not favor SAV growth.

Around the lower Delaware Estuary, the SAV species most frequently observed is widgeongrass (*Ruppia maritima*), primarily confined to small salt marsh ponds that have permanent water, or to larger man-made coastal impoundments.

Plant species of special concern

Several plant species listed in the Delaware Natural Heritage Program's (DNHP) *Rare*

Native Plants of Delaware (DNHP 1996) have been found within boundaries of the Upper Blackbird Creek Reserve. Marsh marigold (*Caltha palustris*) and rough avens (*Geum virginiana*) are both given an S1 ranking by the DNHP. This ranking is defined as an extremely rare species with 5 or fewer occurrences in the state of Delaware. Canada lily (*Lilium canadense*) and nodding bur-marigold (*Bidens cernua*) are both given an S2 classification. This ranking is defined as very rare, with 6-20 occurrences in the state. Another rare plant on the Blackbird Reserve is swamp milkweed (*Asclepias incarnata*), which is ranked as SH, historically known but not verified for an extended period (usually 15 years).

Plankton

Phytoplankton assemblages

A major source of aquatic organic matter found in estuarine waters is produced by phytoplankton. The phytoplankton community is especially important because it provides oxygen for fish and other aquatic organisms, and serves as a major food source in aquatic food webs. Phytoplankton data from both Reserve sites are combined on Table 9.

Phytoplankton surveys conducted by Environmental Consulting Services, Inc. (ECSI) at three locations per Reserve site (Figures 8 and 9) show that during 1995 and 1996, Blackbird Creek supported phytoplankton from at least 42 taxa represented by two kingdoms and at least four divisions. These included the Monera division Cyanophycota (blue-green algae), and the Protozoa divisions Bacillariophyta (diatoms), Chlorophycota (green algae) and Pyrrhophycota (dinoflagellates). Of the 30 taxa which comprised over 90% of the total phytoplankton represented, fifteen were diatoms, eight were green algae, six were blue-green algae, and one was a composite group of unidentifiable phytoflagellates. The diatoms *Skeletonema spp.*, *Melosira spp.*, and *Nitzschia spp.* made up the most abundant taxa, followed by the blue-green algae *Anabaena spp.*, and *Microcystis spp.* The dominant green algae were made up of *Actinastrum spp.*, *Scenedesmus spp.*, *Ankistrodesmus spp.*, *Volvox spp.*, *Hydrodictyon spp.*, *Tetraedron spp.*, unidentified Chlorophycota, and *Chlamydomonas spp.*

Upper Blackbird Creek supported most phytoplankton during the summer with the winter having the fewest species represented. The overall diversity of phytoplankton was also greatest in the summer and least during fall. During each season, diatoms were the most abundant taxa and the most represented division of phytoplankton.

Phytoplankton of the St. Jones River were more diverse than the Blackbird Creek community, having at least 44 taxa represented by two kingdoms and at least five divisions. These included the Monera division Cyanophycota, and the Protozoa divisions Bacillariophyta, Chlorophycota, Cryptophycota, and Pyrrhophycota. Of the 26 taxa which comprised over 90% of the total phytoplankton represented, thirteen were diatoms, six were green algae, three were blue-green algae, two were dinoflagellates, one was a cryptomonad, and one was an unidentified phytoflagellate. The diatoms *Melosira spp.* and *Guinardia spp.* were most abundant, followed by the dinoflagellate *Ceratium spp.* and the diatom *Biddulphia spp*. The dominant green algae were *Volvox spp.*, *Ankistrodesmus spp.*, *Scenedesmus spp.*, *Chlamydomonas spp.*, *Chlorella spp.*, and *Hydrodictyon spp*. The dominant blue-green algae were comprised of *Anabaena spp.*, *Microcystis spp.*, and *Oscillatoria spp*.

The Lower St. Jones River supported the most phytoplankton in spring and least in winter. The greatest diversity was observed in summer, and least diverse collections came in fall. Diatoms were either the most or second most abundant taxa during all seasons, and were the most frequently represented division of phytoplankton.

Kingdom Monera
  Division Cyanophycota (blue-green algae)
    Anabaena spp.
    Anacystis spp.
    Microcystis spp.
    Oscillatoria spp.
    Sphaerocystis spp.
    Unidentified Cyanophycota

Kingdom Protozoa
  Division Bacillariophyta (Diatoms)
    Class Coscinodiscophyceae (centric diatoms)
      Biddulphia spp.
      Chaetoceros spp.
      Coscinodiscus spp.
      Cyclotella spp.
      Ditylum spp.
      Guinardia spp.
      Leptocylindrus spp.
      Lithodesmium spp.
      Melosira spp.
      Rhizosolenia spp.
      Skletonema spp.
      Unidentified Coscinodiscophyceae
    Class Fragilariophyceae (araphid, pennate diatoms)
      Asterionella spp.
      Fragilaria spp.
      Synedra spp.
      Tabellaria spp.
      Thalassionema spp.
      Thalassiothrix spp.
    Class Bacillariophyceae (raphid, pennate diatoms)
      Achnanthes spp.
      Gyrosigma spp.
      Hantzschia spp.
      Navicula spp.
      Nitzschia spp.
      Pinnularia spp.
      Surirella spp.
  Division Chlorophycota (green algae)
      Actinastrum spp.
      Ankistrodesmus spp.
      Chlamydomonas spp.
      Chlorella spp.
      Hydrodictyon spp. (water nett)
      Pediastrum spp.
      Scenedesmus spp.
      Tetraedron spp.
      Ulothrix spp.
      Unidentified Chlorophycota
      Volvox spp.
  Division Cryptophycota (cryptomonads)
    Class Cryptophyceae
      Cryptomonas spp.
  Division Pyrrhophycota (dinoflagellates)
      Unidentified Pyrrhophycota
    Class Dinophyceae
      Ceratium spp.
      Gymnodinium spp.
      Noctiluca spp.
      Peridinium spp.

Unidentified phytoplankton
Unidentified Phytoflagellates
      May include:
          Chlorophycota(green algae)
          Chrysophycota (yellow-brown algae)
          Other Unicellular flagellates

Table 9. Phylogenetic Composition of Phytoplankton collected in the Blackbird Creek and St. Jones River areas of the DNERR during 1995 and 1996.

Upper Blackbird Creek and the Lower St. Jones River combined to have 50 phytoplankton taxa representing two kingdoms and at least five divisions. Overall the most abundant taxa collected within the Reserve were the diatoms *Guinardia spp*., *Skeletonema spp*., and *Melosira spp.*, and the dinoflagellate *Ceratium spp.*

Zooplankton assemblages

An important role that phytoplankton play in estuaries is as a food source for zooplankton. The zooplankton can be described in two categories, microzooplankton (<64 micron) and mesozooplankton (<250 micron), both of which are found in abundance in Blackbird Creek and St. Jones River. Table 10 presents data on microzooplankton from the ECSI monitoring reports. Table 11 presents data for mesozooplankton.

In Upper Blackbird Creek, approximately 36 taxa of microzooplankton were found, represented by two kingdoms and at least 11 phyla. These 11 phyla included the Protozoa phyla Ciliophora and Sarcomastigophora, and the Animalia phyla Cnidaria, Platyhelminthes, Nematoda, Nemertea, Rotifera, Tardigrada, Mollusca, Annelida, and Arthropoda.

In the ECSI surveys, 13 taxa in Blackbird Creek accounted for over 90% of the total microzooplankton organisms found. Occurring most were the taxa Copepoda nauplii and the rotifers *Filinia spp*. and *Notholca spp*. Other taxa that commonly occurred were Rotifera, Gastropoda, Bivalvia, Polychaeta, and Oligochaeta.

Copepods and rotifers were always the most abundant microzooplankton in every season. The most diverse time of year was summer and the least diverse season was fall.

The content of the Blackbird Creek mesozooplankton community was somewhat similar to the microzooplankton community, as many of the same taxa were represented. In all, 44 taxa were present, represented by two kingdoms and nine phyla, including the Protozoa phyla Ciliophora and Sarcomastigophora, and the Animalia phyla Cnidaria, Platyhelminthes, Nematoda, Rotifera, Mollusca, Annelida, and Arthropoda.

Of the total numbers of organisms collected, more than 90% of the species came from 25 taxa. The most abundant taxa collected were the cladoceran *Diaphanosoma spp.,* followed by Copepoda nauplii and *Acartia hudsonia.* The rest of the dominant taxa included Copepoda, Polychaeta, Gastropoda, Bivalvia, Cirripedia, *Uca spp.*, Rotifera, Cladocera, and Hydrozoa medusa.

Copepoda comprised the most abundant mesozooplankton taxa in Blackbird Creek during the winter, spring and summer seasons, and polychaeta larvae were the most common in fall. In every season except summer, Copepoda was represented by more taxa than any other. Representatives of the Copepoda taxa included nauplii, copepodites, *Acartia hudsonia*, *A. tonsa*, *Acartia spp.*, *Eurytemora affinis*, *Halicyclops fosteri*, *Ectinosoma spp.*, *Scottolana spp.*, *Cyclops spp.*, *Oithona spp.*, and other unidentifiable copepod species from the orders Calanoida, Cyclopoida, and Harpacticoida. The most diverse season was summer, and the least diverse collections were from winter.

In the Lower St. Jones River, comparable results were found. At least 39 microzooplankton taxa were represented by two kingdoms and at least 11 phyla. The Protozoa phyla Ciliophora and Sarcomastigophora, and the Animalia phyla Cnidaria, Platyhelminthes, Nematoda, Rotifera, Tardigrada, Mollusca, Annelida, Arthropoda, and Chordata were all observed. In all, 20 taxa made up over 90% of the microzooplankton collections. The most commonly found microzooplankton taxa was Copepoda nauplii, followed by three Rotifera taxa including *Keratella spp.*, unidentified Rotifera, and *Notholca spp.* Also dominant in the collections were Polychaeta, Gastropoda,

- Kingdom Protozoa
  - Phylum Ciliophora
    - Subphylum Cyrtophora
      - Class Oligohymenophora
        - Subclass Peritrichia
    - Subphylum Postciliodesmatophora
      - Class Spirotrichea
        - Family Tinttinnididae
          - *Tintinnidium spp.*
  - Phylum Sarcomastigophora
    - Subphylum Sarcodina
      - Class Granuloreticulosea
        - Order Foraminiferida (forams)
      - Class Lobosea
        - Subclass Testacealobosia
          - Order Arcellinida
    - Subphylum Mastigophora
      - Class Zoomastigophora
- Kingdom Animalia
  - Phlum Cnidaria (jellyfish)
    - Unidentified medusa life – stage
  - Phylum Platyhelminthes (flatworms)
    - Class Turbellaria (free-living flatworms)
  - Phylum Nematoda (roundworms)
  - Phylum Rotifera (rotifers)
    - Class Bdelloidea
    - Class Monogononta
      - Order Flosculariacea
        - Family Filiniidae
          - *Filinae spp.*
          - *Tetramastix spp.*
      - Order Ploimida
        - Family Brachionidae
          - *Brachionus spp.*
          - *Keratella spp.*
          - *Notholca spp.*
          - *Kellicottia spp.*
  - Phylum Tardigrada (water bears)
  - Phylum Mollusca (clams and snails)
    - Class Bivalvia (clams)
      - Unidentified veliger larvae
    - Class Gastropoda (snails)
      - Unidentified veliger larvae
  - Phylum Annelida (segmented worms)
    - Class Oligochaeta (aquatic earthworms)
    - Class Polychaeta (clamworms, bristleworms)
      - Unidentified larvae
  - Phylum Arthropoda (insects and crustaceans)
    - Subphylum Mandibulata
      - Class Crustacea (crustaceans)
        - Subclass Copepoda (copepods)
          - Unidentified nauplii larvae
          - Unidentified copepodite larvae
          - Order Calanoida
          - Order Cyclopoida
          - Order Harpacticoida
            - Family Longipedildae
              - *Scottolana spp.*
        - Subclass Ostracoda
        - Subclass Branchiopoda
          - Order Cladocera (water fleas)
            - Family Daphniidae
              - *Daphnia spp.*
            - Family Bosminidae
              - *Bosmina spp.*
            - Family Sididae
              - *Diaphanosome spp.*
        - Subclass Cirripedia (barnacles)
          - Unidentified nauplii larvae
        - Subclass Malacostraca
      - Order Decapoda (shrimp and crabs)
        - Unidentified zoea larvae
  - Phylum Chordata
    - Subphylum Urochordata (invertebrate chordates)
      - Class Ascidiacea (sea squirts)
        - Unidentified organisms
- Unknown 1, possibly a sarcodine protist
- Unknown 2, possibly a monpodeal amoeba
- Unknown 3, possibly a rotifer
- Unknown 4, possibly an unknown larval form
- Unknown 5, possibly a peritrichia protist

Table 10. Phylogenetic Composition of Microzooplankton collected in the Blackbird Creek and St. Jones River areas of the DNERR during 1995 and 1996.

- Kingdom Protozoa
  - Phylum Ciliophora (ciliates)
    - Subphylum Cyrtophora
      - Class Oligohymenophora
        - Subclass Peritrichia
  - Phylum Sarcomastigophora
    - Subphylum Sarcodina
      - Class Granuloreticulosea
        - Order Foraminiferida (forams)
- Kingdom Animalia
  - Phlum Cnidaria (jellyfish)
    - Unidentified medusa life – stage
    - Class Hydrozoa
    - Unidentified medusa life – stage
  - Phylum Platyhelminthes (flatworms)
    - Class Turbellaria (free-living flatworms)
  - Phylum Nematoda (roundwaorms)
  - Phylum Rotifera (rotifers)
    - Class Monogononta
      - Order Floscularìacea
        - Family Filiniidae
          - *Filinae spp.*
      - Order Ploimida
        - Family Brachionidae
          - *Brachionus spp.*
          - *Keratella spp.*
          - *Notholca spp.*
          - *Ploima spp.*
  - Phylum Tardigrada (water bears)
  - Phylum Mollusca (clams and snails)
    - Class Bivalvia (clams)
      - Unidentified veliger larvae
    - Class Gastropoda (snails)
      - Unidentified veliger larvae
  - Phylum Annelida (segmented worms)
    - Class Polychaeta (clamworms and bristleworms)
    - Class Hirudinoidea (leeches)
      - Family Piscicolidae (fish leeches)
  - Phylum Arthopoda (insects and crustaceans)
    - Subphylum Mandibulata
      - Class Entognatha
        - Order Collembola (springtails)
      - Class Crustacea (crustaceans)
        - Subclass Copepoda (copepods)
          - Unidentified nauplii larvae
          - Unidentified copepodite larvae
          - Order Calanoida
            - Family Acartiidae
              - *Acartia spp.*
              - *Acartia hudsonia*
              - *Acartia tonsa*
            - Family Centropagidae
              - *Centropages spp*.
            - Family Diaptomidae
              - *Pseudodiaptomus pelagicus*
            - Family Pontellidae
              - *Labidocera aestiva*
            - Family Temoridae
              - *Eurytemora affinis*
          - Order Cyclopoida
            - Family Cyclopidae
              - *Cyclops spp.*
              - *Halicyclops fosteri*
            - Family Oithonidae
              - *Oithona spp.*
          - Order Harpacticoida
            - Family Canthocarnptidae
              - *Leptastacus spp*.
            - Family Longipedidae
              - *Ectinosoma spp.*
              - *Scottolana spp*.
        - Subclass Ostracoda
        - Subclass Branchiopoda
          - Order Cladocera (water fleas)
            - Family Daphniidae
              - *Daphnia spp*.
            - Family Bosminidae
              - *Bosmina spp*.
            - Family Sididae
              - *Diaphanosome spp*.
        - Subclass Cirripedia (barnacles)
          - Unidentified nauplii larvae
        - Subclass Malacostraca
          - Order Isopoda (isopods or pillbugs)
          - Order Mysidacea (mysid shrimp)
            - *Neomysis americana* (opossum shrimp)
          - Order Amphipoda (amphipods or scuds, sideswimmers)
            - Family Gammaridae
              - *Corophium spp.*
              - *Gammarus spp.* (scuds)
          - Order Decapoda (shrimp and crabs)
            - Unidentified zoea larvae
            - Infraorder Caridea (caridean shrimp)
              - Family Palaemonidae
                - *Palaemonetes spp*. (grass shrimp) larvae
                - *Palaemonetes pugio* (common grass shrimp)
            - Infraorder Brachyura (true crabs)
              - Family Ocypodidae
                - *Uca spp.* (fiddler crabs) zoea larvae
              - Family Xanthidae (mud crabs)
                - *Rhithropanopeus spp*. (white-fingered mud crabs) zoea larvae
  - Phylum Echinodermata
    - Unidentified dipleurula larvae
  - Phylum Chordata
    - Subphylum Urochordata (invertebrate chordates)
      - Class Ascidiacea (sea squirts)
        - Unidentified ‘tadpole’ larvae
- Unidentified organisms
- Unknown 1, possibly a sarcodine protist
- Unknown 3, possibly a rotifer
- Unknown 4, possibly an unknown larva

Table 11. Phylogenetic Composition of Mesozooplankton collected in the Blackbird Creek and St. Jones River areas of the DNERR during 1995 and 1996.

Ascidiacea, Bivalvia larvae, the cladoceran *Daphnia spp.*, rotifer taxa *Brachionus spp.* and *Filinia spp.*, and Protozoans *Tintinnidium spp.*, Zoomastigophora, Peritrichia, and Arcellinida.

During fall, spring, and summer in the Lower St. Jones River, Copepoda nauplii was the most abundant microzooplankton taxa. In winter, an unidentified Rotifera was most commonly collected. In any season, the dominant taxa usually consisted of Copepoda nauplii, Rotifera, Polychaeta larvae, or Cladocera. In the Lower St. Jones River, the greatest diversity of microzooplankton was found in the summer, while the least diversity was found in the fall.

The mesozooplankton community of the Lower St. Jones River was the most abundant and diverse of all. At least 53 taxa were represented by at least 11 phyla. These phyla included the Protozoa phylum Ciliophora, and the Animalia phyla Cnidaria, Platyhelminthes, Nematoda, Rotifera, Tardigrada, Mollusca, Annelida, Arthropoda, Echinodermata, and Chordata (Table 11). The collections were dominated by 32 taxa, which made up over 90% of the total. Polychaeta larvae was the most abundant taxa, followed by 14 taxa of Copepoda, including copepod nauplii, *Acartia tonsa*, *Eurytemora affinis*, *Acartia spp.*, *Oithona spp.*, copepodites, *Ectinosoma spp.*, Calanoida, *Leptastacus spp.*, Cyclopoida, *Cyclops spp.*, *Halicyclops fosteri*, *Pseudodiaptomus pelagicus*, and Harpacticoida. The other dominant taxa included the cladocerans *Diaphanosoma spp.*, *Bosmina spp.*, and *Daphnia spp.*, mysid shrimp *Neomysis americana*, crab larvae of *Uca spp.*, and *Rhithropanopeus spp.*, Cirripedia, Ascidiacea, Nematoda, the protozoan Peritrichia, the rotifers *Brachionus* spp., unidentified Rotifera, and *Notholca* spp., Gastropoda, Cnidaria medusa, and Tardigrada. The mesozooplankton community of the entire length of the tidal St. Jones River is composed of freshwater/oligohaline species, as well as higher salinity estuarine species. Polychaeta larvae were the most abundant mesozooplankton organisms collected in the Lower St. Jones River during spring and summer, the copepod *Eurytemora affinis* was the most abundant in fall, and Nematoda were the most abundant organisms collected in winter. There was no taxa that was consistently dominant for all, or even most, of the seasons.

Combining the two DNERR Reserve sites, at least 45 taxa of microzooplankton were represented by two kingdoms and at least 12 phyla. The most abundant microzooplankton taxa collected were Copepoda nauplii, followed by the Rotifera taxa *Notholca spp.*, *Filinia spp.*, and unidentified Rotifera. At least 61 taxa of mesozooplankton were represented by two kingdoms and at least 12 phyla. The most abundant mesozooplankton taxon was the freshwater cladoceran *Diaphanosoma spp.* The next most abundant taxa were the freshwater/estuarine forms of Copepoda nauplii, followed by Polychaeta larvae.

As shown in Table 12, total net plankton density is comparable between the two Reserve sites. In general, greater density occurs in the upper reaches of both Blackbird Creek and the St. Jones River, mainly due to the higher abundance of rotifers and cladocerans upstream than down. Highest plankton densities occurred in summer, with the exception of phytoplankton in the St. Jones, for which the highest density occurred in spring.

Aquatic Macroinvertebrates

Subtidal benthic/parabenthic macroinvertebrates

Upper Blackbird Creek and Lower St. Jones River are hosts to a great diversity of benthic and parabenthic macroinvertebrates. ECSI performed surveys of benthic and parabenthic populations to characterize abundance at each site. The results are presented in Table 13 (Blackbird Creek) and Table 14 (St. Jones

	Blackbird Creek			**St. Jones River**		
	Phytoplankton n/ml	Microzooplankton n/m^3	Mesozooplankton n/m^3	Phytoplankton n/ml	Microzooplankton n/m^3	Mesozooplankton n/m^3
Fall 1995	2662	16235	2977	2392	7824	2086
Winter 1995 – 1996	1732	5241	788	1721	8641	1199
Spring 1996	4972	14525	6476	11120	4949	2472
Summer 1996	7587	27901	11305	3978	15223	8235
Annual Average 1995 - 96	6450	25608	10940	8797	14518	6162
Upper	4794	50233	11071	9115	17439	6431
Middle	5185	13491	6895	6526	13893	4367
Lower	6822	9910	6655	7670	6774	4865

Table 12. Total net plankton density.

Taxon	Tidal river stations				
	Upper	Lower	Mean	% total	Cum % total
Oligochaeta	646	2599	1623	42.3%	42.3%
Chironomidae	167	1668	918	23.9%	66.2%
Corophium sp.	22	1254	638	16.6%	82.8%
Gammarus sp.	129	269	199	5.2%	87.9%
Cyathura polita	81	274	178	4.6%	92.6%
Polydora ligni	75	54	65	1.7%	94.3%
Edotea triloba	0	102	51	1.3%	95.6%
Xanthidae	22	59	40	1.1%	96.6%
Gammaridae	0	65	32	0.8%	97.5%
Scolecolepides viridis	16	48	32	0.8%	98.3%
Parapluestes aestuarius	48	0	24	0.6%	98.9%
Nereis succinea	16	5	11	0.3%	99.2%
Hypaniola florida	5	11	8	0.2%	99.4%
Neomysis americana	5	11	8	0.2%	99.6%
Streblospio benedicti	11	0	5	0.1%	99.8%
Melita nitida	0	5	3	0.1%	99.9%
Nemertea	0	5	3	0.1%	99.9%
Rhithropanopeus harrisi	0	5	3	0.1%	100.0%
Totals	1243	6437	3840		

Taxon	2^o channel stations				
	Upper	Lower	Mean	% total	Cum % total
Oligochaeta	1937	1222	1580	77.1%	77.1%
Chironomidae	452	118	285	13.9%	91.1%
Nereis succinea	172	16	94	4.6%	95.7%
Gammarus sp.	38	22	30	1.4%	97.1%
Scolecolepides viridis	0	43	22	1.1%	98.2%
Edotea triloba	11	5	8	0.4%	98.6%
Hypaniola florida	16	0	8	0.4%	98.9%
Nemertea	0	11	5	0.3%	99.2%
Ceratopogonidae	5	0	3	0.1%	99.3%
Chiridotea almyra	5	0	3	0.1%	99.5%
Corophium sp.	5	0	3	0.1%	99.6%
Diptera	5	0	3	0.1%	99.7%
Neomysis americana	5	0	3	0.1%	99.9%
Xanthidae	0	5	3	0.1%	100.0%
Totals	2653	1442	2048		

Table 13. Benthic macroinvertebrate mean densities (number / m^2) from the tidal river and 2^0 channels of Blackbird Creek, all seasons combined (summer and fall 1994, and spring 1995).

Taxon	Tidal river stations				
	Upper	Lower	Mean	% total	Cum % total
Oligochaeta	1302	1335	1319	34.9%	34.9%
Chironomidae	1765	118	942	24.9%	59.8%
Corophium sp.	1103	11	557	14.7%	74.5%
Edotea triloba	226	135	180	4.8%	79.3%
Neomysis americana	318	27	172	4.6%	83.8%
Ilyanassa sp.	0	312	156	4.1%	88.0%
Gammarus sp.	151	16	83	2.2%	90.2%
Gammaridae	145	0	73	1.9%	92.1%
Polychaeta	0	135	67	1.8%	93.9%
Bivalvia	5	102	54	1.4%	95.3%
Streblospio benedicti	5	91	48	1.3%	96.6%
Scolecolepides viridis	11	54	32	0.9%	97.4%
Polydora ligni	27	22	24	0.6%	98.1%
Cyathura polita	38	0	19	0.5%	98.6%
Nemertea	32	0	16	0.4%	99.0%
Nereis succinea	22	11	16	0.4%	99.4%
Eurypanopeus depressus	0	16	8	0.2%	99.6%
Caecidotea sp.	11	0	5	0.1%	99.8%
Isopoda	0	5	3	0.1%	99.9%
Spionidae	5	0	3	0.1%	99.9%
Idotea sp.	0	5	3	0.1%	100.0%
Xanthidae	5	0	3	0.1%	100.1%
Totals	5172	2395	3781		

Taxon	2^{o} gut				
	Upper	Lower	Mean	% total	Cum % total
Oligochaeta	2142	565	1354	58.9%	58.9%
Streblospio benedicti	11	457	234	10.2%	69.1%
Polydora ligni	70	328	199	8.7%	77.8%
Chironomidae	205	16	110	4.8%	82.6%
Scolecolepides viridis	48	124	86	3.7%	86.3%
Gammaridae	124	11	67	2.9%	89.2%
Edotea triloba	75	22	48	2.1%	91.3%
Corophium sp.	5	91	48	2.1%	93.4%
Gammarus sp.	54	32	43	1.9%	95.3%
Cyathura polita	59	0	30	1.3%	96.6%
Hypaniola florida	0	27	13	0.6%	97.2%
Polychaeta	22	5	13	0.6%	97.8%
Nemertea	16	5	11	0.5%	98.2%
Neomysis americana	11	5	8	0.4%	98.6%
Ilyanassa sp.	0	16	8	0.4%	98.9%
Nereis succinea	0	16	8	0.4%	99.3%
Palaemonetes sp.	0	11	5	0.2%	99.5%
Chiridotea almyra	0	5	3	0.1%	99.6%
Eurypanopeus depressus	0	5	3	0.1%	99.8%
Turbellaria	0	5	3	0.1%	99.9%
Bivalvia	0	5	3	0.1%	100.0%
Totals	2842	1754	2298		

Taxon	2^{o} channel				
	Upper	Lower	Mean	% total	Cum % total
Oligochaeta	5839	737	3288	74.7%	74.7%
Turbellaria	581	59	320	7.3%	82.0%
Neomysis americana	22	301	161	3.7%	85.7%
Gammarus sp.	22	237	129	2.9%	88.6%
Streblospio benedicti	11	183	97	2.2%	90.8%
Corophium sp.		172	86	2.0%	92.8%
Chironomidae	140	11	75	1.7%	94.5%
Nereis succinea	22	108	65	1.5%	96.0%
Polydora ligni	38	65	51	1.2%	97.1%
Edotea triloba	81	16	48	1.1%	98.2%
Scolecolepides viridis	32	0	16	0.4%	98.6%
Sphaeriidae	32		16	0.4%	99.0%
Gammaridae	16	5	11	0.2%	99.2%
Xanthidae	5	11	8	0.2%	99.4%
Hypaniola florida	5	5	5	0.1%	99.5%
Nassarius sp.		11	5	0.1%	99.6%
Nemertea	11	0	5	0.1%	99.8%
Bivalvia		5	3	0.1%	99.8%
Hirudinea		5	3	0.1%	99.9%
Limulus polyphemus		5	3	0.1%	99.9%
Melita nitida		5	3	0.1%	100.0%
Totals	6857	1943	4400		

Table 14. Benthic macroinvertebrate mean densities (number / m^2) from the tidal river, 2^{o} channels, and 2^{o} guts of the St. Jones River, all seasons combined (summer and fall 1994, and spring 1995).

River). Sampling locations are shown in Figures 39 and 40.

Upper Blackbird Creek represents the limnetic/oligohaline portion of the Reserve, where salinities generally range between 0.1 and 5.0 ppt, while the Lower St. Jones River represents the mesohaline portion of the Reserve, where salinities generally range between 3.0 to 16.5 ppt. The taxonomic composition of each site reflects the difference in salinities. There were similarities between the two sites, but taxa that usually prefer lower salinities were found in Blackbird Creek, and taxa known to prefer higher salinities were found in the Lower St. Jones River. Overall, the two sites contained 37 taxa of five phyla: Annelida, Arthropoda, Mollusca, Platyhelminthes, and Nemertea (Tables 13 and 14). A higher number of benthic macroinvertebrate taxa were collected in the Lower St. Jones River (33) than in Upper Blackbird Creek (21). A higher number of parabenthic macroinvertebrate taxa were collected in the Upper Blackbird Creek (11) than in the Lower St. Jones River (9).

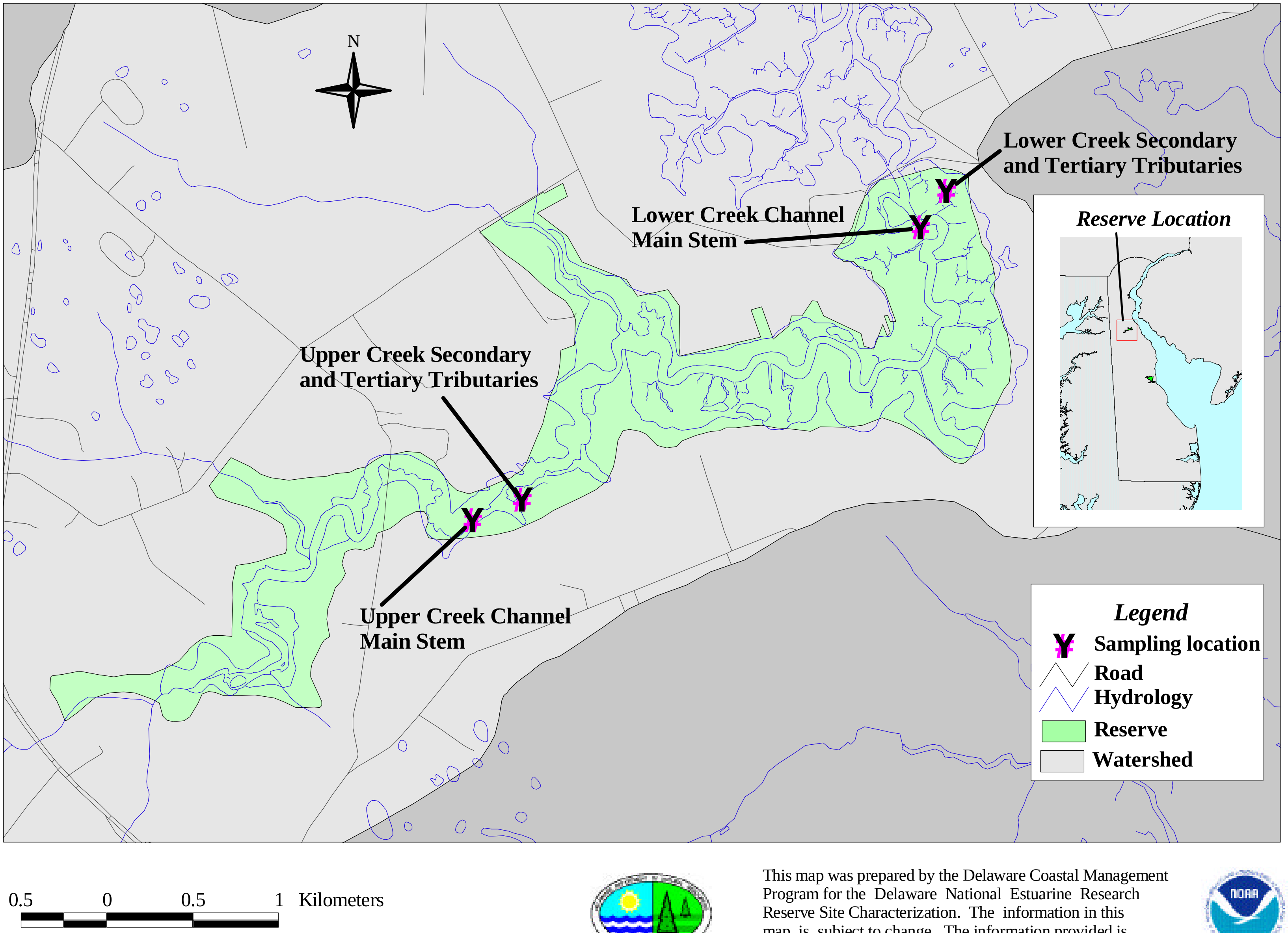
The Upper Blackbird Creek benthic macroinvertebrate community was represented by 21 taxa of three phyla, including Annelida (segmented worms), Arthropoda (insects and crustaceans), and Nemertea (ribbon worms). Five taxa comprised over 92% of the total. In order of decreasing abundance, these five taxa were: oligochaeta, chironomidae, the amphipods *Corophium sp.* and *Gammarus sp.*, and the isopod *Cyathura polita.*

The oligochaetes (aquatic earthworms) represented 54% of the total benthic macroinvertebrate catch in Upper Blackbird Creek. This was over 2.6 times greater than the next most abundant taxon, the chironomids (midges, a fly with aquatic immature stages). Both larval and pupal chironomids were taken, but the larval lifestage was vastly predominant.

The amphipods (scuds or sideswimmers) *Corophium sp.* and *Gammarus sp.* represented nearly 11% and 4%, respectively, of the total macroinvertebrate catch in Upper Blackbird Creek. The isopod (aquatic pillbug) *Cyathura polita* comprised 3% of the total. Of the 16 remaining taxa, representing less than 6% of the total mean densities, five were clamworms, eight were crustaceans, two were insect larvae, and one was a ribbonworm. The blue crab, *Callinectes sapidus*, and mud crabs of the family Xanthidae were collected quite frequently throughout the site, except in the permanent pool areas. The total densities of benthic macroinvertebrate organisms present in Upper Blackbird Creek ranged from a minimum of 2,040/m^2 during summer to the seasonal maximum of 4,289/m^2 in spring. During all three seasons, oligochaetes were always the most abundant taxon sampled. They composed from 41% to over 62% of the density sampled.

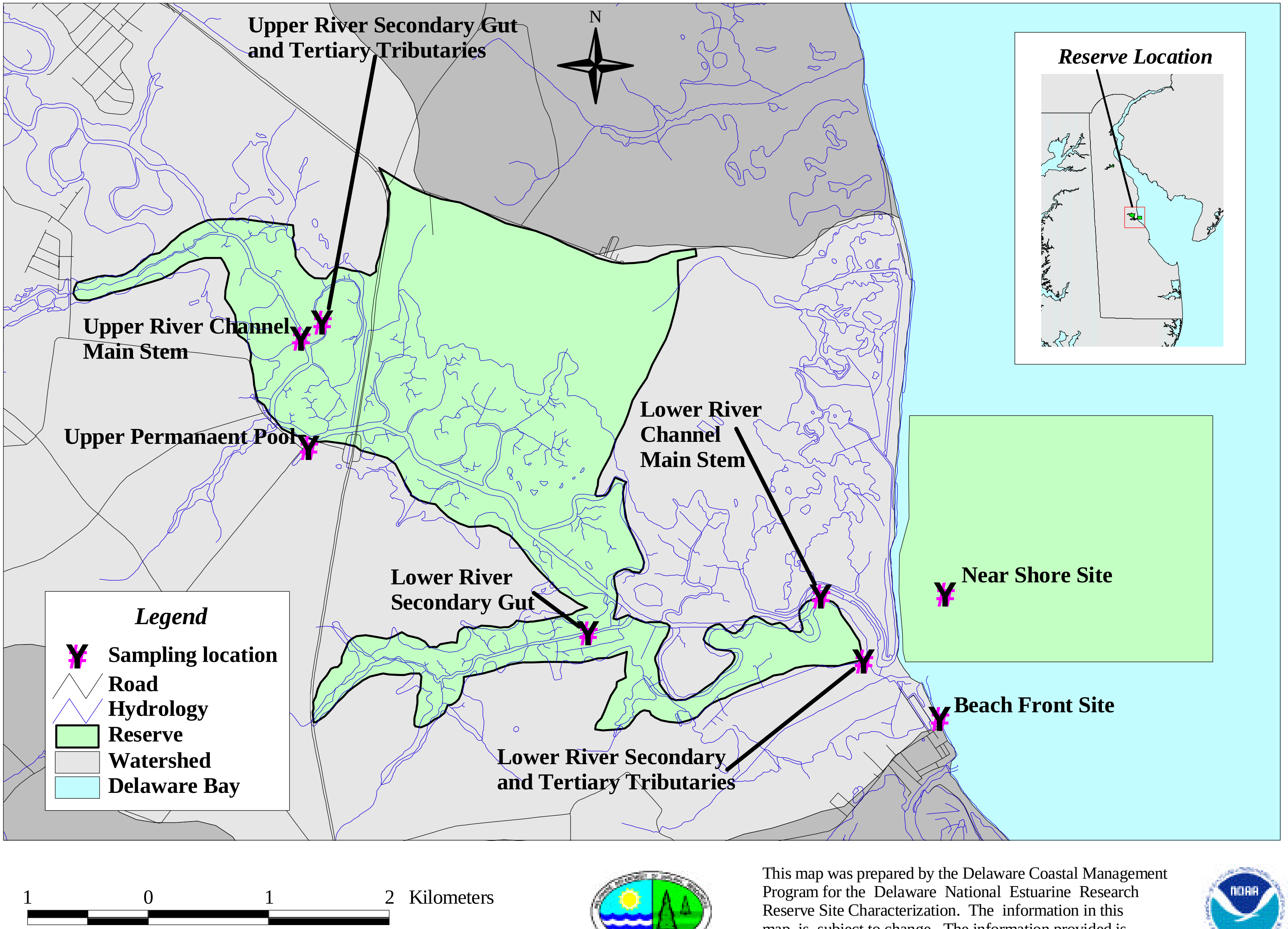
The Upper Blackbird Creek parabenthic macroinvertebrate community was represented by 11 taxa of four phyla, including Arthropoda, Annelida, Cnidaria (jellyfish) and Ctenophora (comb jellies). Four taxa, all crustaceans, comprised almost 95% of the parabenthos total. In order of decreasing abundance, these four taxa include the grass shrimp *Palaemonetes sp.*, the amphipod *Gammarus sp.*, the opossum shrimp *Neomysis americana*, and the scud *Corophium sp.* The remaining seven taxa represented less than 3% of the parabenthos community.

The Lower St. Jones River benthic macroinvertebrate community was represented by 33 taxa of five phyla. The five phyla represented were: Annelida (segmented worms), Arthropoda (insects, crustaceans, and horseshoe crabs), Platyhelminthes (flatworms), Mollusca (snails and clams), and Nemertea (ribbonworm). Ten taxa represented 92% of the total catch. In order of decreasing abundance, these 10 taxa were: oligochaeta, chironomidae, *Corophium sp.*, polychaeta, *Neomysis americana*, *Edotea triloba*,



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 39. Upper Blackbird Creek Reserve: Finfish and Macroinvertebrate Sampling Locations



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 40. Lower St. Jones River Reserve: Finfish and Macroinvertebrate Sampling Locations

Streblospio benedicti, *Gammarus sp.*, *Ilyanassa sp*., and turbellaria.

The oligochaetes or aquatic earthworms, a class of annelid, was the most abundant benthic macroinvertebrate taxa collected in the Lower St. Jones, comprising over 58% of the total catch. They were six times more numerous as the next most abundant taxon, the chironomids or midge larvae. Chironomids represented over 9% of the total.

The remaining dominant benthic macroinvertebrate taxa in the Lower St. Jones, in order of decreasing abundance, are as follows: the scud, *Corophium sp*. (5%); unidentified clamworms of the class Polychaeta (3%); the opossum shrimp, *Neomysis americana* (3%); the aquatic pillbug, *Edotea triloba* (3%); the clamworm, *Streblospio benedicti* (3%); the scud, *Gammarus sp*. (2%); the mud snail, *Ilyanassa sp*. (2%); and free-living flatworms or turbellarians (2%). Of the 23 remaining benthic macroinvertebrate taxa found in the Lower St. Jones, comprising 6% of the total mean densities observed, ten were crustaceans, six were sandworms (polychaetes), four were mollusks, one was the horseshoe crab, one was a leach, and one was a nemertean ribbonworm. The total densities of benthic macroinvertebrate taxa collected in the Lower St. Jones River ranged from 3,850/m^2 during summer to the seasonal maximum of 4,573/m^2 in spring, exhibiting densities similar to those observed for Blackbird Creek

The Lower St. Jones River parabenthic community was represented by nine taxa in four phyla: Arthropoda, Annelida, Cnidaria, and Ctenophora. However, only the arthropods, and more specifically one species of crustacean, the opossum shrimp *Neomysis americana,* predominated. This single species made up over 92% of the total parabenthic specimens collected. Of the remaining eight parabenthic taxa, only two contributed more than 1% of the total density. These eight minor taxa included six crustaceans, midge larvae, and the horseshoe crab.

The total densities of parabenthic macroinvertebrate organisms collected in the Lower St. Jones River ranged from a minimum of 578/m^2 during summer to the maximum of 21,210/m^2 in fall. For all seasons, the dominant group of parabenthic taxa were crustaceans, except for 18% of the summer sample that were midge larvae. For the fall and spring seasons, *Neomysis americana* was the predominant taxon. Its density of 20,460/m^2 in the fall was far above that of any other taxa in any season. During the summer, the isopod *Edotea triloba* had the highest densities at 160/m^2.

Casual observations were also made on a variety of other benthic macroinvertebrates found in the Lower St. Jones River that were not directly collected in the ECSI surveys. Live eastern oysters (*Crasssostrea virginica)* are very common and were noted during every season sampled. Just inside the mouth of the St. Jones River is a large oyster bed that could not be sampled with the equipment available. Blue crabs (*Callinectes sapidus*) were frequently observed, and numerous crab pots are set in the lower river and adjacent Delaware Bay for their harvest. Adult horseshoe crabs (*Limulus polyphemus)* were seen on the beach at the St. Jones River's mouth in the summer, and were captured quite often in the nets used to sample for finfish.

Marsh surface aquatic macroinvertebrates

In late summer, 1997, ECSI (1998) conducted a survey at the Lower St. Jones River Reserve to provide quantitative baseline characterizations for targeted dominant macroinvertebrates found in mesohaline tidal marsh surface habitats. Invertebrates of interest included fiddler crabs (*Uca* spp.), saltmarsh snails (*Melampus bidentatus*), marsh crabs (*Sesarma reticulatum*), grass shrimp (*Palaemonetes* spp.), Atlantic ribbed mussels (*Geukensia demissa*), amphipods (*Orchestia grillus* and *Gammarus* spp.), isopods (*Edotea* *triloba*), mud snails (*Ilyanassa obsoletus*), and blue crabs (*Callinectes sapidus*).

The study site was the emergent saltmarsh adjacent to the new boardwalk near the marsh's northern upland border, extending seaward to the St. Jones River. The most extensive marsh habitat within the study area was dominated by short- and tall-form *Spartina alterniflora* (saltmarsh cordgrass). The other habitats studied were those containing *Spartina cynosuroides* (big cordgrass), *Spartina patens*/*Distichlis spicata* (salt hay), *Phragmites australis* (reed grass), high salinity shrubs, marsh pools or potholes, marsh pannes or mudflats, and the intertidal areas of secondary and tertiary tributary streambanks. The sampling design examined 1.0 m^2 quadrat samples. Excluded from this survey by prescription were aerial or non-aquatic insects found amongst the vegetation. Water in pools and along streambanks was examined for grass shrimp by a series of 10 one-meter sweeps of a dip net, with the catch reported as mean number per sweep.

Thirty 1.0 m^2 quadrats were examined within nine different habitats, yielding seven macroinvertebrate species (Table 15). For all quadrats combined, the mean density (n/m^2) of all marsh surface macroinvertebrates combined was 44.0, with individual species densities in individual quadrats ranging from 0 to 350. The most numerous species collected was the saltmarsh snail *M. bidentatus*, which had a total mean density of 37.6 for all habitats combined, with densities in individual quadrats ranging from 0 to 348. Listed in order of decreasing abundance, the remainder of the macroinvertebrates found in all habitats combined were: red-jointed fiddler crab *U. minax* (mean density of 3.3 and a range of 0 to 25); saltmarsh flea *O. grillus* (mean 1.1, range 0 to 9); marsh fiddler crab *U. pugnax* (mean 1.0, range 0 to 12); ribbed mussel *G. demissa* (mean 0.6, range 0 to 17); grass shrimp *P. pugio* (mean 0.3, range 0 to 2.5); and marsh crab *S. reticulatum* (mean 0.1, range 0 to 1). Species of interest not collected during this study included blue crabs, mud snails, and isopods.

Marsh surface habitats containing one of the three *Spartina* species were characterized by having the highest mean densities of marsh surface macroinvertebrates. The highest densities of macroinvertebrates were found within the *S. alterniflora* habitat, which had a total mean density (n/m^2) of 135.4 (Table 16). All taxa of interest except the grass shrimp were found within this habitat. *M. bidentatus* was the dominant organism, having a mean density of 119.8, representing more than 88% of the total organisms collected. *Uca* spp. were moderately abundant with a maximum density of 25. The other macroinvertebrates found are listed in decreasing order of abundance by mean density: *U. minax* (8.0); *O. grillus* (3.6); *G. demissa* (3.4); *U. pugnax* (0.4); and *S. reticulatum* (0.2). The importance of saltmarsh cordgrass (*S. alterniflora)* areas in salt marshes is confirmed by these relatively high findings of surface macroinvertebrates.

The remaining marsh surface habitats, ranked in order of decreasing total mean density (n/m^2) of marsh surface macroinvertebrates, are as follows: *S. cynosuroides* (87.3); *S. patens* / *D. spicata* (46.3); *P. australis* (27.3); high salinity shrub (22.0); pool/pothole (9.0); secondary tributary intertidal (7.8); tertiary tributary intertidal (6.9); and panne/mudflat (2.0).

The density of fiddler crabs within secondary tributary intertidal habitats was observed from a distance to be occasionally much higher than this study's randomly picked quadrat methodology would indicate. This observation results from differential usage of this habitat over length of day and tidal cycle, and the speed at which fiddler crab concentrations would seek cover upon detection of human approach. Aggregations of *Uca* spp. crabs along tributary channel banks and edges were commonly observed to have densities of between approximately 50 and 120 individuals per square meter. If secondary tributary

Quadrat number	Habitat Description	***Melampus bidentatus***	***Uca minax***	***Orchestria grillus***	***Uca pugnax***	***Geukensia demissa***	***Palaemonetes pugio***	***Sesarma reticulatum***	Total number of individuals per square meter
28	*Spartina alterniflora (short form)*	348	0	0	2	0	0	0	350.0
1	*Spartina alterniflora (short form)*	185	10	0	0	17	0	0	212.0
5	*Spartina cynosuroides*	115	8	5	1	0	0	0	129.0
20	*Spartina patens / Distichlis spicata*	102	2	2	0	0	0	0	106.0
14	*Spartina cynosuroides*	95	6	0	0	0	0	0	101.0
8	*Phragmites australis*	74	0	3	0	0	0	0	77.0
13	*Spartina alterniflora (short form)*	36	25	9	0	0	0	1	71.0
26	High salinity shrub	45	0	0	2	0	0	0	47.0
2	*Spartina alterniflora (short form)*	28	5	9	0	0	0	0	42.0
11	*Spartina cynosuroides*	31	1	0	0	0	0	0	32.0
4	*Spartina patens / Distichlis spicata*	22	0	0	0	0	0	0	22.0
3	*Spartina alterniflora (tall form)*	15	0	1	0	1	0	0	17.0
24	Pool / pothole	7	3	0	6	0	0	0	16.0
30	Tertiary tributary intertidal	0	15	1	0	0	0	0	16.0
17	Secondary tributary intertidal	0	0	0	12	0	2.5	0	14.5
25	High salinity shrub	9	1	3	0	0	0	1	14.0
10	*Spartina patens / Distichlis spicata*	8	2	1	0	0	0	0	11.0
23	Pool / pothole	0	7	0	0	0	0	0	7.0
12	Panne / mudflat	0	6	0	0	0	0	0	6.0
9	Secondary tributary intertidal	0	1	0	3	0	1.3	0	5.3
7	High salinity shrub	3	2	0	0	0	0	0	5.0
21	*Phragmites australis*	0	4	0	0	0	0	0	4.0
22	Pool / pothole	2	1	0	1	0	0	0	4.0
16	Secondary tributary intertidal	0	0	0	1	0	1.6	1	3.6
19	Tertiary tributary intertidal	0	0	0	1	0	2.3	0	3.3
15	*Spartina alterniflora (short form)*	2	0	0	0	0	0	0	2.0
18	Tertiary tributary intertidal	0	0	0	1	0	0.5	0	1.5
27	*Phragmites australis*	0	1	0	0	0	0	0	1.0
6	Panne / mudflat	0	0	0	0	0	0	0	0.0
29	Panne / mudflat	0	0	0	0	0	0	0	0.0
	Total collected	1127	100	34	30	18	8.2	3	1320.2
	Total Mean Density	37.6	3.3	1.1	1.0	0.6	0.3	0.1	44.0
	Percent of total	85.4%	7.6%	2.6%	2.3%	1.4%	0.6%	0.2%	

Table 15. Marsh surface macroinvertebrate densities by 1.0m^2 quadrat, in descending order of total abundance, for St. Jones River marsh, September 13, 14 and 18, 1997. Note: *Palaemonetes pugio* densities are the average of 10 dip net sweeps.

Quadrat number	Habitat Description	***Melampus bidentatus***	***Uca minax***	***Orchestria grillus***	***Uca pugnax***	***Geukensia demissa***	***Palaemonetes pugio***	***Sesarma reticulatum***	Total number of individuals per square meter
1	*Spartina alterniflora (short form)*	185	10	0	0	17	0	0	212
2	*Spartina alterniflora (short form)*	28	5	9	0	0	0	0	42
13	*Spartina alterniflora (short form)*	36	25	9	0	0	0	1	71
15	*Spartina alterniflora (short form)*	2	0	0	0	0	0	0	2
28	*Spartina alterniflora (short form)*	348	0	0	2	0	0	0	350
3	*Spartina alterniflora (tall form)*	15	0	1	0	1	0	0	17
	Mean	119.8	8.0	3.6	0.4	3.4	0.0	0.2	135.4
5	*Spartina cynosuroides*	115	8	5	1	0	0	0	129
11	*Spartina cynosuroides*	31	1	0	0	0	0	0	32
14	*Spartina cynosuroides*	95	6	0	0	0	0	0	101
	Mean	80.3	5.0	1.7	0.3	0.0	0.0	0.0	87.3
4	*Spartina patens / Distichlis spicata*	22	0	0	0	0	0	0	22
10	*Spartina patens / Distichlis spicata*	8	2	1	0	0	0	0	11
20	*Spartina patens / Distichlis spicata*	102	2	2	0	0	0	0	106
	Mean	44.0	1.3	1.0	0.0	0.0	0.0	0.0	46.3
8	*Phragmites australis*	74	0	3	0	0	0	0	77
21	*Phragmites australis*	0	4	0	0	0	0	0	4
27	*Phragmites australis*	0	1	0	0	0	0	0	1
	Mean	24.7	1.7	1.0	0.0	0.0	0.0	0.0	27.3
7	High salinity shrub	3	2	0	0	0	0	0	5
25	High salinity shrub	9	1	3	0	0	0	1	14
26	High salinity shrub	45	0	0	2	0	0	0	47
	Mean	19.0	1.0	1.0	0.7	0.0	0.0	0.3	22.0
22	Pool / pothole	2	1	0	1	0	0	0	4
23	Pool / pothole	0	7	0	0	0	0	0	7
24	Pool / pothole	7	3	0	6	0	0	0	16
	Mean	3.0	3.7	0.0	2.3	0.0	0.0	0.0	9.0
9	Secondary tributary intertidal	0	1	0	3	0	1.3	0	5.3
16	Secondary tributary intertidal	0	0	0	1	0	1.6	1	3.6
17	Secondary tributary intertidal	0	0	0	12	0	2.5	0	14.5
	Mean	0	0.33	0	5.33	0	1.8	0.33	7.8
18	Tertiary tributary intertidal	0	0	0	1	0	0.5	0	1.5
19	Tertiary tributary intertidal	0	0	0	1	0	2.3	0	3.3
30	Tertiary tributary intertidal	0	15	1	0	0	0	0	16
	Mean	0	5	0.3	0.67	0	0.933	0	6.9
6	Panne / mudflat	0	0	0	0	0	0	0	0
12	Panne / mudflat	0	6	0	0	0	0	0	6
29	Panne / mudflat	0	0	0	0	0	0	0	0
	Mean	0.0	2.0	0.0	0.0	0.0	0.0	0.0	2.0

Table 16. Marsh surface macroinvertebrate densities by habitat, in descending order of total abundance, for St. Jones River marsh, September 13, 14 and 18, 1997. Note: *Palaemonetes pugio* densities are the average of 10 dip net sweeps.

intertidal habitats could have been sampled more accurately during these times of fiddler crab concentration, given the range of observed values this type of marsh surface habitat would rank second or third overall by total mean density, ahead of the *S. cynosuroides* and *S. patens*/*D. spicata* habitats.

High salinity shrub habitats were the driest areas within the salt marsh, but had higher densities of macroinvertebrates than did the pools, intertidal streambanks, and panne areas. The panne/mudflat habitat was uniformly almost devoid of any macroscopic surface invertebrates, although mobile forms such as *Uca* spp. were found within one of the sample areas. Harsh environmental conditions of alternating wet/dry conditions and high salinities from evaporation probably accounted for the lack of surface macroinvertebrates, although one could expect the sediments of marsh pools and panne/mudflat areas to have numerous infaunal invertebrates. The *P. australis* habitat would have ranked even lower (second from last, just above the panne/mudflat habitat) in total mean density had it not been for one sample in which 74 *M. bidentatus* individuals were collected. Except for this one sample, *Phragmites* habitat did not contain many invertebrates at all.

Melampus bidentatus (the saltmarsh snail) was the most abundant saltmarsh surface macroinvertebrate with a total mean density (n/m^2) of 37.6 (Table 15), comprising more than 85% of the total mean density of organisms. Found in all but three habitats (it was absent from secondary and tertiary tributary intertidal areas and pannes), they were most abundant and consistently found within *Spartina* spp. dominated habitats. The highest single-sample density of 348 was within *S. alterniflora* habitat. When collected in wet pool/pothole habitat, they were found only on the emergent stalks of vegetation. As pulmonate snails, they cannot breathe underwater and are intolerant of submersion. In other habitats, they were found upon marsh surface mud, on the stems of vegetation, and just within openings of fiddler crab burrows.

Uca minax (the red-jointed fiddler crab) was the second most abundant marsh surface organism. It was the only macroinvertebrate found within all habitats, and had a mean total density (n/m^2) of 3.3, or 7.6% of the total. The highest single-sample density (25) was measured within *S. alterniflora* habitat, although it was found only in one-half of the samples taken there. It was found both above and below water (in the secondary tributaries and pools), within or outside of burrows, upon vegetation and beneath vegetative litter. It was more abundant and found in more habitats than the other fiddler crab *U. pugnax*, and was often found far from standing water. *Uca minax* is known to prefer less saline waters than *U. pugnax.*

Orchestia grillus (the saltmarsh flea) was the third most abundant marsh surface organism with total mean density (n/m^2) of 1.1, or 2.6% of the total. It was found both hopping about on the marsh surface, or swimming sideways within the surface film or within flooded crab burrows. The highest densities (9) were found within *S. alterniflora* habitat, although it was not found in all of the samples collected within this habitat. The saltmarsh flea was not collected within marsh pool, secondary tributary intertidal channel, nor panne habitats.

Uca pugnax (the marsh fiddler crab) was the fourth most abundant marsh surface macroinvertebrate, with total mean density (n/m^2) of 1.0, or 2.3% of the total. It tended to be found in close association with standing or flowing water. It was most abundant within the secondary and tertiary tributary intertidal zones, with individual sample densities ranging to 12. It was also found within *S. alterniflora*, high salinity shrub, and *S. cynosuroides* habitats. The shrub areas were the driest habitats examined, and here the fiddler crabs were found no more than 2 meters (6 ft) from water edge of a secondary tributary.

The fifth most abundant marsh surface macroinvertebrate was the ribbed mussel *Geukensia demissa*, with a total mean density (n/m^2) of 0.6, or 1.4% of the total. It was only found within two of the six quadrats taken within the *S. alterniflora* habitat, with a highest single sample density of 17.

The sixth most abundant marsh surface macroinvertebrate was the grass shrimp *Palaemonetes pugio*, with a total mean density (n/m^2) of 0.3, or 0.6% of the total. It was only found within flowing water channels adjacent to the secondary and tertiary tributary intertidal zones. It was not found within marsh pool habitat, nor was it observed within flooded crab burrows, nor within the surface film flooding some *S. alterniflora* habitats.

The marsh crab *Sesarma reticulatum* was the seventh most abundant organism found during this survey, with a total mean density (n/m^2) of 0.1, or 0.2 % of the total. It was found within three different habitats: *S. alterniflora*, high salinity shrub, and the secondary tributary intertidal.

Horseshoe crabs

The Delaware Bay shoreline is host to the largest concentration of spawning horseshoe crabs (*Limulus polyphemus)* in their entire Atlantic coast range (Botton *et al*, 1994). Horseshoe crab eggs are an important food source for hundreds of thousands of migrating shorebirds, preparing the birds for the last leg of their journey to Arctic nesting grounds. Not only are the horseshoe crabs ecologically important, but they play an economically important role as well. Horseshoe crab blood is used for pharmaceutical purposes, and the crabs are also valuable bait in eel and conch fisheries.

During spawning season, large numbers of adult horseshoe crabs come ashore near the St. Jones River DNERR site, along Delaware Bay shoreline beaches of the Delaware Division of Fish and Wildlife’s Ted Harvey Conservation Area.

The Delaware Coastal Programs Section is working on a project to develop an efficient, standardized sampling method for determining densities of *Limulus* eggs dispersed in beach sediments. In 1998, they completed the second year of a study to: 1) quantify egg population densities on four beaches; 2) establish a procedure to compare annual variations of spawning activity on a particular beach; and 3) evaluate beach erosion or beach replenishment efforts on *Limulus* spawning. The beaches sampled were Slaughter Beach, North Bowers, Ted Harvey, and Port Mahon. Each site was sampled shortly after each lunar tide (full and new moon), when large numbers of *Limulus* spawn.

In May 1998, an international shorebird banding team studying shorebird migration, conservation and ecology, conducted research along Delaware Bay. The red knot (*Calidris canutus*) is the focus of this team's research. It is believed that red knots have the highest energetic requirements of any shorebirds that feed on the horseshoe crab eggs. Although they arrive fat free, the birds double their weight during their stay in Delaware, at a rate that is believed unprecedented among shorebirds anywhere else in the world. Two other species being studied are ruddy turnstone (*Aranaria intrepres*) and sanderling (*Calidris alba*). Using an array of techniques this research will attempt to determine the nutritional value of *Limulus* eggs to red knots, measure maximum intake rates of eggs, study the transformation of *Limulus* eggs into the shorebirds' fuel for flight, and reconstruct the overall energy budget of red knots on Delaware Bay beaches.

Saltmarsh Mosquitoes and Their Control

The Upper Blackbird Creek and Lower St. Jones River DNERR sites provide excellent habitat for many species of pestiferous biting flies. Both aedine and culicine saltmarsh mosquitoes, tabanids such as greenheads and deer flies, and biting gnats (ceratopogonids) are the main insect pests that can cause serious problems, by being general nuisances, causing monetary losses to tourist-based recreational or agricultural economies, and sometimes transmitting diseases (Sutton *et al*, 1996). The most important of these pest species is the saltmarsh mosquito, *Aedes sollicitans*. This species is not only considered a serious nuisance, but is also a primary carrier and transmitter of Eastern Equine Encephalitis, a disease that is often fatal to humans as well as horses.

The Mosquito Control Section of DNREC Division of Fish and Wildlife has two primary methods of control for saltmarsh mosquitoes: the use of insecticides and source reduction techniques (Daiber, 1986 and 1987). Insecticides have been used to control mosquito populations since the early 1900's. Broad spectrum insecticides, often toxic to many non-target species as well as the environment, were used from the early 1900's to the early 1960's. These early insecticides were usually contact poisons that killed the target species upon exposure, or produced a film on the water surface which would suffocate the pest species of concern. Some of these early insecticides included DDT, benzene hexachloride, and Paris green. These chemicals were very good at eliminating mosquitoes in the area, but they also eliminated many other non-target species, and put a severe strain on the environment.

By the early 1960's, there was an increased concern over insecticides and the environment, which lead to the development of more “environmentally friendly” pesticides. These insecticide are still widely used today, and include organophosphates such as temephos (Abate) and naled (Dibrom). Temephos is a primary larvicide and naled is a primary adulticide both used by the Delaware Mosquito Control Section. Newer, more target-specific larvicides such as methoprene (Altosid) and Bti are now also widely used by the Section, and synthetic pyrethroids are also used as adulticides. These insecticides are applied by airplane, helicopter, truck-mounted sprayers, or sometimes even hand-sprayers. Selected wetlands of the Lower St. Jones River Reserve are occasionally sprayed with mosquito control insecticides as warranted. In general, the insecticides currently used by the Delaware Mosquito Control Section are chosen based on pest control effectiveness, target specificity, degree of environmental and health impacts, and cost effectiveness (DNREC 1992).

With the increased concern over pesticide use, source reduction techniques have been developed over the years as a means of effectively controlling mosquitoes without the use of potentially harmful chemicals. There are several types of source reduction techniques that have been implemented, including parallel-grid ditching, Open Marsh Water Management (OMWM), creation of impoundments, and biological control by stocking larvivorous fish species.

Parallel-grid ditching began in the 1930's when many tidal wetlands along the Atlantic Coast were extensively altered (Daiber, 1986 and 1987). Parallel ditches, designed to drain surface water from the marsh, were excavated in hopes of reducing the habitat where saltmarsh mosquitoes breed. In many cases, this ditching not only drained the targeted areas, but it also drained many larger non-breeding ponds. These ponds were valuable to other marsh animals, especially juvenile estuarine fishes which use the ponds as nursery areas, and to waterfowl, wading birds and shorebirds. Marsh vegetation was also altered through deposition of spoil and lowering of water levels. Often the level of mosquito control achieved as a result of this ditching was insignificant. Today, many parallel-grid-ditched marshes still produce mosquitoes and require treatment. Within the DNERR, almost all marsh areas in the Lower St. Jones River site have been parallel-grid-ditched. Because of its lack of effectiveness and negative impacts on the marshes, parallel-grid-ditching became less popular as other source reduction methods were developed.

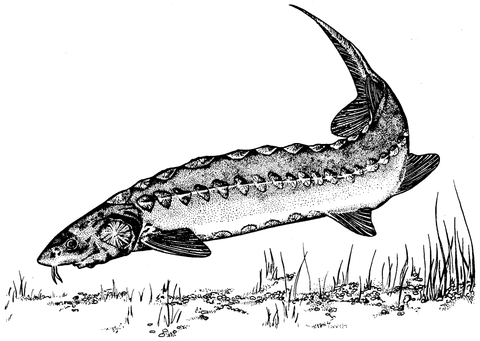
Open Marsh Water Management (OMWM) is a source reduction technique that has become very popular on the East Coast. This method relies on using selective ponding and ditching only in confirmed mosquito breeding habitat. OMWM reduces mosquito production and promotes biological control of mosquitoes through their consumption by larvivorous fish (e.g. by the mummichog, *Fundulus heteroclitus*). OMWM can provide effective control of mosquitoes, and can play a very important part in the enhancement and restoration of habitat in previously parallel-grid-ditched marshes. Since the beginning of OMWM’s use in Delaware in the early 1980's, over 6,000 acres of tidal wetlands have been removed from routine aerial spraying (Meredith, pers. comm., 1998). Most OMWM-treated areas in Delaware can be found in the southern part of the state, on public and private lands. Presently OMWM is not envisioned for Upper Blackbird Creek Reserve, because neither the characteristics of the area nor the types of mosquitoes produced there presently cause need for such. However, because of the nature of tidal marshes in the Lower St. Jones River Reserve and their proximity to Dover, there are several candidate areas for future OMWM work, primarily in salt hay patches, behind creekside levees, or near upland fringes of the marsh. Installing OMWM systems in the Lower St. Jones River Reserve should reduce or eliminate the need for insecticides, while restoring dewatered habitats in a previously parallel-grid-ditched marsh.

Finfishes

ECSI has performed finfish population surveys at each DNERR site. The finfish communities of Upper Blackbird Creek and Lower St. Jones River were characterized within five estuarine community types. These habitats included Near-shore Delaware Bay; Beach-front Delaware Bay; Estuarine Channel (primary, secondary, and tertiary creeks); Permanent Tidal Pools; and Emergent Marsh Cover. The finfish communities in Blackbird Creek and St. Jones River were sampled on a quarterly basis during the summer and fall of 1994 and the spring of 1995. Sampling techniques used included trawling, seining, throw trapping, and channel netting (WRA and ECSI, 1995).

The Upper Blackbird Creek finfish community was represented by 21 species of fish (Table 17). Four species comprised over 95% of the total catch. In order of decreasing abundance, the most dominant species were spot, Atlantic menhaden, white perch, and mummichog. These four species are representative of estuarine-resident (white perch and mummichog) or estuarine-dependent (spot and Atlantic menhaden) finfish. In general, the greatest number of finfish were collected from the secondary tributaries, which represented 92% of the total catch.

Spot, *Leiostomus xanthurus*, represented 47% of the total catch in Blackbird Creek, with 2,319 specimens collected. They are commonly found throughout the Delaware Estuary, and have a considerable economic



Species	Sample location		Subtotal	Percent of total	Cumulative Percent of total
	Blackbird creek	St. Jones river			
Spot	2319	829	3148	32.80%	32.80%
Mummichog	523	1143	1666	17.36%	50.15%
Atlantic menhaden	1241		1241	12.93%	63.08%
Atlantic silverside	18	1198	1216	12.67%	75.75%
White perch	585	342	927	9.66%	85.40%
Sheepshead minnow		634	634	6.60%	92.01%
Bay anchovy	3	281	284	2.96%	94.97%
Hogchoker	78	65	143	1.49%	96.46%
Weakfish	19	51	70	0.73%	97.19%
Striped bass	36	29	65	0.68%	97.86%
American eel	20	32	52	0.54%	98.41%
Spotted hake		31	31	0.32%	98.73%
Black drum	5	21	26	0.27%	99.00%
Brown bullhead	16		16	0.17%	99.17%
Silvery minnow	15		15	0.16%	99.32%
Atlantic herring		12	12	0.13%	99.45%
Atlantic croaker		10	10	0.10%	99.55%
Channel catfish	4	4	8	0.08%	99.64%
Silver perch		5	5	0.05%	99.69%
Striped killfish		4	4	0.04%	99.73%
Striped mullet		4	4	0.04%	99.77%
Gizzard shad	3		3	0.03%	99.80%
Inland silverside	1	2	3	0.03%	99.83%
Black sea bass		2	2	0.02%	99.85%
Bluefish		2	2	0.02%	99.87%
Northern searobin		2	2	0.02%	99.90%
Oyster toadfish		2	2	0.02%	99.92%
Yellow perch	2		2	0.02%	99.94%
Banded killifish		1	1	0.01%	99.95%
Black crappie	1		1	0.01%	99.96%
Blueback herring	1		1	0.01%	99.97%
Bluegill	1		1	0.01%	99.98%
Pumpkinseed	1		1	0.01%	99.99%
Summer flounder		1	1	0.01%	100.00%
Subtotals =	4892	4707	9599	= Grandtotal	

Table 17. Total numbers of fish collected from the upper Blackbird Creek and lower St. Jones River for the summer and fall of 1994, and the spring of 1995.

importance to the region (Sutton et al, 1996). The highest numbers of specimens captured were from secondary tributaries; i.e. the creeks that drain empty at low tide. None were collected from either tertiary tributaries or tidal pools.

Atlantic menhaden, *Brevoortia tyrannus*, represented 25% of the total catch in Blackbird Creek with 1,241 specimens collected. They are commonly found along the eastern coast from Maine to Florida. Atlantic Menhaden support one of the largest fisheries in the United States, even though they are not considered edible, nor are they sought for recreational purposes (Sutton et al, 1996). Primarily used for fertilizer and oil, they were the most economically important species in the Delaware Estuary up until the 1960's. Menhaden found in Upper Blackbird Creek were collected almost exclusively from the secondary tributaries; none were taken from the main tributaries or tidal pools.

White perch, *Morone americana*, represented almost 12% of the total catch in Blackbird Creek, with 585 specimens collected. The highest numbers of specimens were collected in secondary tributaries. Commercially, the white perch is ranked fifth most important finfish in the Delaware Estuary, although the harvest has decreased over the past one hundred years (Sutton et al, 1996). White perch are also a very important recreational fish species.

Mummichog, *Fundulus heteroclitus*, represented almost 11% of the total catch. The mummichog was the only finfish captured from all three estuarine channel types, with the majority collected from secondary tributaries. Ecologically, they are one of the most important fish species in Upper Blackbird Creek, because of their resident abundance and role as predator and prey. The mummichog can effectively control mosquito populations by feeding on mosquito larvae produced in high-marsh pothole habitats. This species also serves as a primary food source for wading birds, blue crabs, and many fish.

Seasonally, the total number of finfish collected in Upper Blackbird Creek ranged from a minimum of 164 in spring, 1995 to a maximum of 4,541 in summer 1994.

The Lower St. Jones River finfish community was represented by 25 different species (Table 17). Six species comprised over 94% of the total catch. In order of decreasing abundance, the most dominant species were Atlantic silverside, mummichog, spot, sheepshead minnow, white perch, and bay anchovy. These are typical estuarine species, able to tolerate a wide range of salinities. They include five estuarine-resident species (Atlantic silverside, mummichog, sheepshead minnow, white perch, bay anchovy) and one estuarine dependent species (spot). Similar to Blackbird Creek, the greatest numbers of fish were found in secondary tributaries. The absence of Atlantic menhaden in the St. Jones River during the 1994-95 studies, which was the second most abundant species in Blackbird Creek, was undoubtedly caused by sampling artifact. Menhaden have been collected in the St. Jones River on many other occasions, and have been the primary fish species involved in past fishkills in the St. Jones River.

Atlantic silverside, *Menidia menidia*, represented 25% of the total catch in the Lower St. Jones River, with 1,198 specimens collected. The greatest numbers were collected in samples taken from the secondary tributaries and Delaware Bay shore zone areas. The Atlantic silverside plays a very important ecological role in mid- Atlantic estuaries. Serving as prey for larger fish species, blue crabs, wading birds, and terns, the Atlantic silverside links upper level consumers with lower level producers. The fact that the Atlantic silverside was the most abundant species collected in the Lower St. Jones River reflects its abundance throughout inshore Delaware Bay habitats.

Mummichog, *Fundulus heteroclitus,* represented 24% of the total catch in the St. Jones River, and were collected almost exclusively from samples taken in secondary tributaries and permanent pools.

Spot, *Leiostomus xanthurus*, represented 18% of the total catch, with 829 specimens collected. They were taken primarily in samples collected within secondary tributaries.

Sheepshead minnow, *Cyprinodon variegatus,* represented 13% of the total catch in the St. Jones River, with 634 specimens collected. They were taken almost exclusively from samples collected from permanent marsh pools. The sheepshead minnow plays a similar ecological role as the mummichog, acting as a predator on aquatic invertebrates and as prey for wading birds and larger fish. They are also very adaptive to variable environmental conditions, tolerating wide ranges of dissolved oxygen, salinity, and temperature (Smith, 1995). Absence of sheepshead minnows from catches in Upper Blackbird Creek was probably caused by sampling artifact. White perch, *Morone americana,* represented 7% of the total catch in the St. Jones River and were collected primarily in secondary tributaries and guts.

Bay anchovy, *Anchoa mitchilli*, represented 6% of the total catch in the St. Jones River, with 281 specimens collected. They were taken mostly in samples collected in the Delaware Bay shorezone habitats. Bay anchovy is a seasonally abundant species that serves in the same predator-prey roles as Atlantic silverside, and is similarly abundant throughout Delaware Bay.

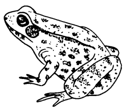
With the stock recovery coastwide of striped bass, *Morone saxatilis,* this important species was collected at both Reserve sites, and is now often caught by recreational anglers in the Lower St. Jones River and Delaware Bay.

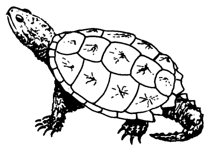
Seasonally, the total number of finfish collected in the Lower St. Jones River ranged from a minimum of 193 in spring 1995, to a maximum of 3,864 in summer 1994.

The primary recreational species sought by anglers in DNERR waters, particularly in the Lower St. Jones River and nearby inshore waters of Delaware Bay, are weakfish, striped bass, white perch, summer flounder, and bluefish.

Reptiles and Amphibians

Reptiles and amphibians play important ecological roles in some estuarine habitats. Not only do they provide food sources for raptors, wading birds, and larger mammals, they also provide trophic links between wetland and upland environments. Frogs, toads, and salamanders all rely on wetland habitats for breeding purposes, and require clean, unpolluted waters to deposit their eggs. Several species of snakes and turtles are found in freshwater wetlands and tidal marshes of Upper Blackbird Creek and Lower St. Jones River. The diamondback terrapin and two frog species were observed during a 1994 biotic inventory of the St. Jones River by the Delaware Natural Heritage Program (Table 18).



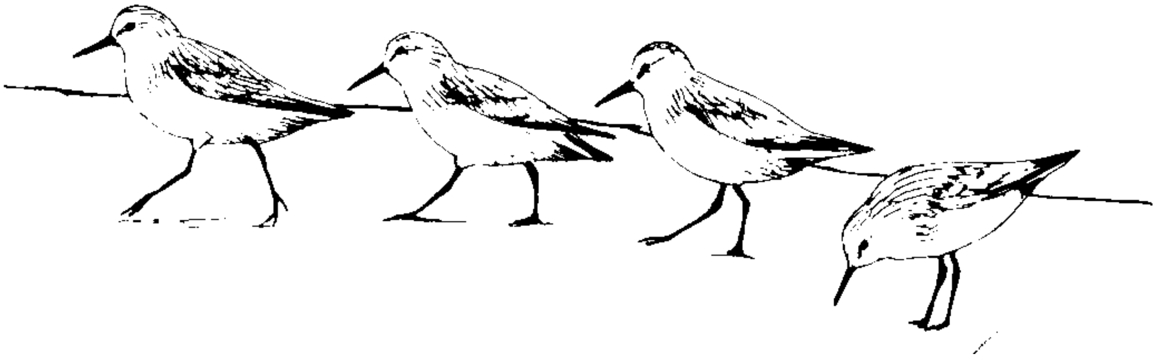


Several species of turtles occur within the DNERR Reserve. Northern diamondback terrapins (*Malaclemys terrapin*) and snapping turtle *(Chelydra serpentina)* are two common species, both with local economic importance to surrounding communities as food. Other marsh turtles commonly found in Delaware coastal areas are eastern mud turtle *(Kinosternon subrubrum)* and red-bellied turtle

Common name	Scientific name	Status*
BIRDS		
American avocet	*Recurvirostra americana*	M
American black duck	*Anas rubripes*	B
American robin	*Turdus migratorius*	B
American goldfinch	*Carduelis tristis*	B
Bald eagle	***Haliateeus leucocephalus***	**B (nest failed)**
Barn swallow	*Hirundo rustica*	B
Belted kingfisher	*Ceryle alcyon*	B
Black skimmer	***Rynchops niger***	**B?**
Blue jay	*Cyanocitta cristata*	B
Boat-tailed grackle	*Quiscalus major*	B
Brown-headed cowbird	*Molothrus ater*	B
Carolina chickadee	*Parus carolinensis*	B
Carolina wren	*Thryothorus ludovicianus*	B
Clapper rail	*Rallus longirostris*	B
Common grackle	*Quiscalus quiscula*	B
Common snipe	*Gallinago gallinago*	?
Common tern	*Sterna hirunda*	M
Common yellowthroat	*Geothlypis trichas*	B
Eastern kingbird	*Tyrannus tyrannus*	B
Eastern wood pewee	*Contopus virens*	B
European starling	*Sturnus vulgaris*	B
Fish crow	*Corvus ossifragus*	B
Forster’s tern	*Sterna forsteri*	M
Glossy ibis	***Plegadis falcinellus***	**M**
Great black-backed gull	*Larus marinus*	M
Great blue heron	***Ardea herodias***	**M\B**
Great egret	*Casmerodius albus*	M
Great crested flycatcher	*Myiarchus crinitus*	B
Green-backed heron	*Butorides striatus*	B
Gray catbird	*Dumetella carolinensis*	B
Herring gull	*Larus argentatus*	M
Killdeer	*Charadrius vociferus*	B
Laughing gull	*Larus atricilla*	M
Least tern	*Sterna antillarum*	M
Mallard	*Anas platyrhynchos*	B
Marsh wren	*Cistothorus palustris*	B
Mourning dove	*Zenaida macroura*	B
Northern cardinal	*Cardinalis cardinalis*	B
Northern harrier	*Circus cyaneus*	M
Red eyed vireo	*Vireo olivaceus*	B
Red-tailed hawk	*Buteo jamaicensis*	B
Red-winged blackbird	*Agelaius phoeniceus*	B
Red knot	*Calidris canutus*	M
Ring-billed gull	*Larus delawarensis*	B
Royal tern	*Sterna maxima*	M
Ruby crowned kinglet	*Regulus calendula*	W
Ruddy turnstone	*Arenaria interpes*	M
Sanderling	*Calidris alba*	M
Seaside sparrow	***Ammodramus maritimus***	**B**
Scarlet tanager	*Piranga piranga*	B
Sharp-shinned hawk	*Accipenser striatus*	M
Snowy egret	*Egretta thula*	M
Song sparrow	*Melospiza melodia*	B
Tree swallow	*Tachycineta bicolor*	B
Tufted titmouse	*Parus bicolor*	B
Turkey vulture	*Cathartes aura*	B
Yellow-rumped warbler	*Dendrocia dominica*	M
Yellow warbler	*Dendrocia petechia*	B
Willet	*Catoptrophorus semipalmatus*	B
REPTILES AND AMPHIBIANS		
Diamond-backed terrapin	*Malaclemys terrapin*	B
Northern spring peeper	*Hyla crucifer*	B
Southern leopard frog	*Rana sphenocephala*	B
MAMMALS		
River otter	*Lutra canadensis*	B
Muskrat	*Ondatra zibethicus*	B
White-tailed deer	*Odocoileus virginianus*	B

*(B = Nesting within study area; M = migrant through study area; W = wintering within study area; a combined rank is given if the species equally depends on the study area for migratory, breeding or wintering space.)

Table 18. Animal species found during 1994 inventory of the St. Jones River. Those in boldface represent Species of Special Concern. (Source: Delaware Natural Heritage Program).



(Pseudemys rubriventris). Several species of marine turtles use Delaware Bay on a seasonal basis. The loggerhead turtle *(Caretta caretta),* listed as threatened on the federal endangered species list, is the most common sea turtle in Delaware Bay. The Kemp's Ridley *(Lepidochelys kempii)* and green sea turtle *(Chelonia mydas),* also listed on the federal endangered species list, utilize Delaware Bay for its abundance of crustaceans, mollusks, and fish. None of these sea turtles nest along Delaware Bay's shoreline, but strandings of live specimens occasionally occur on beachfronts.

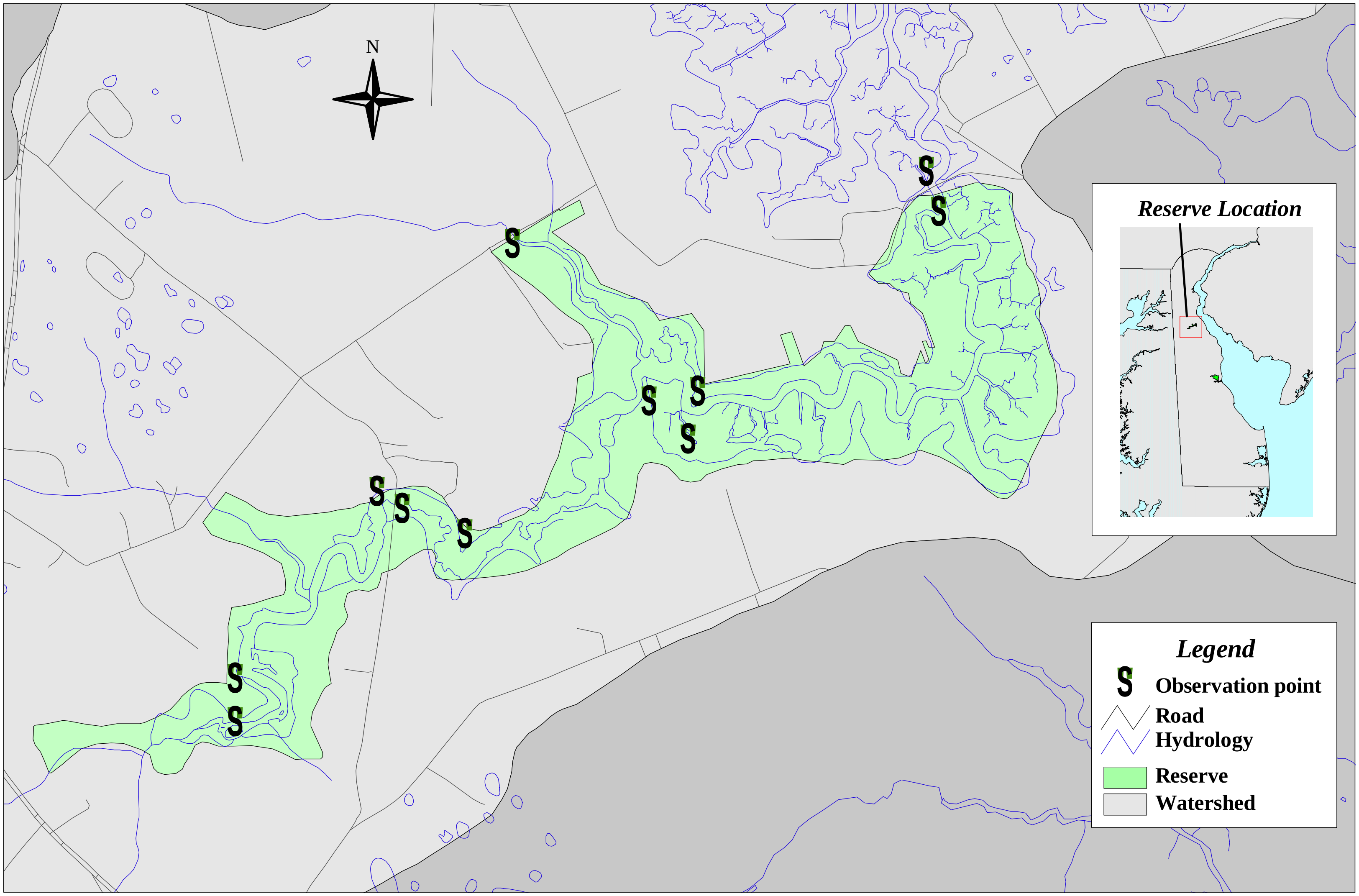
A few species of snakes are common in the DNERR Reserve. The northern water snake *(Nerodia sipedon)* and black rat snake (*Elaphe obsoleta)* are found in wetlands and uplands of Upper Blackbird Creek and the Lower St. Jones River. These snakes feed on prey ranging from fish, the primary food item of the northern water snake, to small mammals.

Amphibians found in the DNERR Reserve, particularly in the Upper Blackbird Creek area, include frogs such as bullfrog *(Rana catesbeiana),* green frog *(Rana melanota),* wood frog *(Rana sylvatica)*, northern spring peeper (*Hyla crucifer),* southern leopard frog (*Rana sphenocephala),* as well as salamanders such as the red-backed salamander *(Plethodon cinereus*) and northern two-lined salamander *(Eurycea bislineata).* These species are common in flooded or moist woodlands, and are often found along streams or brooks. The two species of salamanders are both very sensitive to polluted waters and are good indicators of a healthy, clean ecosystem.

Amphibians are more common in the Upper Blackbird Creek Reserve as opposed to the Lower St. Jones River Reserve, because of the abundance and diversity of freshwater wetland habitats along Upper Blackbird Creek. Additionally, freshwater coastal plain ponds ("Delmarva Bays") in forested wetlands of Blackbird State Forest, just west of Upper Blackbird Creek Reserve, provide valuable habitat for several amphibian species of special concern.

Birds (waterbirds, raptors and passerines)

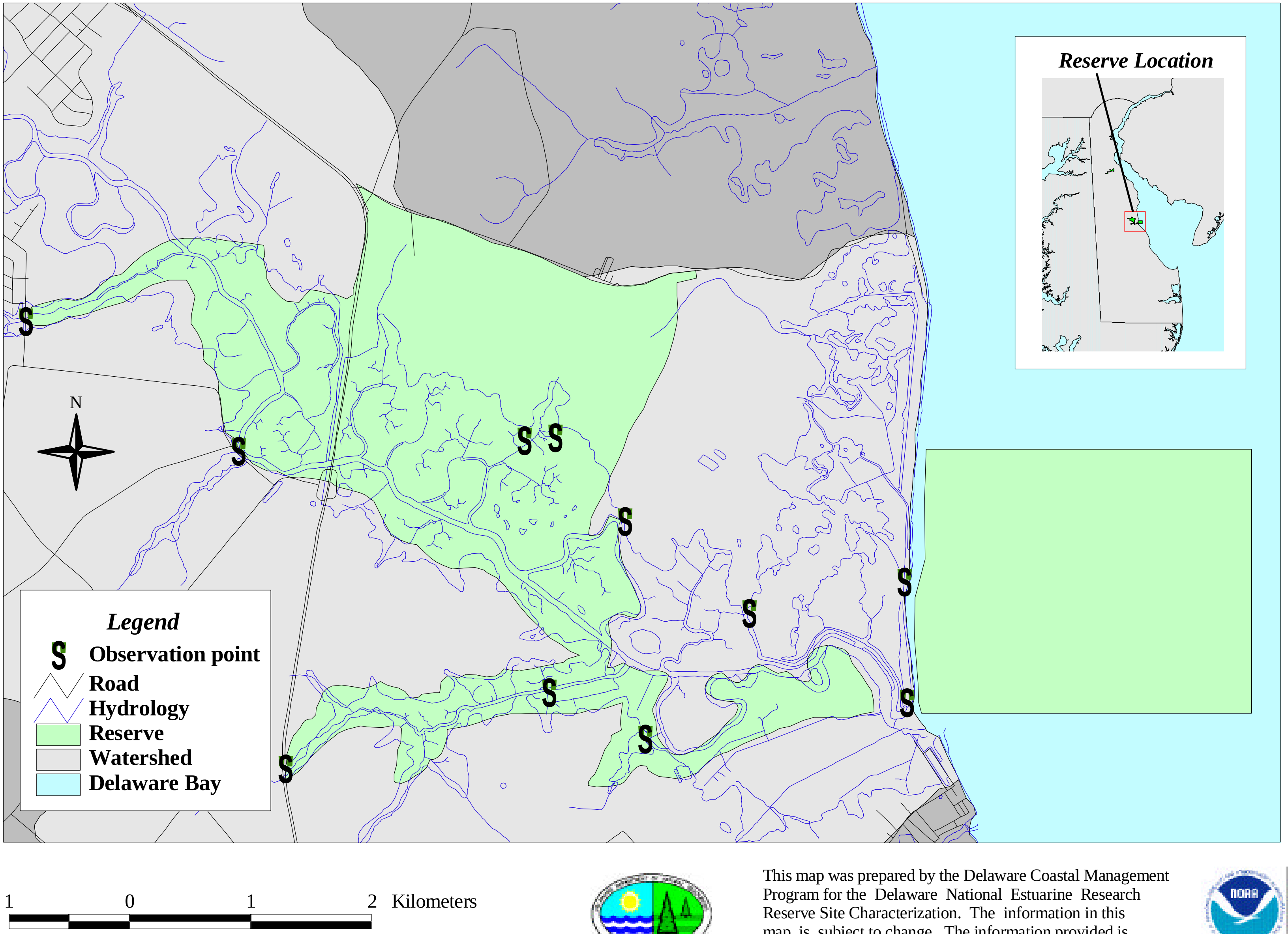
A diverse population of waterbirds, raptors, and passerines occurs in both the Blackbird Creek and St. Jones River DNERR sites (Figures 41 and 42, Tables 18 and 19) (WRA, 1995). The two DNERR sites are located close to the Bombay Hook National Wildlife Refuge/Little Creek-Ted Harvey State Wildlife Area complex, famous in mid-Atlantic birding circles for its diversity of habitats and an abundance of birds within a relatively small geographic area. Because of differences in habitats between the two sites, some differences in species composition occur. There are several species listed on Delaware's Animal Species of Conservation Concern list (DNHP) that are found in the Blackbird Creek and St. Jones River sites, including a breeding pair of bald eagles along Upper Blackbird Creek, plus wood ducks and northern shovelers (Table 19).



0.5 0 0.5 1 Kilometers

This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 41. Upper Blackbird Creek Reserve: Water Bird Observation Points



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 42. Lower St. Jones River Reserve: Water Bird Observation Points

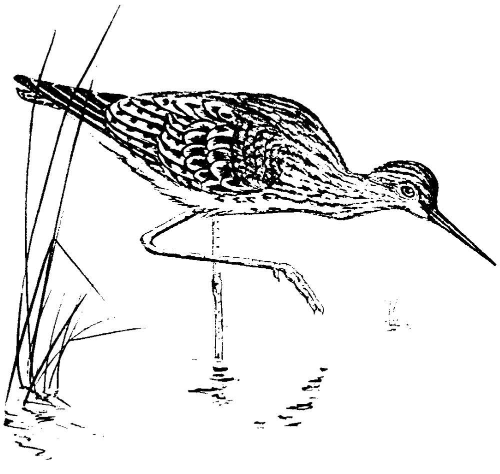
BIRD SPECIES	NHI STATUS	BLACKBIRD CREEK	ST.JONES RIVER
American Black Duck	S4B		*
American Coot	**S1B,S2N**		*
American Crow	S5	*	*
American Goldfinch	S5	*	*
American Robin	S5	*	*
Bald Eagle	**S1B, S2N**	*	
Barn Swallow	S5	*	*
Belted Kingfisher	**S3**	*	*
Black-bellied Plover	S4N		*
Black Skimmer	**S1B**		*
Black Vulture	**S2B**	*	*
Blue Jay	S5	*	
Blue-winged Teal	**S3B**		*
Boat-tailed Grackle	S4	*	*
Canada Goose	S5N, S3B	*	*
Carolina Chickadee	S5	*	
Carolina Wren	S4	*	*
Cattle Egret	**S1B**	*	
Chimney Swift	S5B		*
Clapper Rail	S5		*
Common Grackle	S5	*	*
Common Merganser	S3N		*
Common Snipe	S3N		*
Common Tern	**S1B, S3N**	*	*
Common Yellowthroat	S5B	*	*
Double-crested Cormorant	**S1B, S2N**	*	*
Downy Woodpecker	S5	*	*
Dunlin	**S3N**		*
Eastern Blue Bird	S4	*	
Eastern Kingbird	S5B	*	*
Eastern Meadowlark	**S3**	*	
Eastern Wood-Pewee	S4B	*	
Fish Crow	S5	*	*
Forster's Tern	**S1B, SZN**	*	*
Glossy Ibis	**S1B**	*	*
Great Black-backed Gull	**S1B, S5N**		*
Great Blue Heron	**S2B**	*	*
Great Crested Flycatcher	S5B	*	*
Great Egret	**S1B**	*	*
Great Horned Owl	S5	*	
Greater Yellowlegs	S3N	*	*
Green-backed Heron	S5B	*	*
Green-winged Teal	S4N	*	*
Grey Catbird	S5	*	*
Hairy Woodpecker	**S3**	*	
Herring Gull	**S3B, S5N**	*	*
House Wren	S5B		*
Indigo Bunting	S5B	*	*
Killdeer	S5B	*	*
Laughing Gull	S3B, S4N	*	*
Least Tern	**S1B, S2N**		*
Mallard	S5B	*	*
Marsh Wren	S4B	*	*
Mockingbird	S5	*	
Mourning Dove	S5	*	*
Night Heron sp.	**S1B,S2B**	*	
Northern Bobwhite	S5	*	*
Northern Cardinal	S5	*	*
Northern Flicker	S5	*	*
Northern Harrier	**S1B, S4N**	*	*
Northern Pintail	S4N		*
Northern Shoveler	**SHB, S4N**		*
Orchard Oriole	S4B	*	
peeps	n. a.	*	*
Pileated Woodpecker	**S3**	*	
Purple Martin	S5B	*	
Red Head	**S2N**		*
Red Knot	**S2N**		*
Red-bellied Woodpecker	S5	*	*
Red-breasted Merganser	S4N		*
Red-eyed Vireo	S5	*	
Red-tailed Hawk	S5	*	*
Red-winged Blackbird	S5	*	*
Ring-billed Gull	S5N	*	*
Ruby-throated Hummingbird	S5B		*
Ruddy Duck	S2N		*
Ruddy Turnstone	**S2N**		*
Rufous-sided Towhee	S5B,S3N	*	*
Sanderling	**S2N**		*
Savannah Sparrow	S4N	*	
Scarlet Tanager	S5B	*	
Seaside Sparrow	S3	*	*
Sharp-shinned Hawk	S3N	*	
Sharp-tailed Sparrow	**S3B,S1N**		*
shore birds - mixed flocks	n. a.	*	*
Short-billed Dowitcher	S3T		*
Snow Goose	S5N	*	*
Snowy Egret	**S1B**	*	*
Song Sparrow	S5	*	*
Spotted Sandpiper	**SU**	*	
Swamp Sparrow	**S3B, S4N**		*
Tree Swallow	S4B	*	*
Tufted Titmouse	S5	*	
Turkey Vulture	S5B	*	*
White-crowned Sparrow	S4N		*
White-eyed Vireo	S5B,SZN	*	*
White-throated Sparrow	S5N	*	
Willet	S4B		*
Wood Duck	**S1N, S3B**	*	
Wood Thrush	S5	*	
Yellow-billed Cuckoo	S4B	*	*
Yellow-rumped Warbler	S5N	*	
Yellow Warbler	S4B	*	*

Table 19. Avian Species – Occurrence and Status. Based on surveys conducted 5/94 through 6/95. Species in bold type are listed in Animal Species of Conservation Concern, Delaware Natural Heritage Inventory Program, November 1995.

The Blackbird Creek DNERR Reserve site consists of a fresh to slightly brackish tidal wetlands system. Much of the upper portion of the site is made up of scrub/shrub wetlands bordered by wooded wetlands and uplands. In addition to waterbirds, these habitats readily support many passerine species, either resident or neotropical migrants. Wood ducks and kingfishers are frequently found along the forested corridor of Upper Blackbird Creek.

Seven species of wading birds were observed in Upper Blackbird Creek during routine point counts. These species included cattle egret, glossy ibis, great blue heron, great egret, green-backed heron, snowy egret, and an unidentified species of night heron. Black-crowned night herons are known to be much more abundant in Delaware than yellow-crowned night herons. The most common waders observed were great blue heron and snowy egret, with sightings of all waders increasing going downstream. Little blue heron and tricolored heron can be occasionally seen.

Due to limited appropriate habitat, few shorebirds frequent Upper Blackbird Creek. However, four species or taxa were observed, including greater yellowlegs, killdeer, spotted sandpiper, and unidentified peeps. The most common shorebird was the greater yellowlegs, found most often in spring and fall.

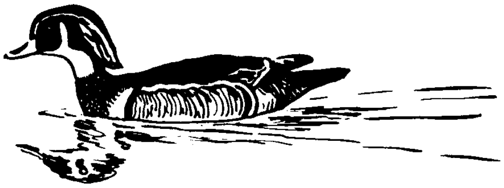


The St. Jones River DNERR site is primarily a mesohaline tidal wetlands system that is composed of extensive emergent tidal marsh, scrub/shrub wetland, and adjacent wooded wetlands and uplands. Five species of wading birds were observed in the Lower St. Jones River DNERR site during point counts. These include glossy ibis, great blue heron, great egret, green-backed heron, and snowy egret. In addition, little blue heron have been occasionally observed foraging at several places in the St. Jones River site. The most common waders were the great blue heron and snowy egret.

Nearby areas within the Delaware Division of Fish and Wildlife's Ted Harvey Conservation Area provide Delaware Bay shoreline habitat (including open estuarine waters and sandy shore) and a managed pool/wetland impoundment complex (Logan Lane), adding to habitat types along the Lower St. Jones River. The diversity of habitats here results in a great array of avian species, ranging from migratory waterfowl to breeding neotropical migrants. Dabbling ducks including American black duck, gadwall, mallard, northern pintail, American wigeon, northern shoveler, and green-winged and blue-winged teals are common during migratory seasons in open water habitats of the DNERR. The expansive open waters of the Logan Lane Impoundment in the Ted Harvey Conservation Area provide excellent feeding and resting areas for these marsh ducks, and good habitat for diving ducks such as canvasback, redhead, and ring-necked ducks. A study of the impoundment's benthic community, which is a primary food source for waterbirds foraging in the impoundment, was recently completed under auspices of a NERRS nationwide competitive research grant (Stocks and Grassle, 1998), and found high abundances in impoundment bottoms of oligochaetes (*Paranais littoralis, Tubificidae* sp.), burrowing anemones, and chironomid larvae. Other waterbirds frequenting the impoundment include pied-billed grebe, ruddy duck, and American coot. Canada and snow geese are also commonly observed in the Ted Harvey Conservation Area. The Logan Lane Impoundment has also been the location of sightings of unusual birds, such as whiskered and white-winged terns of Eurasian origins. These sightings brought hundreds of birders from all over the country to this managed wetlands. Logan Lane Impoundment attracts the highest number of species of any observation point in the Lower St. Jones River watershed. The second richest area for avian species is the mouth of the St. Jones River just north of Bowers Beach.

There were twelve species of shorebirds observed during the St. Jones River 1994-95 survey, mainly concentrated along the Delaware Bay shoreline. Shorebird species observed included black-bellied plover, common snipe, dunlin, greater yellowlegs, killdeer, red knot, ruddy turnstone, sanderling, short-billed dowitcher, willet, and peeps (including least sandpiper, semi-palmated sandpiper, and western sandpiper). The largest numbers of shorebirds were observed in May during the peak northward migration season, with smaller numbers of southbound migrants scattered through late summer and early fall. In general, the Delaware Bay shoreline attracts large numbers of shorebirds during migration (Table 20), as well as scoters, diving ducks and other open water waterfowl during the fall, winter, and early spring.

Along the Delaware Bay shoreline, an important ecological phenomenon occurs, peaking during the months of May and June. The Atlantic Coast's largest concentration of horseshoe crabs (*Limulus polyphemus*) emerge from the sea to lay their eggs on bayfront beaches, just as the second largest concentration of shorebirds in the Western Hemisphere is approaching on their last leg of northward migration. Huge populations of shorebirds (dominated by ruddy turnstones, semipalmated sandpipers, red knots, and sanderlings) use this opportunity to maximize their fat reserves by feeding upon the horseshoe crab eggs, so they can finish their long journey to their Arctic tundra nesting grounds. Studies indicate that the shorebirds can gain up to 50% of their body weight in fat, over their one to three week stopover in May and early June (Sutton et al, 1996). This is extremely important, as these birds have endured a non-stop flight of up to 3,000 miles from South America before reaching Delaware Bay. According to several surveys, up to 70% of the North American red knot population is present in Delaware Bay during this spring stopover, and percentages for other species are very similar. This amazing phenomenon demonstrates the ecological importance of Delaware Bay shorelines, including the bayfront beaches near the Lower St. Jones River Reserve.



Waterbirds commonly seen in nearshore Delaware Bay waters off bayfront beaches include common and red-throated loons, horned grebe, double-crested cormorant, northern gannet, snow goose, common and red-breasted mergansers, surf and black scoters, bufflehead, oldsquaw, and lesser scaup. The most commonly observed gulls are herring, ring-billed, greater black-backed, and laughing gulls. The most commonly observed terns are common, Forster's, and little (least) terns, with occasional sightings of royal and Caspian terns. Black skimmers are frequently seen throughout the summer at the mouth of the St. Jones River, and are often observed skimming over open shallow waters of the Logan Lane Impoundment. As part of a U.S. Fish and Wildlife Service study of seabird mortality caused by gill netting, a DNERR Graduate Research Fellow participated in a late winter/early spring 1998 survey of "seabirds" in inshore areas of Delaware Bay from Bowers Beach south to Primehook Beach (beachfront to 500 meters offshore).

Species	**Range of Peak Counts**	**Average Peak Count**
Semipalmated Sandpiper (*Calidris pusilla)*	42,630 (1992) - 267,348 (1986)	114,533+/- 32,576
Ruddy Turnstone *(Arenaria interpres)*	32,301 (1990) – 105,160 (1989)	66,086 +/- 9,665
Red Knot *(Calidris Canutus)*	25,595 (1992) – 94,460 (1989)	46, 513 +/- 8,888
Sanderling *(Calidris alba)*	5,305 (1991) – 33,795 (1986)	14,719 +/- 4,355
Dunlin *(Calidris alpina)*	2,474 (1989) – 11,245 (1992)	5,870 +/- 1,295
Dowitcher *(Limnodromus* spp.*)*	166 (1986) – 6,335 (1992)	1,698 +/_ 805
TOTAL SHOREBIRDS	105,985 (1990) – 425,162 (1986)	216,177 +/- 44,094

Table 20. Average (of each yearly peak) and range of peak daily counts of six shorebird species in Delaware Bay, May – June, 1986-1992.

Open salt marsh habitats within the Reserve support large numbers of wetlands species. In addition to wading birds, waterfowl, and shorebirds, other waterbirds frequently seen in tidal wetlands of both DNERR sites include clapper, king and Virginia rails, willet, laughing gull, and Forster's tern. Passerine species frequently seen in the DNERR's tidal wetlands include marsh wren, red-winged blackbird, boat-tailed grackle, common yellowthroat, and seaside and sharp-tailed sparrows. Passerine species that would find forested bottomlands of Upper Blackbird Creek good habitat include northern parula warbler, prothonotary warbler, and swamp sparrow. One of the most common birds found on each site is the red-winged blackbird, which is plentiful in all seasons and could explain why Blackbird Creek received its name.

Red-tailed hawks are frequently seen in both DNERR sites, and less frequently sharp-shinned hawks are observed. Turkey vultures are common. The raptor most frequently observed flying low over the DNERR's tidal wetlands is the northern harrier, and in winter short-eared owls and rough-legged hawks occasionally cruise over the marsh. A breeding pair of bald eagles is found along Upper Blackbird Creek. Habitat in the forested bottomlands along Upper Blackbird Creek is probably excellent for barred owls and red-shouldered hawks. Great horned and screech owls will occur in the DNERR's woodlands.

Ospreys are only infrequently seen at either DNERR site, possibly reflecting less than ideal foraging habitats (relative to other coastal areas). This could be the result of a shortage along the Delaware Bay coast of lagoonal habitats containing clear waters. Osprey reproductive success along the lower Delaware River and around Delaware Bay is thought to be differentially suppressed in comparison to other regional areas, because of a relatively greater eggshell thinning that still seems to be occurring in Delaware Estuary ospreys, caused by past use of the discontinued organochlorine insecticide DDT (Steidl et al., 1991a). Contaminant levels in osprey eggs laid at Delaware River or Bay sites for DDE and DDD (metabolites of DDT), plus other toxics like dieldrin, heptachlor and PCBs, were twice as high as found in eggs for ospreys nesting along New Jersey's eastern Atlantic coast. Osprey prey fish also showed this geographic difference, suggesting that metabolites of DDT and other contaminants are still relatively elevated in Delaware Estuary habitats, working their way into and up the food web (Steidl et al., 1991b).

Both DNERR sites have diverse habitats for many upland species. By known geographic ranges, characteristic birds of open fields, wet meadows, brushy hedgerows, roadsides and other open or semi-open habitats in the DNERR would include: American kestrel, northern bobwhite, ring-necked pheasant, mourning dove, northern flicker, eastern phoebe, eastern kingbird, house wren, barn and tree swallows, American crow, brown thrasher, northern mockingbird, eastern bluebird, American robin, eastern meadowlark, common grackle, European starling, brown-headed cowbird, northern oriole, American goldfinch, bobolink, cedar waxwing, northern cardinal, indigo bunting, yellow warbler, prairie warbler, yellow-breasted chat, blue grosbeak, northern junco, and song, field, savannah, chipping and house sparrows.

Birds characteristic of shrubby thickets, woodlots or woodlands in the DNERR would include: downy and red-bellied woodpeckers, eastern pewee, blue jay, Carolina chickadee, tufted titmouse, nuthatches, brown creeper, kinglets, blue-gray gnatcatcher, gray catbird, wood thrush, red-eyed and white-eyed vireos, yellow-rumped warbler, black-throated blue warbler, Kentucky warbler, American redstart, ovenbird, scarlet tanager, rufous-sided towhee, and fox and white-throated sparrows.

Common and scientific names of birds known to occur or possibly found in the DNERR are given in Table 21.

Mammals (terrestrial, aquatic and marine)
Almost all mammals commonly found in Delaware occur in the freshwater wetlands, salt marshes, wooded fringes, or upland forests of the two DNERR sites. Forested areas and upland edges support an abundance of white-tailed deer, gray squirrel, raccoon, red and gray foxes, opossum, woodchuck, striped skunk, long-tail weasel, cottontail rabbit, and various shrews, voles, mice and bats. In freshwater wetlands and brackish marshes, muskrats are common with lesser numbers of river otter and mink. Beavers are occasionally found in non-tidal reaches (DNREC, 1992).

The white-tailed deer (*Odocoileus virginianus*) is the most abundant large wild mammal found in the DNERR. A favorite to wildlife observers and hunters, the white-tailed deer brings in a substantial amount of money each year through hunting and recreational observation. Very adaptive to its surroundings, the white-tailed deer can survive in a variety of habitats (Reynolds 1995). Because of this adaptivity, white-tailed deer can become a serious nuisance to farmers by devouring crops, and to homeowners by eating gardens and shrubbery.

The muskrat (*Ondatra zibethicus*) is a semi-aquatic rodent that is commonly found in marshlands of Upper Blackbird Creek and Lower St. Jones River. It is the most valuable fur-bearing animal in the Delaware Estuary in terms of numbers harvested and revenue from pelts. Over 30,000 animals are trapped annually by licensed trappers in Delaware (McConnell and Powers 1995). The muskrat can be a nuisance in some areas by causing severe vegetation depletion, or by damage to privately-owned farm pond levees. Overpopulated areas can result in serious damage to flora, creating loss of marsh habitat and food resources. Proper harvest management of muskrat is needed in order to prevent habitat loss and serious population declines.

The river otter (*Lutra canadensis*) is often considered one of the best indicators of a healthy, productive aquatic environment. They are sensitive to pollution and are readily affected by negative changes in the environment. River otters play an important ecological role by acting as a top-level predator, feeding on fish, crustaceans, and other prey. River otters are known to occupy areas also containing beavers, after beavers have stabilized water and food resources (McConnell and Powers, 1995).

At one time, beaver (*Castor canadensis*) numbers were close to extirpation in Delaware, but now there are about 2,000 beavers in the state. Beavers thrive in nearly every waterway in Delaware, including upper reaches of both Reserve sites (Moore 1995). Beavers are well known for their dam construction abilities and acknowledged for restoring healthy fish and wildlife habitats,

Common loon	*Gavia immer*
Red-throated loon	*Gavia stellata*
Pied-billed grebe	*Podilymbus podiceps*
Horned grebe	*Podiceps auritus*
Double-crested cormorant	*Phalacrocorax auritus*
Northern gannet	*Morus bassanus*
Tundra swan	*Cygnus columbianus*
Canada goose	*Branta canadensis*
Greater snow goose	*Anser caerulescens atlanticus*
American black duck	*Anas rubripes*
Gadwall	*Anas strepera*
Mallard	*Anas platyrhynchos*
American wigeon	*Anas americana*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Green-winged teal	*Anas crecca*
Blue-winged teal	*Anas discors*
Wood duck	*Aix sponsa*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Bufflehead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
Common goldeneye	*Bucephala clangula*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Surf scoter	*Melanitta perspicillata*
Black scoter	*Melanitta nigra*
White-winged scoter	*Melanitta fusca*
Ruddy duck	*Oxyura jamaicensis*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Hooded merganser	*Lophodytes cucullatus*
Herring gull	*Larus argentatus*
Ring-billed gull	*Larus delawarensis*
Greater black-backed gull	*Larus marinus*
Laughing gull	*Larus atricilla*
Bonaparte=s gull	*Larus philadelphia*
Common tern	*Sterna hirundo*
Forster=s tern	*Sterna forsteri*
Little (least) tern	*Sterna antillarum*
Gull-billed tern	*Sterna nilotica*
Caspian tern	*Sterna caspia*
Royal tern	*Sterna maxima*
Black skimmer	*Rynchops niger*

Great egret	*Casmerodius albus*
Snowy egret	*Egretta thula*
Cattle egret	*Bubulcus ibis*
Great blue heron	*Ardea herodias*
Tricolored heron	*Egretta tricolor*
Little blue heron	*Egretta caerulea*
Black-crowned night heron	*Nycticorax nycticorax*
Yellow-crned night heron	*Nycticorax violacea*
Green-backed heron	*Butorides virescens*
American bittern	*Botaurus lentiginosus*
Least bittern	*Ixobrychus exilis*
Glossy ibis	*Plegadis falcinellus*
Clapper rail	*Rallus longirostris*
King rail	*Rallus elegans*
Virginia rail	*Rallus limicola*
Sora	*Porzana carolina*
American coot	*Fulica americana*
Common moorhen	*Gallinula chloropus*
American oystercatcher	*Haematopus palliatus*
American avocet	*Recurvirostra americana*
Black-necked stilt	*Himantopus mexicanus*
Black-bellied plover	*Pluvialis squatarola*
Ruddy turnstone	*Arenaria interpres*
Semipalmated plover	*Charadrius semipalmatus*
Killdeer	*Charadrius vociferus*
Semipalmated sandpiper	*Calidris pusilla*
Least sandpiper	*Calidris minutilla*
Western sandpiper	*Calidris mauri*
White-rumped sandpiper	*Calidris fuscicollis*
Sanderling	*Calidris alba*
Red knot	*Calidris canutus*
Dunlin	*Calidris alpina*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Willet	*Catoptrophorus semipalmatus*
Solitary sandpiper	*Tringa solitaria*
Upland sandpiper	*Bartramia longicauda*
Pectoral sandpiper	*Calidris melanotos*
Spotted sandpiper	*Actitis macularia*
American woodcock	*Philohela minor*
Common snipe	*Gallinago gallinago*
Wild turkey	*Meleagris gallopavo*
Ring-necked pheasant	*Phasianus colchicus*
Northern bobwhite	*Colinus virginianus*

Table 21. Common and scientific names of Birds known to occur or possibly found in the DNERR.

Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Turkey vulture	*Cathartes aura*
Black vulture	*Coragyps atratus*
Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*Buteo lineatus*
Broad-winged hawk	*Buteo platypterus*
Rough-legged hawk	*Buteo lagopus*
Northern harrier	*Circus cyaneus*
Sharp-shinned hawk	*Accipiter striatus*
Cooper=s hawk	*Accipiter cooperii*
American kestrel	*Falco sparverius*
Merlin	*Falco columbarius*
Peregrine falcon	*Falco peregrinus*
Great horned owl	*Bubo virginianus*
Barred owl	*Strix varia*
Short-eared owl	*Asio flammeus*
Common barn owl	*Tyto alba*
Eastern screech owl	*Otus asio*
Rock dove	*Columba livia*
Mourning dove	*Zenaida macroura*
Yellow-billed cuckoo	*Coccyzus americanus*
Common nighthawk	*Chordeiles minor*
Whip-poor-will	*Caprimulgus vociferus*
Chimney swift	*Chaetura pelagica*
Ruby-thrted hummingbird	*Archilochus colubris*
Belted kingfisher	*Ceryle alcyon*
Red-bellied woodpecker	*Melanerpes carolinus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
Northern flicker	*Colaptes auratus*
Eastern wood peewee	*Contopus virens*
Acadian flycatcher	*Empidonax virescens*
Willow flycatcher	*Empidonax traillii*
Eastern phoebe	*Sayornis phoebe*
Great-crested flycatcher	*Myiarchus crinitus*
Eastern kingbird	*Tyrannus tyrannus*
Horned lark	*Eremophila alpestris*
Purple martin	*Progne subis*
Tree swallow	*Tachycineta bicolor*
Bank swallow	*Riparia riparia*
Barn swallow	*Hirundo rustica*
Blue jay	*Cyanocitta cristata*
American crow	*Corvus brachyrhynchos*
Fish crow	*Corvus ossifragus*

Carolina chickadee	*Parus carolinensis*
Tufted titmouse	*Parus bicolor*
Red-breasted nuthatch	*Sitta canadensis*
White-breasted nuthatch	*Sitta carolinensis*
Brown creeper	*Certhia americana*
Marsh wren	*Cistothorus palustris*
Sedge wren	*Cistothorus platensis*
Carolina wren	*Thryothorus ludovicianus*
House wren	*Troglodytes aedon*
Winter wren	*Troglodytes troglodytes*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Blue-gray gnatcatcher	*Polioptila caerulea*
Eastern bluebird	*Sialia sialis*
Veery	*Catharus fuscescens*
Swainson=s thrush	*Catharus ustulatus*
Hermit thrush	*Catharus guttatus*
Wood thrush	*Hylocichla mustelina*
American robin	*Turdus migratorius*
Gray catbird	*Dumetella carolinensis*
Northern mockingbird	*Mimus polyglottos*
Brown thrasher	*Toxostoma rufum*
Water pipit	*Anthus spinoletta*
Cedar waxwing	*Bombycilla cedrorum*
Loggerhead shrike	*Lanius ludovicianus*
White-eyed vireo	*Vireo griseus*
Red-eyed vireo	*Vireo olivaceus*
Common yellowthroat	*Geothlypis trichas*
Northern parula warbler	*Parula americana*
Prothonotary warbler	*Protonotaria citrea*
Yellow warbler	*Dendroica petechia*
Chestnut-sided warbler	*Dendroica pensylvanica*
Magnolia warbler	*Dendroica magnolia*
Black-throated blue warb	*Dendroica caerulescens*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated green warb	*Dendroica virens*
Pine warbler	*Dendroica pinus*
Prairie warbler	*Dendroica discolor*
Palm warbler	*Dendroica palmarum*
Blackpoll warbler	*Dendroica striata*
Black-and-white warbler	*Mniotilta varia*
American redstart	*Setophaga ruticilla*
Ovenbird	*Seiurus aurocapillus*
Northern waterthrush	*Seiurus noveboracensis*
Kentucky warbler	*Oporornis formosus*
Canada warbler	*Wilsonia canadensis*
Yellow-breasted chat	*Icteria viren*

Table 21. (Cont.) Common and scientific names of Birds known to occur or possibly found in the DNERR.

Red-winged blackbird	*Agelaius phoeniceus*	American goldfinch	*Carduelis tristis*
Rusty blackbird	*Euphagus carolinus*	Pine siskin	*Carduelis pinus*
Brown-headed cowbird	*Molothrus ater*	Rose-breasted grosbeak	*Pheucticus ludovicianus*
Common grackle	*Quiscalus quiscula*	Blue grosbeak	*Guiraca caerulea*
Boat-tailed grackle	*Quiscalus major*	Indigo bunting	*Passerina cyanea*
Bobolink	*Dolichonyx oryzivorus*	Rufous-sided towhee	*Pipilo erythrophthalmus*
Eastern meadowlark	*Sturnella magna*		
European starling	*Sturnus vulgaris*	American tree sparrow	*Spizella arborea*
Orchard oriole	*Icterus spurius*	Chipping sparrow	*Spizella passerina*
Northern oriole	*Icterus galbula*	Field sparrow	*Spizella pusilla*
		Savannah sparrow	*Passerculus sandwichensi*
Scarlet tanager	*Piranga olivacea*	Seaside sparrow	*Ammospiza maritima*
Summer tanager	*Piranga rubra*	Sharp-tailed sparrow	*Ammospiza caudacuta*
House sparrow	*Passer domesticus*	Swamp sparrow	*Melospiza georgiana*
Dark-eyed junco	*Junco hyemalis*	Fox sparrow	*Passerella iliaca*
Snow bunting	*Plectrophenax nivalis*	Song sparrow	*Melospiza melodia*
Northern cardinal	*Cardinalis cardinalis*	White-throated sparrow	*Zonotrichia albicollus*
House finch	*Carpodacus mexicanus*	White-crowned sparrow	*Zonotrichia leucophrys*
Purple finch	*Carpodacus purpureus*		

Table 21. (Cont.) Common and scientific names of Birds known to occur or possibly found in the DNERR.

beneficially increasing biodiversity and enhancing water quality in many areas.

There are a variety of small mammals found at the DNERR sites, some which are very common. These species can include shrews such as short-tail, masked and least; meadow and pine voles; white-footed and meadow jumping mice; and marsh rice rats. These small mammals play an important ecological role as prey for other animals, including owls, hawks, foxes, snakes, weasels, and mink. In most cases, when populations of small mammals are high, the populations of predators that feed on them fare well.

Bat species within the Reserve could include little brown myotis, eastern pipistrel, and big brown bat, and the more highly migratory silver-haired, hoary, and red bats.

Several species of marine mammals utilize the waters of Delaware Bay. Most are attracted to the Bay for its seasonally warmer waters, and to nourish themselves during their annual migrations (Schoelkopf and Stetzar, 1995). The largest marine mammals that occur in the bay are whales. There have been several instances of whale sightings in Lower Delaware Bay over the past several years, enough that "whale-watching" cruises have been departing from of Lewes, Delaware and other towns in New Jersey. Most of the whales observed in the estuary are juvenile humpback whales *(Megaptera novaeangliae),* but northern right whales *(Balaena glacialis)* have also been seen on several occasions. A finback whale *(Balaenoptera physalus)* was in the bay in 1995, but was unfortunately killed when struck by a passing vessel. These three whale species are all listed as endangered on the federal endangered species list.

The bottlenose dolphin *(Tursiops truncata)* is the most common marine mammal in Delaware Bay. Bottlenose dolphins usually are seen from spring through fall, typically in groups consisting of mothers and calves. This species is the marine mammal most often found dead or stranded on Delaware's beaches. Harbor porpoises *(Phocoena phocoena)* also utilize the waters of Delaware Bay, but little is known about their occurrences in the Bay. The harbor seal (*Phoca vitulina)* is another marine mammal occasionally seen in Delaware Bay, most often observed in lower parts of the bay during the winter months. According to the Marine Mammal Stranding Center in Brigantine, New Jersey, at least one dozen seals are washed up on the New Jersey shores of Delaware Bay every year (Sutton et al, 1996).

Common and scientific names of mammals known to occur or possibly found in the DNERR are given in Table 22.

Special Ecological Areas

Ted Harvey Conservation Area

The Ted Harvey Conservation Area, owned and managed by DNREC's Division of Fish and Wildlife (Figure 3), is an intensively-managed wildlife conservation area adjacent to the St. Jones River DNERR site, between the Reserve and Delaware Bay. With approximately 817 ha (2,019 acres) of land, including agricultural, wooded and upland areas, as well impounded tidal wetlands and Delaware Bay shoreline, the Ted Harvey Conservation Area offers diverse habitat for deer, small game, waterbirds (including waterfowl, wading birds, and shorebirds), and many fish species. Attractive to hunters and anglers, this wildlife area offers 21 deer stands, 21 waterfowl blinds, and a large handicapped freshwater fishing area. Use of the area by numerous and varied waterbirds has been well documented and already discussed. The Ted Harvey Conservation Area is very popular during spring for birders (bird watching), when many species of shorebirds and waterfowl stop over on their migration. Sightings of unusual birds, such as the whiskered and white-winged terns, continue to attract birders throughout summer and fall. According to surveys conducted by WRA, the

Common Name	Scientific Name
Opossum	*Didelphis marsupialis*
Short-tail shrew	*Blarina brevicauda*
Masked shrew	*Sorex cinereus*
Least shrew	*Cryptotis parva*
Little brown myotis	*Myotis lucifugus*
Eastern pipistrel	*Pipistrellus subflavus*
Big brown bat	*Eptesicus fuscus*
Silver-haired bat	*Lasionycteris noctivagans*
Hoary bat	*Lasiurus cinereus*
Red bat	*Lasiurus borealis*
Raccoon	*Procyon lotor*
Long-tail weasel	*Mustela frenata*
Mink	*Mustela vison*
River otter	*Lutra canadensis*
Striped skunk	*Mephitis mephitis*
Red fox	*Vulpes vulpes*
Gray fox	*Urocyon cinereoargenteus*
Woodchuck	*Marmota monax*
Gray squirrel	*Sciurus carolinensis*
Southern flying squirrel	*Glaucomys volans*
Beaver	*Castor canadensis*
Muskrat	*Ondatra zibethicus*
Rice rat	*Oryzomys palustris*
White-footed mouse	*Peromyscus leucopus*
Meadow jumping mouse	*Zapus hudsonius*
Meadow vole	*Microtus pennsylvanicus*
Pine vole	*Microtus pinetorum*
Eastern cottontail rabbit	*Sylvilagus floridanus*
White-tailed deer	*Odocoileus virginianus*
Harbor seal	*Phoca vitulina*
Bottlenose dolphin	*Tursiops truncatus*
Harbor porpoise	*Phocoena phocoena*
Common blackfish (pilot whale)	*Globicephala melaena*
Humpback whale	*Megaptera novaeangliae*
Northern right whale	*Balaena glacialis*
Finback whale	*Balaenoptera physalus*

Table 22. Common and scientific names of Mammals known to occur or possibly found in the DNERR.

Logan Lane Tract, an impounded wetland complex within the Ted Harvey Conservation Area, had the highest bird species diversity and counts of any observation point along the Lower St. Jones River (Wetlands Research Associates, Inc., 1995).

The Logan Lane Impoundment is one of three high-level tidal impoundments in east-central Kent County managed by the Delaware Division of Fish and Wildlife. These impoundments were built in the mid-1950's through the 1960's to improve waterfowl habitat and provide mosquito control. The goals of impoundment management have expanded to include providing forage for migratory shorebirds and wading birds and habitat for estuarine fishes. Management practices have evolved in order to meet these changing goals. Initial management practices included filling (pumping) the impoundments in fall to provide the combination of open water and vegetation most attractive to migratory waterfowl. During spring and summer water levels were allowed to drop to promote growth of vegetation for the next migration, with total evaporation of impoundment pools often occurring by mid-summer. During the mid-1980's management practices were improved to keep soil salinity below 20 ppt. The primary change was that water levels are now controlled by repeatedly flooding and draining the impoundments, instead of allowing evaporation to dictate water levels. Frequent tidal exchanges within the impoundments now occur, managed by new water control structures.

Nearshore Delaware Bay

Along the Delaware Bay coast, unique and diverse habitats exist, consisting of broad marsh areas, narrow buffers of low barrier dunes, sandy bayfront beaches and shallow inshore bay waters. This combination provides excellent resources for a variety of organisms. Encompassing representative habitat of open Delaware Bay gives the DNERR opportunity to examine many important and interesting natural features of the bay.

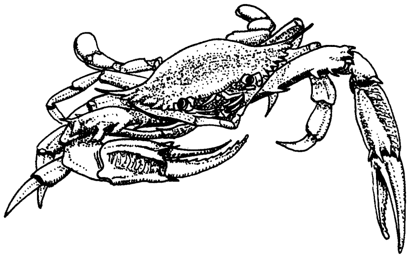
Nearshore bottom sediments in Delaware Bay near the mouths of both the St. Jones River and Blackbird Creek are made up of mucky fine silts and clays (70-100 % silt/clay) having high organic content (Maurer et al, 1978). This sediment type is typical of many shallow inshore basins and tributary river mouths around Delaware Bay. Sediments are primarily fine to medium sands in the bay's channel bottom, and in lower bay shoal deposits along beaches or offshore. Coarse sand deposits are found at the bay's mouth and in areas adjacent to eroding headlands.

In certain areas along the bay shoreline, there is no sandy beach and the marsh meets directly with the bay. This occurrence is known as a sodbank, and is often associated with large intertidal mud flats seaward from the beach (Sutton et al, 1996). The intertidal bay mudflats are excellent habitat for many plant and animal species, from microscopic edaphic algae to migrating shorebirds.

The most commonly observed inshore "seabirds" along mid-Delaware Bay open coast are common and red-throated loons, horned grebe, double-crested cormorant, northern gannet, snow goose, red-breasted merganser, surf and black scoters, bufflehead, lesser scaup, common tern, and several gull species (herring, greater black-backed, ring-billed, laughing). The most common shorebirds along mid-Delaware Bay beachfronts include semipalmated sandpiper, sanderling, red knot, ruddy turnstone, dunlin, short-billed dowitcher, semipalmated plover, black-bellied plover, greater yellowlegs, and willet (DNREC Delaware Bay Shorebird Viewing Guide, 1998).

An important member of the Delaware Bay ecosystem in inshore and deeper areas, the eastern oyster (*Crassostrea virginica)* has both ecological and economic significance. Its ability to tolerate a wide range of environmental conditions allows this bottom-dwelling mollusk to occur widely within the bay. Colonies of oysters, known as oyster beds, provide habitat for many species of benthic invertebrates. These invertebrates in turn provide a strong base in the food web, providing food for many important finfish. Oysters can also be good indicators of water quality. They obtain their food by filtering plankton from the water while also removing toxins and other substances, including viruses and bacteria. These substances are then concentrated in their own tissues instead of the water column, helping to cleanse the water, but also present contamination problems for human consumption.

The blue crab *(Callinectes sapidus)* also plays important roles, both ecologically and economically, in Delaware Bay. The basis of the most important inshore bay fishery, the blue crab is pursued by many fishermen every year. Blue crabs play two important ecological roles in Delaware Bay. Juvenile crabs provide an important food source for many important commercial and recreational finfish including striped bass and weakfish, as well as many bird species including gulls. Adult blue crabs are important because they aid in regulating populations of mollusks, shrimp, and plant material, as well as other organic debris found on the bay's bottom.



As mentioned previously in discussion of the Reserve's birds, during late spring the sandy shorelines of Delaware Bay host the largest population of spawning horseshoe crabs (*Limulus polyphemus*) on the Atlantic Coast. These crabs come inshore from deeper waters in order to deposit their eggs in beachface sand. Migrating shorebirds use this opportunity to replenish their fat reserves, in order to finish their long migration northward to the Arctic tundra where they breed. Horseshoe crabs are also commercially harvested as an important bait for other marine fisheries, as well as for medical uses of its blood.

CONSUMPTIVE USES OF LIVING RESOURCES

With exception of waterfowl hunting or muskrat trapping that occurs in the DNERR's tidal wetlands or other nearby marshes, most human uses of living resources center on Delaware Bay commercial and recreational fisheries. Some of these fisheries extend landward into the DNERR subestuaries.

Furbearers

In past times, the trapping of furbearers, especially muskrats, was an important source of supplemental income for many coastal marsh landowners in Delaware. Fur trapping still continues today in marshes in or near the DNERR sites and in many other wetlands throughout the state, but to a much lesser extent. Muskrat (*Ondatra zibethicus*) still remains the most important furbearer that's harvested -- an estimated 30,000 muskrats per year are trapped statewide, with about 2/3's of the harvest coming from tidal wetlands (McConnell and Powers, 1995). Decreased market demand for furs has decreased prices for muskrat pelts to as little at $2 to $4 dollars each, causing muskrat trapping effort to decline in comparison to historical levels. Some muskrats trapped for their pelts have their meat sold locally in Delaware as food for human consumption. River otter and mink also contribute to Delaware's wetland furbearer harvest, but at much lower levels of capture, and in more upland areas raccoons and opossums can be captured in box traps.

Waterfowl hunting

Hunting in all its various forms involved over 40,000 participants in Delaware in 1996, who spent over $28 million in pursuit of their sport (USDOI/USDOC, 1996). Waterfowl hunting is an important recreational and economic activity in the state's coastal wetlands, and the state has a long history as a storied waterfowl hunting area. Much waterfowl hunting activity goes on in marshes and nearby uplands at or near the DNERR sites, on both publicly-owned State Wildlife Areas, and on private lands within the DNERR's designated boundaries and on adjacent properties.

Migratory Canada geese (*Branta canadensis*) were an important species to hunt in Delaware as recently as the mid-1980's, but overharvesting along the Atlantic Flyway and a series of weather-induced poor reproductive success on their northern nesting grounds has caused their decline. Today approximately only 73,000 Canada geese use the Delaware Estuary, with many of them now being non-migratory resident birds that locally often create nuisance problems; because of locations for resident geese in places like city parks or golf courses, they are not very susceptible to culling by hunting, although there is a bag limit of 5 per day wherever resident geese can be taken (Whittendale, 1995). Low numbers of migratory Canada geese have led to closed hunting seasons in Delaware for migrant geese for the past several years.

In contrast to Canada geese, greater snow geese (*Anser caerulescens atlanticus*) have dramatically increased in Delaware since the 1970's, with over 120,000 migratory birds now seasonally occurring in the Delaware Estuary. Snow geese behavior makes their numbers difficult to control by hunting. Around the DNERR and elsewhere along the Delaware Bay coast in Kent and Sussex Counties, their large flocks (often numbering 5000-10,000 birds) can cause extensive damage to winter field crops, and their presence near the Dover Air Force Base creates a continuous safety hazard for planes landing or taking off. Snow goose herbivory has also created problems and set-backs with management efforts to restore or enhance saltmarsh cordgrass growth in coastal impoundments, and their grazing has denuded extensive acreage in Delaware's open salt marshes. Liberalized hunting regulations (e.g. longer open seasons, higher bag limits, areas where hunting is allowed) and other techniques are being tried to better control snow geese numbers and limit their damage.

Waterfowl hunting in Delaware's coastal wetlands for "puddle ducks" such a mallards, black duck, green-winged and blue-winged teal, gadwall, wigeon, and pintail is still readily available and popular. Wood ducks are often harvested in more landward freshwater portions of Delaware's coastal rivers and creeks. Hunting for diving ducks such as scaups, bufflehead, canvasback and redhead, as well as mergansers, occurs in more open waters along the coast. A limited amount of hunting also occurs in offshore waters of Delaware Bay for sea ducks such as scoters, eiders and old squaw. However, hunting for some of these species is more tightly controlled than others, due to selected concerns for their population levels. For example, the black duck (*Anas rubripes*) has declined along the Atlantic Flyway by more than 50% in comparison to population levels in the 1960's, although recent populations in the Delaware Estuary have been fairly stable (and there's even indication of increasing numbers in Delaware of wintering black ducks), leading to more restrictive open seasons and bag limits for black ducks in comparison to other species (Whitman and Castelli, 1995). Concerns for pintail and canvasback populations have also led to relatively more restrictive regulations for their harvests.

Popular forms of upland game hunting occurring on or near DNERR lands include white-tailed deer and wild turkey hunting, as well as small game hunting for rabbit, squirrel, pheasant, quail, woodcock and dove.

Eastern oyster

The eastern oyster *(Crassostrea virginica)* has been economically important for several centuries. In 1880, the first year that official harvest records were kept, an estimated 2.4 million bushels of oysters were harvested in Delaware Bay (Ingersoll, 1881). Delaware Bay oysters are still in great demand, and a change in current populations and harvests would have a large economic impact on the Delaware shellfishery.

The eastern oyster has been harvested from Delaware Bay ever since Native Americans realized their utility and abundance. By the late 1600's, commercial harvests for oysters had begun, and oysters were on their way to becoming a very profitable industry for the Delaware Bay region. By the early 1700's, oysters were harvested and shipped to Philadelphia, New York, and the West Indies. Delaware had established private canning houses for processing oysters by the early 1800's, and the industry reached its peak in the early 1900's. By this time, there was legislation regulating and managing oyster harvests. However, during the mid-1900's poor management practices, severe weather conditions, increased natural predation, and the Great Depression all contributed to the start of a serious decline in the oyster industry. Between 1956 and 1960, annual oyster harvests dropped dramatically from 711,000 bushels to 49,000 bushels, primarily due to disease. Figure 43 displays historic trends in the Delaware Bay oyster harvest over the past century.

The major reason for the oyster's decline in the late 1950's was MSX or "multinucleated sphere unknown," a protozoan parasite (*Haplospridium nelsoni)* which wiped out approximately 95% of the harvest (Ford, 1994). Other factors involved with the decline of Delaware Bay oyster populations include bacterial contamination; Dermo (caused by an oyster parasite, *Perkinsus marinus)*; and the oyster drill *(Urosalpnx spp.)*, a predatory snail common in Delaware Bay waters.

The oyster drill is a major cause of low oyster harvests and populations. This predatory snail is quite abundant, and very adaptable to a wide range of temperatures and salinities. The two most common oyster drill species found in Delaware Bay are *Urosalpinx cinerea* and *Eupleura caudata.* These snails also feed on mussels and other bottom dwelling organisms like clams, crabs, other drills, and even dead fish.

Today the Delaware oyster industry relies on approximately 1,000 acres of state-controlled oyster seed beds, as well as several private beds (Figure 44). Most of the state- controlled oyster beds can be found between Port Mahon and Woodland Beach, while other oyster beds occur along the bay coastline from Woodland Beach to Big Stone Beach. Populations of oysters can also be found in several of Delaware's coastal rivers, including the lower portion of the St. Jones River.

Since the late 1980's the oyster industry has seen many hardships, including the recent closing of seed beds for over four years, caused by factors such as disease, bacterial contamination, and poor setting of seed oysters. The future of the oyster industry in Delaware Bay is hard to predict, as many factors are involved. New strains of parasite-resistant oysters are being examined, and hopefully they might bring the commercial industry back to former levels. In using or developing disease-resistant oysters, there would be an obvious preference for native species stock to avoid any potential problems with stocking non-indigenous species. Whether the oyster industry recovery in Delaware Bay could ever involve introducing Pacific oysters (e.g. *Crassostrea gigas)* is presently highly contentious, because of legitimate concerns with possible adverse impacts of non-native species. However, even if someday more disease-resistant oysters are established, there will still probably remain problems with harvest in many inshore locations, due to bacterial contamination from upland runoff or seepage.

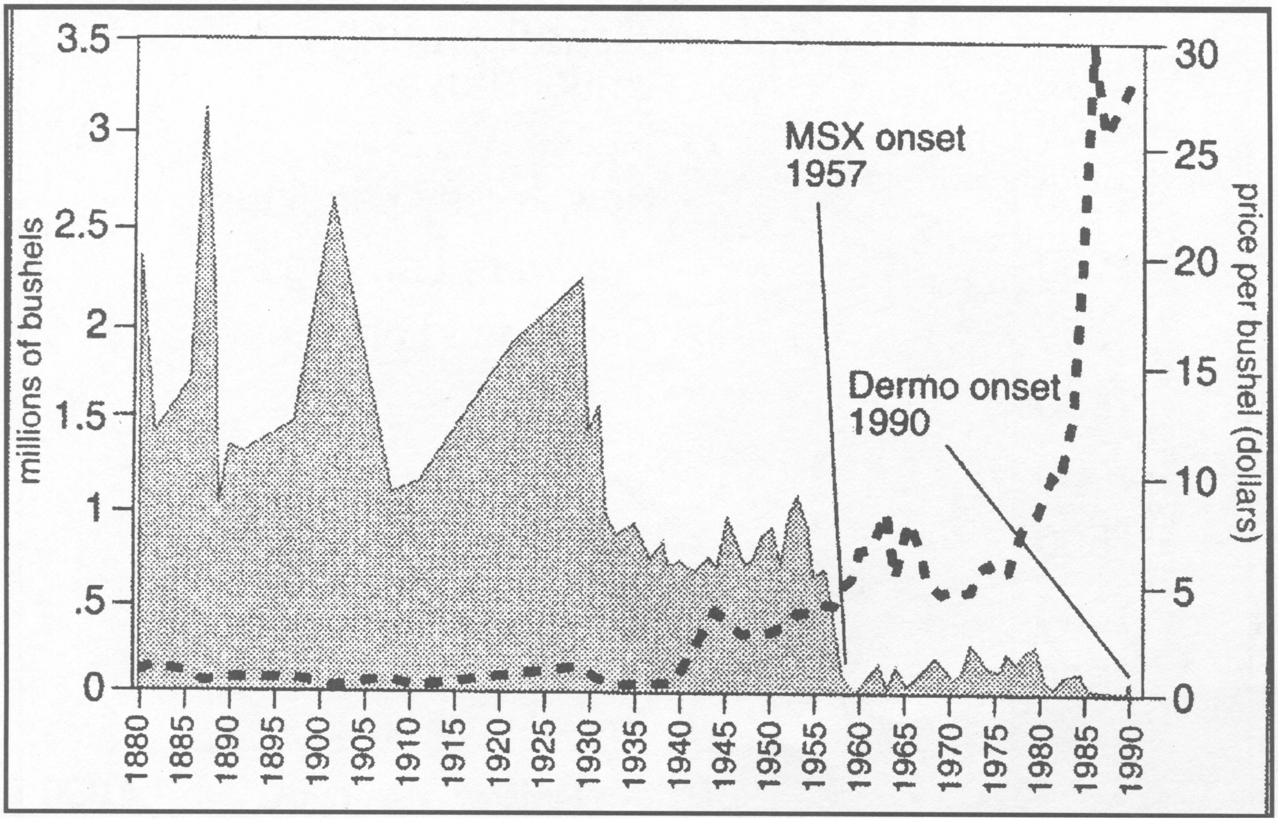
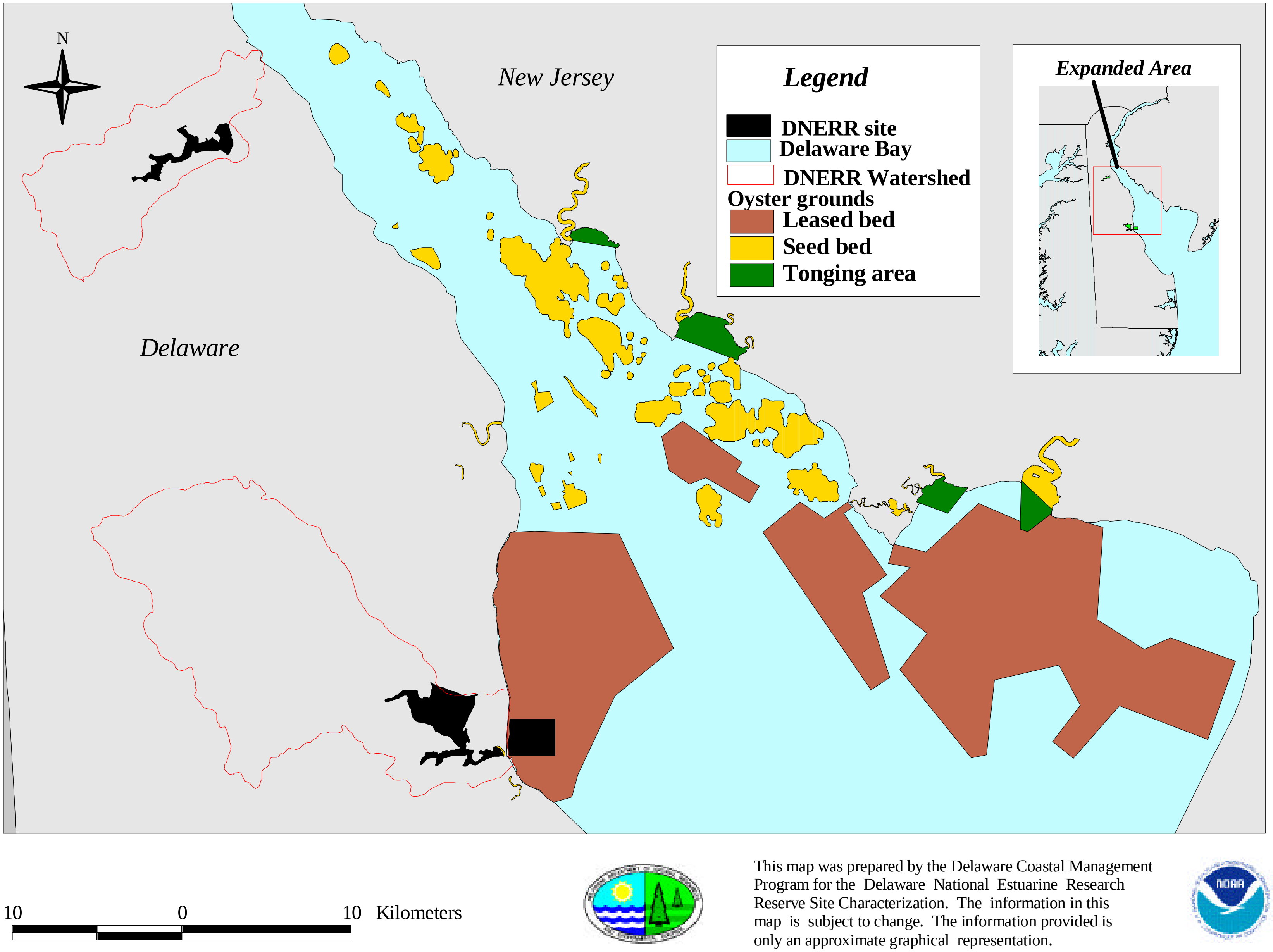


Figure 43. The Delaware Estuary's oyster fishery landed more than 25 million pounds of oysters annually during the late 1800s. This rate gradually dropped until the mid-1900s when a combination of over-harvesting and the introduction of MSX parasite decimated the industry. The chart shows the New Jersey harvest price of oysters (dotted line) from 1880 to 1990. The left column represents millions of bushels and the right column is the price per bushel in dollars. Over the last four years there was only one year, 1991, when there was enough oysters to actually harvest. In that year, all the oysters taken to the seed beds died with the onset of Dermo. Source: Rutgers University Haskin Shellfish Research Laboratory (1991).



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 44. Oyster Grounds in Upper Delaware Bay

Blue crab

The blue crab *(Callinectes sapidus)* fishery plays a large economic role in residential communities surrounding Delaware Bay. Both commercial and recreational fishermen utilize Delaware Bay to harvest large populations of blue crabs (Figure 45). Because of its economic importance, conservation regulations that reduce the blue crab harvest are almost always initially opposed by members of local bayside communities.

Regionally, the blue crab supports the most important inshore fishery in the mid-Atlantic (Epifanio, 1995). In terms of dollar value, the blue crab exceeds all other shellfisheries in Delaware. One of the more popular varieties of Delaware seafood, people come from all over to Delaware Bay and its tidal tributaries to harvest blue crabs. This has an important effect on the local economy, and supports many businesses and restaurants. The blue crab is harvested year-round, by a crab pot fishery from late April through October, and by a winter dredge fishery from December through March. Record Delaware landings of 6.3 million pounds occurred in 1995 (DNREC, 1998). Annual harvests can be quite variable, dependent upon factors like nearshore ocean currents affecting larval dispersion and recruitment patterns, or excessively cold water temperatures killing overwintering buried adults. A bi-state Blue Crab Fishery Management Plan is currently under development by Delaware and New Jersey.

A limited amount of hard clams (*Mercenaria mercenaria*) are incidentally harvested in lower Delaware Bay, as bycatch of the blue crab winter dredge fishery. Conch (*Busycon* spp.) are also harvested in Delaware Bay, both as incidental bycatch of the blue crab winter dredge fishery, and by pot and dredge fisheries.

Horseshoe crab

Horseshoe crabs *(Limulus polyphemus)* have been harvested since the 1800’s for animal feed and fertilizer. Periods of high harvests have been followed by relative scarcities. Over the past decade in Delaware, their harvest has again increased dramatically, with an estimated 422,000 adults (2.1 million pounds) collected in 1996 (DNREC, 1998). About 80% of the harvest comes from a shore-based hand-collection fishery, and the rest from a bottom dredge fishery. Because of declines in other shellfisheries, commercial fishermen are beginning to harvest horseshoe crabs at higher rates. There is a serious concern that overharvesting of horseshoe crabs along Delaware Bay could have detrimental effects on migratory shorebirds during spring migration. These birds consume large numbers of horseshoe crab eggs as part of their energy needs to complete northbound migration to their Arctic nesting grounds. This concern has lead to calls for better protection and conservation of horseshoe crabs and their eggs, and state agencies are now more actively regulating harvests.

Currently, the State of Delaware regulates the harvesting of horseshoe crabs by issuing only 50 permits for horseshoe crab shoreline collection plus 5 dredging permits. From May 1 through June 30, only these shoreline permittees may collect horseshoe crabs (only using state and federal lands on Tuesdays and Thursdays, and non-state and federal lands on Mondays, Wednesdays and Fridays). Only three people may assist each shoreline permittee in harvesting. There is a plan under review to possibly revise these state regulations.

A Fishery Management Plan (FMP) for horseshoe crabs was approved in October 1998 by the Atlantic States Marine Fisheries Commission (ASMFC). The Horseshoe Crab FMP will provide more uniform management objectives for horseshoe crab harvests along the Atlantic Coast. This should reduce overharvesting of crabs that would probably continue in some areas if only individual state management objectives apply.

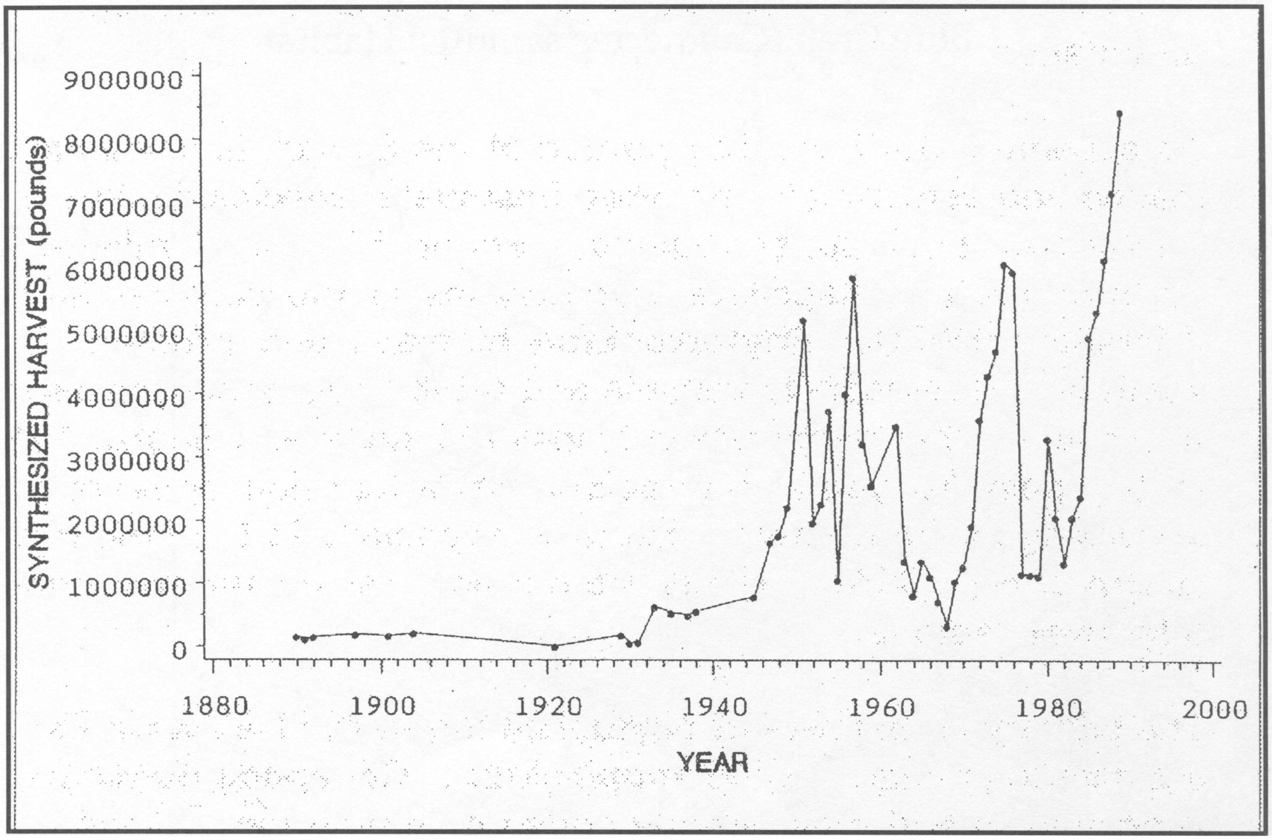


Figure 45. Synthesized estuary-specific blue-crab harvest (in pounds) between 1880 and 1990. Source: “An Assessment of Fisheries Landings Records in the Delaware River Estuary.” Prepared by Killiam and Richkus (September, 1992).

According to trawl studies by the DNREC Division of Fish and Wildlife that began in 1992, the highest concentrations of juvenile horseshoe crabs in Delaware have been found near the mouth of the St. Jones River (Jamison 1996). Therefore, the conservation of this species near the Lower St. Jones River Reserve is important to its continued perpetuation.

Finfisheries

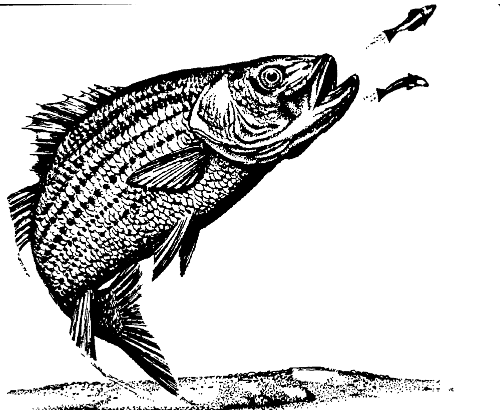
The finfish community has always been an important component of inshore Delaware Bay. Native Americans utilized finfish for food and fertilizer. The diversity and abundance of fish species within Delaware Bay still supports several important commercial and recreational finfisheries (Table 23).

Delaware Bay supports a small commercial inshore gill net fishery, which is active all year for drift netting. Anchoring of nets (staked netting) is permitted in winter, early spring and fall. Most gill netting in Delaware Bay is done between Port Penn and Broadkill Beach. The most common commercial species caught in gill nets include white perch, weakfish, American shad, and striped bass.

The American shad (*Alosa sapidissima)* commercial fishery collapsed in the early 1900's, and harvests have remained relatively low ever since. The ongoing recovery of American shad spawning stock in the upper Delaware River, associated with water quality improvements along the industrialized lower Delaware River, might someday help restore the Delaware Bay shad fishery.

Atlantic menhaden (*Brevoortia tyrannus*), once caught with purse seines in Delaware Bay, were used for fertilizer and animal feed. Up until the late 1950’s, the port of Lewes was a major menhaden processing center, but overharvesting has made this fishery a thing of the past in or near Delaware waters. Purse seine fishing was eliminated in Delaware’s tidal waters in 1992. Presently, limited amounts of menhaden are caught with gill nets and used for bait. About a decade ago menhaden appeared to be increasing in abundance, but in recent years are again becoming scarcer. In 1991, for example, 82% of the statewide landings were of age two and younger fish. This age structure is indicative of heavy fishing pressure and of a fishery dependent on too few age classes, perhaps reflecting today’s relative scarcity of menhaden in mid-Atlantic coastal waters.

There has been a steadily growing interest in the American eel (*Anguilla rostrata*) fishery in Delaware Bay and its tidal tributaries. During the 1994 season, 58 eeling licenses were issued in Delaware, allowing use of eel pots or small fyke nets to catch eels. In 1990 and 1991, approximately 250,000 pounds of American eel were landed each year in Delaware, up from approximately 103,900 pounds landed in 1989 (Fahay 1995). The shipping of live, immature eels (elvers) to Japan has become a very lucrative practice, and there is growing concern in New England and mid-Atlantic states for potentially overharvesting the eel population.



The four most popular recreational fish species caught in Delaware Bay are weakfish, bluefish, summer flounder, and most recently striped bass, all pursued from headboats, charter boats, private craft, and shoreline. Each of these species has become increasingly more important to the recreational fishery than the commercial fishery. Weakfish (Delaware’s official “state fish”) declined in availability in

Sharks (includes dusk shark, dogfish, and spiny dogfish)
Atlantic Sturgeon
American Eel*
Blueback Herring*
Alewife*
American Shad*
Atlantic Menhaden*
Common Carp*
Catfish (includes white catfish, brown bullhead, and channel catfish)
Silver Hake
Red Hake
White Perch*
Striped Bass*
Black Sea Bass
Bluefish*
Scup
Weakfish*
Spot*
Atlantic Croaker*
Black Drum
Tautog
Atlantic Mackerel
Spanish Mackerel
Butterfish
Summer Flounder
Windowpane

*These species variously were major contributors to the economic value of the estuary fishery for nine years of record, 1947 – 1990 (Killiam and Richkus, 1992).

Sources: Frithsen, Killiam and Young (1991); Grimes(1984); Killiam and Richkus (1992).

Table 23. Fishes of the Delaware Estuary Contributing to the Historic and/or Recent Commercial Fishery.

the 1980's (Sutton et al, 1996), but there are now indications of its regional recovery. Striped bass as recreationally-caught fish have been increasing during the last eight years, with 19,600 striped bass caught and kept statewide in 1997, associated with this species coastwide stock recovery. However, the bluefish recreational harvest has been declining, apparently due to a coastwide stock decline or geographic shift. Other popular types of recreational fishing in Delaware Bay include bottom fishing for sea bass, tautog, scup, black drum and other structure-oriented fishes, plus various types of shark fishing.

Turtles

Snapping turtles and diamondback terrapins are again becoming more popular as a hunted food source. Demand for these turtles increases as more people consume snapper soup and terrapin stew. Although seemingly common now, the numbers of breeding-size adults for both species have decreased since their economic value has increased (Sutton et al, 1996). Regulations have been passed in New Jersey limiting the numbers of turtles allowed to be harvested, and requiring special permits for those who seek to trap turtles in larger numbers. There are no harvest limits for diamondback terrapins in Delaware, although the open season for their capture is only 2-1/2 months. Similarly, snapping turtles have no harvest limits in Delaware during an open season that lasts 11 months, but all snappers must be at least 8” long. Regulations are pending in Delaware that might create more restrictive harvest conditions for these two species.

HISTORIC AND CULTURAL RESOURCES

Lower St. Jones River Reserve

The Lower St. Jones River DNERR Reserve includes the interface between two environmental zones of importance in prehistoric settlement systems. Both mid-drainage and coastal environmental zones in the St. Jones Reserve provided favorable settings for large and small prehistoric settlements. The diversity of animal and plant species generally found where these two zones meet provides a rich resource base for people who hunted and gathered. Sites in this area provide an opportunity to examine human adaptation to a developing estuarine environment over a span of more than 8,000 years. In the mid-drainage zone of the St. Jones Reserve, there is a probability of base camps and procurement sites from the Archaic Period (6500 B.C. to 3000 B.C.) and the Woodland II Period (A.D. 1000 to A.D. 1600). There is also a high probability for sites through the entire span of the Woodland I Period (3000 B.C. to A.D. 1000). In the coastal zone of the St. Jones Reserve, there is a probability of Archaic procurement sites and high probability of Woodland I and Woodland II base camps and procurement sites. A total of 32 prehistoric archeological sites in upland areas fringing the St. Jones River marsh have been reported in the Cultural Resource Survey maintained by the Delaware Bureau of Archaeology and Historic Preservation.

Historic period sites in the Lower St. Jones River Reserve include the earliest settlements in Kent County (e.g. Kingston-Upon-Hull and Town Point), and present an opportunity to study an early period of European settlement, removed from population centers in New Castle and Philadelphia. The historic John Dickinson (“Penman of the Revolution”) Plantation and Mansion, on the north side of the St. Jones River and east of Route 113, is adjacent to the St. Jones Reserve.

Upper Blackbird Creek Reserve

The Blackbird Creek DNERR Reserve is in an environmental setting similar to that of the Lower St. Jones River component, and therefore has similar probabilities for base camps and procurement sites. A total of 73 prehistoric archaeological sites in upland areas fringing Blackbird Creek marsh have been reported in the Cultural Resource Survey. Blackbird Creek uplands and stream courses were intensively used from 3000 B.C. to A.D. 1000. The large number of bay/basin features between Blackbird Creek's mid-drainage and coastal environmental zones favored establishment of sites of large size and permanence at the convergence of these zones. Changes in settlement patterns by the Woodland II Period (A.D. 1000 to A.D. 1650) focused food acquisition strategies primarily on estuarine resources in the floodplain, rather than in upland areas.

Although the Upper Blackbird Creek area has been identified as a focus of European settlement in the 17th century, no sites from this time period have been identified in archaeological collections, so nothing is known about the Contact Period in this area. This period covers the time from first contact on the Delmarva Peninsula between Native Americans and Europeans (about A.D. 1600), to the disappearance of recognizable Native American tribal groups in the first half of the 18th century. The earliest historic period settlement in Upper Blackbird Creek is the Huguenot House (built in the first quarter of the 18th century), which is listed on the National Register of Historic Places.

ENVIRONMENTAL STRESSORS (PAST, PRESENT AND FUTURE)

Water Quality and Toxics

Many factors are responsible for degradation of water quality in Upper Blackbird Creek and the Lower St. Jones River. These factors are common throughout the Delaware Estuary, and include chemical toxins such as heavy metals, pesticides, polychlorinated biphenyls (PCBs), and hydrocarbons, as well as excessive levels of nutrients (nitrogen and phosphorus) and bacteria (Sutton et al, 1996).

PCB contamination

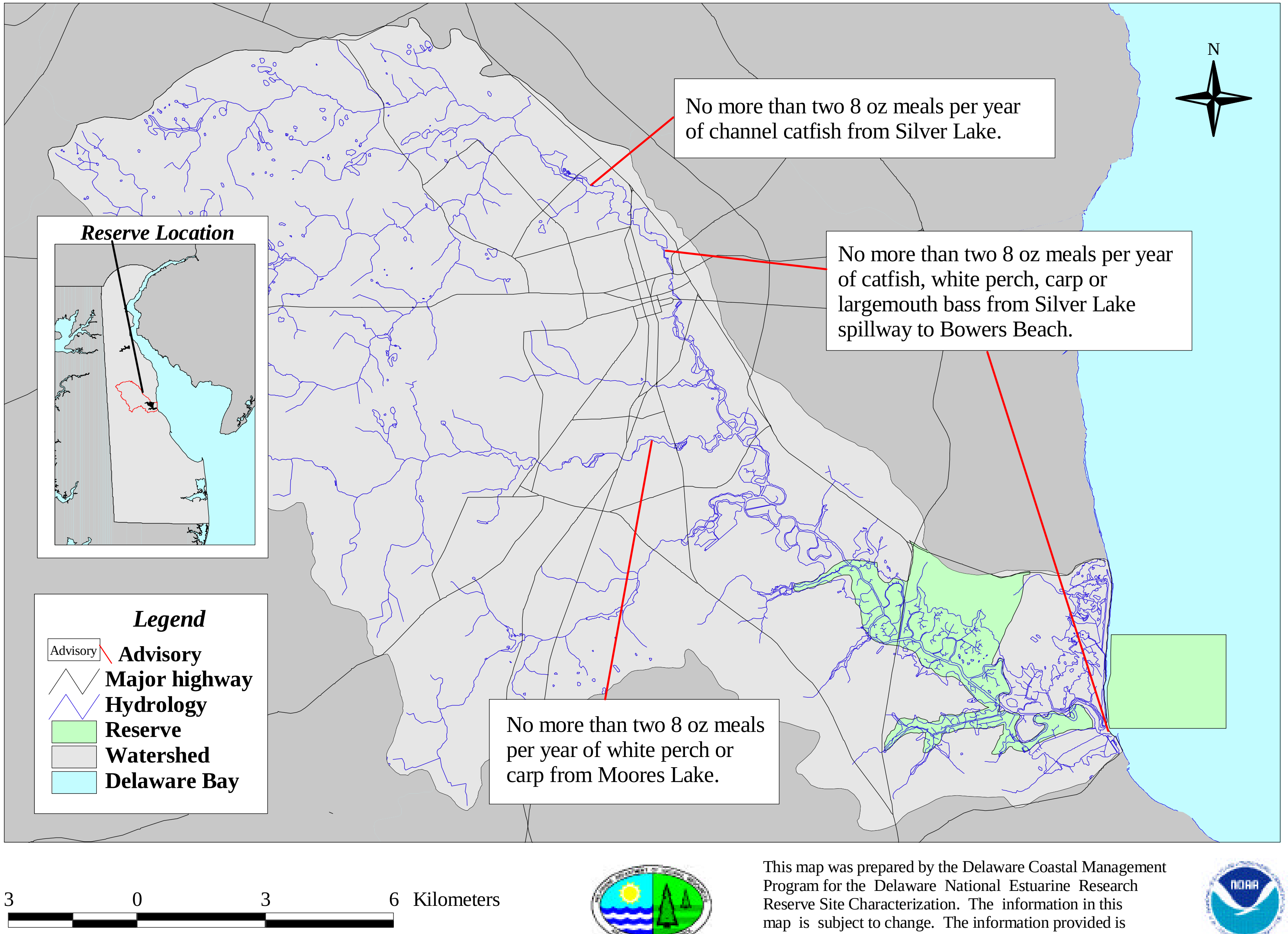
Of the two Reserve sites, the Lower St. Jones River has more recognized problems in terms of water quality, in large measure caused by urbanization of the upper watershed.

Surface water, groundwater, sediment, and tissue samples from various fish species all were found to contain high concentrations of PCBs (DNREC, 1995). Contamination of fish tissue by PCBs has been a problem in the St. Jones River watershed for many years, in many tidal and several non-tidal reaches. According to DNREC reports, recent tests have confirmed the presence of elevated levels of PCBs in several fish species taken from different locations. A health advisory issued on March 18, 1993 for the St. Jones River states that no more than two 8-ounce meals per year of catfish (white, brown, or channel), white perch, carp or largemouth bass, caught in upper portions of the St. Jones River downstream to Bowers Beach, should be eaten due to cancer risks from PCBs (Figure 46). Other species found in the St. Jones to contain PCBs were American eel and blue crab, but no health advisories have been placed on them (DNREC, 1993b). It is not well understood where the PCBs in the St. Jones River watershed originated, but they might well have been from now discontinued point-source discharges. There is not much effort underway to remediate what has accumulated throughout the watershed, but the situation does not seem to be getting worse.

Contamination from PCBs and other toxic substances is occurring throughout the Delaware Estuary as well, and is affecting many fish, shellfish, and birds. High levels of toxins have been observed in striped bass, white catfish, osprey, mussels, and oysters. Toxins polluting the sediments and waters of the Delaware Estuary are the result of both point and nonpoint-sources of pollution.

Point-source pollution

Point-source pollution is characterized as anthropogenic (human-induced) pollution from specific sources or locations, usually industrial or municipal in nature. Point-source pollution makes up about 62% of the toxic substances that enter the Delaware Estuary (Sutton et al, 1996). Common substances associated with point-source pollution include



No more than two 8 oz meals per year of channel catfish from Silver Lake.

No more than two 8 oz meals per year of catfish, white perch, carp or largemouth bass from Silver Lake spillway to Bowers Beach.

No more than two 8 oz meals per year of white perch or carp from Moores Lake.

This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 46. St. Jones River Watershed: Delaware Fish Consumption Advisory Areas, as issued in a health advisory on March 18, 1993 by the Delaware Department of Health and Social Services and the Department of Natural Resources and Environmental Control.

metals such as lead, zinc, copper, mercury, arsenic, chromium, and silver, as well as volatile organics including 1,2 dichloroethane and tetrachloroethene. All of these substances can have negative effects on aquatic and human health.

Dover's central sewer system (which eventually feeds into Kent County's sewage treatment plant on the Murderkill River near Frederica) has occasional problems with combined sewage overflows during heavy rainfalls, as well as occasional breakdowns of sewage pump stations. Both periodically contribute untreated wastewaters to the St. Jones River at specific (point-source) locations. There are also four sites within the St. Jones River watershed under the auspices of DNREC's National Pollution Discharge Elimination System (NPDES) which constitute permitted point-source discharges of industrial wastewaters – McKee Run, Reichold, Playtex, and City of Dover power plant. There are no NPDES-sites in the Blackbird Creek watershed.

Overall, as in many other areas of the state and country, problems with point-source discharges of contaminants are now relatively well understood, identified, and for the most part under control.

Nonpoint-source pollution

The Delaware Nonpoint Source Pollution Program describes nonpoint-source pollution as any human-induced pollution that does not come from a precisely defined location (DNREC, 1995). Nonpoint-source (NPS) pollution includes, but is not limited to, pollution from agriculture, construction, urban runoff, resource extraction, land disposal, atmospheric deposition, and unknown nationwide sources. Nonpoint-source pollution is currently responsible for about 45% of all pollution impacts to estuarine ecosystems (Sutton et al, 1996). The most common sources of nonpoint-source pollution within the Delaware Estuary are urban runoff, agricultural runoff, and atmospheric deposition. Toxic substances commonly associated with nonpoint-source pollution include polychlorinated biphenyls (PCBs), usually from Superfund sites; polycyclic aromatic hydrocarbons (PAHs), usually from atmospheric deposition; and DDT and chlordane in various runoff. Many federal, state and local programs are currently being developed or implemented to combat nonpoint-source pollution, but more resources are needed if substantial reductions are to be achieved.

Nonpoint-source pollution is causing water quality problems in the St. Jones River and Blackbird Creek watersheds. According to reports from the Delaware Nonpoint Source Pollution Program, there is a high level of concern over contaminated surface and ground water in the St. Jones River watershed stemming from problems with nonpoint-source pollution from agriculture, silviculture, and urban runoff (DNREC, 1995). Because of increased development and construction near the Lower St. Jones River, an increase in polluted runoff is anticipated over the next several years. In the Blackbird Creek watershed, there is high level of concern over nonpoint-source pollution problems associated with silviculture, as well as problems associated with nonpoint-source pollution from agriculture runoff and land disposal (DNREC 1995).

Nutrients in the form of nitrogen and phosphorus are of considerable concern for water quality in the Delaware Estuary. There are multiple industrial and agricultural sources of both nutrients in upper reaches of the estuary, coming from both point and nonpoint-sources. Of particular concern in both Reserve watersheds is the contribution of dissolved and particulate nutrients (primarily nitrogen and phosphorus) and suspended sediments from agricultural runoff, associated primarily with corn and soybean production or animal feedlot operations. However, in the St. Jones River watershed, significant contributions of nonpoint-source pollution also occur from developed areas with impervious surfaces and residential landscapes, and in upper reaches of the Blackbird Creek watershed from silviculture activities. A major concern with excessive nonpoint-source nutrient runoff in Delaware and elsewhere is its contribution to creating or exacerbating eutrophication of estuarine waters, which in some areas might manifest itself in nuisance or harmful algae blooms, or in low nighttime dissolved oxygen concentrations. Leaching of nutrients and bacteria from septic fields into surface and ground waters, and atmospheric deposition of nutrients and toxic chemicals to surface waters, also contribute to nonpoint-source pollution problems.

The effects on nutrient loading (with emphasis on nitrogen) from differing land uses in the St. Jones River watershed are being examined by the DCPS. Data from over 150 stormwater runoff samples of six land use types were used to develop Event Mean Concentrations (EMC) values for nutrients in surface runoff. Preliminary analysis indicates agriculture and single family residential lots of less than 0.2 ha (0.5 ac) have the highest loading rates of 2.56 and 2.21 ppm total nitrogen respectively. It must be noted that the agricultural sites were all farming operations that employed Best Management Practices (erosion reducing practices), and might not be values typical of all agricultural locations. The other locations ranged from 1.77 to 1.27 ppm total nitrogen in the following decreasing order: residential greater than 0.2 ha. (0.5 ac), forest, multi-family, and commercial/industrial locations. Phosphorus EMC values portray agriculture having significantly higher values of 0.35 ppm, as compared to 0.10 to 0.20 ppm for the other sites. These values, however, must be coupled with increased runoff amounts from urbanized land uses to fully understand the impact of development on surface runoff. Additionally, the influences of increased nutrient values in groundwater under agricultural lands, and subsequent baseflow from these groundwaters, also have to be included in determination of the total watershed nutrient loads. A complete analysis of nitrogen loading from all sources, and results of a numerical model of the watershed dynamics of the St. Jones River, will be available by mid-1999.

As compared to other aquatic systems, the Delaware Estuary experiences almost double the phosphorus loading and four times the nitrogen loading as does northern San Francisco Bay, and over ten times the level that Chesapeake Bay receives for nitrogen and phosphorus (Sutton et al, 1996). The only large area in the U.S. with heavier nutrient loading is the apex of New York Bight. However, beginning at Marcus Hook, Pennsylvania, there is a progressive decline in nutrient concentrations going downstream in the Delaware Estuary. The lowest nutrient concentrations are found at the mouth of the Delaware Bay. This pattern reflects the intensive urbanization that affects the Delaware River as it passes through the Philadelphia/Camden urban area.

Land-use Conversions and Corollary Impacts

Going beyond the obvious large-scale, permanent conversions of originally forested lands to agriculture fields or population centers, several other forms of land-use conversions or alterations have negatively affected water quality and wildlife habitat in both Reserve watersheds. These conversions include highway construction, development of exurban residential subdivisions, creation of borrow pits for sand and gravel mining, installation of septic systems in environmentally sensitive areas, non-selective ditching of coastal marshes for mosquito control, and operation of a major airbase.

Highway construction has become a concern to upstream areas of the Upper Blackbird Creek DNERR site. Construction of the Route 13 Relief Route will directly affect the most landward portion of upper tidal Blackbird Creek, by reducing existing wildlife habitat and possibly degrading water quality from sediment runoff and other contaminants. Once highway construction is complete, the rate of development of nearby areas is expected to increase dramatically. Accelerated land conversions will undoubtedly occur along or near Blackbird Creek in the form of “bedroom” residential communities, since the new highway will improve the commute to urban work centers in northern New Castle County. This in turn will probably lead to increases in septic system problems. Along with new residential subdivisions will come more land conversions for schools, roadside shopping centers, golf courses, etc. This increased development is sure to further encroach on wildlife habitat. Some other concerns include polluted runoff from the new road, as well as dangers to wildlife posed by traffic. Even given the county’s recently adopted Uniform Development Code, land-use regulations currently in place in New Castle County might not be effective for the Upper Blackbird Creek Reserve in preventing substantial water quality or habitat degradation caused by future overdevelopment.

As a result of the increase of residential developments in Delaware, there has been an increase in problems associated with sewer and septic systems, especially in environmentally sensitive areas. Due to the aggressive development of central sewer systems as desirable alternatives to on-site septic systems, there have been fewer problems associated with septic systems in New Castle County than in Kent or Sussex Counties. In Kent County, septic system problems exist in many localized areas, especially in tidal beach communities such as Woodland Beach. In Woodland Beach, faulty septic systems are being blamed for recent bacterial contamination of local shellfish beds (DNREC, 1995). Communities associated with failing septic systems within the Lower St. Jones River watershed are Kitts Hummock and Pickering Beach.

Wenner et al. (1998) used NERRS System-wide Monitoring Program (SWMP) water quality data from five southeastern NERRS sites and Charleston Harbor, S.C. to determine that salinities fluctuate over greater ranges during rainfall events for tidal creeks with urban, industrial or suburban land cover, as opposed to forested cover. The researchers attributed this higher variability in salinities in creeks surrounded by development to “flashier” runoff events resulting from increased amounts of impervious surfaces (e.g. roofs, roads, parking lots). Wider or more extreme fluctuations in salinities can adversely affect estuarine organisms.

Mining of sand and gravel occurs frequently at borrow pits throughout Delaware, including within the DNERR’s watersheds. In recent years, there has been much concern over adverse effects and environmental stresses that borrow pits have on surrounding environments. Both active and abandoned pits pose problems for local county regulators.

Active borrow pits pose a variety of environmental problems and concerns. The lowering of ground water tables is a problem that affects surrounding residents who share the same ground water. Contamination of ground and surface waters from fuel and other industry-related materials leaching into borrow pits poses threats not only to humans who use the water, but also to fish and wildlife (DNREC, 1995).

Another major concern arises from abandoned borrow pits. Sites that have been shut down or abandoned pose problems because they are frequently converted into illegal dumping sites. According to reports by the Delaware Nonpoint Source Pollution Program, borrow pits in this category are common in Delaware (DNREC, 1995).

It is the responsibility of each county in Delaware to properly regulate borrow pits. In New Castle County, applicants must go through a tedious process for pit approval.

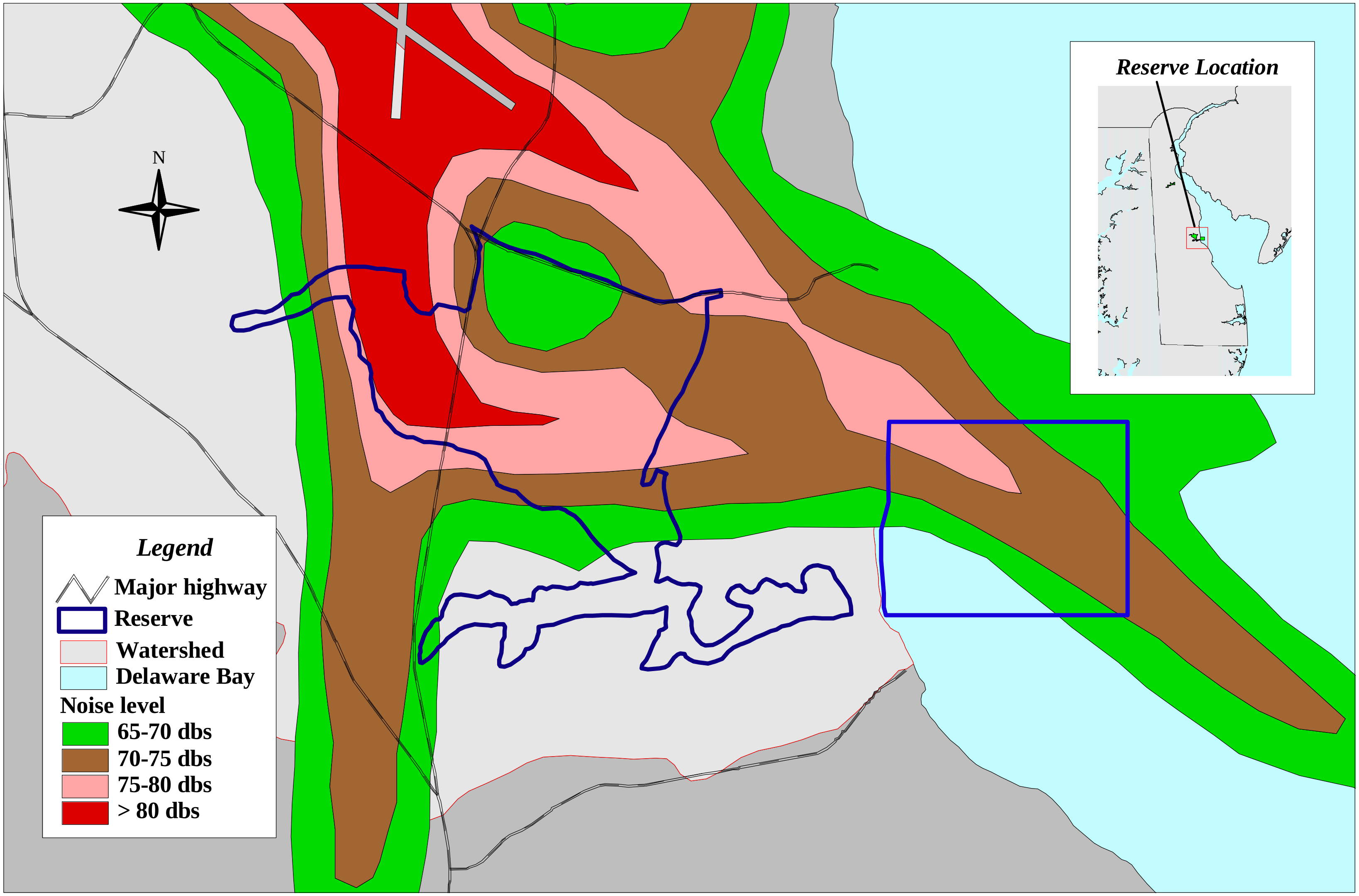
Applications for permits must contain many regulatory supplements including erosion control plans, sediment control plans, restoration plans, and future groundwater monitoring plans. Presently, Kent County is not accepting new applications for borrow pits, and will not do so until new state regulations are passed.

As mentioned earlier, land-use conversions to residential development along certain watercourses can create septic system problems that eventually lead to bacterial contamination of inshore shellfish beds. The oyster bar at the mouth of the St. Jones River is closed to harvest. Prohibitions against harvesting shellfish on a year-round or seasonal basis are now in effect for 109 sq. km (42 sq. mi) of Delaware Bay (NOAA, 1994). A concern that now exists is even if oyster diseases are eradicated, in many areas bacterial contamination associated with development will still prohibit oyster harvests.

A form of land-use conversion, or more accurately a type of land-cover alteration, was done in the name of mosquito control to thousands of hectares (acres) of Delaware's coastal marshes between the 1930's and 1960's. In the 1930's, in order to reduce the problems associated with saltmarsh mosquito production and to create jobs during the Great Depression, the Civilian Conservation Corps initiated a program of excavating a series of shallow, parallel ditches about 46 m (150 ft) apart in marshes where saltmarsh mosquito breeding was prolific. The simplistic reasoning behind this action was that since mosquitoes breed in marsh water, widespread drainage of marshlands would solve the problem. In a majority of the cases over time, this technique did not work as well as desired, and often had many more negative effects than positive ones. This technique seriously altered marsh hydrology, and also drained a substantial amount of marsh ponds and pannes that were considered quality fish and wildlife habitat. Many of these areas never bore mosquitoes. Unfortunately, the majority of tidal wetlands in Delaware were parallel-grid-ditched (DNREC, 1992), including extensive alterations to marsh surfaces in the Lower St. Jones River Reserve.

As a result of parallel-grid-ditching for mosquito control, marsh vegetation was greatly affected, due to lowered subsurface water levels and spoil deposition. As the ditched areas became altered and drained, high marsh and upland vegetation often began to take over in dewatered marsh areas or on elevated spoil piles (Daiber, 1986 and 1987). The level of saltmarsh mosquito control achieved by parallel-grid-ditching was often not acceptable, and today a majority of ditched high marshes continue to produce saltmarsh mosquitoes and are often sprayed. Fortunately, the damage that parallel-grid-ditching did to the marshes of Delaware has been partially restored in certain locations by modern use of Open Marsh Water Management (OMWM) for mosquito control (Sutton et al, 1996). OMWM, with its selective ponding and ditching for biological control of mosquitoes, might someday be implemented in the Lower St. Jones River Reserve, which should help both to reduce current use of insecticides and restore marsh surface waters.

A unique stressor that was addressed when considering development of the Lower St. Jones River DNERR site was the effects of flight paths and noise levels of aircraft using nearby Dover Air Force Base (Figure 47). Since only a small portion of the St. Jones River Reserve is located within an "Accident Potential Area" as labeled by the Air Force Base, noise level from planes landing and taking off is really the primary concern. However, only a small upland area within the boundaries of the Reserve is located within noise contours of >70-80 decibels (greater than 75 db equals "High Noise Zone"). Fortunately, the location for the new DNERR facility, slated for completion by mid-1999, is in an area where overhead aircraft noise is relatively tolerable (DNREC, 1992). Additionally, because the structure is designed to absorb as much sound as possible, the impacts from



This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 47. St. Jones River Reserve: Noise levels from Dover Air Force Base

aircraft noise on DNERR educational and research activities taking place in this facility should be minimal. However, the extent of aircraft noise impacts to the Reserve's wildlife is unknown -- aircraft passing overhead have been observed to put resting waterfowl or feeding shorebirds into temporary alarm flights, performed at some energetic cost to the birds. At one time the DNERR sought funds from the U.S. Air Force (Department of Defense) to study such noise effects on wildlife, but to date no support has materialized.

Dredging and Channel Maintenance

Dredging of the Delaware River has been a necessary operation ever since the late 1800's, and has affected both shoreline and open water habitats. The first Congressionally-approved dredging of the Delaware River channel occurred in 1885, in order to accommodate larger vessels that were then using the waterway. The channel was repeatedly dredged as needed, until it became an established annual operation by the mid-1900's. By 1967, approximately one billion cubic yards of sediment had been removed from the Delaware River and deposited in various tidal marshes along the river's shoreline (United States Army Corps of Engineers, 1967). It was about this time that dredge spoil disposal had become a substantial problem. Many dredge spoil disposal areas were created along the Delaware River, and most of these sites have the capacity to accept more dredge spoil for up to about 50 years (Sutton et al, 1996).

As a result of deepening the Delaware River channel, there have been some noticeable effects in upper and lower portions of the Delaware Estuary. In the upper portions, an increase in tidal amplitudes was seen following dredging. Throughout the entire estuary slight changes in salinity, turbidity, oxygen levels, and water quality occurred soon after dredging (Sharp et al, 1994). Even though these changes are slight, they can affect many organisms that are sensitive to changes in their environment.

The current proposal by the U.S. Army Corps of Engineers to deepen the main shipping channel of Delaware Bay and River by an additional 1.5 m (5 ft) has created new environmental concerns. How such a deepening might affect the DNERR lands cannot be said with certainty, but most effects will probably be minor since both DNERR sites are not in close proximity to dredging areas. The most substantial effect might involve the potential for using some main channel dredged material to nourish Delaware Bay shorelines, in areas where erosion has caused problems to beachfront developments, such as at Bowers Beach or Kitts Hummock near the Lower St. Jones River Reserve. It is even possible that some of this main channel dredge material might be used to replenish the Bay shoreline at the Ted Harvey Conservation Area in order to protect the Logan Lane Impoundment levee, and to try to maintain good habitats for horseshoe crab spawning and migratory shorebird feeding. However, before any beachfront placement of dredged spoil occurs, any concerns about the dredged material's suitability would first have to be fully resolved (e.g. issues regarding appropriate grain size and composition, or presence of toxic contaminants).

Shoreline Erosion Problems and Relative Sea-level Rise

Shoreline erosion has become a major problem in many areas along Delaware River and Bay. Along with rising relative sea levels, shoreline erosion is a major concern in wetland shoreline protection and maintenance. The primary causes of shoreline erosion are waves generated within the Bay (Delaware Coastal Management Program, 1978). Shoreline protection techniques range from structural "hardening" techniques to non-structural dune stabilization methods.

In the past, popular methods of controlling shoreline erosion have been the installation of bulkheads, seawalls and other permanent structures. These structures have had varying degrees of success in addressing property protection, but in many cases have seriously altered surrounding environments, eliminating critical habitat for animals including shorebirds and horseshoe crabs. Treated wooden bulkheads have also been known to contaminate areas with wood preservatives. In general, these structures have posed many water quality and geomorphologic problems to surrounding ecosystems, and have often accelerated beach erosion instead of decreasing it.

In 1974, the Federal Shoreline Erosion Control Demonstration Act was passed, which generated funds specifically for the installation of offshore breakwater structures at Kitts Hummock (Fordes, 1981), near the Lower St. Jones River Reserve. This breakwater was installed to reduce wave height and energy, intending to reduce the on-going erosion of the Kitts Hummock shoreline. Recently, newer methods, known as natural non-structural control methods, have been implemented to combat shoreline erosion (DNREC, 1993a).

Natural non-structural control methods are less severe to surrounding ecosystems and often are just as effective in certain areas. Constructing gentle slopes, then planting them with saltmarsh cordgrass (*Spartina alterniflora),* greatly reduces the strain that waves put on shorelines and naturally stabilizes the system. These methods often create more habitat for many fish and wildlife species, and the results are much more beneficial than structural control methods such as rip-rap or bulkheads.

The effects of relative sea-level rise and associated processes (shoreline retreat and coastal inundation) are known to have significant impacts on estuarine environments. Mean sea-level has been rising relative to the land surface of Delaware and New Jersey shorelines for the past 14,000 years. The approximate rate of sea-level rise relative to the coast of Delaware Bay is presently averaging 30 cm/century (1 ft/ century) (Kraft et al, 1987). As relative sea-level rises, some tidal marshes may undergo increased rates of inundation and flooding, while others might migrate landward or become infilled with sediments. Schuyler (1993) reported shifts in the distribution of brackish and freshwater aquatic plant species in the upper Delaware River Estuary that are consistent with relative sea-level rise. Species such as *Spartina alterniflora* now occur farther up river than in previous surveys.

The predicted increase in rate of sea-level rise due to expected global warming from the "greenhouse effect" suggests that a 1 to 3^{o} C (3 to 10^{o} F) increase in global temperature could result in a 30 to 60 cm (1 to 2 ft) rise in mean global sea-level over the next century (Titus, 1988). Combined with local land subsidence, the relative rate of sea-level rise along the Delaware Estuary coast could possibly be higher.

U.S. Environmental Protection Agency projections are for mean sea-level to rise between 4.9 and 17.1 cm (0.16 and 0.56 ft) between 1995 and 2000. By 2100, projections show a rise from 54 cm (1.8 ft) to possibly 3.4 meters (11.3 ft) (Kraft, 1988). Eventually these increases will pose severe problems for human and natural communities along the Delaware Bay shoreline. Potential impacts at the Reserve sites include a landward shift in tidal wetland vegetation and a loss of tidal marsh in areas of steep upland slopes or hardened shorelines. These topics are currently being researched by a DNERR Graduate Research Fellow associated with the University of Delaware, College of Marine Studies (Vinton Valentine, pers. comm.). This investigation includes consideration of channel straightening and other anthropogenic effects.

At a minimum at both Reserve sites, accelerated relative sea-level rise will involve a landward transgression of emergent wetlands into areas that are currently uplands, and a seaward loss of tidal marsh caused by increasing inundation. How well Reserve lands (and other areas) handle this inevitable change, especially in terms of maintaining tidal wetlands quantity, will depend in large measure upon land-use policies along the wetlands' upland borders, and perhaps upon how well engineered remedies (e.g. thin-layer spoil disposal, or levee construction with managed tidal flows) are used or not used.

Landfills/Industrial Waste Sites

Landfills and industrial plants constructed and operated during eras of less restrictive or non-existent environmental regulations can present serious on-site toxic contamination problems to wildlife, and cause both on-site and off-site degradation of surface and ground water quality arising from site leachates. As such, depending upon types of contaminants involved and areal extents of problem sites, landfills and industrial operations can contribute to both point- and nonpoint-source pollution.

A few dozen federal Superfund sites are found in Delaware. The St. Jones River watershed has three federal Superfund sites, which are locations of serious contamination listed on the EPA's National Priority List (i.e. NPL-sites) – Wildcat Landfill, Dover Gas Light Company, and Dover Air Force Base. No federal NPL-sites are in the Blackbird Creek watershed.

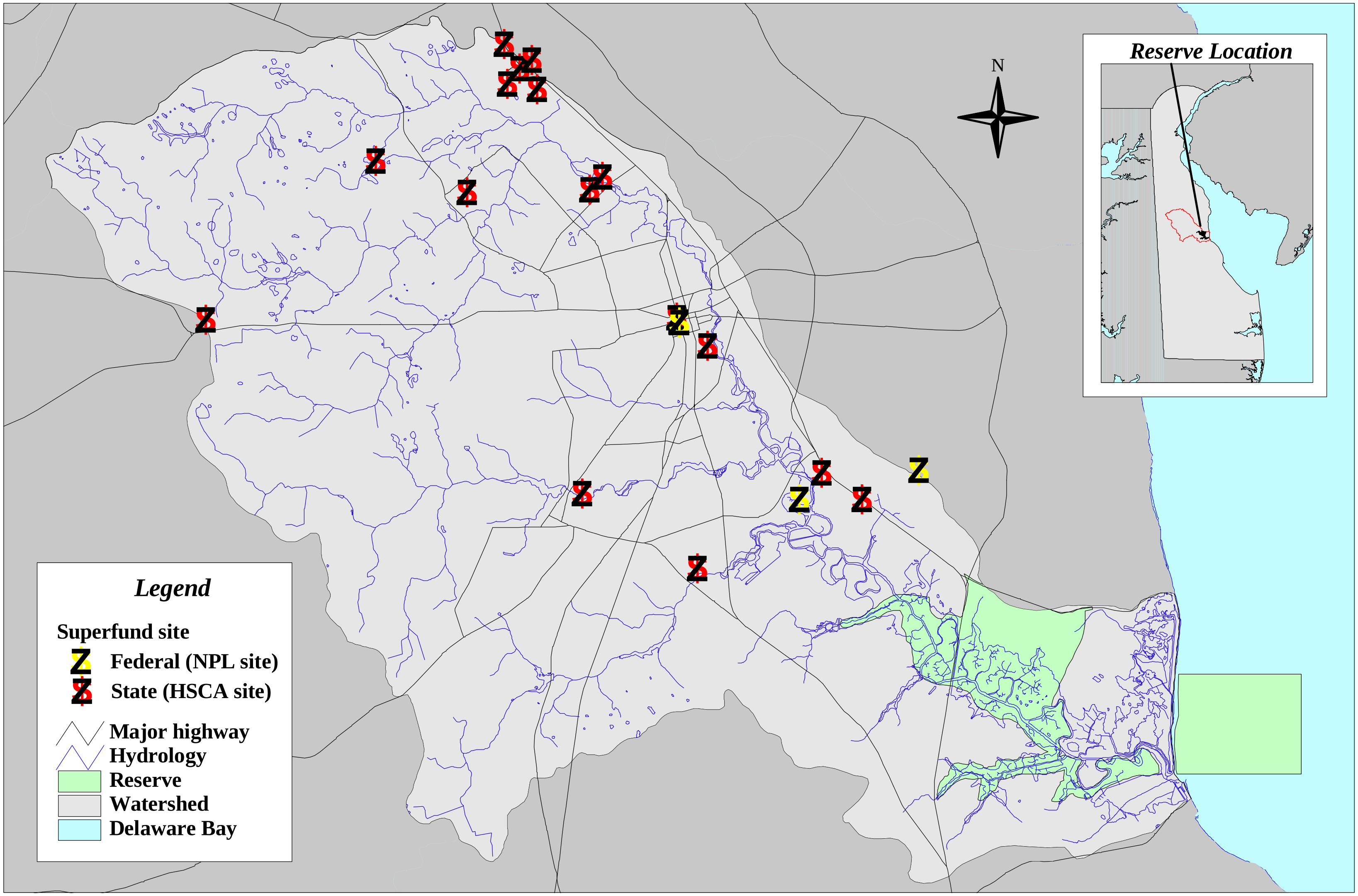
The Wildcat Landfill, located along the St. Jones River's banks about 3.7 km (2 miles) upstream of the Reserve's western boundary, was a privately owned and operated industrial and municipal waste disposal facility, closed in 1973 due to permit violations. The wastes were being disposed of illegally in uncovered drums, as well as into marshes and ponds. As a result of these poor disposal practices, ground water, surface water and soil sediments along the St. Jones River corridor were contaminated with PCBs and other toxins (DNREC, 1994).

Remedial actions at Wildcat Landfill began in 1991 and have been completed. A soil cap was installed, leachate seeps were removed, and a pond that was used for disposal was drained and mitigated. The restoration process was a success, and what used to be an industrial waste disposal facility has been reclaimed for wildlife purposes, serving as an excellent model for rehabilitating other landfills. There are still high concentrations of PCBs found within the St. Jones River, but the Wildcat Landfill is no longer a source of these toxins.

The Dover Gas Light Company site, located in downtown Dover, produced gas from coal for street lamps from the late 1800's to middle 1900's. In 1989, the site was put on the EPA's National Priority List because of heavy contamination by coal tar in surrounding soils and groundwater. According to the Delaware Nonpoint Source Pollution Program, the Dover Gas Light Company was also a source of PCB contamination in the St. Jones River watershed (DNREC, 1995). As of fall 1998, contaminated soil is being excavated and a groundwater treatment system is in design. The location of this NPL-site is not as problematic for the Lower St. Jones River Reserve, and contaminant remediation is currently underway.

The third NPL-site is the Dover Air Force Base. Ground water contamination with volatile organic compounds (solvents and gasoline) resulting from over 50 years of aircraft operations is a problem, which is currently being remediated by several measures. A few contaminated ground water plumes from the base might have reached small tributaries of the St. Jones River, but based upon ecological screenings to date, impacts to the river appear to be negligible. There are also some possible impacts to surface waters by heavy metals associated with stormwater runoff and by the base's industrial wastewater treatment plant, which are currently being evaluated.

In addition to federal Superfund NPL-sites, there are also many locations where lesser but still problematic contamination problems have occurred. In Delaware, the identification and remediation of these contaminated sites, which also primarily involve abandoned landfills and industrial plants, is handled by DNREC’s Division of Air and Waste Management under Delaware’s Hazardous Substance Control Act, essentially involving state-level “superfund” sites (HSCA-sites). Within the St. Jones River watershed there are 33 HSCA-sites (Figure 48), while none occur in the Blackbird Creek watershed.



2 0 2 4 Kilometers

This map was prepared by the Delaware Coastal Management Program for the Delaware National Estuarine Research Reserve Site Characterization. The information in this map is subject to change. The information provided is only an approximate graphical representation.

Figure 48. St. Jones River Watershed: Federal and State Superfund Sites

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