

Accomack Literature Review

K. Hill, September 2009

Overview

Many planning agencies can benefit from an up-to-date review of the existing scientific literature on topics that might be relevant to contemporary public policy decisions. The Green Infrastructure Center (GIC) seeks to provide support to Accomack County on developing a strategy for conserving biodiversity and cultural resources in the County. This literature review is intended to be a resource to both the County and the GIC as they consider how to develop strategies for the County in relation to its biodiversity resources.

This review is organized into three sections. The first is a brief categorization that identifies the author type and content type of each of the studies reviewed. The second identifies particularly useful studies that provide information about assets, risks, and recommendations for Accomack County. The third section contains a comparison of the issues raised by the Accomack County planning staff, noted by the GIC, and the available literature (providing a research gap assessment).

I examined 108 references provided by the Green Infrastructure Center that were listed in the electronic document "Accomack Literature Review Draft, 6-30-09 ag_clc.xls." I also included 12 additional documents, which contain information from Federal agencies and non-profit organizations that may be of use to the GIC and Accomack County. The primary goal of the review was to assess whether there is an existing literature base on topics of use to Accomack County planning staff. Since effective planning generally relies on a standard that is often described as "best available science," this review distinguishes between research studies that have been subjected to blind peer-review and studies that may have been peer-reviewed in other ways, or that were probably not subjected to peer-review at all. While the information available in any of these types of studies may be valuable, peer-reviewed scientific research is the most defensible basis on which to draw generalizable conclusions about dynamics that may affect resources, ecosystems and species before weighing public policy decisions.

Those three categories provided a framework for assessing the literature in this review. Most of the literature reviewed here has been published in peer-reviewed journals (44%). The next largest group of studies was published by government agencies (34%), which often involve internal peer review. The final group was published by non-governmental organizations or by academic research institutions with funding from government agencies, but no peer review appears to have been applied to them (22%).

In addition to the question of whether a study was peer-reviewed or not, it is useful to know whether the research consists of a description of the status of a population or resource at a single moment in time, or whether it assesses changes in that resource or population over time. This distinction is important because studies that ask questions about change over time are more useful to planning efforts that must project the future status of a valued resource or species in order to advise policymakers about how to

sustain those resources or populations. In this study, 51% of the studies reviewed were descriptive assessments of the status of a landform, ecosystem, or species. 54% of the studies included information about either (1) change over time, (2) causal links related to these changes, or (3) strategic recommendations for managers. About 8% of the studies reviewed here contained analyses that attempt to predict future trends.

In addition to studies of change over time, some studies tested hypotheses using statistical methods. These are particularly important because they provide the most defensible context for making inferences about whether the observations made in a specific study can reasonably be generalized to other locations and instances. Approximately 8% of the studies reviewed here included statistical tests of hypotheses. These 8 studies examined the factors that influence nest sites for birds on barrier islands (Rounds et al, 2004); land use factors that might influence estuary health (Rodriguez et al, 2007); the influence of nitrogen on the decline of native marsh grasses (Day et al, 2004); the influence of flooding on insect diversity (Brust et al 2005); fire history and recurrence intervals on the Delmarva Peninsula (Kirwan and Shugart, 2000); the ways in which gaps in shrub vegetation on barrier islands contribute to diversity in those ecosystems (Crawford and Young 1998); the rates at which saltmarshes assimilate carbon (Kathilankal et al 2008); and identified predation as a significant cause of decline in bird populations on barrier islands, rather than habitat loss alone (Wilson et al 2007).

Of the trends identified in the literature, several are likely to be of paramount importance to future spatial planning efforts. Over the near term, avian and mammalian predator influences on population declines of shore birds seem to be of high importance, since the Accomack County shoreline is of such significance to these species on a continental scale as a breeding or stop-over location. Invasion of native marshes by *Phragmites* grasses is also a very important near-term concern, since it eliminates high-quality habitat areas and can be managed if landowners choose to do so (Virginia Dept. of Conservation and Recreation 2009). Beach erosion seems to also be a problem for species of federal conservation concern, such as plovers (see Watts et al 1996, for example) and Northeastern beach tiger beetles (Fenster et al 2006), a negative trend that may be addressed through beach nourishment. In addition, nitrogen moving from farmland to the eastern shore of Accomack County is clearly an issue for management of fisheries and ecosystems associated with Chesapeake Bay (see the State of Virginia's Tributary Strategy for the Eastern Shore, published in 2005, for a comprehensive review of this issue). On the positive side, loggerhead sea turtles appear to increasingly select nest sites on Assateague Island and other Eastern Shore locations, which are in what has been considered the northernmost part of this species' range. Artificial egg relocation efforts as well as more northerly dispersal by females have affected this positive trend (Boettcher et al 2007).

Over the medium and longer term of 50 to 100 years, conservation of groundwater resources is likely to become a more significant issue. Data show that the rate of sea level rise is increasing, and various predictive models suggest that this increase in rate could be dramatic over a 75 to 100 year timeframe (Gutierrez et al/USGS 2007). Rising sea levels will likely lead to increased problems with saltwater intrusion in groundwater supplies,

given the current depths to saline water (Nowroozi et al. 1999). This trend will also affect infrastructure situated near the shoreline, particularly transportation routes. In addition, sea level rise will have very significant repercussions for coastal habitat conservation, since the predicted levels of inundation are likely to cause a large-scale loss of natural barrier islands and wetlands along both the seaside and the bayside of the Eastern Shore (Titus et al., 2009).

SECTION I. Categorization of research literature

Since effective planning generally relies on a standard that is often described as “best available science,” this review distinguishes between research studies that have been subjected to blind peer-review and studies that may have been peer-reviewed in other ways, or that were probably not subjected to peer-review at all. While the information available in any of these types of studies may be valuable, peer-reviewed scientific research is the most defensible basis on which to draw generalizable conclusions about dynamics that may affect resources, ecosystems and species before weighing public policy decisions.

In addition to the question of whether a study was peer-reviewed or not, it is useful to know whether the research consists of a description of the status of a population or resource at a single moment in time, or whether it assesses changes in that resource or population over time. This distinction is important because studies that ask questions about change over time are more useful to planning efforts that must project the future status of a valued resource or species in order to advise policymakers about how to sustain those resources or populations.

Table 1. Classification of the literature by author and type of study. (Individual studies are typically included in only 1 “author” category but in more than 1 “type” category.)

<i>Author categories</i>	<i>Number of studies</i>
Government documents, not externally peer reviewed:	36
NGO/academic studies, not peer reviewed:	23
Peer reviewed scientific studies:	47
 <i>Types of studies</i>	
Descriptive status assessments:	54
Change over time assessments:	18
Causal link assessments:	19
Hypothesis testing studies:	8

Predictive studies:	8
Studies that include strategic recommendations:	19
TOTAL NUMBER reviewed:	106

This categorization reveals that there are only a small number of studies that could potentially provide the most defensible and generalizable type of causal evidence for the purpose of developing public policy (i.e., the 8% that test hypotheses using inferential statistics). Fortunately, the literature is dominated by peer-reviewed publications, which provide the next highest level of defensibility. In addition, 44 studies address either change over time, causal linkages, or predictions of future system states. These should be most helpful to planners, who must project trends into the future in order to make strategic decisions.

A significant number of studies reviewed here (23) were performed by faculty and graduate students at institutions such as the Virginia Institute of Marine Sciences (VIMS), or William and Mary’s Institute for Conservation Biology, with support from the Coastal Zone Management Program and the National Oceanic and Atmospheric Administration, or by non-profit groups who play an important role in assessing biological resources in the Chesapeake Bay. These contain important information, but – depending on the rigor of the methods used and the training of the people who participated – the quality of that information may be limited, or the motives of advocacy groups may cast doubt on their objectivity. These should be examined on a case-by-case basis, and concurrence with other sources of information should be sought before their conclusions are taken at face value.

SECTION II. Identification of key research studies

This section uses a set of sub-headings that are intended to represent Accomack County’s most significant natural assets. The studies listed under each may describe, test hypotheses about causal links, or otherwise investigate the distribution in space and/or time of these resources. They also identify risks to the persistence of these resources, so the section is titled “Assets and risks.” Sub-headings are meant to break out components of the most important natural resources and ecosystems for individual attention. Brief summaries or characterizations are provided for the literature that is relevant to each significant asset or risk.

A. Assets and Risks

Shoreline areas, biodiversity, and freshwater resources

Before breaking this large topic area down into its component parts, it seems wise to note that resources exist which comprehensively discuss shoreline trends and challenges for the medium and long-term in the Accomack region. There are two new federal resources specific to coastal areas that comprehensively incorporate new scientific evidence behind climate change predictions and provide tools and guidance for adapting to climate change trends. The Environmental Protection Agency's (EPA) coastal toolkit is one example, which includes advice on adaptation planning, identifies data resources, and organizes the best available science relevant to climate change predictions:

<http://www.epa.gov/CRE/toolkit.html>

In addition, a major new report was released in January of 2009 by the EPA as part of the federal government's climate change science program. That report details the likely impacts and policy choices facing coastal areas in the US Mid-Atlantic region, including Virginia's Eastern Shore. It is quite comprehensive, and the chapters on vulnerable species, land use and infrastructure, public recreational resources, and adaptation strategies are very useful for planning and conservation purposes. They detail some of the most vulnerable ecosystems and built systems, and provide a very helpful overview of the spatial distribution of valuable coastal systems that appears to be rare in the existing literature. That new report is titled:

Titus, J., et al., "Coastal Sensitivity to Sea-Level Rise: A focus on the mid-Atlantic region," US Climate Change Science Program, Synthesis and Assessment Product 4.1, January, 2009.

More specific local shoreline surveys have been conducted by researchers at VIMS. In particular, researchers and graduate students have conducted a visual survey from boats of shoreline conditions throughout Accomack County. This is a rapid assessment technique which does not involve extensive field work, but provides a useful approximation of the conditions found along the entire shoreline of the county.

Berman, Marcia; Harry Berquist, Sharon Dewing, Julie Glover, Carl Hershner, Tamia Rudnicki, Dan Schatt, 2002. "Accomack County Shoreline Situation Report," Special Report in Applied Marine Science and Ocean Engineering No. 374 of the Virginia Institute of Marine Science.

The review noted below by the National Wildlife Federation has useful maps and species-level assessments, but the federal study cited above has superseded it since the information contained in that federal publication is more recent.

Glick, P.; J. Clough; B. Nunley, 2008. "Sea level rise and coastal habitats in the Chesapeake Bay region," National Wildlife Federation, Technical Report.

The increasing rate of sea level rise in the Virginia area is the subject of a report by the USGS, published in 2007. This study provides maps of vulnerability that are coarse, but do show meaningful differences along the Eastern Shore.

Gutierrez, B.T., Williams, S.J., and Thieler, E.R., 2007. "Potential for shoreline changes due to sea-level rise along the U.S. Mid-Atlantic region." U.S. Geological Survey Open-File Report 2007-1278. Web only, available at <http://pubs.usgs.gov/of/2007/1278>.

Finally, this somewhat older study documents the validity of Bruun's Rule for the Chesapeake Bay shoreline of Accomack County. Bruun's Rule states that for every increment of sea level rise, the profile of a beach will move inland by a factor of 80-100 times the increment of sea level rise. In other words, if sea level rises by 1 meter over the next 100 years, beach profiles will move inland 80 to 100 meters, due to the dynamic equilibrium established by wave action and sediment transport. This is an important consideration as planners try to estimate the impacts of accelerated sea level rise on coastal areas in Accomack County.

Rosen, P. S., 1978. A regional test of the Bruun Rule on shoreline erosion. *Marine Geology* 26, Letters Section, M7-M16.

The following sub-headings of this review address the major components of these dynamic shoreline systems one at a time.

Dune systems

Dune ecosystems are very significant as breeding areas for threatened species, such as plovers, sea turtles, and beach tiger beetles. In addition to their value for biodiversity, dunes play a very important role in preventing inundation of coastal areas by storms. Natural erosion processes cause these features to be dynamic, but as long as the transportation of sand along the nearshore zone continues and the dunes are allowed to migrate both along the shoreline and inland as sea levels rise, there is potential for these systems to persist over the long-term on the Eastern Shore.

Recreational development of the Maryland coast of the Delmarva Peninsula has limited the longshore transport of sand that would naturally re-supply dunes on the Eastern Shore for decades, and some authors note that Assateague Island and other barrier islands off Accomack County experience significantly accelerated rates of erosion as a result of these coastal interventions to the north. Assawoman Island also shows exceptionally high rates of erosion.

The best article for understanding the biodiversity impacts and linkages of these dynamic dune systems is:

Wilson, M. D., B. D. Watts, and J. E. LecLerc. 2007. Assessing habitat stability for disturbance-prone species by evaluating landscape dynamics along the Virginia barrier islands. Center for Conservation Biology Technical Report

Series, CCBTR-07-06. College of William and Mary, Williamsburg, VA.

The best review of the history of the Virginia dunes in relation to land use and regulations is Varnell and Hardaway 2007, but it is important to note that this file also contains a basic overview of dune geomorphology and ecology that is specific to Virginia's Eastern Shore and very helpful to planners who wish to understand the way that dunes and their associated ecosystems change over time.

Varnell, Lyle, and C. Scott Hardaway, 2007. "The Coastal Primary Sand Dune and Beach Act: Recommendations to Update the Act and Complete the Oversight of Virginia Tidal Shorelines," Virginia Institute of Marine Sciences.

Map-based surveys have been completed of the Accomack dune systems by researchers at VIMS. They have summarized their maps and observations in the following two documents:

Hardaway, C. Scott, Jr, Donna A. Milligan, Lyle M. Varnell, Christine Wilcox, George R. Thomas, 2006. "Dune Evolution in Accomack County, Virginia, Chesapeake Bay Shorelines," Shoreline Studies Program, Department of Physical Sciences and Office of Research and Advisory Services, Virginia Institute of Marine Science College of William & Mary, Gloucester Point, Virginia.

Hardaway, C. Scott, Jr, Donna A. Milligan, Lyle M. Varnell, Christine Wilcox, George R. Thomas, Linda M. Meneghini, Thomas A. Barnard, 2004. "Accomack County Dune Inventory," Shoreline Studies Program, Department of Physical Sciences and Wetlands Program, Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Wetlands

Wetland ecosystems are significant sinks for nutrients such as nitrogen, which is taken up by marsh plants. They also play a major role in supporting aquatic and terrestrial biodiversity, since many species of birds, amphibians, insects, and other forms of life depend on marsh areas for food or refuge. Wetlands also provide significant storm surge buffering, by acting as a sort of bowl or sponge that provides space for floodwaters that originate either on land, driven by rainfall events, or from the sea, driven by wind and tides.

Wetlands are being inundated and eroded in Accomack County, on both the Bay side and the sea side of the Eastern Shore. Rates of sea level rise, storm frequencies, changes in the volume of sediment supplies from rivers or offshore sand bars, and shoreline hardening by property owners all have an effect on the rate at which marshes can accumulate height, and be sustained as the land subsides and relative sea levels continue to rise.

(NOTE: More studies of wetland ecosystems in Accomack County or the region are included under the biodiversity section of this review, because their primary purpose was to study marsh systems in relation to particular birds or other species.)

The Virginia DCR study of wetland restoration potential includes 3 sites in Accomack County proposed for wetland restoration:

Virginia Department of Conservation and Recreation, Division of Natural Heritage, 2008. "Wetland Restoration Catalog."

The spatial issues and landuse management challenges associated with the invasion of native marsh areas by *Phragmites* grasses are best addressed by this study, which contains the most recent maps of *Phragmites* distribution along the Accomack seaside:

Myers, R.K., K.E. Heffernan, P.A. Clarke, and D.P. Field. 2009. "Management and education to control *Phragmites* on the Seaside of Virginia's Eastern Shore." Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. Final report for Year Six of the Seaside Heritage Program submitted to USDC National Oceanic and Atmospheric Administration. Natural Heritage Technical Report # 09-05.

Consequences for avian biodiversity are addressed in Paxton, 2006 (below), with links to maps of specific locations online. These maps should be useful for reviewing other assessments of the biodiversity value of specific patches, since patches that are already invaded by *Phragmites* should be considered of lesser habitat value:

Paxton, B. J. 2006. "Potential Impact of Common Reed Expansion on Threatened High-marsh Bird Communities on the Seaside: Assessment of *Phragmites* Invasion of High Marsh Habitats." Center for Conservation Biology Technical Report Series, CCBTR-06-17. College of William and Mary, Williamsburg, VA.

Relevant to the subject of how and why *Phragmites* replaces native marsh grasses, this study (Day et al 2004) observes that increasing nutrient loads (N) seems to reduce the competitiveness of *Spartina* saltmarsh grasses:

DAY, F.P.; CONN, C.; CRAWFORD, E., and STEVENSON, M., 2004. Long-term effects of nitrogen fertilization on plant community structure on a coastal barrier island dune chronosequence. *Journal of Coastal Research*, 20(3), 722–730.

Submerged Aquatic Vegetation (SAV) beds

Submerged aquatic vegetation beds are the nursery and refuge for many aquatic species during some phase of their lives, including molting blue crabs. These sub-tidal seagrass meadows were once extensive and continuous around the margins of Chesapeake Bay. Reductions in water quality (specifically in the amount of light that can penetrate the water column due to increased amounts of suspended sediments) and erosive storm events such as hurricanes and nor-easter's are major drivers of loss for SAV beds.

Efforts are being made to restore SAV beds in the Bay, with some significant results after simply broadcasting seeds and observing successful germination. There are other limits to the success of these restoration efforts, however, since more rapid rates of sea level rise and shoreline erosion will likely increase turbidity and make it harder to restore these ecosystems to the Bay.

The study noted below by Moore (2006) is a powerpoint presentation that summarizes the issues relating sea level rise to losses of SAV beds.

Moore, K., 2006. "How global warming and climate change may be accelerating losses of Chesapeake Bay seagrasses." The Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Orth et al (2002) includes a very good overview of the causes of SAV bed loss, although the geographic area studied is a bit northwest of Accomack County.

Orth, R., K. Moore, J. Fishman, D. Wilcox, L Karrh and T. Parham, 2002. "Causes of Submerged Aquatic Vegetation Declines in Tangier Sound, Chesapeake Bay." Report prepared for the Chesapeake Bay Program. Virginia Institute of Marine Science, College of William and Mary, Gloucester point, VA.

Halka (2005) provides the best overview of the sedimentation issues that are linked to SAV decline.

Halka, J., 2005. "Sediment in the Chesapeake Bay and Management Issues: Tidal erosion processes," Tidal Sediment Task Force of the Sediment Workgroup under the Chesapeake Bay Program, Nutrient Subcommittee, CBP-TRS276-05, May.

Shrublands

Although ecologists and others recognize shrub ecosystems as important, particularly on barrier islands where they may provide cover for shorebird nests, very little recent research on this ecosystem type was identified for this review. The one piece on the subject is by Crawford and Young (1998), and the introduction provides a valuable overview of the role played by shrub thickets in sustaining biodiversity on Accomack County's islands.

Crawford, E., and D. Young, 1998. "Comparison of gaps and intact shrub thickets on an Atlantic Coast barrier island," Am. Midl. Nat. 140:68-77.

Fauna/flora (biodiversity)

Virginia's State Wildlife Action Plan, specifically, "Chapter 4. Virginia's Coastal Plain," has the best descriptions of species life histories and locations where they occur. This is the best single resource for information about the species that Accomack County staff has identified as of interest to them. Other Tier I, II, III and IV species are included as well.

In summary, these Accomack County species are considered "Tier I," and their habitat needs are primarily in marshes, grasslands, and barrier islands. Predation by mammals and gulls, and disturbance by humans during nesting season (April 1 – July 31, collectively) are considered leading causes of their population declines.

Table 2. Habitat needs of Tier I species in Accomack County. For all of these species, sites in Accomack County are considered very important for reproduction or refuge.

Tier I species	Habitat needs
Loggerhead sea turtle	Seaside beaches above high tide
Piping plover	Seaside barrier islands
Wilson's plover	Seaside barrier islands
Peregrine falcon	Coastal bridges, towers, nest platforms
Henslow's sparrow	Bayside grasslands and marshes
Gull-billed tern	Nests in marshes or barrier island beaches, mammalian nest predators a big problem
Black rail	High salt marshes (<i>Phragmites</i> invasion a big problem)

A multi-agency map has been produced that shows the typical habitats of shorebirds of concern, and the ownership pattern of coastal land that is important to these birds. This file is named "nestingmapbarrierislands.pdf" in the literature files that accompany this review.

A draft introduction to an EIS that was done to study the possible effects of introducing a non-native oyster provides an excellent overview of the biodiversity issues in Chesapeake Bay. This file is called "Oyster introduction - Draft EIS - overview of CBay ecological issues.pdf"

There are many studies related to the status and life history of individual species. The best overview of shorebird issues is:

Watts, B. and B. Truitt, 2000. "Abundance of Shorebirds along the Virginia Barrier Islands During Spring Migration," Vol 71, No 2, The Raven.

The best (and only) reference on the federally-threatened beach tiger beetle is here (note relationship to beach nourishment, which seems to benefit this species):

FENSTER, M.S.; KNISLEY, C.B., and REED, C.T., 2006. Habitat preference and the effects of beach nourishment on the federally threatened northeastern beach tiger beetle, *Cicindela dorsalis dorsalis*: Western Shore, Chesapeake Bay, Virginia. *Journal of Coastal Research*, 22(5), 1133–1144.

Hildebrand et al (2007) is the most useful reference to Delmarva Fox Squirrel population dynamics in relation to change over time in landscape patterns, below.

Hildebrand, R., R. Gardner, M. Ratnaswamy, C. Keller, 2007. "Evaluating population persistence of Delmarva fox squirrels and potential impacts of climate change," *Biological Conservation* 137:70-77.

The actual surveys of squirrel population size are summarized here:

US Fish and Wildlife Service, 2007. "Delmarva Peninsula Fox Squirrel, 5 year Review: Summary and Evaluation," Chesapeake Bay Field Office, Annapolis, Maryland.

Discussions of reintroducing the fox squirrel to additional areas in Accomack County have been initiated by the VA Dept. of Game and Inland Fisheries, below.

"The Delmarva Squirrel Reintroduction Program on Virginia's Eastern Shore," Prepared by the Department of Game and Inland Fisheries, Wachapreague, VA and Terwilliger Consulting, Inc., Locustville, VA 23404, March 2008.

Finally, Kirwan and Shigart (2000) discuss fire frequency and vegetation patterns in relation to increasing drought periods that may be driven by climate change. These dynamics could have a significant impact on the Delmarva Fox Squirrel, as the authors point out, by reducing the extent of suitable vegetation for this mammalian species.

Kirwan, J., and H. H. Shugart 2000. "Vegetation and Two Indices of Fire on the Delmarva Peninsula," *Journal of the Torrey Botanical Society*, Vol. 127, No. 1 (Jan. - Mar.), pp. 44-50.

Shellfish resources

The best resources on oyster and clam habitat in Accomack County are located on a VIMS website:

<http://ccrm.vims.edu/resources/index.html>

The best concise overview of the issues is in this VMRC statement to the US House of Representatives:

Wesson, J., "Testimony by the Virginia Marine Resources Commission Division of Fisheries Management, Department of Conservation and Replenishment," U. S. House of Representatives Committee on Resources Subcommittee on Fisheries Conservation, Wildlife and Oceans, Oversight Hearings on the Efforts to Introduce Non-Native Oyster Species to the Chesapeake Bay, October 14, 2003.

The best maps of Accomack County's potential oyster beds, and the risks to their sustained health, are in a document prepared by VIMS for the VA CZM program, listed here by its title in digital form:

oyster and clam_vulnerability model and maps_2007.pdf

Spatial integrity of protected coastal zones

A multi-agency map has been produced that shows the typical habitats of shorebirds of concern, and the ownership pattern of coastal land that is important to these birds. This file is named "nestingmapbarrierislands.pdf" in the literature files that accompany this review.

In addition, one study of landscape dynamics and fragmentation exists which is useful for understanding both the spatial/temporal patterns and their links to biodiversity along the seaside of Accomack County:

Wilson, M. D., B. D. Watts, and J. E. LecLerc. 2007. Assessing habitat stability for disturbance-prone species by evaluating landscape dynamics along the Virginia barrier islands. Center for Conservation Biology Technical Report Series, CCBTR-07-06. College of William and Mary, Williamsburg, VA.

Groundwater

Groundwater is a significant asset both for the County's drinking water supply and for agricultural irrigation purposes. It is at risk of contamination by fertilizers applied to farm fields and residential lawns, as well as aging septic fields that no longer absorb pathogens or nutrients, and from saltwater intrusion due to excessive pumping and an increasing relative sea level.

A major study of this asset exists from 1992:

“Groundwater Supply Protection and Management Plan for the Eastern Shore of Virginia,” Prepared by Horsley Witten Hegemann, Inc., May 5, 1992.

The table of contents for this report looks promising, but the actual report was not included in the literature set for this review. Ideally, the report might contain a map of the groundwater recharge zone that could be used to plan some kind of conservation district, if such a district has not already been established in the County.

In addition, a report exists that considers the actual and potential saltwater intrusion into Accomack’s freshwater resources (Nowroozi et al 1999). This issue will become increasingly important, economically and spatially, as sea level rise accelerates and salt water gets closer to the surface under the Eastern Shore. The actual study, however, is limited in its usefulness by the low resolution of the maps included in the publication.

Nowroozi, A., S. Horrocks, P. Henderson, 1999. “Saltwater intrusion into the freshwater aquifer in the easter shore of Virginia: a reconnaissance electrical resistivity study,” *Journal of Applied Geophysics* 42:1-22.

B. Recommendations

The recommendations in this section were made by the authors of publications that were included in this review, not by the Green Infrastructure Center.

1. Reduce nutrient quantities applied to agricultural fields, and filter the nutrients that are applied:

Murphy, T., 2005. “Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for Virginia’s Eastern Shore,” Department of Natural Resources, Commonwealth of Virginia, Richmond, VA.

2. Increase the spatial continuity of riparian systems:

Murphy, T., 2005. “Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for Virginia’s Eastern Shore,” Department of Natural Resources, Commonwealth of Virginia, Richmond, VA.

3. Protect spatial continuity of coastal habitats:

A multi-agency map has been produced that shows the typical habitats of shorebirds of concern, and the ownership pattern of coastal land that is important to these birds. This file is named “nestingmapbarrierislands.pdf” in the literature files that accompany this review.

The most significant medium and long-term risk to the spatial continuity of coastal ecosystems is an accelerated rate of relative sea level rise, which is predicted for the 21st century and is already being observed. The USGS has produced a useful overview of the spatial distribution of this problem in the mid-Atlantic region of the United States, below:

Gutierrez, B.T., Williams, S.J., and Thieler, E.R., 2007. "Potential for shoreline changes due to sea-level rise along the U.S. Mid-Atlantic region." U.S. Geological Survey Open-File Report 2007-1278. Web only, available at <http://pubs.usgs.gov/of/2007/1278>.

A comprehensive summary of the risks to coastal ecosystem assets, along with recommendations for adaptation, are presented by this new federal study of the mid-Atlantic region:

Titus, J., et al., "Coastal Sensitivity to Sea-Level Rise: A focus on the mid-Atlantic region," US Climate Change Science Program, Synthesis and Assessment Product 4.1, January, 2009.

4. Isolate low-quality habitat patches (*Phragmites* patches, etc.)

Myers et al (2009) contains the most recent maps of *Phragmites* distribution along the Accomack seaside.

Myers, R.K., K.E. Heffernan, P.A. Clarke, and D.P. Field. 2009. "Management and education to control *Phragmites* on the Seaside of Virginia's Eastern Shore." Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. Final report for Year Six of the Seaside Heritage Program submitted to USDC National Oceanic and Atmospheric Administration. Natural Heritage Technical Report # 09-05.

Paxton, B. J. 2006. "Potential Impact of Common Reed Expansion on Threatened High-marsh Bird Communities on the Seaside: Assessment of *Phragmites* Invasion of High Marsh Habitats." Center for Conservation Biology Technical Report Series, CCBTR-06-17. College of William and Mary, Williamsburg, VA.

5. Replace coastal habitats lost to erosion and inundation

Glick, P.; J. Clough; B. Nunley, 2008. "Sea level rise and coastal habitats in the Chesapeake Bay region," National Wildlife Federation, Technical Report.

Titus, J., et al., “Coastal Sensitivity to Sea-Level Rise: A focus on the mid-Atlantic region,” US Climate Change Science Program, Synthesis and Assessment Product 4.1, January, 2009.

6. Protect groundwater recharge zone, initiate drinking water conservation programs and re-use systems for irrigation purposes

The County has probably already made plans to protect its groundwater recharge zones. The study below, by Nowroozi et al (1998), emphasizes the importance of this as salt water levels rise in relation to the Delmarva Peninsula – and specifically, Virginia’s Eastern Shore. This study is now 10 years old, and it would seem to be a high priority for the County to have an updated study that reflects the current position of relative sea level and projects a future position in the medium term, based on observed rates of sea level rise from recent data.

Nowroozi, A., S. Horrocks, P. Henderson, 1999. “Saltwater intrusion into the freshwater aquifer in the easter shore of Virginia: a reconnaissance electrical resistivity study,” *Journal of Applied Geophysics* 42:1-22.

7. Enhance dunes for shoreline protection and habitat expansion for bird and beetle species currently in decline

The three studies listed below discuss different perspectives on dune and wetland systems in relation to flood protection, nutrient retention, and biodiversity values. All of them imply that careful programs of beach nourishment could benefit shorebirds, the northeastern beach tiger beetle, and even loggerhead sea turtles.

Varnell, Lyle, and C. Scott Hardaway, 2007. “The Coastal Primary Sand Dune and Beach Act: Recommendations to Update the Act and Complete the Oversight of Virginia Tidal Shorelines,” Virginia Institute of Marine Sciences.

Erwin, R. M., M. Haramis, M. Perry, B Watts, 2007. “Waterbirds of the Chesapeake Region: An Introduction,” *Waterbirds* 30 (Special Publication 1): 1-3.

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SECTION III. Research “gap assessment”

Each of the issues raised by planners in Accomack County is represented in the literature reviewed here. Notably, several species or groups of species are not commonly studied, including clams, Loggerhead Sea Turtles, American Black Ducks, migratory songbirds, the Northeastern Beach Tiger Beetle, Black-bellied Plovers, and Whimbrels.

Oysters are well-studied by government scientists and institutions working under government contracts, but there are no studies of oyster dynamics that were published in the peer-reviewed scientific literature that was included here. This is a significant gap, particularly since oyster population dynamics are expected to have major impacts on the Bay's ecosystem over time.

Upland scrub-shrub vegetation is not represented in the literature reviewed for this study, although there is one study of shrub patterns and biodiversity implications on barrier islands.

Table 3. Number of studies that address topics raised by planners in Accomack Comprehensive Plan or staff from the Nature Conservancy.

Animal species	Number of relevant studies
Oysters	9
Clams	1 (VIMS CCRM 2007)
Loggerhead Sea Turtle	1 (Boettcher et al 2007)
American Black Duck	1 (Costanzo and Hindman, 2007)
Delmarva Fox Squirrel	4
Migratory Songbirds	1 (Paxton and Watts, 1999)
Northeastern Tiger Beetle	1 (Fenster, Knisley and Reed, 2006)
American Oystercatcher	8
Black Skimmer	6
Five species of nesting terns	8
Piping Plovers	5
Wilson's Plovers	4
Black-bellied plovers	2
Red Knot	3
Whimbrel	2
Vegetation communities	
Mixed hardwood and pine forests	5
Salt marsh grasses	8
Eelgrass / SAV	4
Upland scrub/shrub communities	1 coastal shrub ref. (Crawford and Young, 1998)
