Species Status Assessment Report for the Yellow Lance (*Elliptio lanceolata*) Version 1.3

Yellow Lances from the Tar River, NC (credit: Sarah McRae, USFWS)

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U.S. Fish and Wildlife Service
Region 4
Atlanta, GA

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Suggested reference:

U.S. Fish and Wildlife Service. 2018. Species status assessment report for the Yellow Lance (*Elliptio lanceolata*). Version 1.3. January, 2018. Atlanta, GA.

Summary of Version Updates

The changes from version 1.0 (December 2016) and 1.1 (February 2017) are minor and do not change the SSA Analysis for Yellow Lance. The changes were:

1) Changed title of Figure 3-19 from Yellow Lance Current Representation to Yellow Lance Current Condition.
2) Revised Section 4.5 to include additional relevant references; restructured to clarify content.
3) Added new references from revised Section 4.5 to References.
4) Removed mention of likelihood of scenario occurrence at 10-year time step due to confusion in initial expert application and subsequent interpretation in report.

The changes from version 1.1 (February 2017) and 1.2 (March 2017) were also minor and do not change the SSA Analysis for Yellow Lance. The changes were:

1) Revised Section 4.6 to include additional relevant references; added information to clarify content.
2) Added new references from revised Section 4.6 to References.

The changes from version 1.2 (March 2017) and 1.3 (January 2018) included minor edits and clarifications suggested from the public comments received on the proposed rule to list Yellow Lance as a threatened species (82 FR 16559), but they did not change the SSA Analysis. The changes were:

1) Addition of recent survey locations for upper Nottoway River and Johns Creek.
2) Addition of Hungry Run 2011 survey data in Rappahannock Subbasin.
3) Multiple additional mentions of comprehensive, current survey data from state agency/museum databases used in analyses.
4) Addition of information provided by Sound Rivers, Inc. regarding monthly flow data comparisons, Section 3.3.1, p.24.
5) Table 3-2: added "+" to Rappahannock MU to indicate more than one observation in past 10 years.
6) Included information on TMDLs and the Triennial Review Process in section 4.2.
7) Addition of agriculture BMP and groundwater pumping information in section 4.4.
8) Correction of page number for Allan 1995 reference.
9) Additional information provided about uncertainties associated with SLEUTH BAU model in section 5.1.

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Yellow Lance (*Elliptio lanceolata*)
Prepared by the
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EXECUTIVE SUMMARY

This species status assessment (SSA) reports the results of the comprehensive status review for the Yellow Lance (*Elliptio lanceolata* (Lea 1828)), documenting the species' historical condition and providing estimates of current and future condition under a range of different scenarios. The Yellow Lance is a freshwater mussel species native to the Atlantic Slope drainages in Maryland, Virginia, and North Carolina. The species occurs in streams and rivers, generally in clean, coarse to medium sands and sometimes in gravel substrates.

The SSA process can be categorized into three sequential stages. During the first stage, we used the conservation biology principles of resiliency, redundancy, and representation (together, the 3Rs) to evaluate individual mussel life history needs (Table ES-1). The next stage involved an assessment of the historical and current condition of species' demographics and habitat characteristics, including an explanation of how the species arrived at its current condition. The final stage of the SSA involved making predictions about the species' responses to positive and negative environmental and anthropogenic influences. This process used the best available information to characterize viability as the ability of a species to sustain populations in the wild over time.

To evaluate the current and future viability of the Yellow Lance, we assessed a range of conditions to allow us to consider the species' resiliency, representation, and redundancy. For the purposes of this assessment, populations were delineated using the eight river basins that Yellow Lance mussels have historically occupied (i.e., Patuxent, Potomac, Rappahannock, York, James, Chowan, Tar, and Neuse River basins). Because the river basin level is at a very coarse scale, populations were further delineated using Management Units (MUs). MUs were defined as one or more HUC10 watersheds that species experts identified as most appropriate for assessing population-level resiliency.

Resiliency, assessed at the population level, describes the ability of a population to withstand stochastic disturbance events. A species needs multiple resilient populations distributed across its range to persist into the future and avoid extinction. A number of factors, including (but not limited to) water quality, water quantity, habitat connectivity, and instream substrate, may influence whether Yellow Lance populations will occupy available habitat. As we considered the future viability of the species, more populations with high resiliency distributed across the known range of the species can be associated with higher species viability. As a species, the Yellow Lance has extremely limited resiliency, with the majority of populations in low condition or presumed extirpated condition.

Redundancy describes the ability of the species to withstand catastrophic disturbance events; for the Yellow Lance, we considered whether the distribution of resilient MUs within populations was sufficient for minimizing the potential loss of the species from such an event. The Yellow Lance historically ranged from the Patuxent River Basin in Maryland to the Neuse River Basin in North Carolina, but both the number and distribution of populations occupying that historical range has declined over the past 60 years.

Representation characterizes a species' adaptive potential by assessing geographic, genetic, ecological, and niche variability. The Yellow Lance has exhibited historical variability in the physiographic regions it inhabited, as well as the size and range of the river systems it inhabited. The species has been documented from small streams to large rivers in multiple physiographic provinces, from the foothills of the Appalachian Mountains through the Piedmont and into the Coastal Plain. Much of the representation of the Yellow Lance has been lost; physiographic variability has been lost with 70% loss in occupancy in the Coastal Plain and 56% loss in the Piedmont, and although the species persists in the majority of historically known river basins, those occurrences are represented by very few individuals in few locations.

Together, the 3Rs comprise the key characteristics that contribute to a species' ability to sustain populations in the wild over time (i.e., viability). Using the principles of resiliency, redundancy, and representation, we characterized both the species' current viability and forecasted its future viability over a range of plausible future scenarios. To this end, we ranked the condition of each population by assessing the relative condition of occupied watersheds using the best available scientific information.

The analysis of species' current condition revealed that Yellow Lance abundance and distribution has declined, with the species currently occupying approximately 43% of its historical range. Most of the remaining populations are small and fragmented, only occupying a fraction of reaches that were historically occupied. This decrease in abundance and distribution has resulted in largely isolated contemporary populations. Evidence suggests that the range reduction of the species corresponds to habitat degradation resulting from the cumulative impacts of land use change and associated watershed-level effects on water quality, water quantity, habitat connectivity, and instream habitat quality. The effects of climate change (e.g., increasing temperatures, droughts) have begun to be realized in the current Yellow Lance range and may have contributed to habitat degradation.

To assess the future condition of the Yellow Lance, a variety of stressors, including pollution, reduced stream flow, and continued habitat fragmentation, and their (potential) effects on population resiliency were considered. Populations with low resiliency are considered to be more vulnerable to extirpation, which, in turn, would decrease species' level representation and redundancy. To help address uncertainty associated with the degree and extent of potential future stressors and their impacts on species' requisites, the 3Rs were assessed using four plausible future scenarios (Table ES-2). These scenarios were based, in part, on the results of urbanization (Terando et al. 2014) and climate models (International Panel on Climate Change 2013) that predict changes in habitat used by the Yellow Lance.

An important assumption of the predictive analysis was that future population resiliency is largely dependent on water quality, water flow, and riparian and instream habitat conditions. Our assessment predicted that all currently extant Yellow Lance populations would experience negative changes to these important habitat requisites; predicted viability varied among scenarios and is summarized below, and in Table ES-3 and Figure ES-1.

Given Scenario 1, the "Status Quo" option, a substantial loss of resiliency, representation, and redundancy is expected. Under this scenario, we predicted that no MUs would remain in high condition, two in moderate condition, two in low condition, and the remaining MUs would be likely extirpated. Redundancy would be reduced with likely extirpation in eight of twelve currently extant MUs; only the Tar Population would retain more than one moderately resilient MU. Representation would be reduced, with only two (25%) of the former river basins occupied, and with reduced variability in the Mountains, Piedmont, and Coastal Plain.

Given Scenario 2, the "Pessimistic" option, we predicted a near complete loss of resiliency, representation, and redundancy. Redundancy would be reduced to two populations (i.e., likely extirpation of six populations), and the resiliency of those populations is expected to be very low. Nearly all MUs were predicted to be extirpated, and, of the remaining three MUs, all would be in low condition. All three measures of representation are predicted to decline under this scenario, leaving remaining Yellow Lance populations underrepresented in River Basin, Latitudinal, and Physiographic variability. Nearly all Piedmont representation is predicted to be lost.

Given Scenario 3, the "Optimistic" option, we predicted slightly higher levels of resiliency, representation, and redundancy than was estimated for current condition. Two MUs are predicted to be in high condition, two in moderate condition, five in low condition, and the three currently presumed extirpated MUs would remain extirpated. Despite predictions of population persistence for all populations, only the Tar Population is expected to retain a high level of resiliency. Existing levels of representation are predicted to remain unchanged under this scenario.

Given Scenario 4, the "Opportunistic" option, we predicted reduced levels of resiliency, representation, and redundancy. No MUs would be in high condition, two would be in moderate condition, four in low condition, and six would be likely extirpated. Redundancy would be reduced by half with six of twelve MUs predicted to be extirpated. Representation is predicted to be reduced with only four (50%) of the former eight river basins occupied, and with reduced variability in the Mountains, Piedmont, and Coastal Plain.

Table ES-1. Summary results of the Yellow Lance Species Status Assessment.

3Rs	Needs	Current Condition	Future Condition (Viability)
Resiliency (Large populations able to withstand stochastic events)	• Excellent water quality • Flowing river ecosystems • Suitable substrate: clean, coarse sands and gravels • Multiple occupied management units per population	• 7 (of 8) populations known to be extant • Currently extirpated from 3 of the 12 Management Units • Population status: 1 moderate resiliency 4 low resiliency 2 very low resiliency	Projections based on future scenarios in 50 years: • Status Quo: Threats continue on current trajectory and species maintains current level of response. Six populations (8 MUs) are expected to be extirpated; remaining two populations have reduced resiliency • Pessimistic: higher level of threats and reduced species response. Six populations (9 MUs) are expected to be extirpated; remaining two have considerable reduced resiliency • Optimistic: minimal level of threats and optimistic species response. One population remains likely extirpated; all others maintain (and one improves) existing resiliency condition • Opportunistic: moderate level of threats and selective species response. Four populations are expected to be extirpated; remaining four have reduced resiliency
Representation (genetic and ecological diversity to maintain adaptive potential)	• Genetic variation is assumed to exist between river basin populations • Ecological variation exists between small streams and larger rivers, and between physiographic provinces	Compared to historical distribution: • 87% of river basin variability retained, however most remaining populations are in low condition • Low genetic representation (due to very low abundances) in remaining populations • Limited physiographic variability in Mountains, Piedmont, and Coastal Plain	Projections based on future scenarios in 50 years: • Status Quo: 75% of river basin variability lost; considerable losses in physiographic variability in Mountains (75%), Piedmont (84%), and Coastal Plain (80%) • Pessimistic: 75% river basin variability lost; substantial losses in physiographic variability in Mountains (75%), Piedmont (91%), and Coastal Plain (80%) • Optimistic: 13% of river basin variability lost; maintain moderate physiographic variability in Mountains (50%) and Piedmont (44%), limited in the Coastal Plain (30%) • Opportunistic: 50% of river basin variability lost; moderate loss in physiographic variability in Mountains (50%), considerable losses in the Piedmont (69%) and Coastal Plain (80%)
Redundancy (number and distribution of populations to withstand catastrophic events)	• Multiple resilient MUs within populations in each area of representation	• One of eight populations is presumed extirpated • Six of the seven extant populations have only one MU currently occupied • Tar River Population has three MUs currently occupied • Overall 57% reduction in redundancy across range (20 out of 46 HUC10s currently occupied)	Projections based on future scenarios in 50 years: • Status Quo: two populations expected to persist; 8 of 12 MUs likely extirpated • Pessimistic: two populations expected to persist; 9 of 12 MUs likely extirpated • Optimistic: seven populations expected to persist; 3 of 12 MUs likely extirpated • Opportunistic: four populations expected to persist; 6 of 12 MUs likely extirpated

Table ES-2. Future scenario and condition category descriptions for each of four scenarios used to predict Yellow Lance viability.

			Future Condition Category Descriptions			
Scenario Name	**Climate Future**	**Urbanization**	**Species Condition**	**Water Quality Condition**	**Water Quantity Condition**	**Habitat Condition**
1) Status Quo Scenario	Current Climate effects continue on trend into the future, resulting in increased heat, drought, storms and flooding	Urbanization continues on trend with current levels	Current level of species response to impacts on landscape; current levels of propagation & augmentation and/or translocation capacity	Current level of regulation and oversight, including limited protective WQ[5] standards requirements and utilization of basic technologies for effluent treatment	Current level of regulation and oversight, including sustained IBTs[6] and irrigation withdrawals; current flow conditions	Current level of regulation, barrier improvement/removal projects, and riparian buffer protections
2) Pessimistic Scenario	Moderate to Worse Climate Future (RCP8.5[1])- exacerbated effects of climate change experienced related to heat, drought, storms and flooding	Urbanization rates at high end of BAU[4] model (~200%)	Species response to synergistic impacts on landscape result in significant declines coupled with limited propagation capacity and/or limited ability to augment/reintroduce propagules	Declining water quality resulting from increased impacts, limited regulation and restrictions, and overall reduced protections	Degraded flow conditions resulting from climate change effects, increased withdrawals and IBTs, limited regulation, and overall reduced protections	Degraded instream and riparian habitat conditions from increased impacts, limited regulation, fewer barrier improvement/removal projects, and overall reduced riparian buffer protections
3) Optimistic Scenario	Moderate to Improved Climate Future (trending towards RCP 2.6[2]) resulting in minimal effects of heat, drought, storms and flooding	Urbanization rates realized at lower levels than BAU model predicts (<100%)	Optimistic species response to impacts; targeted propagation and/or restoration efforts utilizing existing resources and capacity	Slightly increased impacts tempered by utilizing improved technologies and implementing protection strategies	Improved flow conditions through increased oversight and implementation of flow improvement strategies	Existing resources targeted to highest priority barrier removals; riparian buffer protections remain intact; targeted riparian connectivity projects; regulatory mechanisms remain the same
4) Opportunistic Scenario	Moderate Climate Future (RCP4.5/6[3]) - some climate change effects experienced; some areas impacted more than others by heat, drought, storms and flooding	Moderate BAU urbanization rates (~100%) realized	Selective improved species response to impacts as a result of targeted propagation and/or restoration efforts utilizing current resources and capacity	Moderate increase in WQ impacts resulting from continued levels of regulation, protection, and technology	Targeted strategies to improve flow conditions in priority areas	Targeted increase in riparian connectivity and protection of instream habitat in priority areas through targeted conservation efforts

[1]Representative concentration pathway 8.5
[2] Representative concentration pathway 2.6
[3] Representative concentration pathway 4.5/6
[4]Business as usual
[5]Water quality
[6]Interbasin transfer

Table ES-3. Current Condition and predicted Yellow Lance population conditions under each of four plausible scenarios. Predictions were made using a 50-year time interval.

		Future Scenarios of Population Conditions			
Populations: Management Units	Current	#1 Status Quo	#2 Pessimistic	#3 Optimistic	#4 Opportunistic
Patuxent	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
Potomac	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Rappahannock	Low	Likely Extirpated	Likely Extirpated	Moderate	Low
York	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
James: Johns Creek	Low	Low	Low	Low	Low
Chowan: Nottoway	Low	Likely Extirpated	Likely Extirpated	Low	Low
Chowan: Meherrin	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Tar: Upper/Middle Tar	High	Low	Likely Extirpated	Moderate	Low
Tar: Lower Tar	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Tar: Fishing Ck	Moderate	Moderate	Low	High	Moderate
Tar: Sandy-Swift	High	Moderate	Low	High	Moderate
Neuse: Middle Neuse	Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated

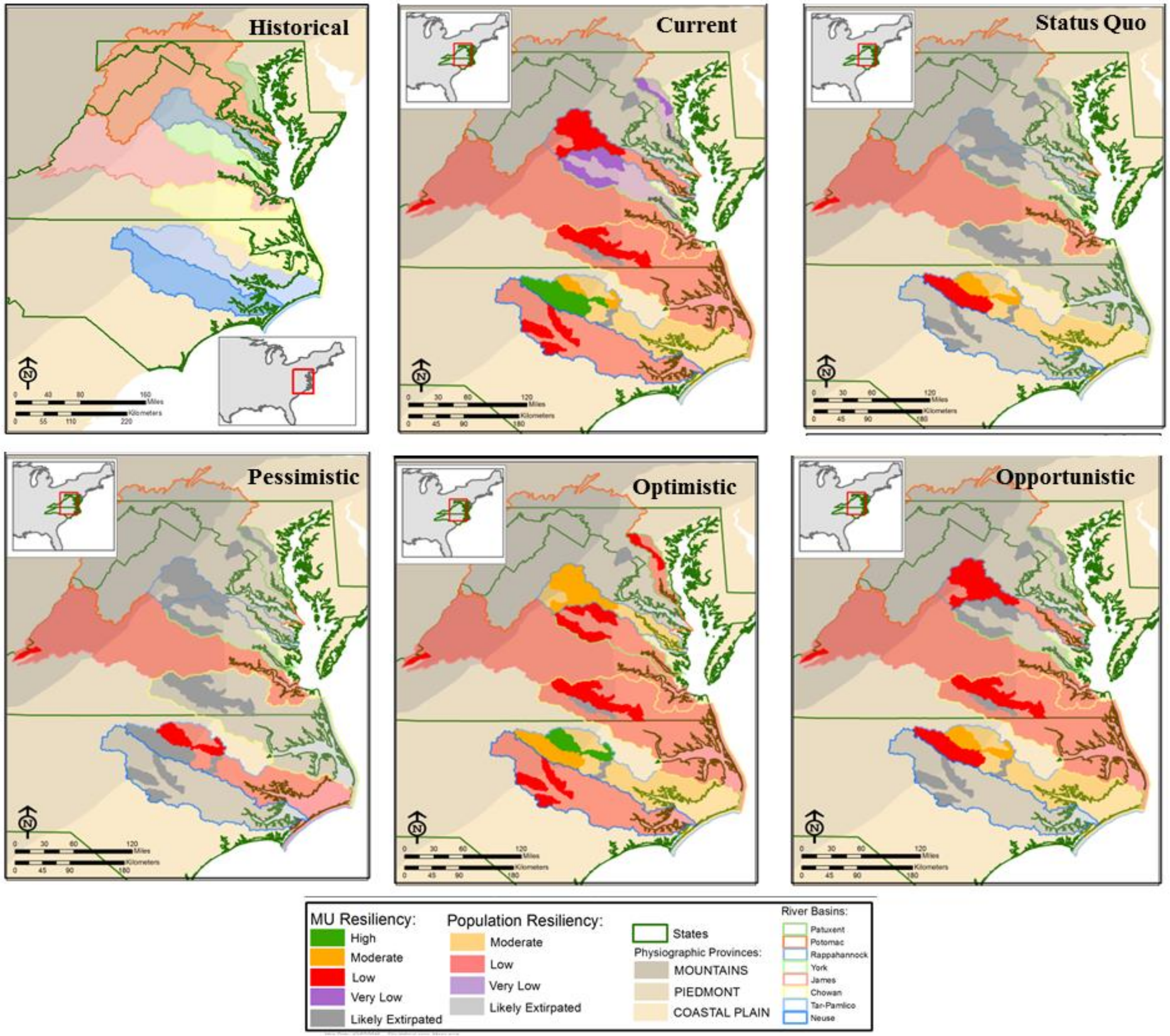

Figure ES-1 Maps of historical range, current condition, and predicted Yellow Lance population conditions under each scenario (see Table ES-3)

Current Viability Summary

The historical range of the Yellow Lance included streams and rivers in the Atlantic Slope drainages from the Patuxent River Basin south to the Neuse River Basin, with the documented historical distribution in 12 MUs within eight former populations. The Yellow Lance is presumed extirpated from 25% (3/12) of the historically occupied MUs. Of the remaining nine occupied MUs, 17% are estimated to have high resiliency, 8% moderate resiliency, and 67% low resiliency. Scaling up from the MU to the population level, one of eight former populations (the Tar Population) is estimated to have moderate resiliency, while the remaining six extant populations (Patuxent, Rappahannock, York, James, Chowan, and Neuse populations) are characterized by low resiliency. The Potomac Population is presumed to be extirpated thus eliminating 13% of the species' historical range. 86% of streams that remain part of the current species' range are estimated to be in low or very low condition, potentially putting the Yellow Lance at risk of extirpation. Once known to occupy streams in three physiographic regions, the species has also lost substantial physiographic representation. An estimated 50% loss has occurred in Mountain watersheds, an estimated 56% loss has occurred in Piedmont watersheds, and an estimated 70% loss has occurred in Coastal Plain watersheds.

Overall Summary

Estimates of current and future resiliency for Yellow Lance are low, as are estimates for representation and redundancy. The Yellow Lance faces a variety of threats from declines in water quality, loss of stream flow, riparian and instream habitat fragmentation, and deterioration of instream habitats. These threats, which are expected to be exacerbated by urbanization and climate change, were important factors in our assessment of the future viability of the Yellow Lance. Given current and future decreases in resiliency, populations become more vulnerable to extirpation from stochastic events, in turn, resulting in concurrent losses in representation and redundancy. Predictions of Yellow Lance habitat conditions and population factors suggest possible extirpation in up to five of seven currently extant populations. The two populations predicted to remain extant at the end of the predictive time horizon are expected to be characterized by low occupancy and abundance.

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CHAPTER 1 - INTRODUCTION

The Yellow Lance is a freshwater mussel found in eight Atlantic Slope drainages from the upper Chesapeake River Basin in Maryland to the Neuse River Basin in North Carolina. The species was petitioned for federal listing under the Endangered Species Act of 1973, as amended (Act), as a part of the 2010 Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States by the Center for Biological Diversity (CBD 2010, p.395).

The Species Status Assessment (SSA) framework (USFWS 2016a, entire) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification decisions (the former four decision types are only relevant should the species warrant listing under the Act).

Because the Yellow Lance SSA has been prepared at the Candidate Assessment phase, it is intended to provide the biological support for the decision on whether to propose to list the species as threatened or endangered and, if so, to determine whether it is prudent to designate critical habitat in certain areas. Importantly, the SSA Report is not a decisional document by the U.S. Fish and Wildlife Service, rather it provides a review of available information strictly related to the biological status of the Yellow Lance. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the *Federal Register,* with appropriate opportunities for public input.

For the purpose of this assessment, we define viability as the ability of the species to sustain resilient populations in natural stream ecosystems for at least 50 years. Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its redundancy, representation, and resiliency (USFWS 2016a, entire; Wolf et al. 2015, entire).

- Resiliency is assessed at the level of populations and reflects a species' ability to withstand stochastic events (arising from random factors). Demographic measures that reflect population health, such as fecundity, survival, and population size, are the metrics used to evaluate resiliency. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of anthropogenic activities.

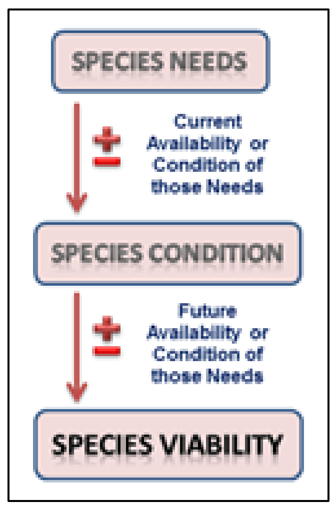


Figure 1-1 Species Status Assessment Framework

- Representation is assessed at the species' level and characterizes the ability of a species to adapt to changing environmental conditions. Metrics that speak to a species' adaptive potential, such as genetic and ecological variability, can be used to assess representation. Representation is directly correlated to a species' ability to adapt to changes (natural or human-caused) in its environment.

- Redundancy is also assessed at the level of the species and reflects a species' ability to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk of such an event across multiple, resilient populations. As such, redundancy can be measured by the number and distribution of resilient populations across the range of the species.

To evaluate the current and future viability of the Yellow Lance, we assessed a range of conditions to characterize the species' redundancy, representation, and resiliency (together, the 3Rs). This SSA Report provides a thorough account of biology and natural history and assesses the risk of threats and limiting factors affecting the future viability of the species.

This SSA Report includes: (1) a description of Yellow Lance resource needs at both individual and population levels (Chapter 2); (2) a characterization of the historic and current distribution of populations across the species' range (Chapter 3); (3) an assessment of the factors that contributed to the current and future status of the species and the degree to which various factors influenced viability (Chapter 4); and (4) a synopsis of the factors characterized in earlier chapters as a means of examining the future biological status of the species (Chapter 5). This document is a compilation of the best available scientific information (and associated uncertainties regarding that information) used to assess the viability of the Yellow Lance.

CHAPTER 2 - INDIVIDUAL NEEDS:
LIFE HISTORY AND BIOLOGY

In this section, we provide basic biological information about the Yellow Lance, including its physical environment, taxonomic history and relationships, morphological description, and reproductive and other life history traits. We then outline the resource needs of individuals and populations. Here we report those aspects of the life histories that are important to our analyses. For further information about the Yellow Lance refer to Alderman (2003) and Bogan et al. (2009).

2.1 Taxonomy

The Yellow Lance (*Elliptio lanceolata*) was originally described as *Unio lanceolatus* in 1828 by Isaac Lea (Lea 1828, p.266; Figure 2-1). T.A. Conrad confirmed Lea's description in 1836 (Conrad 1836, pp. 32-33).

Taxonomic experts agree that the taxon defined by Bogan et al. (2009) as *Elliptio lanceolata* (Turgeon et al. 1998; Integrated Taxonomic Information System 2016) has a past occupied range that includes the Patuxent River Basin in Maryland, possibly the Potomac River Basin in Maryland and Virginia, the Rappahannock, York, James, and Chowan River basins in Virginia, and the Tar and Neuse River basins in North Carolina.

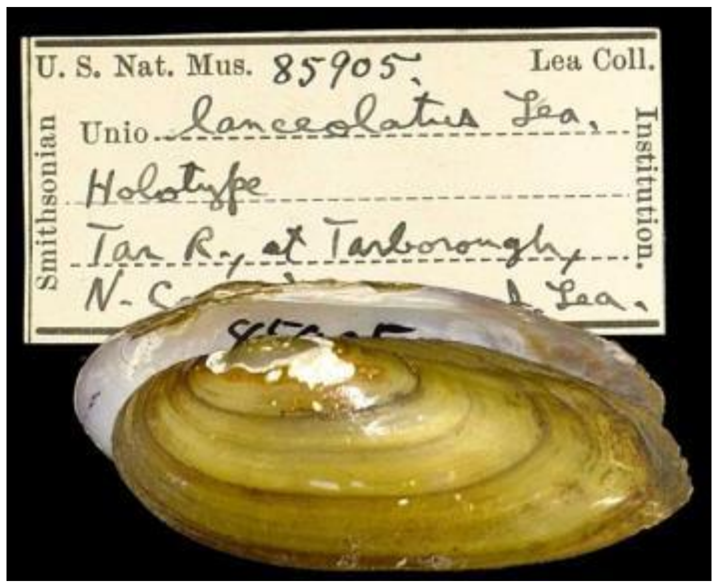


Figure 2-1 Type specimen of Elliptio lanceolata, from National Museum of Natural History (USNM #85905) (credit: Graf and Cummings 2015).

The currently accepted classification is (Integrated Taxonomic Information System 2016):

- Phylum: Mollusca
- Class: Bivalvia
- Order: Unionoida
- Family: Unionidae
- Subfamily: Ambleminae
- Genus: Elliptio
- Species: *Elliptio lanceolata*

Long recognized as a "lanceolate *Elliptio*" species-complex, Johnson (1970) listed 25 species in the synonymy of *Elliptio lanceolata* (p.333-338). Britton and Fuller (1979) noted that the range of *Elliptio lanceolata* extended from the Escambia and Apalachicola River systems in Alabama and Florida, and from the Satilla River system in Georgia to the Susquehanna River system in Pennsylvania, however, the species is no longer recognized from most of those drainages (Bogan et al. 2009, p.5; NatureServe 2015, p.1).

In 1984, Wolfe (referenced in Bogan et al. 2009, p.5) questioned the lumping of the series of described taxa under Yellow Lance by Johnson (1970, pp.333-338), basing his questions on shell morphology and preliminary electrophoretic work of Davis et al. in 1981 (referenced in Bogan et al. 2009, p.5). Bogan et al. (2009, p.9) identified *Elliptio lanceolata* as originally described by Lea as a distinct species, but its placement in the genus *Elliptio* remains questionable. As described in Bogan et al. (2009, p.9) and through recent personal communication with A.Bogan (conference call with S.McRae (USFWS) on 2/2/2016), the true form of Yellow Lance is known from seven river basins, from Patuxent River Basin, the lower Chesapeake Bay basins (Rappahannock, York, James), the Chowan River Basin, and the Tar and Neuse River basins in North Carolina. Specimens from the Roanoke and Potomac River basins were not available, and therefore not included in their analysis.

Figure 2-2 Yellow Lance specimen from Hawlings River (1952), NCMNS Athearn collection (credit: A.Bogan)

Figure 2-3 Yellow Lance from Hawlings River, collected on 6/17/2015 (credit: K.Mack)

It is unclear whether or not the Yellow Lance existed/exists in the Potomac River Basin. The Smithsonian's National Museum of Natural History has several specimens for *Unio lanceolatus* from the Potomac River near Washington DC and the Great Falls area (see Appendix A). A 2004 survey of the Potomac River below the fall line (Villela 2006) documented two live *Elliptio lanceolata*, however no photos nor specimens are available for review. Expert review of specimens acknowledges the potential for Yellow Lance to have historically occurred in the Potomac Basin (A.Bogan (NC Museum of Natural History), M.Ashton (MD Department of Natural Resources), J.McCann (MD Natural Heritage Program), B.Watson (VA Department of Game and Inland Fisheries, pers. comm. via conference call on 2/2/2016; Appendix A).

The National Museum of Natural History has several lots of Yellow Lance (*Elliptio lanceolatus*) specimens from the mainstem Patuxent River in Maryland (USNM 499532, USNM 499533, USNM 252833, Appendix A). A recent discovery in H.D. Athearn's 1952 collection of *Elliptio lanceolatus* specimens (NCSM #54006), in conjunction with recent (2015&2016) surveys by the Montgomery County Department of Environmental Protection and Maryland Department of Natural Resources (M.Ashton (MD DNR), email to S.McRae (USFWS) on 12/1/2016) confirm that Yellow Lance exists in the Hawlings River of the Patuxent River basin in Maryland (Figures 2-2 and 2-3).

2.2 Description

The Yellow Lance is a bright yellow elongate mussel with a shell over twice as long as tall, usually not more than 86mm (3.4 inches) in length. Its periostracum usually has a waxy appearance with brownish growth rests and rarely ever has rays (Alderman 2003, p.6). The interior nacre is usually an iridescent blue color, and usually has white or salmon color on the anterior half of the shell (Lea 1832, p.8). The posterior ridge is distinctly rounded and curves dorsally toward the posterior end (Lea 1828, p.266). The lateral teeth are long, with two in the left valve and one in the right valve; each valve has two psuedocardinal teeth, with the posterior one on the left valve and the anterior one on the right valve being vestigial (Lea 1832, p.8).

2.3 Reproduction, including Fish Host Interaction

As is the case with most freshwater mussels, the Yellow Lance has a unique life cycle that relies on fish hosts for successful reproduction (Figure 2-4):

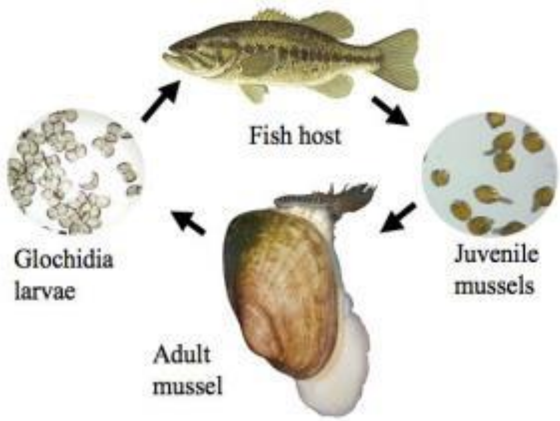


Figure 2-4 Generic illustration of the freshwater mussel reproductive cycle (FMCS 2015)

The Yellow Lance is a short-term brooder, spawning in the spring (late April/early May in North Carolina) with release of "stringy clumps" of glochidia in mucous in the late spring to early summer (C.Eads (NC State University), email to S.McRae (USFWS) on 10/28/2016). The glochidia tend to clump in balls or string in a lab setting (Figure 2-5), but are thought to be more wispy in the wild (C.Eads (NC State University), email to S.McRae (USFWS) on 1/13/2016). Yellow Lance glochidia are hookless (Natureserve 2015, p.6; Figure 2-6).

Figure 2-5 Yellow Lance glochidia in a mucous string/net (credit: C.Eads)

The reproductive strategy used by the Yellow Lance is not known, however it likely passively "targets" drift-feeding minnow species by releasing pelagic clumps of glochidia. Following release from the female mussel, the clumps of glochidia float and occupy the middle water column where

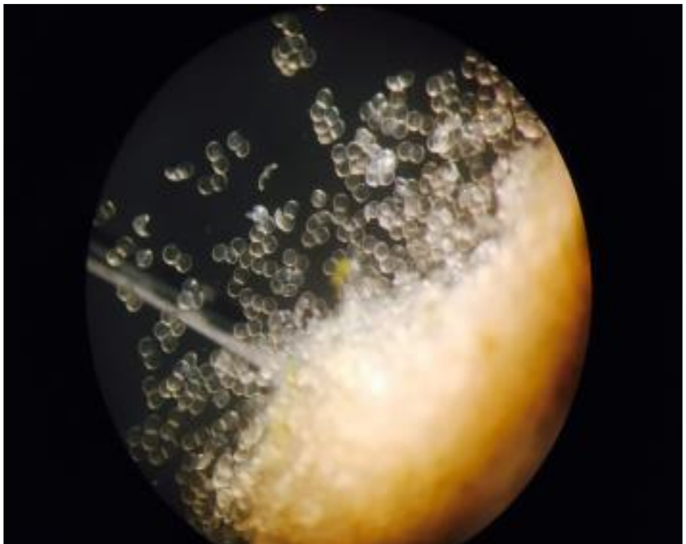


Figure 2-6 Close-up of hookless Yellow Lance glochidia (credit: C.Eads)

the stringy mucous clumps could be targeted by sight-feeding minnows and upon consumption, the glochidia to attach to gills and scales of the host minnows (C.Eads (NCSU) email to S.McRae (USFWS) on 10/28/2016).

Recent lab studies evaluated 26 species of potential host fish and confirmed that White Shiners (*Luxilus albeolus*) and Pinewoods Shiners (*Lythrurus matuntinus*) are the most efficient host in a lab setting (Eads and Levine 2009, p.2). Another study found that Yellow Lance could be successfully propagated using *in vitro* culture techniques (Levine 2012, p.38).

2.4 Diet

Like all mussels, the Yellow Lance is an omnivore that primarily filter feeds on a wide variety of microscopic particulate matter suspended in the water column, including phytoplankton, zooplankton, bacteria, detritus, and dissolved organic matter (Haag 2012, p.26). Juveniles likely pedal feed in the sediment, whereas adults filter feed from the water column. A recent nutrition study found that probiotic bacteria (*Bacillus subtilis*) enhanced early juvenile growth and survival (Eads and Levine 2011, p.3).

2.5 Age, Growth, Population Size Structure, and Fecundity

Very little information is known about the demographics of Yellow Lance populations. As seen in many freshwater mussels, the Yellow Lance's growth is rapid during the first few years of life but slows with increasing age (C.Eads (NC State University), email to S.McRae (USFWS) on 11/1/2016), as resources are likely diverted to reproduction. In the lab, age to sexual maturity is approximately 3 years, and captive individuals produce two to three broods per year (C.Eads (NC State University), email to S.McRae (USFWS) on 2/9/2016). Fecundity for Yellow Lance in the wild is low (4,000-15,000 glochidia) compared to lances held in captivity (20,000-56,000 glochidia) (C.Eads (NC State University), email to S.McRae (USFWS) on 2/9/2016), therefore the species likely relies on a consistent, low-level of reproductive success to maintain populations in the wild. As seen with other species like the Atlantic Pigtoe, this strategy can allow populations to reach high densities over time in stable habitats, but it also makes them susceptible to habitat disturbances (Wolf 2010, p.33). A habitat disturbance which results in the loss of even a small proportion of mussels in a particular population when population levels are already low, or a bad recruitment year, can have a dramatic effect on reproductive success.

2.6 Habitat

The Yellow Lance is a sand-loving species (Alderman 2003, p.6) often found buried deep in clean, coarse to medium sand and sometimes migrating with shifting sands (NatureServe 2015, p.6; Table 2.1), although it has also been found in gravel substrates. Yellow Lances are often found in sand at the downstream end of stable sand/gravel bars, and sometimes near the water's edge within inches of exposed substrate (T.Black (NC Wildlife Resources Commission) email to S.McRae (USFWS) on 9/30/2016). The species is dependent on clean (i.e., not polluted), moderate flowing water with high dissolved oxygen content in riverine or larger creek environments. Historically, the most robust populations existed in creeks and rivers with excellent water quality, and no populations appear to be extant below pollution point sources or areas with increased nutrient loading (Alderman 2003, p.6).

Most freshwater mussels, including the Yellow Lance, are found in aggregations (mussel beds) that vary in size and are often separated by stream reaches in which mussels are absent or rare (Vaughn 2012, p. 983). Genetic exchange occurs between and among mussel beds via sperm drift, host fish movement, and movement of mussels during high flow events. Theoretically, prior to anthropogenic influence, it is likely that Yellow Lance mussel beds were distributed contiguously in suitable habitats throughout its known range. As we discuss in more detail below, the contemporary distribution of Yellow Lance is patchy, resulting in largely isolated populations and, in turn, potentially limited genetic exchange.

Table 2.1 Life history and resource needs of the Yellow Lance.

Life Stage	Resources and/or circumstances needed for INDIVIDUALS to complete each life stage	Resource Function (BFSD*)	Information Source
Fertilized Eggs - early spring	• Clear, flowing water • Sexually mature males upstream from sexually mature females • Appropriate spawning temperatures • Presence of gravid females	B	- Berg et al. 2008, p.397 - Haag 2012
Glochidia - late spring to early summer	• Clear, flowing water • Just enough flow to attract drift feeding minnows • Presence of Host Fish for attachment	B, D	- Levine et al. 2011, p.2 - Haag 2012
Juveniles - excystment from host fish to ~35mm shell length	• Clear, flowing water • Host fish dispersal • Appropriate interstitial chemistry - Low salinity (~0.9ppt) - Low ammonia (~0.7 mg/L) - Low levels of copper and other contaminants - Dissolved oxygen >1.3mg/L • Appropriate substrate for settlement • Adequate food availability	F, S	- Dimmock and Wright 1993 - Sparks and Strayer 1998, p.132 - Augspurger et al. 2003, p.2574 - Augspurger et al. 2007, p.2025 - Strayer and Malcom 2012
Adult - >35mm shell length	• Clear, flowing water • Appropriate substrate (silt-free gravel and stable, coarse sand • Adequate food availability (phytoplankton and detritus) • High Dissolved oxygen (>3mg/L) • Water temperature <35°C	F, S	- Yeager et al. 1994, p.221 - Nichols and Garling 2000, p.881 - Chen et al. 2001, p.214 - Spooner and Vaughn 2008, pp.308,315

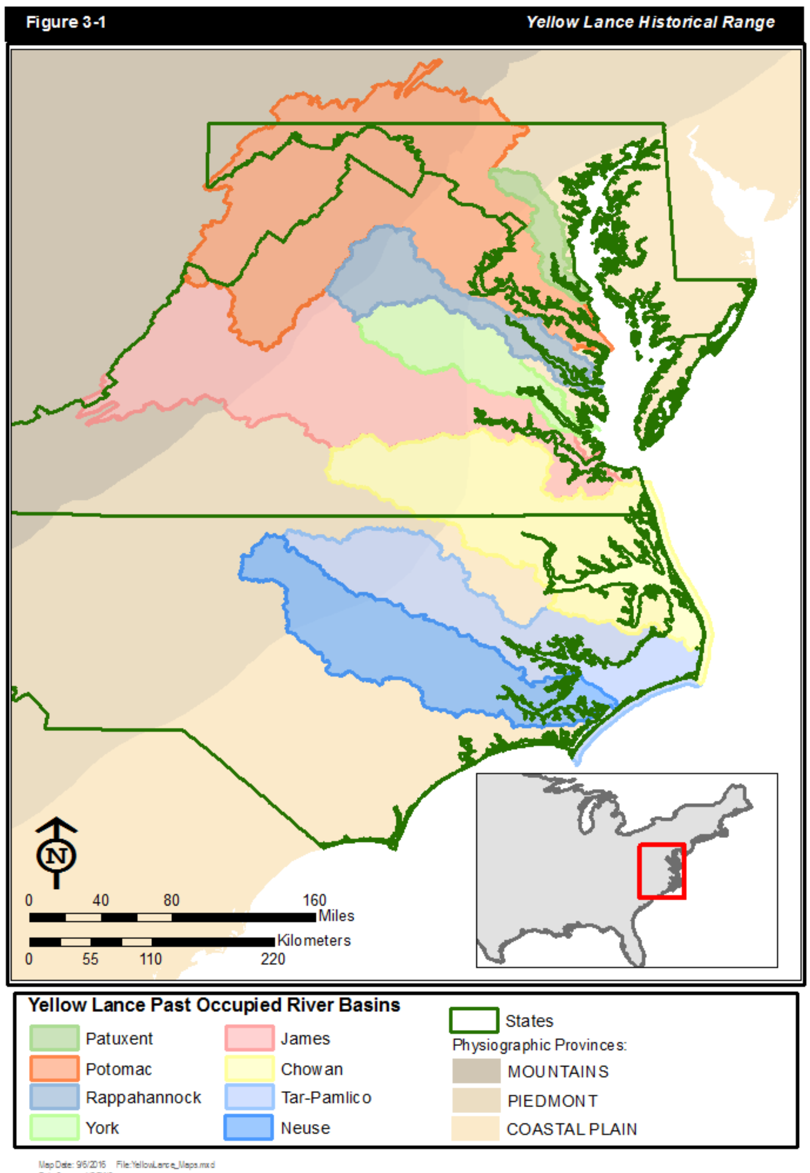
* B=breeding; F=feeding; S=sheltering; D=dispersal

CHAPTER 3 – POPULATION AND SPECIES NEEDS AND CURRENT CONDITION

In this chapter we consider the Yellow Lance's historical distribution, its current distribution, and the factors that contributed to the species current condition. We first review the historical information on the range and distribution of the species. Next we evaluate species' requisites to consider their relative influence to Yellow Lance resiliency, representation, and redundancy. Through the lens of the 3Rs, we then estimate the current condition of Yellow Lance populations.

3.1 Historical Range and Distribution

The Yellow Lance has a historical range from the Patuxent River Basin in Maryland to the Neuse River Basin in North Carolina and has been documented from multiple physiographic provinces, from the foothills of the Appalachian Mountains through the Piedmont and into the Coastal Plain, from small streams (like Johns Creek) to large rivers (like the Tar River) (Figure 3-1).

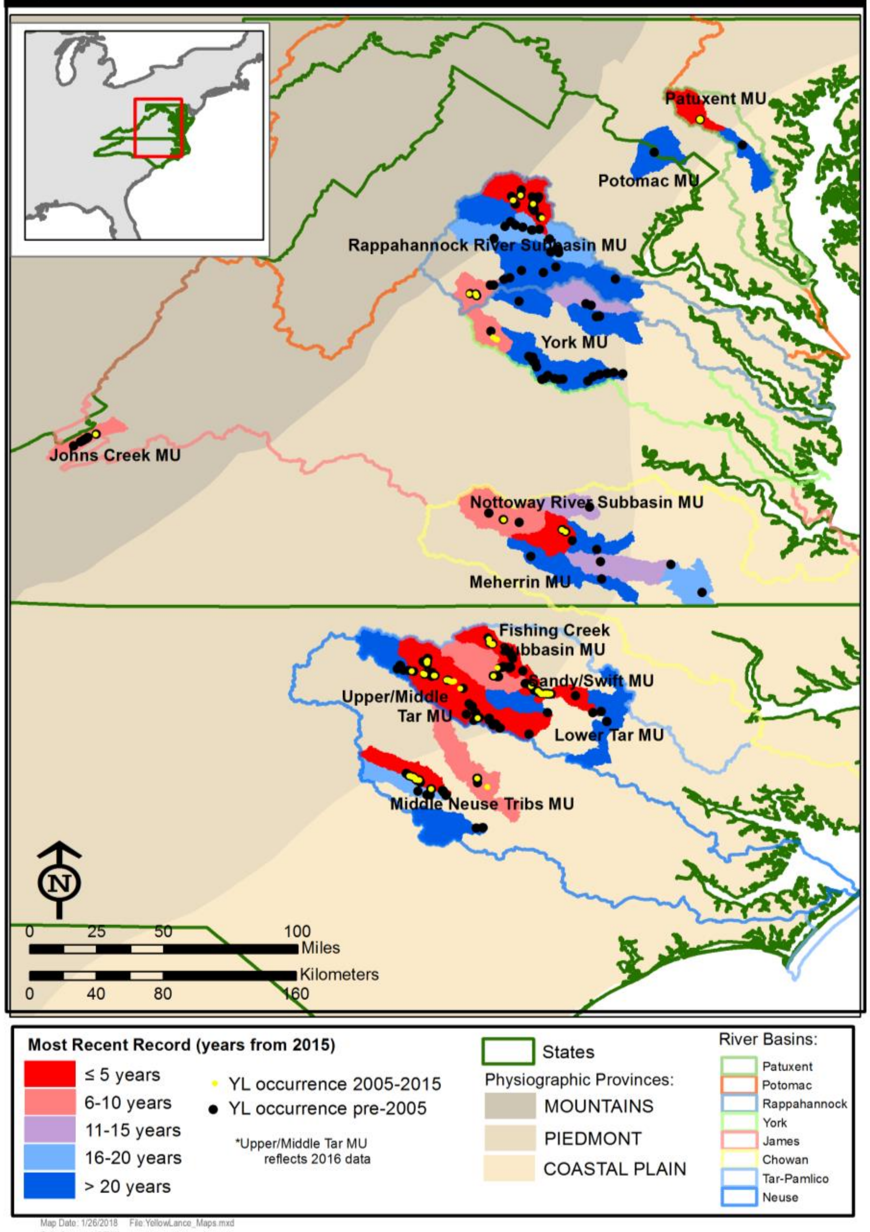


3.2 Current Range and Distribution

For the purposes of this assessment, populations were delineated using the eight river basins that Yellow Lance mussels have historically occupied. This includes the Patuxent, Potomac, Rappahannock, York, James, Chowan, Tar, and Neuse River basins, and from here forward, we will use these terms to refer to populations (e.g., the Tar Population). Of eight historical populations, six are known to have had a Yellow Lance occurrence in the last 10 years, though several of those occurrences were limited to a single location within the river basin.

Because the river basin level is at a very coarse scale, populations were further delineated using management units (MUs). MUs were defined as one or more HUC10 watersheds that species experts identified as most appropriate for assessing population-level resiliency (see Section 3.3; Appendix B). Comprehensive, current range-wide species occurrence data from state agency databases and museum records were used to create "occurrence heat maps" that discretize HUC10 watersheds into 5-year increments based on the date of observed occurrences (see GADNR 2016; Appendix C). These heat maps display recent observed occurrences using various shades of red, while older observed occurrences are displayed in various shades of blue (e.g., Figure 3-2). Documented species occurrences are included to show distribution within HUC10s. Throughout this section, heat maps are used to characterize the historical and current distribution of Yellow Lance among MUs for each of eight populations.

Figure 3-2 ***Yellow Lance Current Distribution***

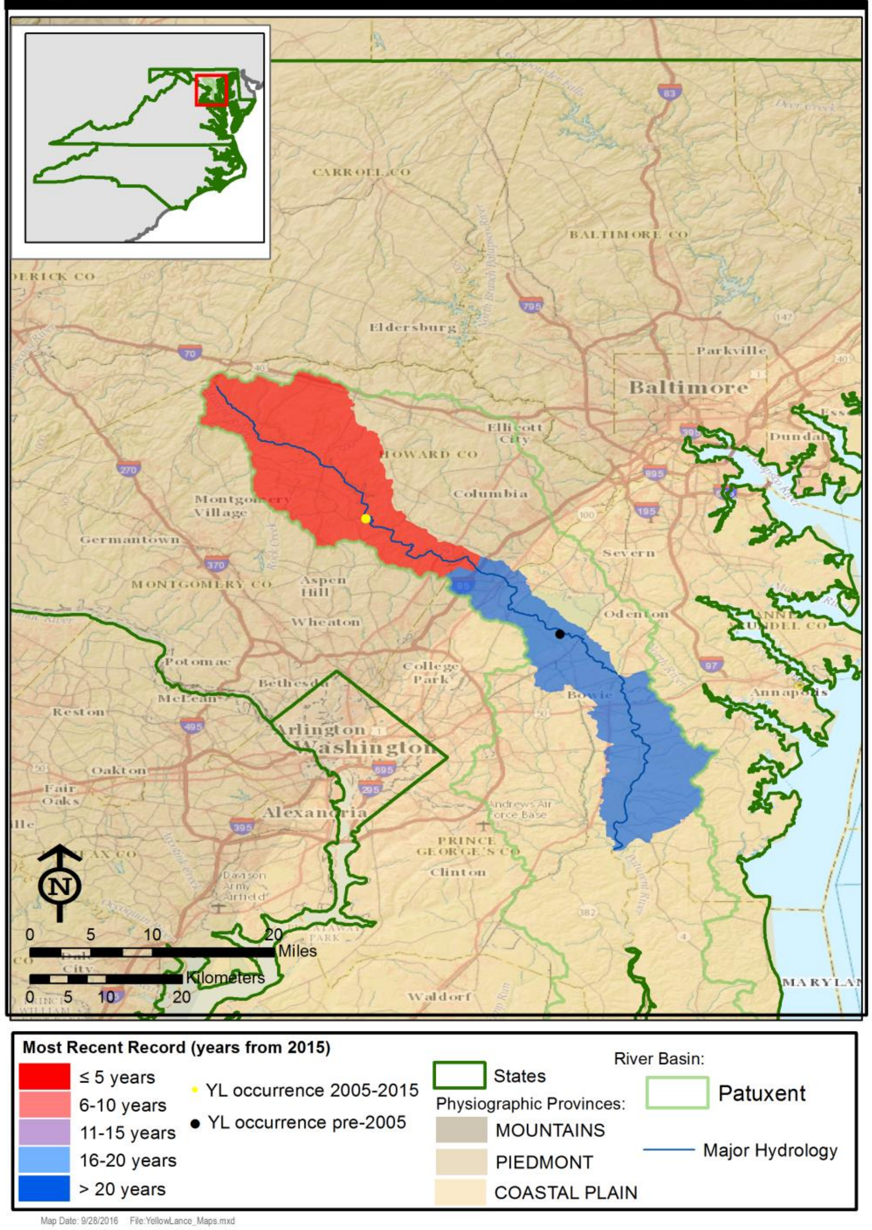


MARYLAND

3.2.1 Patuxent River Population

Basin Overview: The Patuxent River Basin is approximately 937mi^2, and the entire watershed is contained within the state of Maryland. The headwaters rise in the central Piedmont of Maryland and the river flows south into the Chesapeake Bay near Solomons Island. The Patuxent watershed crosses the urbanized corridor between Baltimore and Washington, D.C. Urbanization throughout the watershed has led to high levels of sedimentation, siltation, contamination, and nutrient-loading. Based on the 2011 National Land Cover Data, the Patuxent River Basin was estimated to be approximately 25% developed, 21% agriculture, 7% wetlands, 2% grassland, and 39% forest. The entire watershed is urbanizing as Baltimore and Washington, D.C. grow towards each other, but other municipalities in the basin include Columbia, Bowie and Laurel, MD.

Figure 3-3 Yellow Lance Patuxent River Population

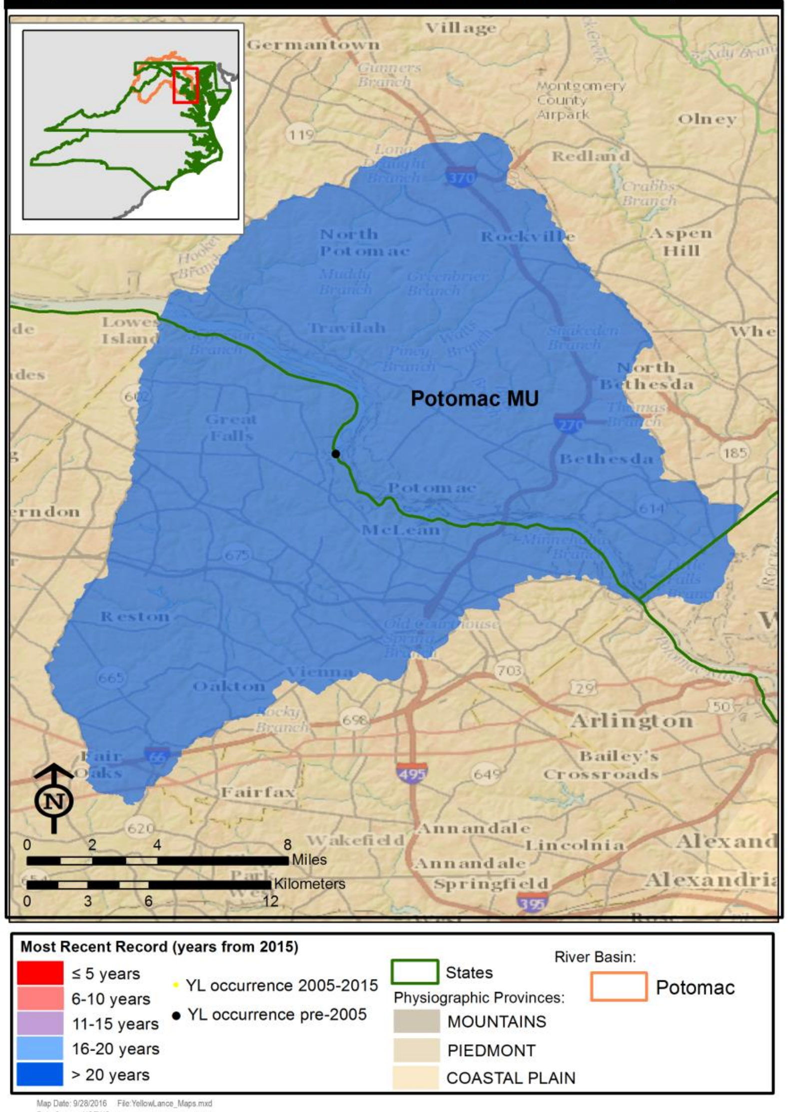


The Patuxent Population contains one MU (including Hawlings River) heretofore referred to as the Patuxent MU. Very few Yellow Lances have been documented from this MU; five were collected prior to 1965, one individual was collected in 2015 and one relic shell was collected in 2016.

3.2.2 Potomac River Population

Basin Overview: The Potomac River Basin area is approximately 14,679 mi^2 making it the fourth largest river along the Atlantic Coast. The river has two sources, the North Branch which originates at the Fairfax Stone in Grant, Tucker and Preston counties in West Virginia, and the South Branch which originates near Hightown in Highland County, Virginia. The two branches join just east of Green Spring, WV to form the Potomac River which flows southeast through the Piedmont and Coastal Plain to become the Potomac River Estuary which flows into the Chesapeake Bay at Point Lookout, MD. The Great Falls of the Potomac River is located just above the fall line, about 14 miles upstream of Washington, D.C.

Figure 3-4 ***Yellow Lance Potomac River Population***



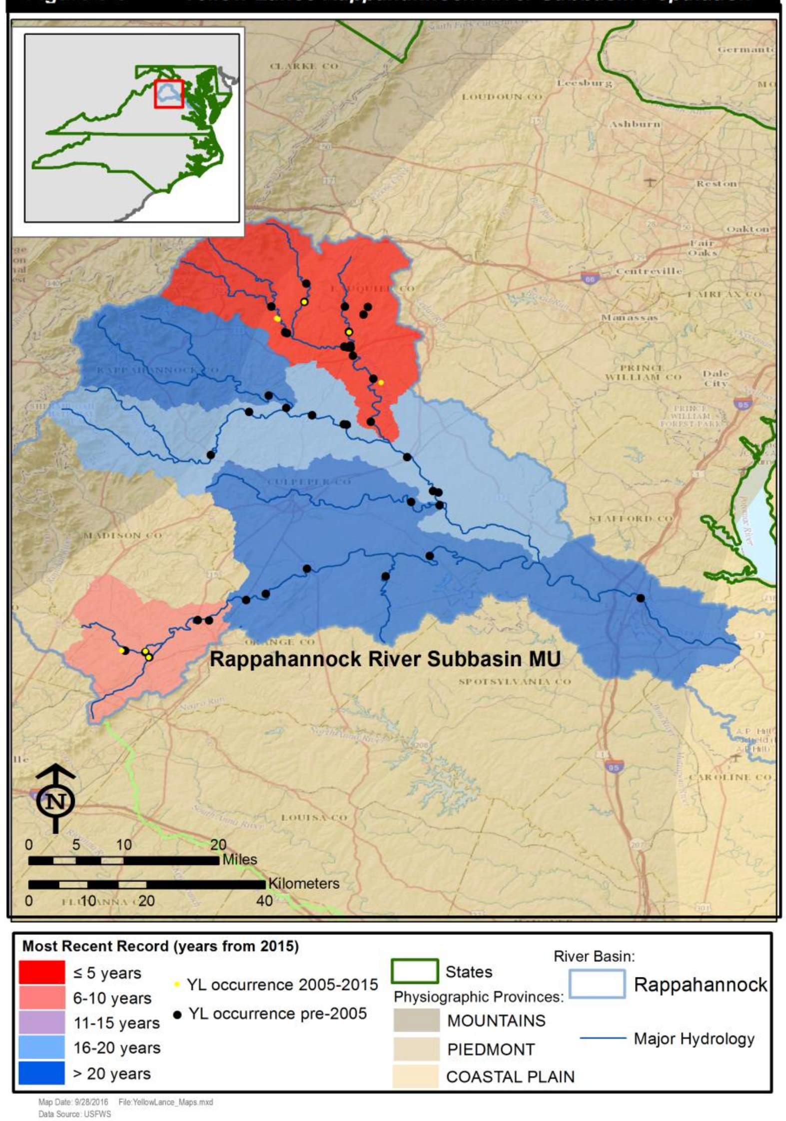
Threats to aquatic habitats within the Potomac River and its tributaries include eutrophication, exposure to heavy metals, pesticides and other toxic chemicals, over-fishing, invasive species, and pathogens associated with fecal coliform bacteria and shellfish diseases (Interstate Commission on the Potomac River Basin 2016, see Appendix B, pg. B87). Furthermore, pollution with endocrine disrupting chemicals have created intersex fish in certain areas of the Potomac River. Based on the 2011 National Land Cover Data, the Potomac River Basin was estimated to be approximately 14% developed area, 26% agriculture, 2% wetlands, 1% grassland, and 53% forest.

The Potomac River Basin contains one MU heretofore referred to as the Potomac MU. One specimen has been documented from a pre-1970 survey (see Appendix A89).

3.2.3 Rappahannock River Population

Basin Overview: The Rappahannock River Basin area is approximately 2,848mi^2. The headwaters begin in the Blue Ridge Mountains at Chester Gap a few miles southeast of Front Royal, Virginia; the river then flows southeast through the Piedmont of north-central Virginia through the Coastal Plain to become a tidal estuary before flowing into the Chesapeake Bay. The Rapidan River is a major tributary, which joins the Rappahannock River just west of Fredericksburg, VA. The upper watershed supports largely agricultural land uses, with industrial uses in the lower watershed (VDGIF 2016). Sedimentation is a problem in the upper watershed, as stormwater runoff from the major tributaries (Rapidan and Hazel rivers) leaves the Rappahannock River muddy even after minor storm events (VDGIF 2016). Based on the 2011 National Land Cover Data, the Rappahannock River Basin has approximately 8% developed area, 28% agriculture, 5% wetlands, 4% grassland, and 48% forest. While much of the watershed is rural and forested, it has experienced increased development from the southward expansion of Washington, D.C. Other developed areas are Culpepper and Fredericksburg, VA.

Figure 3-5 *Yellow Lance Rappahannock River Subbasin Population*

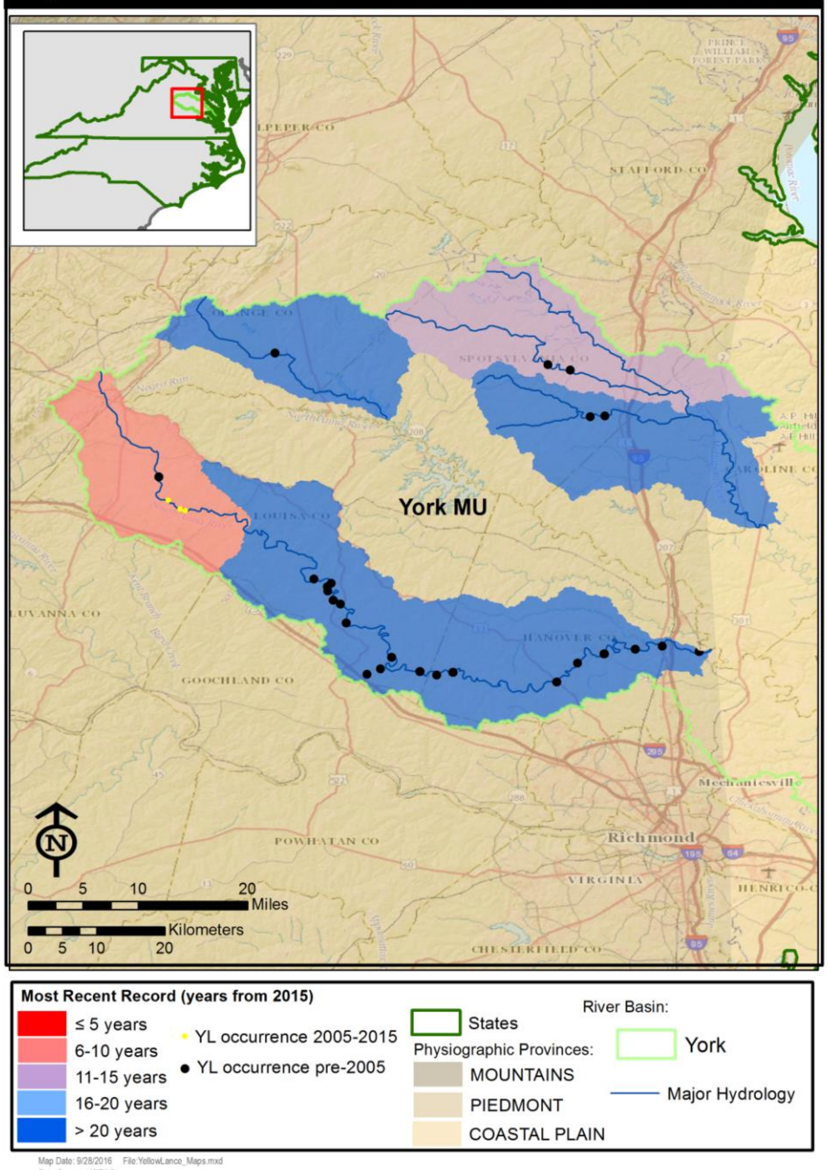


Rappahannock River Basin contains one MU, hereafter referred to as the Rappahannock River Subbasin. Many surveys have documented the presence of Yellow Lance in this MU, with an occasional observation of upwards of 50 individuals. The species was first seen in the late 1980s, and has been observed most recently in 2011: 10 individuals were observed in Hungry Run and very few (3) were observed in the Rappahannock River during that survey.

3.2.4 York River Population

Basin Overview: The York River Basin area is approximately3,270mi^2. The York River is formed at the confluence of the Mattaponi and Pamunkey rivers where if flows southeast to the Chesapeake Bay near Yorktown, VA. The Pamunkey River is formed by the confluence of the North and South Anna rivers near Ashland, VA. The Mattaponi River rises as four streams – The Mat River and the Ta River join to form the Matta River; the Po River and the Ni River join to form the Poni River; the Matta River and the Poni River join to form the Mattaponi River where it flows southeast and joins the Pamunkey River at West Point, VA to form the York River. In 2005 monitoring data indicated that four out seven segments of the York River were impaired; anthropogenic contamination appears to be the predominant source of stress to the benthos but eutrophication and low dissolved oxygen also play a role (Dauer et al. 2005, p.22). Based on the 2011 National Land Cover Data, the York River basin has approximately 7% developed area, 17% agriculture, 10% wetlands, 12% grassland, and 49% forest. Major population centers within the watershed include Ashland, Gloucester Point, Hampton, and West Point.

Figure 3-6 Yellow Lance York River Subbasin Population

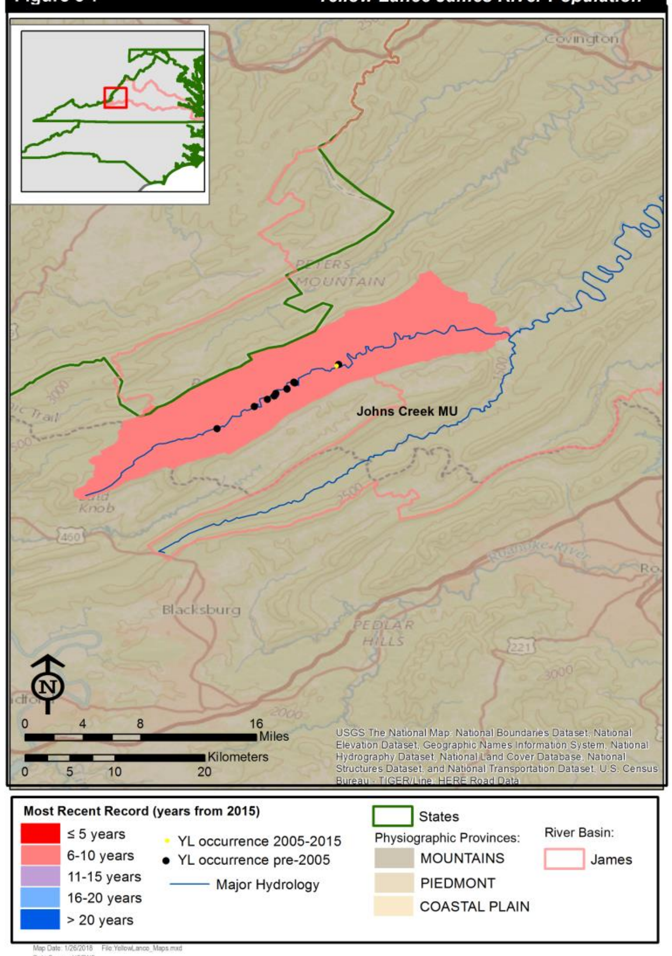


The York River Subbasin Population consists of one MU heretofore referred to as the York MU (including Mattaponi and South Anna rivers). Several surveys document the presence of Yellow Lance in this MU – presumably first seen in 1973, and as recent as 2007 in the South Anna River, although only one individual was observed during that survey.

3.2.5 James River Population

Basin Overview: The James River is mostly contained within the state of Virginia and has a drainage of approximately 10,265mi[2], draining approximately ¼ of the state (VDGIF 2015, p.148). The headwaters (Potts Creek) originate along the Virginia/West Virginia state line; the Jackson and Cowpasture rivers flow through the Alleghany and Blue Ridge Mountains and join to form the James River near Iron Gate, VA and then flows east through the Piedmont and into the Coastal Plain of Virginia where it drains into the Chesapeake Bay at Hampton Roads, VA. Major tributaries include Craig Creek, and the Jackson, Cowpasture, Maury, Tye, Chicahominy, Rivanna, and Appomattox rivers. The James River connects Lynchburg, Richmond, and Newport News, thus making it an important east-west transportation route (Radford University 2014, entire). The James River Basin and its tributaries have excess nutrients and sediment, pollutants that cause a wide variety of problems in the river and streams and serve as indicators of other forms of pollution such as bacteria and toxins (JRA website 2016). Sources of these types of pollution are wastewater, agricultural runoff, and urban stormwater runoff (JRA website 2016). Based on the 2011 National Land Cover Data, the James River Basin has approximately 11% developed area, 14% agriculture, 4% wetlands, 5% grassland, and 63% forest. Development and population growth are centered around Lynchburg, Richmond, Petersburg, and Norfolk, VA.

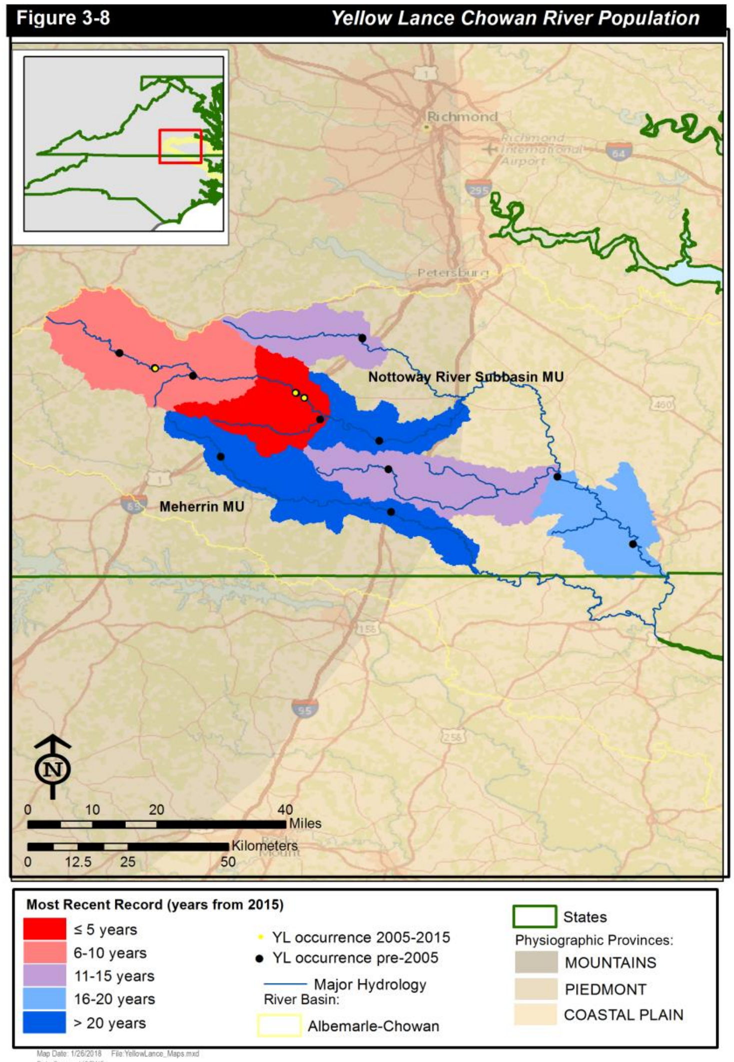
Figure 3-7 *Yellow Lance James River Population*



The James River Population consists of one MU, referred to as the Johns Creek MU. Despite mention by T.A. Conrad that the species occurred in the Cowpasture River (Conrad 1846, pp.404-406), no location information was given, and multiple recent surveys have not detected the species in that system. Yellow Lance was first seen in the Johns Creek MU in 1984, and last observed in 2009 by Virginia Department of Transportation (VDOT). VDOT indicated that repetitive survey results have observed a decreasing number of Yellow Lances with each subsequent survey over time (VDOT public comment letter to USFWS, 6/7/2017).

3.2.6 Chowan River Population

Basin Overview: The Chowan River Basin has a drainage area of approximately 4,800mi^2 with over 3,200 miles of rivers and streams. The Chowan River headwaters, which include the major tributaries the Meherrin, Nottoway, and Blackwater rivers, originate in southeastern Virginia, and the Chowan River forms at the North Carolina-Virginia border where the Blackwater and Nottoway rivers meet. The Chowan River then flows southeast across the Coastal Plain of North Carolina broadening to nearly two miles wide where it meets the Albemarle Sound near Edenton, NC (NCDEQ website 2016). In the past decade, the Nottoway River has suffered from several seasonal low flow events which have not only caused very low dissolved oxygen conditions, but also decreases food delivery because there is no flow and also increased predation rates on fishes that are concentrated into low-flow refugia (VDGIF 2010, p.12). The Emporia Dam on the Meherrin River provides water to the city of Emporia, VA and is also used for hydroelectric power generation (VDGIF website 2016). Based on the 2011 National Land Cover Data, the Chowan River Basin has approximately 14% developed area, 26% agriculture, 2% wetlands, 1% grassland, and 53% forest. While predominantly agriculture land and forest, some development and population growth are centered around Emporia and Franklin, VA and Murfreesboro, NC.

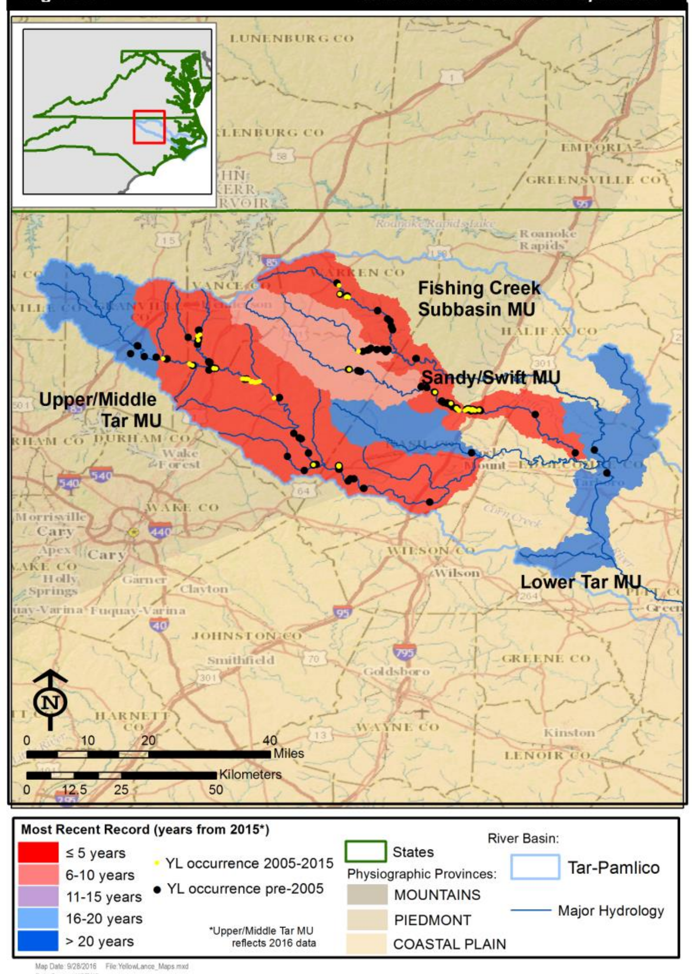


The Chowan Population consists of two MUs hereafter referred to as the Nottoway River Subbasin MU and the Meherrin River MU. Several surveys in the Nottoway River basin have noted the presence of "Yellow Lance" (one with as many as 781 individuals, although the exact identity of each specimen was not confirmed). The species has been seen as recently as 2011 in the Nottoway River, albeit in extremely low (5) numbers. Note, the Little Nottoway HUC is colored pink, however only a relic shell has been observed in last 10 years.

3.2.7 Tar River Population

Basin Overview: The Tar-Pamlico River Basin is contained completely within the state of North Carolina and has a drainage area of approximately 6,148mi^2 with over 2,500 miles of rivers and streams (NCDEQ website 2016). The headwaters of the Tar River originate in the Piedmont of central North Carolina in Person, Granville and Vance counties, and the river flows southeast through the Coastal Plain until it reaches tidal waters near Washington where it becomes the Pamlico River and empties into the Pamlico Sound. The entire basin is classified as Nutrient Sensitive Waters (NSW), meaning excessive amounts of nitrogen and phosphorus run off the land or are discharged into the waters, thus the basin has a special nutrient management plan to help reduce nutrients that cause excessive growth of microscopic or macroscopic vegetation and lead to extremely low levels of dissolved oxygen in the water (NCDEQ website 2016). Based on the 2011 National Land Cover Data, the Tar-Pamlico River basin has approximately 7% developed area, 29% agriculture, 23% wetlands, 12% grassland, and 27% forest. Development and population growth are centered around the municipalities of Greenville, Rocky Mount, and Washington and in rural areas within commuting distance to Raleigh (NCDEQ website 2016).

Figure 3-9 Yellow Lance Tar River Population

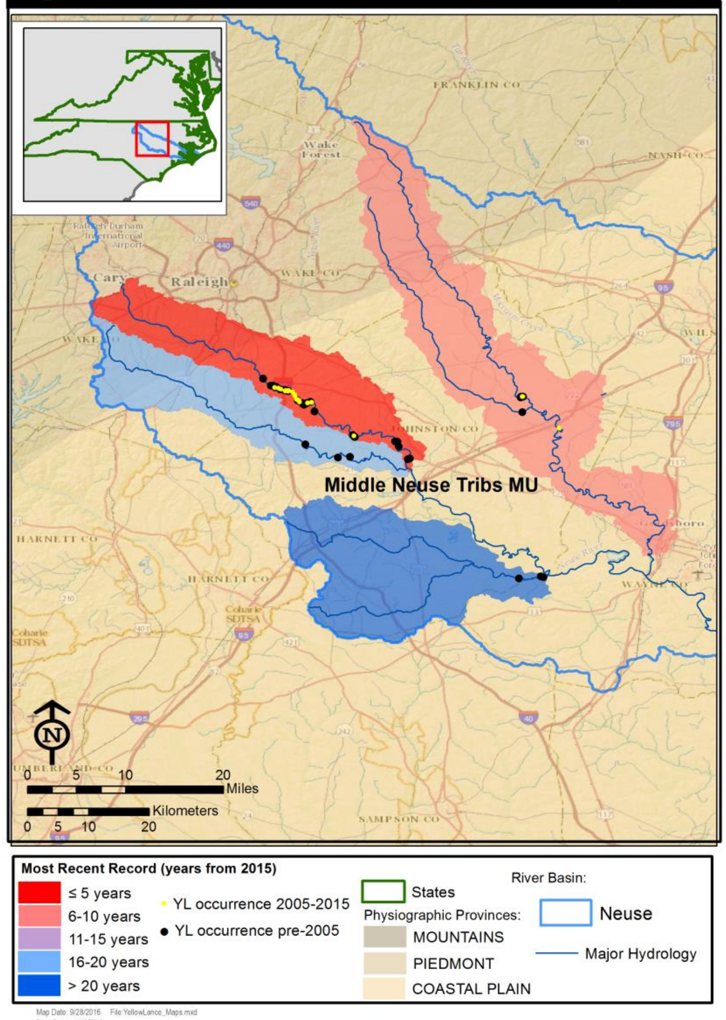


The Tar Population consists of four MUs, hereafter referred to as the Upper/Middle Tar River MU, the Lower Tar River MU, the Sandy-Swift Creek MU, and the Fishing Creek Subbasin MU. Many surveys efforts have documented the presence of Yellow Lance over the years; the species was first seen in 1966 in the Tar River and it has been documented as recently as 2016 in Swift Creek. Surveys in the mainstem Tar in 1990 documented upwards of 100 live individuals; most other surveys have documented between 25 and 31 individuals and the most seen in recent (2014) surveys has been 25 live individuals. Similarly, in the late 1980s and early 1990s, Swift Creek surveys documented hundreds (342 in one instance) of shells, and recent surveys in 2015 and 2016 documented 53 and 45 live individuals, respectively.

3.2.8 Neuse River Population

Basin Overview: The Neuse River Basin is contained completely within the state of North Carolina and has a drainage area of approximately 6,062mi^2 with over 3,400 miles of rivers and streams (NCDEQ website 2016). The headwaters of the Neuse River originate in the Piedmont of central North Carolina in Person and Orange counties, and the river flows southeast through the Coastal Plain until it reaches tidal waters near New Bern where it empties into the Pamlico Sound. Major tributaries include Crabtree, Swift, and Contentnea Creek and the Eno, Little, and Trent rivers. Like the Tar River Basin, the Neuse River Basin is classified as NSW due to large quantities of nutrients (especially nitrogen) contributed by fertilizers and animal waste washed from lawns, urban developed areas, farm fields, and animal operations (NCDEQ website 2016). In addition, more than 400 permitted point source sites discharge wastewater into streams and rivers in the basin (NCDEQ website 2016). Based on the 2011 National Land Cover Data, the Neuse River basin has approximately 13% developed area, 28% agriculture, 21% wetlands, 12% grassland, and 25% forest. Development and population growth are centered around the Triangle (primarily Durham and Raleigh) and the municipalities of Smithfield and Kinston. The Neuse River basin contains one-sixth of the entire state's population (NCDEQ website 2016), and increased development pressure has increased stormwater runoff, contributing to the basin's pollution and flow issues.

Figure 3-10 Yellow Lance Neuse River Population



The Neuse Population consists of one MU hereafter referred to as the Middle Neuse Tributaries MU. The Yellow Lance was first seen in 1991, and most recently one individual was seen in 2015 (this individual was brought into captivity for breeding, but has subsequently died). Most surveys report very low numbers observed (usually only one live individual or just shell material), although one effort in 1994 (Swift Creek) documented 18 live individuals. There have been recent (2014-2016) intensive surveys in the Swift Creek watershed, and only one Yellow Lance has been observed.

3.3 Needs of the Yellow Lance

As discussed in Chapter 1, for the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time (in this case, 50 years). Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs, Figure 3-11). Using various time frames and the current and future characterization of the 3Rs, we thereby describe the species' level of viability over time.

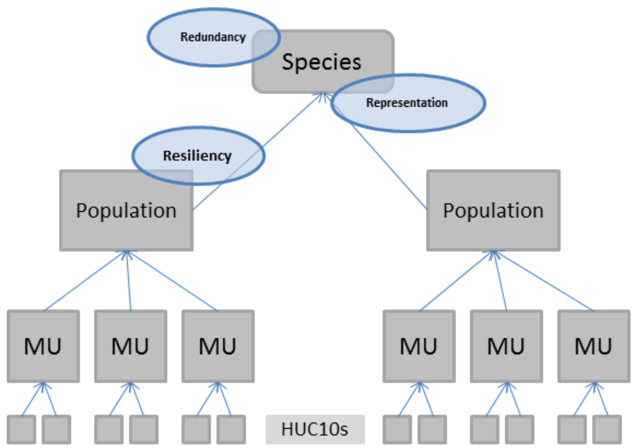


Figure 3-11 Resiliency is measured at the population level, representation is measured at the species and, possibly, population level, and redundancy is measured at the species level (after Fig 4, USFWS 2016a). MU=Management Unit; HUC10 = Hydrologic Unit

3.3.1 Yellow Lance MU Resiliency

As previously described, Yellow Lance populations were delineated at the river basin level, while MUs were defined at a finer geographic scale, which were HUC10 watersheds that encompass historically or currently documented occupied habitat. Note that MUs may be made up of one or more HUC10 watersheds, depending on the distribution of the species (see Section 3.2 and Appendix B). Because the river basin level was determined to be too coarse of a scale at which to estimate the condition of factors influencing resiliency, MUs were used to evaluate this metric. Given the hierarchical nature of the relationship between MUs, populations, and species (Figure 3-11), we first consider resiliency at the level of an MU, then scale up to populations, and, ultimately, make inferences at the species-level.

Resiliency (measured at the population level) is the foundational building block of the SSA Framework; thus, for the Yellow Lance to be viable, some proportion of MUs must be resilient enough to withstand stochastic events. Stochastic events that have the potential to affect mussel populations include high flow events, droughts, pollutant discharge failures, and sediment pulses. Given the rangewide current data available, the metrics that were used to assess resiliency were categorized as population factors (MU occupancy over time, approximate abundance, and recruitment) and habitat elements (water quality, water quantity, habitat connectivity, and instream substrate) (Appendix D). In the next section, we discuss the methods used to estimate resiliency metrics, and we explore potential causal relationships between resiliency and mussel habitat requisites (see Figure 3-15).

Population Factors that Influence Resiliency

Management Unit Occupancy - The known historical and current distribution of the species within HUC10 watersheds was used to document MU occupancy. Yellow Lance presence was compiled from current survey data made available by comprehensive state agency databases. Those surveys involved tactile or visual (viewbucket, snorkel, or surface air-supply systems in deeper (>4ft) waters) methods to detect mussels. Most surveys involved timed searches where species were identified, counted, checked for gravidity, and, in some cases, the presence of juveniles was noted. Most mussels were returned to the river post-identification, although some were retained for propagation.

Approximate Abundance – During stream surveys, mussel abundance was recorded as either a qualitative approximation (e.g., “common” or “rare”) or an actual count of the number of mussels observed in the survey location (e.g., density in a mussel bed). For most surveys, quantitative measures of density were not available and qualitative approximations were only sporadically documented. More often, surveyors recorded the number of live individuals or dead shells observed at a location. Thus, we used the cumulative record of the total number of live individuals and dead shells observed within a MU to provide an approximate estimate of abundance within MUs. We considered MUs with recent (≤ 10 years) documentation of high approximate abundance to be resilient. High approximate abundance is defined as cumulative counts of over 300 individuals observed over the period of record, or more than 100 live individuals observed over the past 10 years (Table 3-4). Pandolfo (2014, p.46) approximated Yellow Lance detection probability to be 0.42, although this measure was derived by borrowing information from species associates and was the value for all species in the assemblage. Since abundance estimates did not account for detection probability, the approximate abundances should be considered conservative. That is, Yellow Lances may have been present but not detected during some surveys, and we did not use an estimate of detection probability to account for these occasions.

Reproduction and Recruitment - While measures of population size reflect past influences on the mussel resiliency, reproduction and recruitment reflect where the population may be headed (Figure 3-12). For example, dense mussel beds containing older/senescing (i.e., less-reproductive) individuals may be more susceptible to extirpation because they have few young individuals to sustain the population into the future. Conversely, less dense mussel beds containing many young and/or gravid individuals may be likely to grow more dense, thus sustaining the population into the future.

Figure 3-12 Evidence of Reproduction: Yellow Lance and Atlantic Pigtoe from recent (2016) Swift Creek (Tar Basin) survey (credit: NCWRC)

Detection of very young juvenile mussels during surveys happens extremely rarely due to sampling bias (Shea et al. 2013, p.383). Because mussel surveys involve underwater, tactile and visual searches, mussels less than 35mm are difficult to detect (Wisniewski et al. 2013, p.239; USFWS 2016, p.22). While we do not have specific estimates of detection for juvenile Yellow Lances, detection probability for the species has been approximated to be 0.42 (Pandolfo 2014, p.46). To this end, sampling methods used to estimate reproduction involved repeatedly capturing small-sized individuals near the low end of the detectable size range (<35mm) and by capturing gravid females during the reproductively active time of year (generally, March – August). It should be noted that records of reproduction/recruitment were not consistently documented for all surveys; thus, they should be considered to represent the low end on a spectrum of uncertainty (i.e., it is possible that reproduction occurred but was not documented).

Habitat Elements that Influence Resiliency

Physical, biological, and chemical processes influence instream habitat quality and quantity, which, in turn, influence the condition and abundance of species using that habitat. In the case of the Yellow Lance, breeding, feeding, and sheltering needs such as successful host fish infestation and dispersal, food availability, and suitable habitat are all needs influenced by water quality, water quantity, and suitable in-stream (substrate) habitat and habitat connectivity (Figure 3-15). See Chapter 4 for further discussion about the many factors that influence the condition of these habitat elements.

Figure 3-13 Eutrophication of Potomac River caused by cyanobacteria bloom in 2012 (credit: Wikimedia Commons)

<u>Water Quality</u> - As sessile, benthic filter-feeders, mussels are particularly sensitive to poor water quality (Haag 2012, p. 355). Suitable habitat for mussels includes streams that have un-altered thermal regimes, average pH, low salinity, and negligible chemical pollution. As required by section 303(d) of the Clean Water Act, all waters that do not meet standards for the designated use of a particular waterbody (e.g., to support/protect aquatic life) are placed on the Impaired Streams List. Water quality metrics that reflect aquatic impairment include (but are not limited to): low bioassessment scores, low dissolved oxygen (DO) levels, low/high pH values, high nutrient inputs (Figure 3-13), and high levels of fecal

coliform bacteria. For this assessment, the number and mileage of impaired stream reaches (as designated by state Water Quality programs), as well as the number of National Pollutant Discharge Elimination System (NPDES) point discharges were used to characterize water quality within a given MU. Since every stream is not assessed for impairment, the mileage of impaired stream reaches should be considered a conservative estimate of impairment for each MU.

<u>Water Quantity</u> – Optimal habitats for Yellow Lances are perennial streams with continuous, year-round flow. While mussels can survive low flows and (random) periodic drying events, intermittent stream habitats cannot support mussel populations.

Because a lotic environment is a critical need for the Yellow Lance, perturbations that disrupt natural discharge regimes have a potential negative influence on Yellow Lance resilience metrics. Yellow Lance habitat must have adequate flow to deliver oxygen, enable passive reproduction, and deliver food to filter-feeding mussels (see Table 2-1). Further, flow removes contaminants and fine sediments from interstitial spaces preventing mussel suffocation. Stream velocity is not static over time, and variations may be attributed to seasonal changes (with higher flows in winter/spring and lower flows in summer/fall), extreme weather events (e.g., drought or floods), and/or anthropogenic influence (e.g., flow regulation via impoundments).

While mussels have evolved in habitats that experience seasonal fluctuations in discharge, global weather patterns can have an impact on the normal regimes (e.g., El Niño or La Niña). Even during naturally occurring low flow events, mussels can become stressed either because they exert significant energy to move to deeper waters or they may succumb to desiccation. Because low flows in late summer and early fall are stress-inducing, droughts during this time of year may result in stress and, potentially, an increased rate of mortality. Recent information (Sound Rivers Inc. (SRI) public comment letter to USFWS, 6/5/2017) surmised the median minimum monthly flows for three time periods starting in 1940 have been declining during most months of the year. The declines are slight starting in February, accelerate during May through August, and reach a maximum decline in median minimum flows in October when comparing data from the period 1940 – 1962 with data from 1986 – 2008 (SRI letter to USFWS, 6/5/2017). The flow declines can be related back to growth that leads to increased water use, diversion, and loss of groundwater that recharges the river system; such declining minimum flows can negatively affect stream temperatures, dissolved oxygen levels, nutrient processing, substrate composition, and numerous other parameters, which in turn affect species richness and abundances (SRI letter to USFWS, 6/5/2017).

To understand whether Yellow Lance populations were subject to droughts during low flow times of the year (late summer, early fall), we compiled a series of US Drought Monitor graphics. These were used to assess flow conditions during the first week of September during years 2000 to 2015 to identify times that mussels were exposed to consecutive droughts (see Figure 3-14 below).

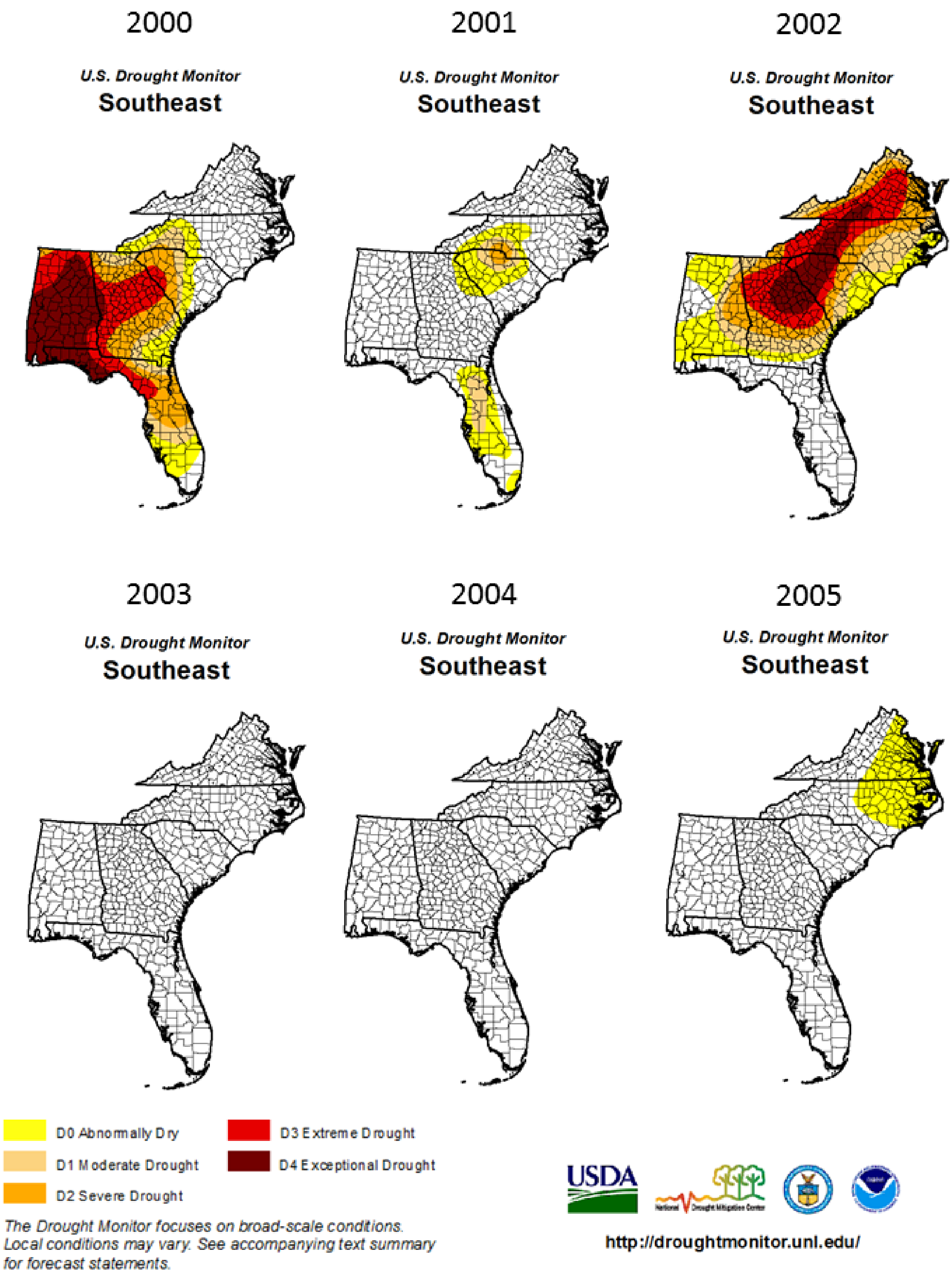


Figure 3-14 Southeast Drought Monitor annual images for 1st week in September. Although MD is not shown on these images, it is assumed that the same conditions that occurred in northeastern VA were similar in Patuxent River basin.

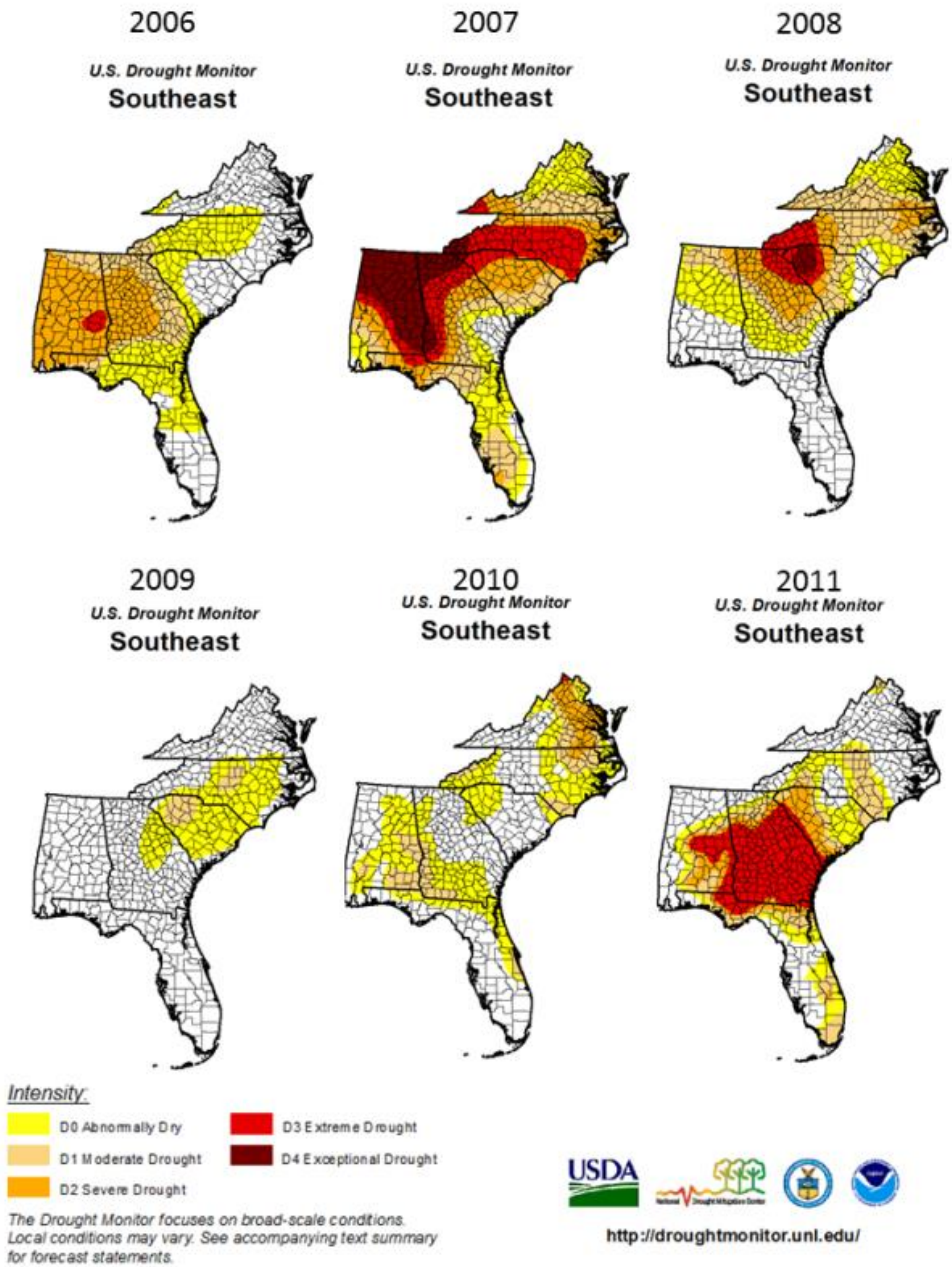


Figure 3-14 (cont) Southeast Drought Monitor annual images for 1st week in September

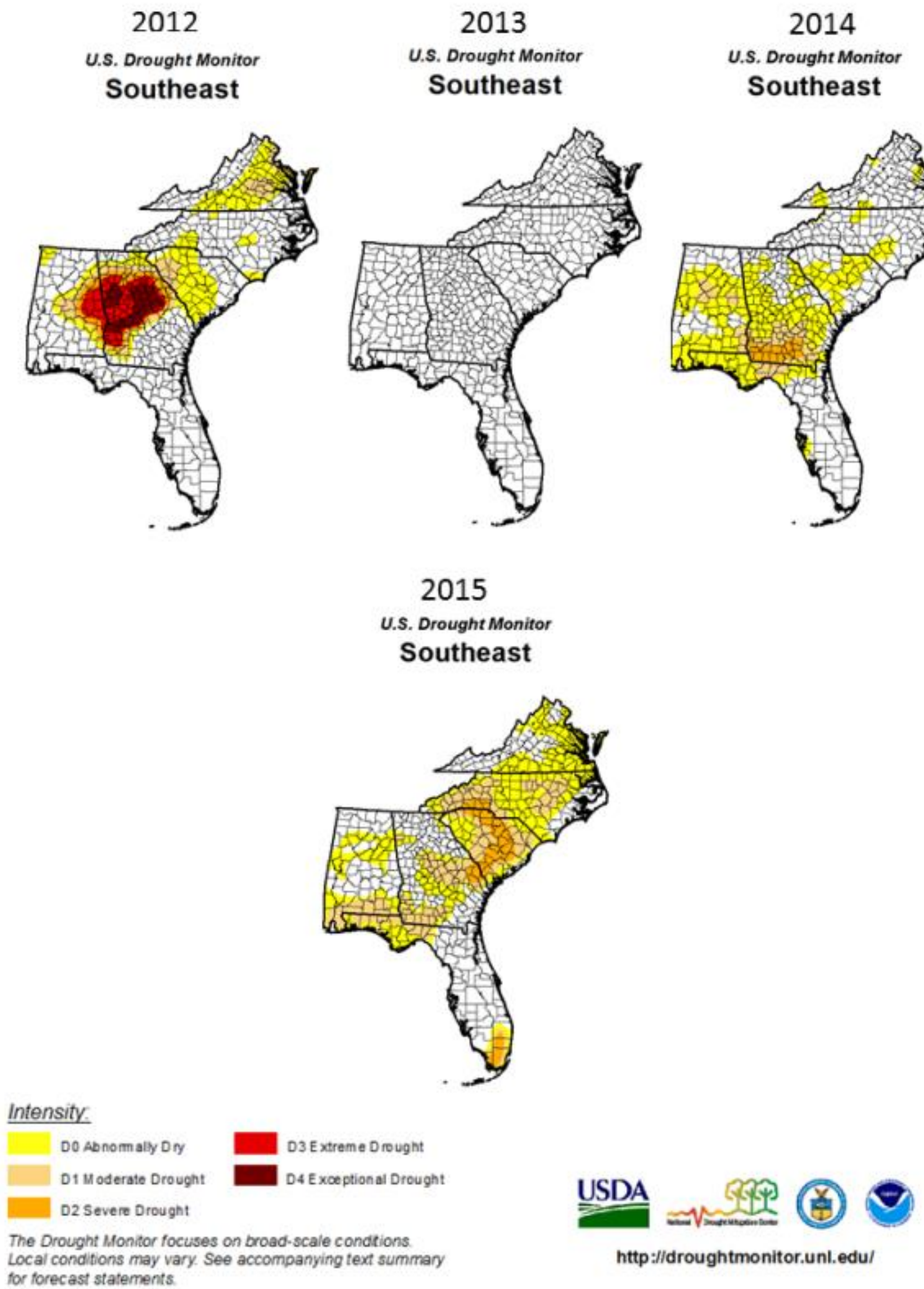


Figure 3-14 (cont) Southeast Drought Monitor annual images for 1st week in September

Substrate - Optimal substrate for the Yellow Lance is predominantly silt-free, detritus-free, stable sand, and gravel benthic habitat. Riparian condition strongly influences the composition and stability of substrates that mussels inhabit (Allan et al., 1997, p.149). Streams with urbanized or agriculturally dominated riparian corridors are subject to increased sediment-loading from unstable banks and/or impervious surface run-off, resulting in less suitable in-stream habitat for mussels as compared to habitat with forested corridors (Allan et al., 1997, p.156). For this assessment, we considered the stream-side riparian condition (as delineated by the Active River Area (ARA; Smith et al. 2008, entire) as an indicator of in-stream habitat condition. Rather than a fixed-width riparian buffer, the spatial extent of an ARA is defined by physical and ecological processes in areas of dynamic connection and interaction between the water and land through which it flows (Smith et al. 2008, p.1).

Habitat Connectivity - The fragmentation of river habitat by dams and other aquatic barriers (like perched or undersized culverts) is one of the primary threats to aquatic species in the U.S. (Martin and Apse 2014, p.7). Dams (whether man-made or nature-made (e.g., from beavers or windthrow)) have a profound impact on in-stream habitat as they can change lotic systems to lentic systems. Moreover, fragmentation by dams or culverts generally involves loss of access to quality habitat for one or more life stages of freshwater species. In the case of mussels, fragmentation can result in barriers to host fish movement which, in turn, may impact mussel distributions. Mussels that use smaller host fish (e.g., darters and minnows) are more susceptible to impacts from habitat fragmentation due to increasing distance between suitable habitat patches and low likelihood of host fish swimming over that distance (C.Eads (NCSU) email to S.McRae (USFWS) on 10/28/2016). Barriers to movement can cause isolated or patchy distributions of mussels which may limit both genetic exchange and recolonization (e.g., after a high flow, scouring event). To assess the influence of factors affecting habitat connectivity in Yellow Lance watersheds, we considered the number of dams from the US Army Corps of Engineers' (US ACE) National Inventory of Dams (NID) as well as the number of road crossings affecting Yellow Lance habitat at the HUC10 scale (see Section 4.1 below).

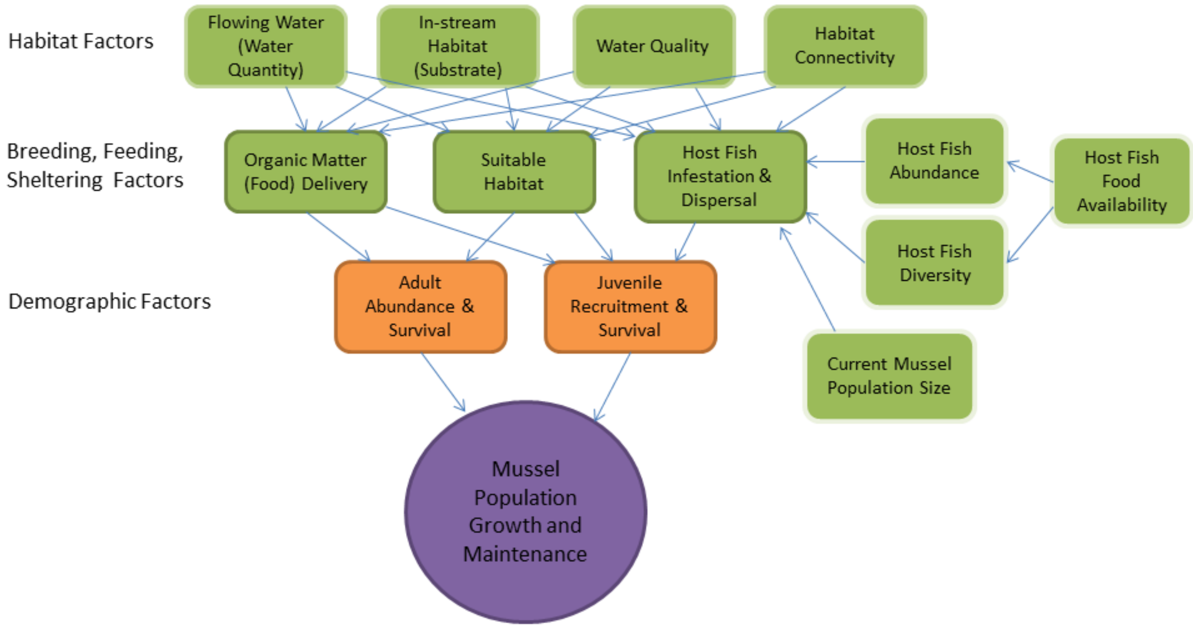


Figure 3-15 Yellow Lance Ecology: Influence diagram illustrating how habitat factors influence breeding, feeding, and sheltering factors, which in turn affect demographic factors that ultimately drive mussel population growth and maintenance. Diagram was developed by a group of freshwater mussel experts and substantiated from literature.

3.3.2 Species Representation

Identifying and evaluating representative units that contribute to a species' adaptive potential are important components of assessing overall species' viability (Shaffer and Stein 2000, entire; USFWS 2016b, p.23). This is because populations that are distributed throughout multiple representative units may buffer a species' response to environmental changes over time. Representation for the Yellow Lance can be described in terms of River Basin Variability, Physiographic Variability, and Latitudinal Variability. Below we examine these aspects of the historic and current distribution of the Yellow Lance and identify potential causal effects for changes in representation over time.

River Basin Variability - River basin variability for the Yellow Lance has been reduced from eight to seven river basins (Table 3-1); thus, the species has lost approximately 13% of River Basin Variability. However, it should be noted that this is a relatively conservative estimate of loss as variability for each population is largely represented by just one HUC per MU (Table 3-2 below), and several of the populations have five or fewer documented individuals in the past 10 years (Table 3-1).

Table 3-1 Yellow Lance Basin Variability:

Population (River Basin)	# of Historically Occupied MUs	# of Currently Occupied MUs	Total # Live Individuals 2005-2015
Patuxent	1	1	1
Potomac	1	0	0
Rappahannock	1	1	53
York	1	1	5
James	1	1	0*
Chowan	2	1	5
Tar	4	3	171
Neuse	1	1	30

* Yellow Lance assumed to be present (see p.17)

Physiographic Variability - Yellow Lances are found in three physiographic provinces – the Mountains, the Piedmont, and the Coastal Plain, with the largest proportion of their range (historically and currently) in the Piedmont > Coastal Plain > Mountains (Figure 3-16). Monitoring data indicate precipitous declines in occurrence in all three physiographic regions. A 56% decline in occurrence was estimated in the Piedmont Province, and 70% decline in the Coastal Plain, and a 50% decline in the Mountains (Figure 3-16). The species has been almost completely eliminated from its once much larger presence in the Coastal Plain, and has declined by over half in the Piedmont. Finally, the only remaining occurrences of Yellow Lance in the Mountain physiographic region are in Johns Creek and the upper Rappahannock River basin.

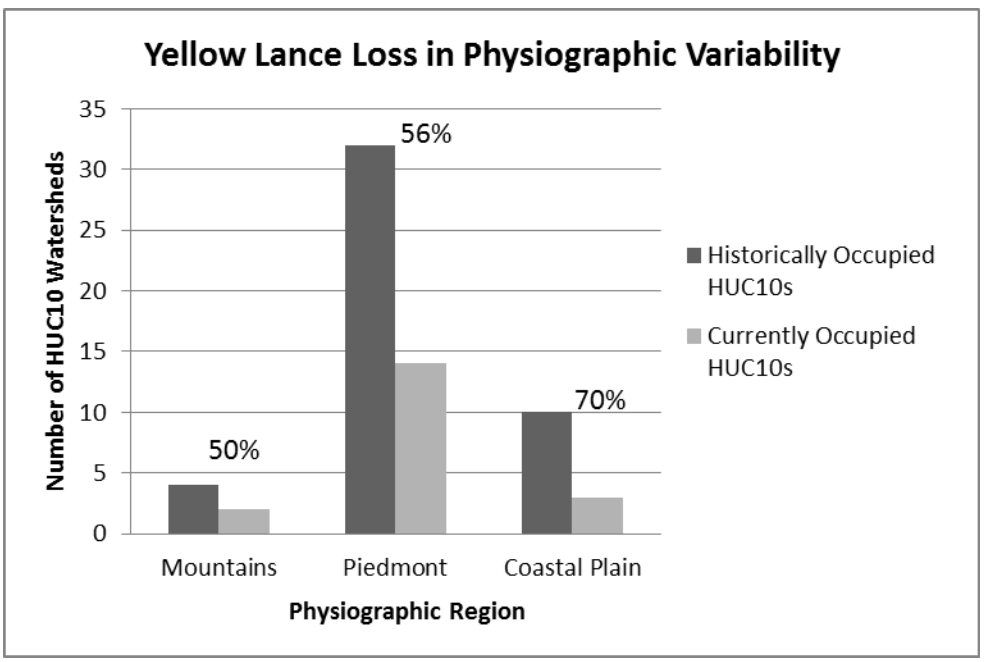
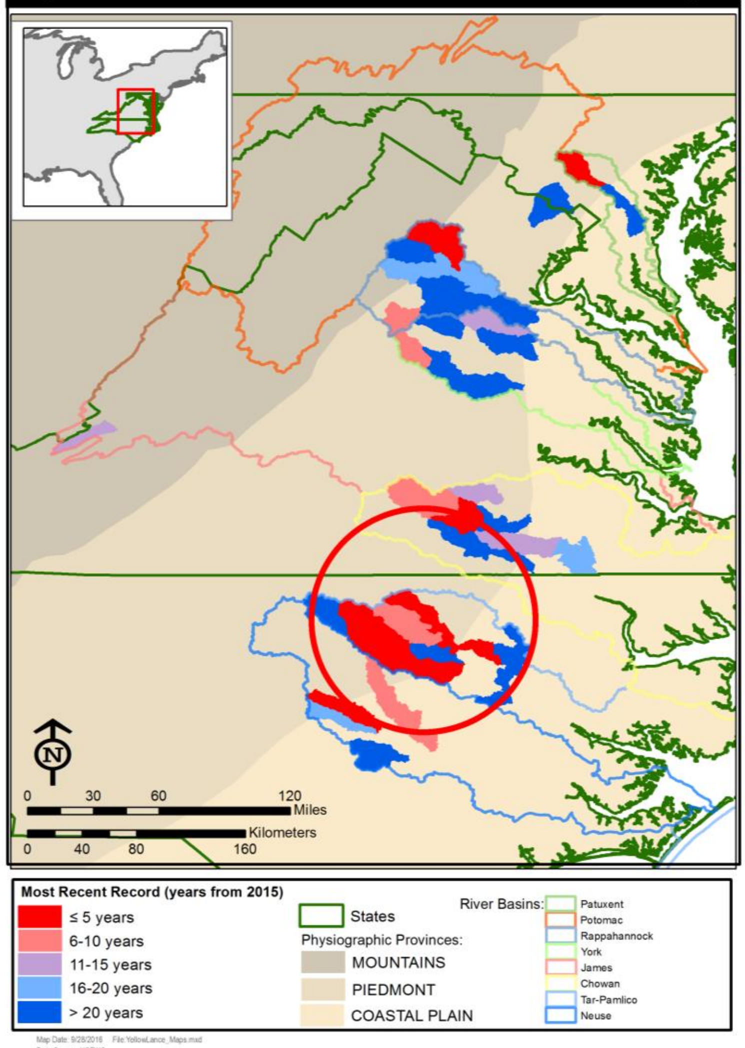


Figure 3-16 Change in physiographic variability for Yellow Lance. Percentages are the proportion lost from historically occupied HUC10s to currently occupied HUC10s.

Latitudinal Variability -
Historically, the Yellow Lance once occurred contiguously in perennial streams from Maryland to North Carolina. Based on recent data, occurrences have become patchy in distribution and it appears as though the range of the Yellow Lance is being contracted, with near extirpation in the northern basins and potential extirpation in the most southern basin (Figure 3-17).

Summary
As evaluated through the lens of river basin, physiographic province, and latitudinal variability, the contemporary distribution of Yellow Lance reflects a considerable loss in historical representation. Because representation is an indirect measure of a species' adaptive potential, this trend is concerning in terms of the ability of the species to respond to a changing environment. Later, we discuss the implications of a potential continued loss in representation.

Figure 3-17 Yellow Lance Contraction of Range



3.3.3 Species Redundancy

Redundancy reduces the risk that a large portion of the species' range will be negatively affected by a natural or anthropogenic catastrophic event at a given point in time. Species that have resilient populations spread throughout their historical range are less susceptible to extinction (Carroll *et al.* 2010, entire; Redford *et al.* 2011, entire). Thus, high redundancy for Yellow Lance is defined as multiple resilient populations (inclusive of multiple, resilient MUs) distributed throughout the species' historical range. That is, highly resilient populations, coupled with a relatively broad distribution, have a positive relationship to species-level redundancy. Evidence indicates that Yellow Lance populations were once much more broadly distributed throughout their historical range (Figure 3-1). However, several factors, including impoundments and unsuitable water quality, have resulted in population fragmentation (see Chapter 4), making repopulation of extirpated locations unlikely without human intervention.

We assessed Yellow Lance redundancy by first evaluating occupancy within each of the hydrologic units (i.e., HUC10s) that constitute MUs, and then we evaluated occupancy at the MU and ultimately the population level. This assessment revealed that of the 46 HUC10s historically occupied by Yellow Lance, only 20 (43%) are currently occupied (Table 3-2). Note that current occupancy was defined as the observation of at least one Yellow Lance during surveys conducted from 2005 to 2015. Of those 20 HUC10s that were counted as occupied, only five had more than one observation during that 10-year sample period (Table 3-2). At the level of MUs, three are likely extirpated, seven have experienced between an estimated 33-83% decline, and only two have experienced no decline. As a result, four populations (Rappahannock, Chowan, Tar, and Neuse) retain redundancy in the form of more than one HUC10 occupied, however, only one population (Tar) has multiple moderate or highly resilient MUs (Table 3-5), thus limiting overall redundancy for the species.

Table 3-2 Yellow Lance occupancy changes over time. Historical occupancy represents detections that occurred from 1966 to 2005, while current occupancy represents a sample period from 2005 to 2015. Note: MUs can be made up of one or more HUC10 watersheds, depending on the distribution of the species (see Section 3.3.1).

Population/ Management Unit	# Historically Documented Occupied HUC10s	# Currently Occupied (2005-2015) HUC10s	% Decline	Appendix Page (for reference)
Patuxent	**2**	**1**	**50**	B93
Potomac	**1**	**0**	**100**	B95
Rappahannock+	**10**	**3**	**70**	B97
York	**6**	**1**	**83**	B104
James/	**1**	**1**	**0**	
Johns Creek	1	1*	0	B108
Chowan/	**9**	**3**	**67**	
Nottoway	7	3	57	B110
Meherrin	2	0	100	B115
Tar/	**12**	**8**	**33**	
Upper/Middle Tar+	6	4	33	B117
Lower Tar	1	0	100	B122
Fishing Ck Subbasin+	3	2	33	B124
Sandy Swift Ck+	2	2	0	B127
Neuse/	**5**	**3**	**40**	
Middle Neuse Tribs+	5	3	40	B129
*Yellow Lance assumed present (p.17)				
+ Management Units containing HUCs with more than one observation in past 10 years (note: Upper Tar has 2 HUCs that fall into this category)				

3.4 Current Conditions

The results of surveys conducted from 2005 to 2015 suggest that the currently occupied range of the Yellow Lance includes 9 MUs from seven populations in Maryland, Virginia, and North Carolina. The majority of these observations (i.e., six of seven river basins) were limited to a single location, with the Tar River Basin as the one population with multiple occupied MUs. For context, Table 3-3 shows the current species status as tracked by national and state entities that track conservation status of species:

Table 3-3 Current species status/ranks by other entities who track conservation status of Yellow Lance

Entity	Status/Rank	Notes	Reference
NatureServe	G2N2 (Imperiled)	Species appears to be in decline throughout its historical range	NatureServe 2015
IUCN	NT (Near Threatened)	Annotations indicate this rank needs updating	IUCN 2001
American Fisheries Society (AFS)	Endangered		Williams et al., in press
Maryland	SU (Unknown)	Recently (2015) discovered in this state	M.Ashton (MD-DNR) email to S.McRae (USFWS) on 6/22/2015
Virginia	S2 (Imperiled)		VADCR-NHP 2016
North Carolina	Endangered/S1 (Critically Imperiled)		NCNHP 2014

3.4.1 Current MU/Population Resiliency

Methodology

To summarize the overall current conditions of Yellow Lance MUs, we sorted them into five categories (high, moderate, low, very low, and extirpated (ø)) based on the population factors and habitat elements discussed in Section 3.3.1 above (Table 3-4). MUs assessed include those areas where the species is presumed to be extirpated to portray the difference between the historical and current condition of the species. The current condition category is a qualitative estimate based on the analysis of the three population factors (MU Occupancy, Approximate Abundance, and Recruitment) and four habitat elements (Water Quality, Water Quantity/Flow, Instream Substrate, and Habitat Connectivity). Overall population condition rankings and habitat condition rankings were determined by combining the three population factors and four habitat elements, respectively.

For example, for the James Population, given the categorical scale of: High – Moderate – Low – Very Low – ø (see Table 3-4), the overall Current Population Condition is estimated to be *Low*; the *High* MU Occupancy Condition combined with the *Low* Approximate Abundance Condition is *Moderate* and when that is combined with the *Very Low* Reproduction condition, the overall ranking becomes *Low*:

Population/ Management Unit	MU Occupancy Condition		Approx Abundance Condition		Reproduction Condition	**Current Condition - Population Factors**
James/Johns Creek	**H**	**+**	**L**		**VL**	
		↓				
		M		+	VL	
				L	→	**Low**

Figure 3-18 Current Population Condition calculation is determined by combining the three population factors (MU Occupancy Condition, Approximate Abundance Condition, and Reproduction Condition).

Note: When MU Occupancy Condition was estimated to be ø, this extirpated condition superseded all other category rankings and was assigned as the Population Condition.

For the Habitat Elements, the scale included the following categories: High – Moderate – Low – Very Low. For example, for the Rappahannock Population, the overall Current Habitat Condition was determined by first combining the *Low* Water Quality Condition with the *High* Water Quantity Condition to get *Moderate*; when this *Moderate* was then combined with the *Low* Connectivity Condition and *Moderate* Instream Habitat Condition, the two *Moderate* ranks outweighed the *Low* rank to get an overall Current Habitat Condition of *Moderate*:

Population	Overall Water Quality Condition		Overall Water Quantity Condition	Overall Connectivity Condition		Overall Instream Habitat (Substrate) Condition	**Current Habitat Condition**
Rappahannock	**L**	**+**	**H**	**L**		**M**	
		↓					
		M	+	L	+	M	
				M		→	**Moderate**

Figure 3-19 Current Habitat Condition calculation is determined by combining the four habitat elements (Water Quality Condition, Water Quantity Condition, Connectivity Condition, and Instream Habitat Condition)

Because population factors are direct indicators of Yellow Lance condition (Table 3-5), we weighed population factors (direct measures) two times higher than habitat elements (indirect measures) when estimating the summary Current Condition.

Table 3-4 Population and habitat characteristics used to create condition categories in Table 3-5.

Condition Category	POPULATION FACTORS: MU Occupancy Decline	POPULATION FACTORS: Approximate Abundance	POPULATION FACTORS: Reproduction	HABITAT ELEMENTS: Water Quality	HABITAT ELEMENTS: Water Quantity/Flow	HABITAT ELEMENTS: In-stream substrate	HABITAT ELEMENTS: Habitat Connectivity
High	<30% decline	Cumulative numbers at high end of known range (over 300 individuals observed over time); 100+ live individuals observed in past 10 years	More than 50% of sites with recent (past 10 years) documentation of reproduction (gravidity) or presence of small individuals	Very few (if any) known impairment or contaminant problems (<5 miles impaired streams; no major discharges, <10 non-major discharges)	Optimal flowing water conditions to remove fine sediments, allow for food delivery, and maximize reproduction; no known flow issues; isolated low flow/drought periods; not flashy flow regime	Predominantly natural (>70% forested) ARA; <6% impervious surfaces in HUC10 watershed	Very little (if any) known habitat fragmentation issues (<10 dams per MU; avg # of Road Crossings <300 per MU)
Moderate	31-50% decline	Moderate numbers (101 to 300) of individuals observed over time; 51-100 live individuals observed in past 10 years	25-50% of sites with recent documentation of reproduction or presence of small individuals	Impairment or contaminants known to be an issue, but not at a level to put population at risk of being eliminated (5-50 miles impaired streams; 1-3 major discharges; 10-25 non-major discharges)	Water flow not sufficent to consistently remove fine sediments, drying conditions which could impact both food delivery and successful reproduction; moderate flow issues, including 3 to 4 years of consecutive drought or moderately flashy flows	20-70% forested ARA; 6-15% impervious surfaces in HUC10 watershed	Some habitat fragmentation issues (10-30 dams per MU; Avg # of Road Crossings 300-500 per MU)
Low	51-70% decline	Low numbers (11-100) of individuals observed over time; 11-50 live individuals observed in past 10 years	Fewer than 25% of sites with documentation of recent reproduction or presence of small individuals	Impairment or contaminants at levels high enough to put the population at risk of being eliminated (>50 miles impaired streams; >4 major discharges; 25+ non-major discharges)	Water not flowing - either inundated or dry; severe flow issues; more than 4 consecutive years of drought; flashy flow regime	<20% forested ARA; >15% impervious surfaces in HUC10 watershed	Habitat severely fragmented (30+ dams in MU; 500+ Avg Road Crossings per MU)
Very Low	>70% decline	Very few (less than 10) individuals observed over time; 10 or fewer live individuals observed in past 10 years	Reproduction data are older than 10 years	Impairment or contaminant at levels that cannot support species survival	Flow conditions do not support species survival	Instream habitat unable to support species survival	Habitat extremely fragmented and unable to support species survival
Ø	Total Loss	Only shells observed over time (no live)	Population is extirpated or no data	N/A	N/A	N/A	N/A

Table 3-5 Resiliency of Yellow Lance populations. See Table 3-4 for condition categories. Data for categorization are found in Appendix D.

	Population Factors				Habitat Elements					
Population/ Management Unit	**MU Occupancy**	**Approx Abundance**	**Reproduction**	**Combined Population Factors**	**Water Quality**	**Water Quantity**	**Connectivity**	**Instream Habitat (Substrate)**	**Combined Habitat Elements**	**Current Condition**
Patuxent	Moderate	Very Low	Ø	Very Low	Low	High	Moderate	Low	Moderate	Very Low
Potomac	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
Rappahannock	Low	Moderate	Low	Low	Low	Moderate	Low	Moderate	Moderate	Low
York	Very Low	Very Low	Ø	Very Low	Moderate	Moderate	Low	Moderate	Moderate	Very Low
James										Low
Johns Creek	High	Very Low	Low	Low	High	High	High	High	High	Low
Chowan										Low
Nottoway	Low	Very Low	Low	Low	Moderate	Moderate	Low	Moderate	Moderate	Low
Meherrin	Ø	Very Low	Ø	Ø	Moderate	Moderate	High	Moderate	Moderate	Ø
Tar										Moderate
Upper/Middle Tar	Moderate	High	High	High	Low	Low	Moderate	Moderate	Moderate	High
Lower Tar	Ø	Low	Ø	Ø	Moderate	Moderate	High	Low	Moderate	Ø
Fishing Ck Subbasin	Moderate	Low	Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate
Sandy Swift Ck	High	High	High	High	High	Low	Moderate	Moderate	Moderate	High
Neuse	Moderate	Low	Low	Low	Low	Low	Low	Low	Low	Low

Combined habitat elements, representing overall habitat condition, were high in one MU, moderate in nine MUs, and low in two MUs (Table 3-5). Combined population factors, representing a combination of occupancy, approximate abundance, and reproduction, was estimated to be high for two MUs, moderate for one MU, low for five MUs, very low for one MU, and extirpated for three MUs (Table 3-5). As noted in Section 3.3.1, both approximate abundances and recruitment should be considered conservative estimates.

At the population level, the overall current condition (= resiliency) was estimated to be moderate for the Tar Population, low for the Rappahannock, James, Chowan and Neuse populations, very low for the Patuxent and York, and extirpated for the Potomac Population (Table 3-5).

3.4.2 Current Species Representation

We estimated that the Yellow Lance currently has low adaptive potential due to limited representation in seven river basins and three physiographic regions (Figure 3-20). While the species retains 87% of its known River Basin variability, its distribution has been greatly reduced in the Rappahannock, York, Chowan, and Neuse River populations. In addition, compared to historical distribution, the species retains limited physiographic variability in the Coastal Plain (30%) and moderate variability in the Piedmont (44%) and in the Mountains (50%). Latitudinal variability is also reduced, as much of the species current distribution has contracted and is largely limited to the southern portions of its historical range, primarily in the Tar River Basin.

3.4.3 Current Species Redundancy

While the overall range of the Yellow Lance has not changed significantly, the remaining occupied portions of the range have become constricted within each basin. One population (Tar) was estimated to be moderately resilient, and all other extant populations exhibit low resiliency. Redundancy was estimated as the number of historically occupied MUs that remain currently occupied (Table 3-2). The species retains redundancy (albeit in low condition) within the Rappahannock, Chowan, and Neuse River populations, and only one population (Tar) has multiple moderate or highly resilient MUs (Table 3-5), thus limiting overall redundancy for the species. Overall, the species has decreased redundancy across its range due to an estimated 57% reduction in occupancy compared to historical levels.

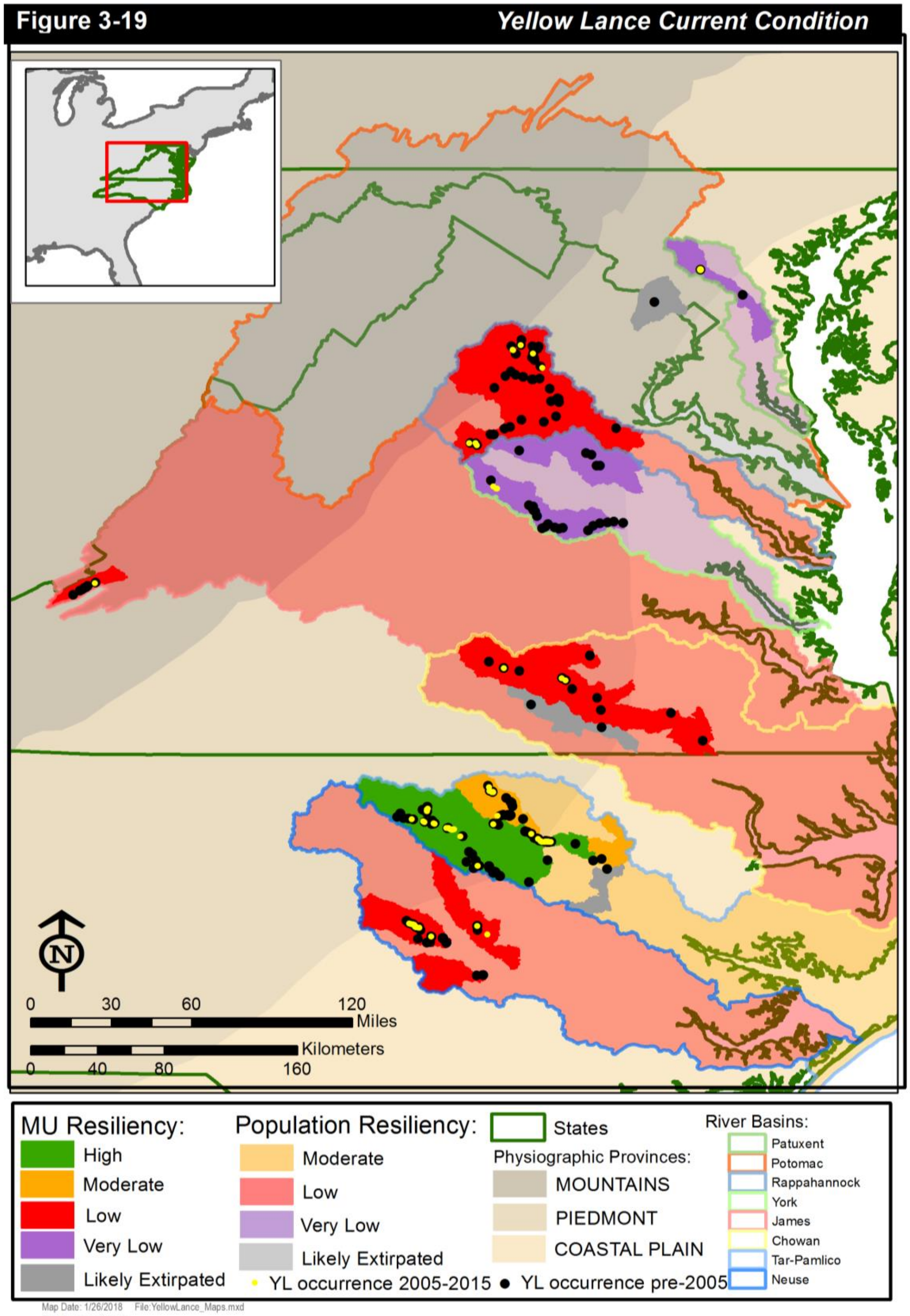


Figure 3-19
Yellow Lance Current Condition
0
30
60
120
Miles
Kilometers
0
40
80
160
MU Resiliency:
High
Moderate
Low
Very Low
Likely Extirpated
Population Resiliency:
Moderate
Low
Very Low
Likely Extirpated
YL occurrence 2005-2015
YL occurrence pre-2005
States
Physiographic Provinces:
MOUNTAINS
PIEDMONT
COASTAL PLAIN
River Basins:
Patuxent
Potomac
Rappahannock
York
James
Chowan
Tar-Pamlico
Neuse
Map Date: 1/26/2018 File:YellowLance_Maps.mxd
Data Source: USFWS

CHAPTER 4 - FACTORS INFLUENCING VIABILITY

In this chapter, we evaluate the past, current, and future factors that are affecting what the Yellow Lance needs for long term viability. Aquatic systems face a multitude of natural and anthropogenic threats and stressors (Neves et al. 1997, p.44). State Wildlife Action Plans have identified several factors that have impacts on habitats (see blue boxes in Figure 4.1 below). Generally, these factors can be categorized as either environmental stressors (e.g., development, agriculture practices, forest management, or regulatory frameworks) or systematic changes (e.g., climate change, invasive species, barriers, or conservation management practices). Current and potential future effects, along with current distribution and abundance help inform viability and, therefore, vulnerability to extinction. Those factors that are not known to have effects on Yellow Lance populations, such as overutilization for commercial and scientific purposes and disease, are not discussed in this SSA report.

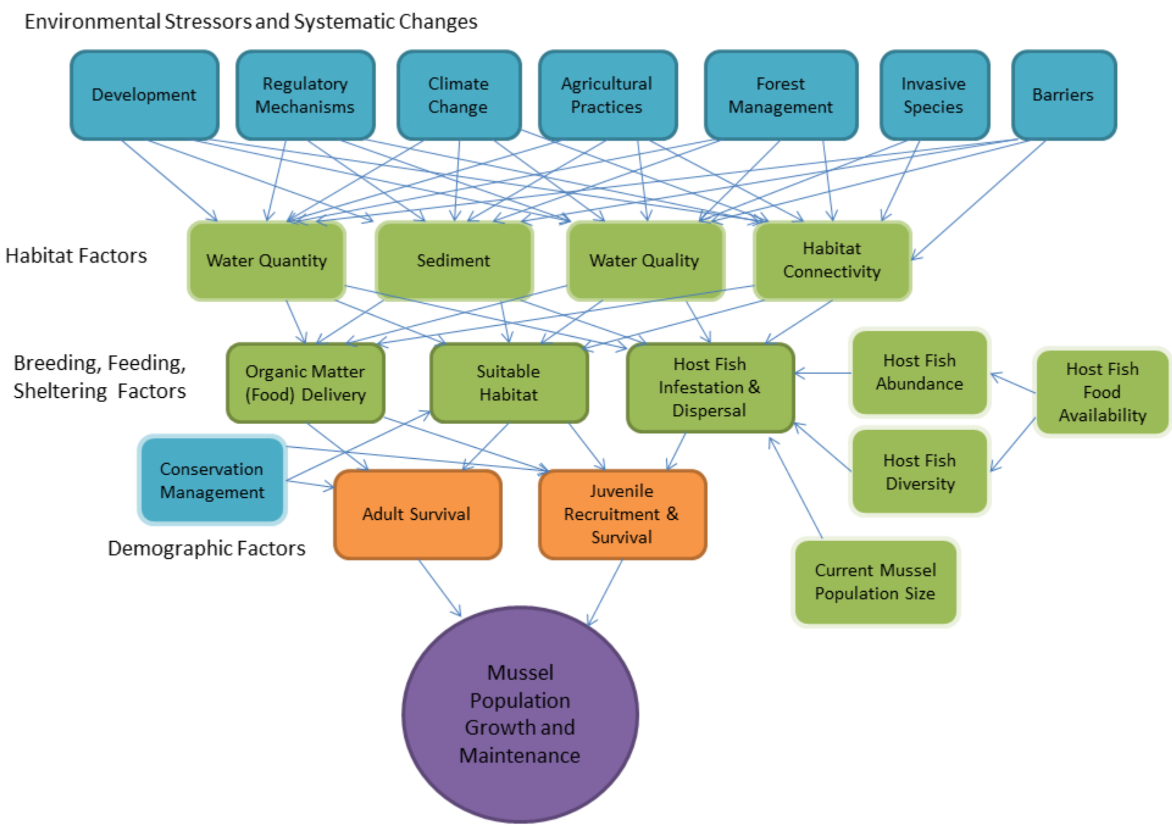


Figure 4-1 Influence diagram illustrating how environmental stressors and systematic changes influence habitat factors which in turn influence breeding, feeding, and sheltering needs of the species; in turn, these affect demographic factors which ultimately influence mussel population growth and maintenance.

4.1 Development

We use the term “development” to refer to urbanization of the landscape, including (but not necessarily limited to) land conversion for urban and commercial use, infrastructure (roads, bridges, utilities), and urban water uses (water supply reservoirs, wastewater treatment, etc.). The effects of urbanization may include alterations to water quality, water quantity, and habitat (both in-stream and stream-side) (Ren et al. 2003, p.649; Wilson 2015, p.424).

“Impervious surface” refers to all hard surfaces like paved roads, parking lots, roofs, and even highly compacted soils like sports fields. Impervious surfaces prevent the natural soaking of rainwater into the ground and ultimately seeping into streams (Brabec et al. 2002, p.499; NHEP 2007, p.2). Instead, the rain water accumulates and flows rapidly into storm drains which drain to local streams (Figure 4-2). This results in effects on streams in three important ways (USGS 2014, p.2-5):

Figure 4-2 Flooding over impervious surface (Credit: MD DNR)

1. Water Quantity: Storm drains deliver large volumes of water to streams much faster than would naturally occur, often resulting in flooding and bank erosion. Increased, high velocity discharges can cause species living in streams to become stressed, displaced, or killed by fast moving water and the debris and sediment carried in it.
2. Water Quality: Pollutants (e.g., gasoline or oil drips, fertilizers, etc) that accumulate on impervious surfaces may be washed directly into the streams during storm events.
3. Water Temperature: During warm weather, rain that falls on impervious surfaces becomes superheated and can stress or kill freshwater species when it enters streams.

Concentrations of contaminants, including nitrogen, phosphorus, chloride, insecticides, polycyclic aromatic hydrocarbons, and personal care products, increase with urban development (Giddings et al. 2009, p.2; Bringolf et al. 2010, p.1311). Water infrastructure development, including water supply, reclamation, and wastewater treatment, results in several pollution point discharges to streams. Urbanization increases the amount of impervious surfaces (CWP 2003, p.1). The resulting stormwater runoff affects water quality parameters such as temperature, pH, dissolved oxygen, and salinity, which in turn alters the water chemistry potentially making it inhospitable for aquatic biota (Figure 4-3).

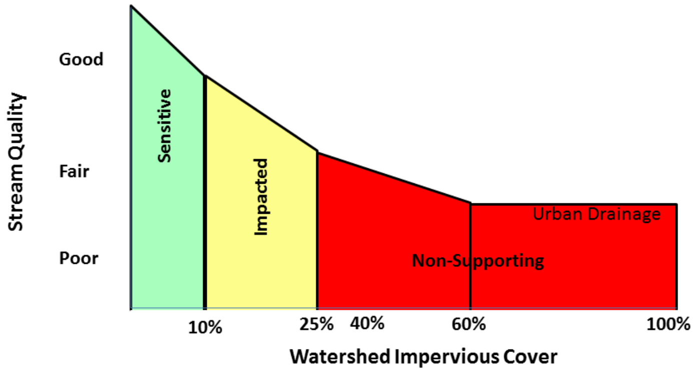


Figure 4-3. Stream Quality is adversely impacted by increased impervious surfaces (from CWP 2003, p.2)

Urban development can lead to increased variability in streamflow, typically increasing the amount of water entering a stream after a storm and decreasing the time it takes for the water to travel over the land before entering the stream (Giddings et al. 2009, p.1). In urban areas, flooding is often reduced by draining water quickly from roads and parking lots which results in increased amounts of water reaching a stream within a short period of time, leading to stream flashiness and altered stream channels (Giddings et al. 2009, p.1). The rapid runoff also reduces the amount of infiltration into the soil to recharge aquifers, resulting in lower sustained streamflows, especially during summer (Giddings et al. 2009, p.1). Ultimately, when the hydrology of the stream is altered and water quantities vary widely, the physical habitat of a stream often becomes degraded from channel erosion or lower summer flows that reduce feeding, spawning, and living spaces of the Yellow Lance and other aquatic biota (Giddings et al. 2009, p.1).

Urban development can alter stream habitat either directly via channelization or clearing of riparian areas, or indirectly via high streamflows that reshape the channel and cause sediment erosion (Giddings et al. 2009, p.2; Figures 4-4 and 4-5).

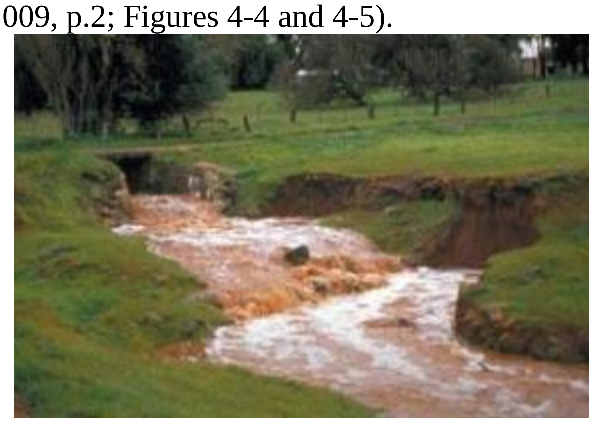


Figure 4-4 Sedimentation from unstable banks, cleared riparian area (credit: Ann Hamblin)

Figure 4-5 Sedimentation from construction flows (credit: Nancy Pierce)

A major aspect of urbanization is the resultant road development. By its nature, road development increases impervious surfaces as well as land clearing and habitat fragmentation. Roads are generally associated with negative effects on the biotic integrity of aquatic ecosystems, including changes in surface water temperatures and patterns of runoff, sedimentation, adding heavy metals (especially lead), salts, organics, ozone, and nutrients to stream systems (Trombulak and Frissell 2000, p.18). In addition, a major impact of road development is improperly constructed culverts at stream crossings (Figure 4-6). These culverts act as barriers, either as flow through the culvert varies significantly from the rest of the stream, or if the culvert ends up being perched, and aquatic organisms, specifically host fish for the Yellow Lance, cannot pass through them.

Figure 4-6 Perched culvert (credit: Raleigh News and Observer)

Utility crossings and rights-of-way (ROW) maintenance are additional aspects of development that impact stream habitats. For example, the proposed Atlantic Coast Pipeline planned to deliver natural gas from supply areas in West Virginia to markets in Virginia and North Carolina, will include the construction, operation, and maintenance of approximately 595 miles of transmission pipeline, crossing hundreds of streams in WV, VA, and NC, including significant Yellow Lance habitats in the Tar and Neuse River basins. Direct impacts from utility crossings include direct exposure or crushing of individuals, sedimentation, and flow disturbance; the most significant cumulative impact involves the cleared ROW that allows for direct runoff and increased temperature at the crossing location, and potentially allows access of all-terrain vehicles from the ROW (which destroy banks and instream habitat).

4.2 Regulatory Mechanisms

State Endangered Species Laws

Each state within the range of the Yellow Lance has state-level legislation modeled after the federal Endangered Species Act: in Maryland, it is the Nongame and Endangered Species Conservation Act, in Virginia it is both the Virginia Endangered Species Act and the Endangered Plant and Insect Species Act, and in North Carolina it is the North Carolina Endangered Species Act. Animal species that are protected by the state laws are regulated by state wildlife agencies; in the case of the Yellow Lance, that is the Maryland Department of Natural Resources, the Virginia Department of Game and Inland Fisheries, and the North Carolina Wildlife Resources Commission.

The state endangered species protection laws allow the state wildlife agencies to identify, document, and protect any animal species that is considered rare or in danger of extinction. In most of the states illegal activities include take, transport, export, processing, selling, offering for sale, or shipping species, and the penalty for doing so is a misdemeanor crime, usually resulting in a fine of no more than $1,000 or imprisonment not to exceed a year (Pellerito 2002, entire). There are no mechanisms for recovery, consultation, or critical habitat designation other than in MD where recommendations, not requirements, can be made for lands to be protected or acquired, and in NC where conservation plans must be developed for all state listed species (Pellerito 2002, Snape and George 2010, p.346). In addition, nothing in the North Carolina Endangered Species Act "shall be construed to limit the rights of a landholder in the management of his lands for agriculture, forestry, development, or any other lawful purpose" (NC GS 113-332).

State and Federal Stream Protections (Buffers & Permits)

A buffer is a strip of trees, plants, or grass along a stream or wetland that naturally filters out dirt and pollution from rain water runoff before it enters rivers, streams, wetlands, and marshes (SELC 2014, p.2). Several state laws require setbacks or buffers, and all allow variances/waivers for those restrictions. In Maryland, the state Forest Conservation Act protects 50-foot buffers on all streams, and the Chesapeake Bay Critical Area Act requires 100-foot mandatory buffers on all tributary streams in the defined Critical Area, although all agricultural and silvicultural lands are exempt. Similar to Maryland, Virginia's Chesapeake Bay Preservation Act requires 100-foot buffers on all perennial streams in designated "Resource Protection Areas." North Carolina previously had buffer requirements in specific watersheds (e.g., Tar-Pamlico, Neuse, Catawba, Jordan Lake, and Goose Creek), however, as described below, the NC Legislature enacted a Regulatory Reform effort, including "Riparian Buffer Reform" that allows for the amendment of the buffer rules to allow/exempt development and delay implementation of nutrient management (see Session Law 2012, section 8 and Session Law 2015-246, House Bill 44, G.S. 143-214.23A

(NCDEQ 2016, entire)). North Carolina also has recommendations for 200 foot riparian buffer protections for streams draining to listed aquatic species habitats (NCWRC 2002, p.11).

Section 401 of the federal Clean Water Act (CWA) requires that an applicant for a federal license or permit provide a certification that any discharges from the facility will not degrade water quality or violate water-quality standards, including state-established water quality standard requirements. Section 404 of the CWA establishes a program to regulate the discharge of dredged and fill material into waters of the United States.

Permits to fill wetlands and fill, culvert, bridge or re-align streams or water features are issued by the U.S. Army Corps of Engineers under Nationwide, Regional General Permits or Individual Permits.

- Nationwide Permits are for “minor” impacts to streams and wetlands, and do not require an intense review process. These impacts usually include stream impacts under 150 feet, and wetland fill projects up to 0.50 acres. Mitigation is usually provided for the same type of wetland or stream impacted, and is usually at a 2:1 ratio to offset losses and make the “no net loss” closer to reality.
- Regional General Permits are for various specific types of impacts that are common to a particular region; these permits will vary based on location in a certain region/state.
- Individual permits are for the larger, higher impact and more complex projects. These require a complex permit process with multi-agency input and involvement. Impacts in these types of permits are reviewed individually and the compensatory mitigation chosen may vary depending on project and types of impacts.

State and Federal Water Quality Programs

Current State regulations regarding pollutants are designed to be protective of aquatic organisms; however, freshwater mollusks may be more susceptible to some pollutants than the test organisms commonly used in bioassays. Additionally, water quality criteria may not incorporate data available for freshwater mussels (March et al. 2007, pp. 2,066–2,067). A multitude of bioassays conducted on 16 mussel species (summarized by Augspurger et al. 2007, pp. 2025–2028) show that freshwater mollusks are more sensitive than previously known to some chemical pollutants, including chlorine, ammonia, copper, fungicides, and herbicide surfactants. Another study found that nickel and chlorine were toxic to a federally threatened mussel species at levels below the current criteria (Gibson 2015, pp. 90–91). The study also found mussels are sensitive to SDS (sodium dodecyl sulfate), a surfactant commonly used in household detergents, for which water quality criteria do not currently exist. Several studies have demonstrated that the criteria for ammonia developed by EPA in 1999 were not protective of freshwater mussels (Augspurger et al. 2003, p. 2,571; Newton et al. 2003, pp. 2,559–2,560; Mummert et al. 2003, pp. 2,548–2,552). However, in 2013 EPA revised its recommended criteria for ammonia. The new criteria are more stringent and reflect new toxicity data on sensitive freshwater mollusks (78 FR 52192, August 22, 2013; p. 2). All of the states in the range of the Yellow Lance have not yet adopted the new ammonia criteria. NPDES permits are valid for 5 years, so even after the new criteria are adopted, it could take several years before facilities must comply with the new limits.

TMDL, or Total Maximum Daily Load, is a regulatory term from the CWA describing a plan for restoring impaired waters that identify the maximum amount of a pollutant that a body of water can receive while still maintaining water quality standards. In North Carolina, despite management actions that started in the mid-1990s, long term monitoring and trend analyses have demonstrated that TMDL goals have not been met: "Despite the fact that the targeted point and nonpoint pollution sources have been able to meet their nutrient reductions, total nitrogen and total phosphorous concentrations do not show a downward trend and loads have not permanently fallen below 1991 baseline load goals" (as referenced (p.6) in SRI public comment letter to USFWS, 6/5/2017).

Under the CWA, states are required to review their water quality standards and classifications every three years to make any modifications necessary to protect the waters of the state (NCDEQ 2016, entire). During this process, known as the Triennial Review, state water quality staff review current EPA guidelines, scientific data, and public comments and make recommendations for any changes of the water quality standards. In North Carolina, the most recent triennial review started in 2007 and was not completed until 2015 (NCDEQ 2016, entire). The state of North Carolina has not addressed water quality standards for several pollutants of concern for freshwater mussles, particularly ammonia, despite the EPA's 2013 recommended ambient water quality criteria for ammonia (as referenced (p.7) in SRI public comment letter to USFWS, 6/5/2017).

In summary, despite existing authorities such as the Clean Water Act, pollutants continue to impair the water quality throughout the current range of the Yellow Lance. State and Federal regulatory mechanisms have helped reduce the negative effects of point source discharges since the 1970s, yet these regulations are difficult to implement and regulate. While new water quality criteria are being developed that take into account more sensitive aquatic species, most criteria currently do not. It is expected that several years will be needed to implement new water quality criteria throughout the range.

Regulatory Reform in North Carolina

North Carolina has undergone regulatory review and reform that is worthy of mention because of implications to stream habitat protections for aquatic species in the state, particularly areas that are the strongholds for species like the Yellow Lance. In the past six years (since 2010), there have been several changes to state regulations, dubbed as "Regulatory Reform" and in 2016, the changes are described in legislation titled as the "Regulatory Reduction Act." These changes have far reach and the most recent reforms have affected significant environmental programs and protections, including (see Smith 2013-2016 for detailed review of applicable Session Laws, House and Senate Bills, and enacted Legislation):

- disinvestment in data collection on rare and endangered species by significant funding reductions to the state's Natural Heritage Program;
- revision of the State Environmental Policy Act review process (from NCDEQ's website):

  > "Session Law 2015-90…overhauled the criteria under which a SEPA review of a proposed project is evaluated. Prior to the passage of SL 2015-90, if a proposed project involved any amount of public funds, involved the use of public lands, or had significant environmental impacts as determined by the minimum criteria, then a

SEPA review was necessary. With the passage of SL 2015-90, two key criteria must now be considered to determine if a proposed action may require a SEPA eview. The first is the funding source. If a proposed action involves more than $10,000,000 of funds provided by the State of North Carolina for a single project or action or related group of projects or actions a SEPA review may be necessary. This is a change over the previous requirement which included any public funds (i.e. city, county, bonds, etc.). The second involves direct impacts resulting from the proposed project. If the proposed action will result in substantial, permanent changes to the natural cover or topography greater than or equal to ten acres of public lands a SEPA review may be required. This is a change over previous requirements that required a SEPA review for impacts to any type or amount of public lands" (NCDEQ 2016, entire);

- eliminating or limiting stormwater and stream buffer rules (and allowing unlimited development in a riparian buffer as long as the project complies with state stormwater requirements) in the Neuse River basin, the Tar-Pamlico River basin and the Jordan Lake watershed;
- change of state water quality rules to include a new stormwater standard which eliminates on-site stormwater controls, unless they are needed to meet specific state or federal laws;
- reduction of 401 certification/404 permitting requirements by eliminating mitigation for projects impacting less than 300 feet of stream and reduced mitigation rations from 2:1 to 1:1;
- limitation of state environmental agency authorities (G.S. 150B-19.3) and local government authorities.

As the title of the legislation states, these regulatory changes are intended to "improve and streamline the regulatory process in order to stimulate job creation, to eliminate unnecessary regulation, to make various other statutory changes, and to amend certain environmental and natural resource laws" (exact title of HB74 2013). The result of these regulatory changes could impact aquatic species such as the Yellow Lance, as well as the habitats that the species require for survival. For example, reduced resources to inventory, compile, and review data as well as changed criteria for project review, changed rules and standards, and reduced mitigation requirements could all result in project implementation without consideration of impacts to species, thus potentially directly or indirectly impacting the habitats the species depend on, resulting in degradation of stream quality and ultimately in species decline.

4.3 Climate Change

As mentioned in the Poff et al. 2002 (pp.ii-v) report on Aquatic Ecosystems and Global Climate Change, likely impacts of climate change on aquatic systems include:

- Increases in water temperatures that may alter fundamental ecological processes, thermal suitability of aquatic habitats for resident species, as well as the geographic distribution of species. Adaptation by migration to suitable habitat might be possible, however human alteration of dispersal corridors may limit the ability of species to relocate, thus increasing the likelihood of species extinction and loss of biodiversity.
- Changes and shifts in seasonal patterns of precipitation and runoff will alter the hydrology of stream systems, affecting species composition and ecosystem productivity. Aquatic organisms are sensitive to changes in frequency, duration, and timing of extreme

precipitation events such as floods or droughts, potentially resulting in interference of reproduction. Further, increased water temperatures and seasonally reduced streamflows will alter many ecosystem processes, including increases in nuisance algal blooms.

- Climate change is an additional stressor to sensitive freshwater systems, which are already adversely affected by a variety of other human impacts, such as altered flow regimes and deterioration of water quality.
- As mentioned by Poff et al. (2002, pp.ii-v), aquatic ecosystems have a limited ability to adapt to climate change. Reducing the likelihood of significant impacts will largely depend on human activities that reduce other sources of ecosystem stress to ultimately enhance adaptive capacity; these include maintaining riparian forests, reducing nutrient loading, restoring damaged ecosystems, minimizing groundwater (and stream) withdrawal, and strategically placing any new reservoirs to minimize adverse effects.
- Specific ecological responses to climate change cannot be easily predicted because new combinations of native and non-native species will interact in novel situations.
- Since sedentary freshwater mussels have limited refugia from disturbances such as droughts and floods, and since they are thermo-conformers whose physiological processes are constrained by water temperature within species-specific thermal preferences, climate-induced changes in water temperature can lead to shifts in mussel community structure (Galbraith et al. 2010, p.1176).

4.4 Agricultural Practices

Agricultural best management practices (BMPs) are changes in agricultural land management that can be focused on achieving multiple positive environmental outcomes. A wide variety of agricultural BMPs exist, including practices such as cover crops, conservation tillage, irrigation efficiency, contour farming, and agroforestry; these practices aim to reduce agrichemical pollution and erosion, manage nutrient and sediment runoff, and protect streams. The US Department of Agriculture's Natural Resource Conservation Service has prepared national technical guidance on conservation practices and activities that can be adapted at the local level, and incentives are available for local farmers to participate in programs to promote agricultural conservation practices (USDA 2018, entire).

Nutrient Pollution

Farming operations, including Concentrated Animal Feeding Operations (CAFOs), can contribute to nutrient pollution when not properly managed (EPA 2016, entire). Fertilizers and animal manure, which are both rich in nitrogen and phosphorus, are the primary sources of nutrient pollution from agricultural sources. If fertilizers are not applied properly, at the right time of the year and with the right application method, water quality in the stream systems can be affected. Excess nutrients impact water quality when it rains or when water and soil containing nitrogen and phosphorus wash into nearby waters or leach into the water table/ground waters causing algal blooms. Fertilized soils and livestock can be significant sources of nitrogen-based compounds like ammonia and nitrogen oxides. Ammonia can be harmful to aquatic life if large amounts are deposited to surface waters (see information in "State Water Quality Programs" section below). The lack of stable stream bank slopes from agricultural clearing and/or the lack of stable cover crops between rotations on farmed lands can increase the amount of nutrients that make their way into the nearby streams by way of increased soil erosion (cover crops and other vegetation will use excess nutrients and increase soil stability). Livestock often use streams or created in-line ponds as a water source; this degrades water quality and stream bank stability and reduces water quantity available for downstream needs.

Pumping for Irrigation

Irrigation is the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall. It is common practice to pump water for irrigation from adjacent streams or rivers into a reservoir pond, or sprayed directly onto crops. If the water withdrawal is excessive (usually over 10,000 gal/day) or done illegally (without permit if needed, or during dry time of year, or in areas where sensitive aquatic species occur without consultation), this may cause impacts to the amount of water available to downstream sensitive areas during low flow months, resulting in dewatering of channels and stranding of mussels. Irrigation water pumped from groundwater sources can also impact stream baseline flows because of hydrologic interconnections (Winter et al. 1998, p.III). Agricultural withdrawals (surface and groundwater combined) are nearly 40million gallons/day in the upper Tar River Basin, and nearly 43million gallons/day in the middle Neuse River Basin (NCDACS 2014, p.9).

Agriculture Exemptions from Permit Requirements

Normal farming, silviculture, and ranching activities are exempt from the 404 permitting process. This includes activities such as construction and maintenance of farm ponds, irrigation ditches, and farm roads. If the activity might impact rare aquatic species, the USACE does require farmers to ensure that any “discharge shall not take, or jeopardize the continued existence of, a threatened or endangered species, or adversely modify or destroy the critical habitat of such species,” and to ensure that “adverse impacts to the aquatic environment are minimized,” however the USACE does not require the farmer to consult with appropriate State or Federal Agencies regarding these sensitive species.

While there is an expectation for farmers to follow best management practices (BMPs), there are often cases where BMPs are not followed and go un-noticed as many farming activities are in rural locations and regulators are spread thin (Wells (USFWS) email to S.McRae (USFWS) on 5/13/2016).

4.5 Forest Conversion and Management

A forested landscape provides many ideal conditions for aquatic ecosystems. Depending on the structure and function of the forest, and particularly if native, natural mixed hardwood

Riparian Buffer Function	Range of reported effective widths (meters)	Average of reported effective widths (meters)	Number of studies included in analysis
Sediment retention	7-300	44	33
Nutrient retention	4-177	25	37
Nitrogen	7-33	18	15
Phosphorus	4-30	16	12
Bacteriological retention	9-58	31	6
Miscellaneous pollutant removal[1]	4-61	27	8
Sustain aquatic biota	23-100	35	13
Detritus input/structural complexity	7-80	37	18
Temperature moderation	8-173	34	17

Table 4-2 Range of buffer widths for specific riparian functional values (from USFWS 2006, p.22)

forests comprise the active river area (ARA), rain is allowed to slowly infiltrate and percolate (as opposed to rapid surface runoff), a variety of food resources enter the stream via leaf litter and woody debris, banks are stabilized by tree roots, habitat is created by occasional windthrow, and riparian trees shade the stream and maintain an ideal thermal climate.

Forested ARAs, or riparian areas, perform many functions that are essential to maintaining water quality, aquatic species survival, and biological productivity (NCWRC 2002, p.6). Specifically, forested riparian areas serve a role as (USFWS 2006, p.6):

- mechanical barriers to runoff, increasing surface roughness to reduce flow velocity and promoting mechanical trapping of suspended solids;
- sediment traps and bank stabilizers, where the tree root structures retain erodible soils and stabilize streambanks;
- cover refugia and nest sites, where woody debris from adjacent forested areas provides structural complexity of instream habitats;
- temperature regulation, as trees in the riparian area provide shading for temperature regulation/microclimate maintenance; and
- food resources, as adequate food input (detritus, allochthonous material) comes from the surrounding riparian zone (Stewart et al. 2000, p.210).

Wide, contiguous forested riparian buffers have greater and more flexible potential than other options to maintain biological integrity (Table 4-2; Horner et al. 1999, p.2) and could ameliorate many ecological issues related to land use and environmental quality (Naiman et al. 1993, p.209).

Silvicultural activities when performed according to strict Forest Practices Guidelines (FPGs) or Best Management Practices (BMPs) can retain adequate conditions for aquatic ecosystems, however, when FPGs/BMPs are not followed, these activities can also "cause measurable impacts" (NCASI 2015, p.1) and contribute to the myriad of stressors facing aquatic systems in the Southeast. Both small and large scale forestry activities have been shown to have a significant impact upon the physical, chemical, and biological characteristics of adjacent small streams (Allan 1995, p.325). Today, forests are harvested and converted for many reasons including, but not limited to: financial gain to the property owner by timber harvest, residential and commercial development, conversion for various agricultural practices, for the manufacturing of wood and paper products, and for fuel for electricity generation (Alig et al. 2010, pp.2-3; Maestas 2013, p.1; National Geographic 2016, entire). In many cases, natural mixed hardwood-conifer forests are clear-cut, then either left to naturally regenerate or replanted in rows of monoculture species such as pine, used for the growing need for timber building supplies and pulp products (Figure 4-8; Allen et al. 1996, p.4; Wear and Greis 2012, p.13; NCFA 2017, entire).

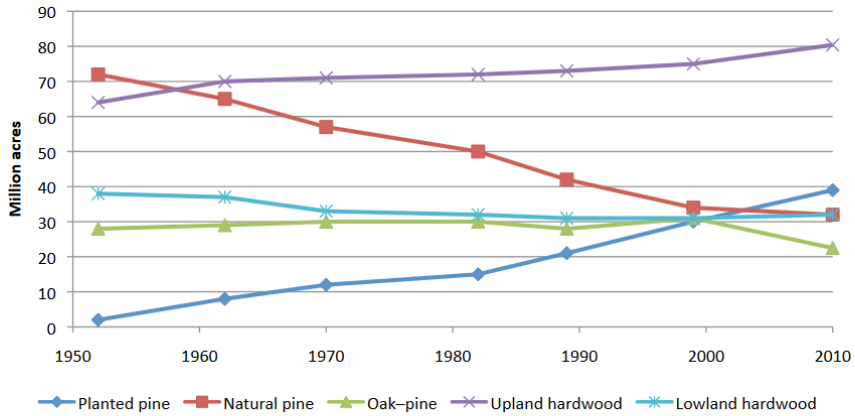


Figure 4-8 Historical trends in forest area by broad management type, showing an increase in planted pine over the past half-century (from Wear and Greis 2012, p.13)

These monoculture stands can impact overall water cycle dynamics (e.g., increased evapotranspiration and overall reduced stream flows)(Swank and Miner, 1968, entire; Swank and Douglass 1974, entire; Riggs et al. 2000, pp.118-119), as well as result in a reduction of biodiversity in the canopy, mid and understory vegetation as well as the fauna that uses this now monoculture area. Furthermore, the aquatic habitats of streams in these monoculture forested areas lose heterogeneity in food resources due to reduced variety in allochthonous (i.e., energy inputs derived from outside the stream system, or leaf matter that falls into stream) inputs, and this effect is mirrored among invertebrate and fish populations, including filter-feeding mussels and benthic insectivorous fish and amphibians (Webster et al. 1992, p.235; Allan 1995, p.129; Jones et al. 1999, p.1454).

The clearing of large areas of forested wetlands and riparian systems eliminates shade once provided by the canopies, exposing streams to more sunlight and increasing the in-stream water temperature (Wenger 1999, p.35). The increase in stream temperature and light after deforestation has been found to alter the macroinvertebrate and other aquatic species richness and abundance composition in streams to various degrees depending on each species tolerance to temperature change and increased light in the aquatic system (Kishi et al. 2004, p.283; Couceiro et al. 2007, p.272; Caldwell et al. 2014, p.3).

Sediment runoff from cleared forested areas is a known stressor to aquatic systems (Webster et al. 1992, p.232; Jones et al. 1999, p.1455; Broadmeadow and Nisbet 2004, p.286; Aust et al. 2011, p.123). The physical characteristics of stream channels are affected when large quantities of sediment are added or removed (Watters 2000, p.263). Mussels and fish are potentially impacted by changes in suspended and bed material load, bed sediment composition associated with increased sediment production and runoff in the watershed, channel changes in form, position, and degree of stability; actively filling or scouring channels; and changes in channel position that may leave mussels or fish exposed (Brim Box and Mossa 1999, p.100; USFWS 2003, p.53). Interstitial spaces in mixed substrates may become clogged with sediment subsequently reducing habitat for the life history needs of aquatic species.

Stream crossings and inadequately buffered clearcut areas can be important sources of sediment entering streams (Taylor et al. 1999, p.13). Many forestry activities are not required to obtain a

CWA 404 permit, as silviculture activities (such as harvesting for the production of fiber and forest products) are exempted (USACE 2016, entire: USEPA 2017, p.1). Because forestry activities often include the construction of logging roads through the riparian zone, this can directly degrade nearby stream environments (Aust et al. 2011, p.123). Logging roads constructed in wetlands adjacent to headwater drains and streams fall into this exemption category, but may impact the aquatic system for years as these roads do not always have to be removed immediately. Roads remain as long as the silviculture operation is ongoing, thus wetlands/streams/ditches draining into the more sensitive areas may be heavily impacted by adjacent fill and runoff if BMP's fail or are not maintained, causing sedimentation to travel downstream into more sensitive in-stream habitats. Requirements maintain that flows are not to be restricted by logging roads, but culverts are only required per BMP's and are not always adequately sized or spaced. Furthermore, stream crossings tend to have among the lowest implementation (Table 4-3), and this is particularly true in North Carolina (NCFS 2011, p.v; NCASI 2015, p.4).

Forestry practices that do not follow BMPs can impact natural flow regime, resulting in altered habitat connectivity. Logging staging areas, logging ruts, and not re-planting are all associated impacts that are a threat to downstream aquatic species. BMP's require foresters to ensure that "the discharge shall not take, or jeopardize the continued existence of, a threatened or endangered species, or adversely modify or destroy the critical habitat of such species," and to ensure that "adverse impacts to the aquatic environment are minimized," however, foresters are not required to consult with appropriate state or federal agencies regarding these sensitive species and ways to best reduce potential impacts prior to moving forward with management.

Around the turn of the 21st century, biologists, foresters, and managers alike recognized the need for wholesale implementation of BMPs to address many of the aforementioned issues related to forest conversion and silvicultural practices. Now, forestry BMP manuals suggest planning road systems and harvest operations to minimize the number of crossings. Proper construction and maintenance of crossings reduces soil erosion and sedimentation with the added benefit of increasing harvest operation efficiency (NCASI 2015, p.2). The non-point source programs for forestry in North Carolina is described as "quasi-regulatory" because it has defined the legal implications of non-compliance in a specific way (NCASI 2015, p. 1). FPGs (specific to North Carolina) are codified performance standards that govern forestry-related land-disturbing activities and BMPs are recommended actions/measures to minimize and control nonpoint pollution runoff from forestry operations. The NC Forest Service has noted that "improving BMP implementation of stream crossing BMPs will have the most positive influence on reducing the risk to water quality on active harvest sites, followed by BMPs for rehabilitation, debris entering streams, skid trails, and SMZs [streamside management zones]" (NCFS 2011, p.vi). In the South, the region-wide average for overall BMP implementation in 2011 was 92% (Table 4-3; NCASI 2015, pp.3-4).

Table 4-3. Forestry Best Management Practices Implementation Rates from the Most Recent Surveys for States in the Southeastern US (Sources: SGSF 2012; NASF 2015 (excerpted from NCASI 2015, p.4)

BMP Category	Range of Implementation Rates in SE States: SGSF (2012)[1]	Range of Implementation Rates in SE States: NASF (2015)[2]	Average Implementation Rate (from SGSF 2012)
Overall BMP Implementation	85% to 99%	85% to 99%	92%
Harvesting	85% to 99%	88% to 99%	95%
Forest Roads	78% to 99%	84% to 99%	90%
Stream Crossings	72% to 98%	72% to 98%	89%
SMZs	85% to 99%	86% to 98%	93%
Site Preparation	74% to 99%	74% to 99%	92%
Firebreaks	33% to 100%	64% to 100%	82%
Chemical Application	94% to 100%	93% to 100%	98.5%

[1]SGSF (2012) includes implementation rates for Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.
[2]NASF (2015) includes implementation rates for Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

While FPGs and BMPs are widely adhered to (Table 4-3), they were not always common practice, and even today there are instances (although rare) that do not rise to a level of threat minimization that is adequate for the sensitive species (e.g., freshwater mussels and fish) in the area. As an example, while NC's FPG .0201 indicates that "a SMZ shall be established and maintained along the margins of intermittent and perennial streams…[and] shall be of sufficient width to confine…visible sediment resulting from accelerated erosion", there is no information on the required width. Even if mandated 50 or 100 foot buffer zones (e.g., in the Neuse and Tar River basins) were enforced (see "Regulatory Reform" section above), data indicate that minimum native, forested buffer widths of 200-feet on perennial streams and 100-feet on intermittent streams, or the full extent of the 100-year floodplain, should be maintained in watersheds supporting federally endangered and threatened aquatic species (NCWRC 2002, pp.10-11; Broadmeadow and Nisbet 2004, p.286; NCNHP 2004, p. 4; USFWS 2006, p.17).

4.6 Invasive Species

The South Atlantic seaboard has many native species that are declining and nonnative nuisance species are one of the major causes. It is estimated that 42% of Federally Threatened or Endangered species are significantly impacted by nonnative nuisance species across the nation and nuisance species are significantly impeding recovery efforts for them in some way (NCANSMPC 2015, pp.8-9). There are many areas across the states of Maryland, Virginia, and North Carolina where aquatic invasive species have invaded aquatic communities; are competing with native species for food, light, or breeding and nesting areas; and are impacting biodiversity.

When an invasive species is introduced it may have many advantages over native species, such as easy adaptation to varying environments and a high tolerance of living conditions that allows it to thrive in its nonnative range. There may not be natural predators to keep the invasive species in check; therefore, it can potentially live longer and reproduce more often, further reducing the biodiversity in the system. The native species may become an easy food source for invasive species, or the invasive species may carry diseases that wipe out populations of native species.

Examples of invasive species that affect freshwater mussels like the Yellow Lance are the Asian Clam (*Corbicula fluminea*), the Flathead Catfish (*Pylodictis olivaris*), and Hydrilla (*Hydrilla verticillata*). The Asian Clam alters benthic substrates, competes with native species for limited resources, and causes ammonia spikes in surrounding water when they die off en masse (Scheller 1997, p.2). The Asian Clam is ubiquitous across the southeastern United States and is present in watersheds across the ranges of the Yellow Lance (Foster et al. 2017, p.1). The Flathead Catfish is an apex predator known to feed on almost anything, including other fish, crustaceans, and mollusks, and to impact host fish communities, reducing the amount of fish available as hosts for the mussels to complete their life cycle (VDGIF 2017, entire; NCANSMPC 2015, p.75). Hydrilla is an aquatic plant that alters stream habitat, decreases flows, and contributes to sediment buildup in streams (NCANSMPC 2015, p.57). High sedimentation can cause suffocation, reduce stream flow, and make it difficult for mussels' interactions with host fish necessary for development. Hydrilla occurs in several watersheds where the Yellow Lance occur, including recent documentation from the Neuse system and the Tar River. The dense growth is altering the flow in these systems and causing sediment buildup, which can cause suffocation in filter-feeding mussels. While data are lacking on Hydrilla currently having population-level effects on the Yellow Lance, the spread of this invasive plant is expected to increase in the future.

4.7 Dams and Barriers

> *One of the greatest known extinction episodes in the first half of the twentieth century took place in the Southeast – the virtual disappearance of the Coosa River molluscan fauna. Dams on the Coosa River destroyed all the shoals on which the snails and mussels depended… Today, most of the remnants of this once diverse fauna teeter on the brink of extinction.* –G.W.Folkerts (1997, p.11)

Extinction/extirpation of North American freshwater mussels can be traced to impoundment and inundation of riffle habitats in all major river basins of the central and eastern United States (NCWRC 2015a, p.109). Humans have constructed dams for a variety of reasons: flood prevention, water storage, electricity generation, irrigation, recreation, and navigation (Eissa and Zaki 2011, p.253). Manmade dams and natural dams (either created by beavers or by aggregations of woody debris) have many impacts on stream ecosystems. Reductions in the diversity and abundance of mussels are primarily attributed to habitat shifts causes by impoundment (Neves et al. 1997, p.63):

- Upstream of dams – the change from flowing to impounded waters, increased depths, increased buildup of sediments, decreased dissolved oxygen, and the drastic alteration in resident fish populations inevitably can threaten the survival of mussels and their overall reproductive success.

- Downstream of dams – fluctuations in flow regimes, minimal releases and scouring flows, seasonal dissolved oxygen depletion, reduced or increased water temperatures, and changes in fish assemblages can also threaten the survival and reproduction of many mussel species.

Dams have also been identified as causing genetic isolation in river systems – resident fish can no longer move freely through different habitats and may become genetically isolated from other fish populations throughout the river; furthermore, as host fish, this can cause genetic segregation in the mussel populations as well.

Interestingly, recent studies have shown that some mussel populations may be more temporally persistent immediately downstream of small dams, more abundant and diverse, and attain larger sizes and grow faster than do conspecifics in populations further upstream or downstream (Gangloff 2013, p.476 and references therein). In today's rapidly changing landscape, it is possible that these small dams and their impoundments may perform some key ecological functions including filtration and detoxification of anthropogenically elevated nutrient loads, oxygenating low-gradient streams during low-water periods, and stabilizing portions of the stream beds that are needed for the persistence of fish and mollusk taxa (Gangloff 2013, pp.478-479). Additional benefits of impoundments may include (Gangloff 2013, p.479 and references therein):

- retention of fine sediments and associated toxicants, as in the case of the Lake Benson Dam in the Swift Creek (Neuse) watershed,
- impediments to the spread of invasive species, as in the case of Bellamy's Mill Dam on Fishing Creek (Tar) that appears to prevent the upstream spread of Flathead Catfish, and
- attenuation of floods from urban or highly agrarian watersheds.

As mentioned above, improperly constructed culverts at stream crossings act as significant barriers, and have some similar effects as dams on stream systems. Fluctuating flows through the culvert can vary significantly from the rest of the stream, preventing fish passage and scouring downstream habitats. If a culvert ends up being perched above the stream bed, aquatic organisms cannot pass through them. These barriers not only fragment habitats along a stream course, they also contribute to genetic isolation of the aquatic species inhabiting the streams.

4.8 Conservation Management

Conservation management actions include *in situ* actions such as habitat protection and stream restoration as well as *ex situ* actions such as captive propagation, ultimately leading to species population restoration.

"It is…widely recognized that the future of rare aquatic species is best secured by protecting and restoring biological integrity of entire watersheds" (Shute et al. 1997, p.448 and references therein). While land acquisition is the most obvious means of affecting watershed protection, it is not feasible to acquire entire watersheds. Shute et al. (1997, p.448) offer up "Ecosystem Management" as the most effective method of protecting the greatest number of species, however, they warn that "the complex nature of aquatic ecosystems and the watershed scale necessary for aquatic ecosystem protection is problematic... [It] is expensive, time consuming, and requires considerable coordination with and commitment from various agencies, organizations, and private individuals."

The Service and State Wildlife Agencies are working with numerous partners to make Ecosystem Management a reality, primarily by providing technical guidance and offering development of conservation tools to meet both species and habitat needs in aquatic systems from Maryland to North Carolina. There is a lot of effort to work with agriculture producers through the U.S. Department of Agriculture's Natural Resource Conservation Service to install riparian buffers along streams (J.Slacum (USFWS) email to S.McRae (USFWS) on 11/30/2016). Land Trusts are targeting key parcels for acquisition, federal and state biologists are surveying and monitoring species occurrences, and recently there has been a concerted effort to ramp up captive propagation and species population restoration via augmentation, expansion, and reintroduction efforts.

In 2014, North Carolina Wildlife Resources Commission staff and partners began a concerted effort to propagate the Yellow Lance in hopes of augmenting existing populations in the Tar and Neuse River basins. In July 2015, 270 Yellow Lances were stocked into Sandy Creek, a tributary of the Tar River (NCWRC 2015b, p.7). Annual monitoring to evaluate growth and survival is planned, and additional propagation and stocking efforts will continue in upcoming years.

4.9 Summary

Of the past, current, and future influences on what the Yellow Lance needs for long term viability, the largest threats to the future viability of the species relate to habitat degradation from stressors influencing water quality, water quantity, instream habitat, and habitat connectivity. All of these factors are influenced by climate change. We did not assess overutilization for scientific and commercial purposes or disease, because these risks do not appear to be occurring at a level that affects Yellow Lance populations. Impairment of water quality, declines in flows, riparian and instream habitat fragmentation and degradation, as well as management efforts, are carried forward in our assessment of the future conditions of Yellow Lance MUs and populations, and the viability of the species overall.

CHAPTER 5 – FUTURE CONDITIONS

Thus far, we have considered Yellow Lance life history characteristics and we have identified the habitat and demographic requisites needed for viability and we estimated the current condition of those needs through the lens of the 3Rs (Chapters 2 and 3). Next, we reviewed the factors that may be driving the historical, current, and future conditions of the species (Chapter 4). In this chapter, we predict the species' future conditions given a range of plausible future scenarios. As with estimates of current condition, future forecasts were made using the concepts of resiliency, redundancy, and representation to describe the future viability of the Yellow Lance.

5.1 Future Scenario Considerations

We identified the main drivers of change for the future scenario analyses to be human population growth and subsequent urbanization rates, both of which are predicted to result in patterns of increased urban sprawl across the landscape (Terando et al. 2014, p.1). According to the United States Census, the human population in the southeastern US has grown at an average annual rate of 36.7% since 2000 (US Census 2016, pp. 1-4), by far the most rapidly growing region in the country. This rapid growth has resulted in expanding urbanization, sometimes referred to as "urban sprawl." Urban sprawl increases the connectivity of urban habitats while simultaneously fragmenting non-urban habitats such as forests and grasslands (Terando et al. 2014, p.1). In turn, species and ecosystems are impacted by the increased sprawl, including impacts to water pollution, local climate conditions, and disturbance dynamics (Terando et al. 2014, p.1). One way to forecast how these changes will affect the Yellow Lance is to look at the spatial pattern and extent of urban sprawl across historically and currently occupied watersheds, and build a model predicting the effects of that sprawl to the habitat elements that influence Yellow Lance populations.

To forecast future urbanization, we developed future scenarios that incorporate the SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model, which simulates patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks, including the sprawling, fragmented, "leapfrog" development that has been the dominant form of development in the Southeast (Terando et al. 2014, p.2). Terando et al. (2014) projected urban sprawl changes for the next 50 years for the fast-growing Southeastern United States, using simulations that point to a future in which the extent of urbanization in the Southeast is projected to increase by 101% to 192%. This projection is based on the "business-as-usual" (BAU) scenario in which the net effect of growth is in line with that which has occurred in the past (Terando et al. 2014, p.1; Figure 5-1), and as mentioned above, is in line with the Southeast being the fastest growing region in the country. While more sophisticated models exist, the SLEUTH model provides scalability, uses commonly available datasets, and is adaptable to focus on patterns of suburban and exurban development (Terando et al. 2014, p.2). The BAU scenario simulations do not consider alternative policies that could promote different urbanization patterns, however, the broad patterns of growth used do reflect recent trends in terms of the speed at which urbanization has progressed in the Southeast and in the locations that are most affected by it (Terando et al. 2014, p.7).

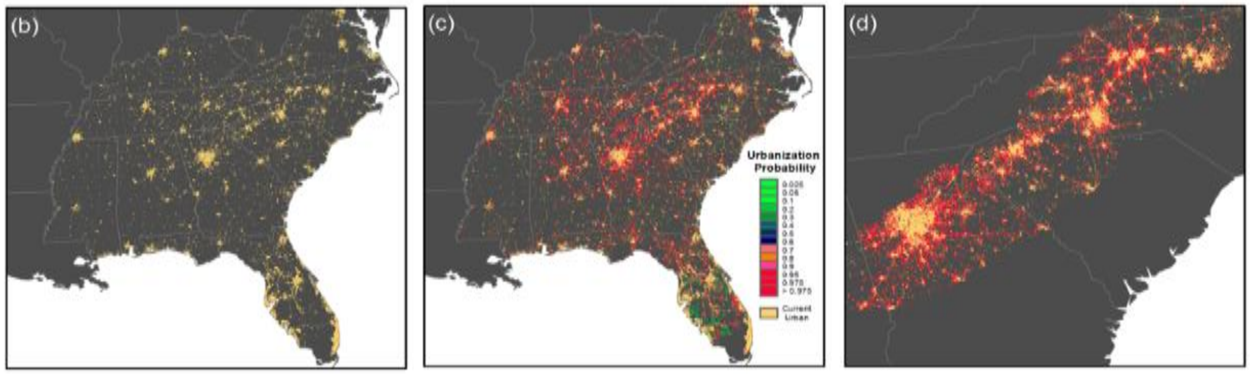


Figure 5-1 "Business-as-usual" urbanization scenario for the Southeast US from Terando et al. 2014, p.3. Red areas are the urban extent as classified by their methodology. (b) is the initial urban land cover in 2009; (c) is the projected urban land cover in 2060; and (d) is the projected urban land cover in the Piedmont ecoregion showing a connected urban landscape.

As discussed in section 4.1, the development promulgated from urban sprawl is expected to impact the habitat elements that were identified as essential for the survival of the Yellow Lance. Consequently, water quality and quantity will likely decline, habitat connectivity will become more fragmented, and instream substrate habitat may become less suitable for the species to survive. As such, urban sprawl will, almost certainly, influence the ability of the species to respond to climate change (Hannah 2011, p. 1141). Given all scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), greenhouse gas emissions are expected to continue at or above current rates which will lead to continued warming (Figure 5-2; IPCC 2013, p.7). Warming in the Southeast is expected to be greatest in the summer (NCCV 2016) which is predicted to increase drought frequency, while annual mean precipitation is expected to increase slightly, leading to increased flooding events (Figure 5-3; IPCC 2013, p.7; NCCV 2016).

In order to predict future changes in climate, scientists rely on climate model simulations that are driven by assumptions about future human population growth, changes in energy generation and land use, socio-economic development, and technology change. The IPCC's Fifth Assessment Report (AR5), published in 2014, presents findings based on a set of scenarios that use Representative Concentration Pathways (RCPs). The RCPs are representative of several different scenarios that have similar greenhouse gas emissions characteristics on a time-dependent trajectory to reach a certain projected outcome (Wayne 2013, p.1). There are four RCPs, identified by the amount of radiative forcing (i.e., the change in energy in the atmosphere due to greenhouse gases) reached by 2100: one high pathway (RCP8.5); two intermediate stabilization pathways (RCP6.0 and RCP4.5); and one low trajectory pathway (RCP2.6 or RCP3PD)(Wayne 2013, p.11).

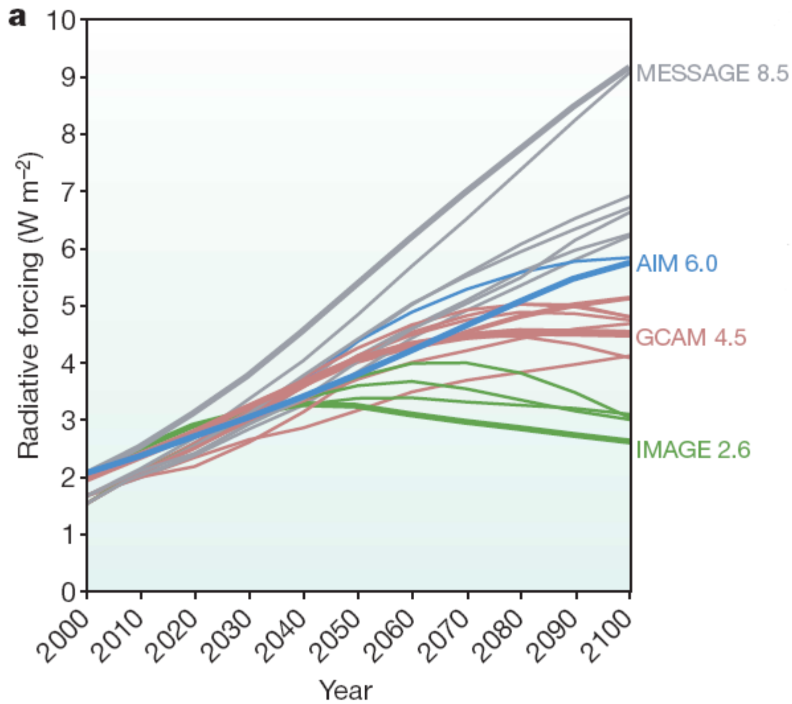


Figure 5-2 Changes in radiative forcing relative to pre-industrial conditions. Bold colored lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing (from Moss et al., 2010).

RCP2.6 assumes that through drastic policy intervention, greenhouse gas emissions would be reduced almost immediately, leading to a slight reduction in today's levels by 2100; RCP8.5 assumes that emissions would be more or less unabated due to a lack of climate-change reversal policies (Wayne 2013, p.15). For RCP4.5 and RCP6.0, emissions are assumed to be relatively stable throughout the century, however RCP6.0 does not incorporate climate-reversal policies into forecasts, while RCP4.5 incorporates a number of climate policies into forecasts (Wayne 2013, p.15). As cited from DeWan et al. (2010, p.4), "it is difficult to predict the human choices that will shape our future emissions, and thus what the world might look like in 2100."

Changes in climate may affect ecosystem processes and communities by altering the abiotic conditions experienced by biotic assemblages resulting in potential effects on community composition and individual species interactions (DeWan et al. 2010, p.7). This is especially true for aquatic systems where climate change can trigger a cascade of ecological effects. For example, increases in air temperatures can lead to subsequent increases in water temperatures which, in turn, may lower water quality parameters (like dissolved oxygen), ultimately influencing overall habitat suitability for species like the Yellow Lance.

Despite the recognition of potential climate effects on ecosystem processes, there is uncertainty about what the exact climate future for the Southeastern US will be and how the ecosystems and species in this region will respond. In the "Threats" section of the North Carolina Wildlife Action Plan (NCWRC 2015a, p.5-48), climate change is seen as a "low" threat to the Yellow Lance, with Small Scope (affecting 1-10% of the total population or occurrences) and Slight Severity (likely to only slightly degrade/reduce affected occurrences or habitat, or reduce the population by 1-10%). Furthermore, in an assessment of ecosystem response to climate change, factors associated with climate change ranked well below other factors that were deemed more imminent risks to Yellow Lance populations (e.g., development, pollution, water withdrawals, flood regime alteration, etc.; NCNHP 2010, entire). However, it should be recognized that the greatest threat from climate change may come from synergistic effects. That is, factors associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats (Arabshahi and Raines 2012, p.8). As a result, impacts from rapid urbanization in the region might be exacerbated under even a mild to moderate climate future.

For future scenario predictions, we considered the "extreme" climate futures under RCPs 8.5 and 2.6 for the Pessimistic and Optimistic Scenarios respectively. Alternate climate scenarios were used to evaluate more moderate and/or stabilizing climate futures for the Status Quo and Opportunistic Scenarios (see Table 5-1 for details). Both of the "stabilizing" RCPs have a similar trajectory given our 50-year time frame (Figure 5-2); therefore, both RCP4.5 or RCP6.0 were used to help inform predictions related to a more moderate climate future. Regardless of a pessimistic, optimistic, opportunistic, or status quo climate future, the following systematic changes are expected to be realized to varying degrees in the Southeastern US (NCILT 2012, p.27; IPCC 2013, p.7):

- More frequent drought
- More extreme heat (resulting in increases in air and water temperatures, Figure 5-3)
- Increased heavy precipitation events (e.g., flooding)
- More intense storms (e.g., frequency of major hurricanes increases)
- Rising sea level and accompanying storm surge

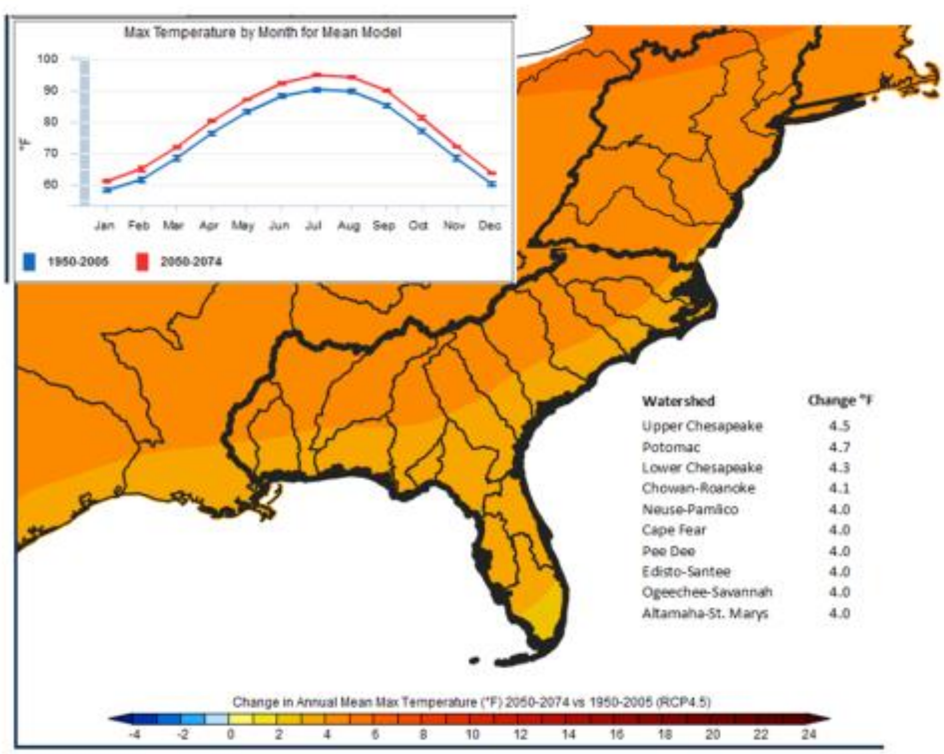


Figure 5-3 Predicted change in annual mean maximum air temperature under RCP4.5 (NCCV 2016)

5.1.1 The Scenarios

The Yellow Lance has declined in overall distribution and abundance. The species currently occupies approximately 43% of its historical range with most remaining populations being small and fragmented, occupying sporadic reaches compared to presumed historical populations, and several are isolated from one another. The prevailing hypothesis for this decline is habitat degradation, resulting from the cumulative impacts of land use change and subsequent watershed-level landscape changes that presumably impacted water quality, water quantity, habitat connectivity, and instream habitat suitability (see Chapter 4).

Populations in both large and small MUs face risks from both natural and anthropogenic sources. Climate change has already begun to affect the watersheds where Yellow Lance occurs, resulting in higher air temperatures and increased evaporation, and changing precipitation patterns such that water levels rangewide have already reached historic lows (NCILT 2012, p.6). These low water levels put the populations at elevated risk for habitat loss.

These risks, alone or in combination, could potentially result in the extirpation of additional populations, increasing population fragmentation, and, in turn, negative effects on species redundancy and representation. Given small and fragmented contemporary populations of Yellow Lance, maintaining future viability is largely reliant on preventing further declines in current populations and restoring/recovering population numbers and connectivity (where feasible). Because we have significant uncertainty regarding if and when additional flow loss, water quality impairment, or connectivity issues may occur, we have forecasted what the Yellow Lance may have in terms of the 3Rs under four plausible future scenarios.

Four scenarios, including a status quo scenario, were used to characterize the uncertainty regarding plausible futures for the Yellow Lance. Resiliency, representation, and redundancy were forecasted for each scenario using each of four possible climate futures coupled with variable levels of urbanization predicted by the SLEUTH BAU. Current levels of conservation management were assumed to be constant across all scenarios unless commitment of specific actions are currently, or will be imminently, in place. The expected future resiliency of each MU was forecasted based on events that were predicted to occur under each scenario. As with current condition estimates, estimates were made at the lowest hierarchical level (MUs) and were then scaled up to the population (i.e., river basin) level.

Predictions of Yellow Lance resiliency, redundancy, and representation were forecasted using a 50-year time horizon. This time horizon was chosen to correspond to the range of available urbanization and climate change model forecasts. Furthermore, 50-years represents a time frame during which the effects of management actions can be implemented and realized on the landscape, and it is a reasonable time frame (including approximately 4-5 generations) for the species to respond to potential changes on the landscape.

For these projections, high condition MUs were defined as those with high resiliency at the end of the predicted time horizon (50 years). MUs in high condition are expected to persist into the future, beyond 50 years, and have the ability to withstand stochastic events. MUs in moderate condition were defined as having lower resiliency than those in high condition but are still expected to persist to 50 years. Populations in moderate condition have lower abundances and reduced reproductive potential than those in high condition. Finally, those MUs in low condition were defined as having low resiliency and may not be able to withstand stochastic events. As a result, low condition MUs were predicted to be much less likely to persist 50 years into the future.

Table 5-1 Future Scenario Summary Table

			Future Condition Category Descriptions			
Scenario Name	**Climate Future**	**Urbanization**	**Species Condition**	**Water Quality Condition**	**Water Quantity Condition**	**Habitat Condition**
1) Status Quo Scenario	Current Climate effects continue on trend into the future, resulting in increased heat, drought, storms and flooding	Urbanization continues on trend with current levels	Current level of species response to impacts on landscape; current levels of propagation & augmentation and/or translocation capacity	Current level of regulation and oversight, including limited protective WQ[5] standards requirements and utilization of basic technologies for effluent treatment	Current level of regulation and oversight, including sustained IBTs[6] and irrigation withdrawals; current flow conditions	Current level of regulation, barrier improvement/removal projects, and riparian buffer protections
2) Pessimistic Scenario	Moderate to Worse Climate Future (RCP8.5[1])- exacerbated effects of climate change experienced related to heat, drought, storms and flooding	Urbanization rates at high end of BAU[4] model (~200%)	Species response to synergistic impacts on landscape result in significant declines coupled with limited propagation capacity and/or limited ability to augment/reintroduce propagules	Declining water quality resulting from increased impacts, limited regulation and restrictions, and overall reduced protections	Degraded flow conditions resulting from climate change effects, increased withdrawals and IBTs, limited regulation, and overall reduced protections	Degraded instream and riparian habitat conditions from increased impacts, limited regulation, fewer barrier improvement/removal projects, and overall reduced riparian buffer protections
3) Optimistic Scenario	Moderate to Improved Climate Future (trending towards RCP 2.6[2]) resulting in minimal effects of heat, drought, storms and flooding	Urbanization rates realized at lower levels than BAU model predicts (<100%)	Optimistic species response to impacts; targeted propagation and/or restoration efforts utilizing existing resources and capacity	Slightly increased impacts tempered by utilizing improved technologies and implementing protection strategies	Improved flow conditions through increased oversight and implementation of flow improvement strategies	Existing resources targeted to highest priority barrier removals; riparian buffer protections remain intact; targeted riparian connectivity projects; regulatory mechanisms remain the same
4) Opportunistic Scenario	Moderate Climate Future (RCP4.5/6[3]) - some climate change effects experienced; some areas impacted more than others by heat, drought, storms and flooding	Moderate BAU urbanization rates (~100%) realized	Selective improved species response to impacts as a result of targeted propagation and/or restoration efforts utilizing current resources and capacity	Moderate increase in WQ impacts resulting from continued levels of regulation, protection, and technology	Targeted strategies to improve flow conditions in priority areas	Targeted increase in riparian connectivity and protection of instream habitat in priority areas through targeted conservation efforts

[1]Representative concentration pathway 8.5
[2] Representative concentration pathway 2.6
[3] Representative concentration pathway 4.5/6
[4]Business as usual
[5]Water quality
[6]Interbasin transfer

5.2 Scenario 1 – Status Quo

Under the Status Quo scenario, factors that influence current populations of Yellow Lance were assumed to remain constant over the 50 year time horizon. Climate models predict that, if emissions continue at current rates, the Southeast Region will experience a rise in low flow (drought) events (IPCC 2013, p.7). Likewise, this scenario assumed the Business as Usual pattern of urban growth which predicted that urbanization would continue to increase rapidly (Terando et al. 2014, p.1). The Status Quo Scenario also assumed that current conservation efforts would remain in place but that no new actions would be taken. Below describe how factors affecting populations, including water quality, flow, and riparian cover, are expected to change given the Status Quo Scenario. Given predicted habitat conditions and current population factors (i.e., initial conditions) we then forecast Yellow Lance viability using the 3R framework.

- Patuxent – Urbanization is predicted to result in up to 50% developed area within the basin in the next 50 years (NLCD 2011; Table 5-1). Urban sprawl felt from Baltimore and Washington DC growing towards each other will likely contribute to an overall decline in water quality, flow conditions, and habitat connectivity in affected watersheds (see Section 4.1). Given this scenario, it is likely that the Patuxent Basin would experience comparable effects, thus resulting in overall decline in Yellow Lance habitat condition (Table 5-2), resulting in the likely extirpation of this population.
- Potomac – Urbanization affecting the Potomac Basin (largely a result of the growing Washington DC metropolitan area) is predicted to increase the proportion of developed area in the Difficult Run MU to over 55% (NLCD 2011; Terando et. al. 2014, p.1). Increased urbanization is expected to lower water quality via increased impervious surface runoff and non-point source pollution (see Section 4.1). Additionally, this basin is already experiencing nutrient loading and associated eutrophication from treated wastewater inputs and stormwater, both of which are expected to continue in the future under the status quo. Urbanization is also expected to increase the number of road crossings, in turn, potentially decreasing habitat connectivity. Lowered habitat quality (Table 5-2), coupled with a projected decline in habitat connectivity is expected limit available habitat where the species was once known to occur, and the Yellow Lance is predicted to remain extirpated under the Status Quo Scenario.
- Rappahannock – While predominantly a rural watershed, urbanization from the continued southward expansion of Washington DC will likely affect portions of the MU in the next 50 years (Terando et al. 2014, p.1). Stormwater runoff and sedimentation are predicted to continue to affect water quality, thus continued low habitat conditions throughout the MU will likely prevent the species from persisting under this scenario (Table 5-2).
- York – While water quantity and habitat connectivity conditions will likely remain the same in the Status Quo Scenario, this basin is predicted to see persistent declines in water quality and instream habitat from continued intensive agriculture practices (NLCD 2011), thus contributing to low habitat conditions that are unsuitable for Yellow Lance persistence in this basin (Table 5-2).
- James – Habitat conditions will likely remain unchanged in the Status Quo Scenario. The extreme headwaters MU for this population will likely remain resilient (albeit at low

levels because of the continued low population factors) through a Status Quo Scenario, resulting in continued low population and high habitat conditions into the future.

- Chowan – Climate induced change, along with continued sedimentation from agricultural practices, is predicted to result in reduced flow in the Nottoway drainage as well as degraded instream habitats in both the Nottoway and Meherrin MUs (B.Watson (VADGIF) email to S.McRae (USFWS) on 10/3/2016; Table 3-2). The Yellow Lance is currently presumed extirpated in the Meherrin MU and re-establishment without human intervention is unlikely. Habitat quality in the Nottoway MU is predicted to decline, thus painting a relatively dire picture for the future of Yellow Lance persistence in the Chowan Basin under the Status Quo Scenario.
- Tar – Continued climate induced changes that reduce flows (NCILT 2012, p.27), coupled with the continuation of water quality impacts are predicted to result in poor habitat conditions throughout the Upper/Middle Tar MU. Factors affecting water quality in the Upper/Middle Tar MU are wastewater treatment (e.g. basic effluent treatment technologies) and reduced riparian habitat protections (see Section 4.2; Table 5-2). Both the Fishing Creek and Sandy/Swift Creek MUs are predicted to maintain moderate habitat conditions in the Status Quo Scenario, thus perpetuating existing moderate/high population conditions into the future.
- Neuse – Urbanization in the Middle Neuse River Basin is predicted to result in continued declines in water quality from stormwater runoff and wastewater effluent issues (see Section 4-1). Additionally, this scenario predicts declines in water quantity as the area continues to withdraw water to support continued population growth and declines in habitat connectivity by maintaining existing dam infrastructure and population-growth inducing more road crossings; all of these factors contribute to declining instream habitat for the species. These factors are likely to contribute to a precipitous overall decline in habitat for the species (Table 5-2).

5.2.1 Resiliency

Given the Status Quo Scenario, extant populations were predicted to persist in MUs where habitat conditions (described above and in Table 5-2) are expected to remain sufficient for Yellow Lance reproduction and survival. Only the Sandy/Swift MU and Fishing Creek MU were predicted to remain moderately resilient, while the Johns Creek MU and the Upper/Middle Tar MU were predicted to have low resiliency at the end of the predictive time horizon (Table 5-2). All other MUs were predicted to become extirpated.

Scaling up to the population level, only one population (Tar) is expected to have moderate resiliency and one population (James) is expected to retain low resiliency under the Status Quo Scenario. All other populations (five of seven currently extant populations) of Yellow Lance are predicted to become extirpated in 50 years under the Status Quo Scenario.

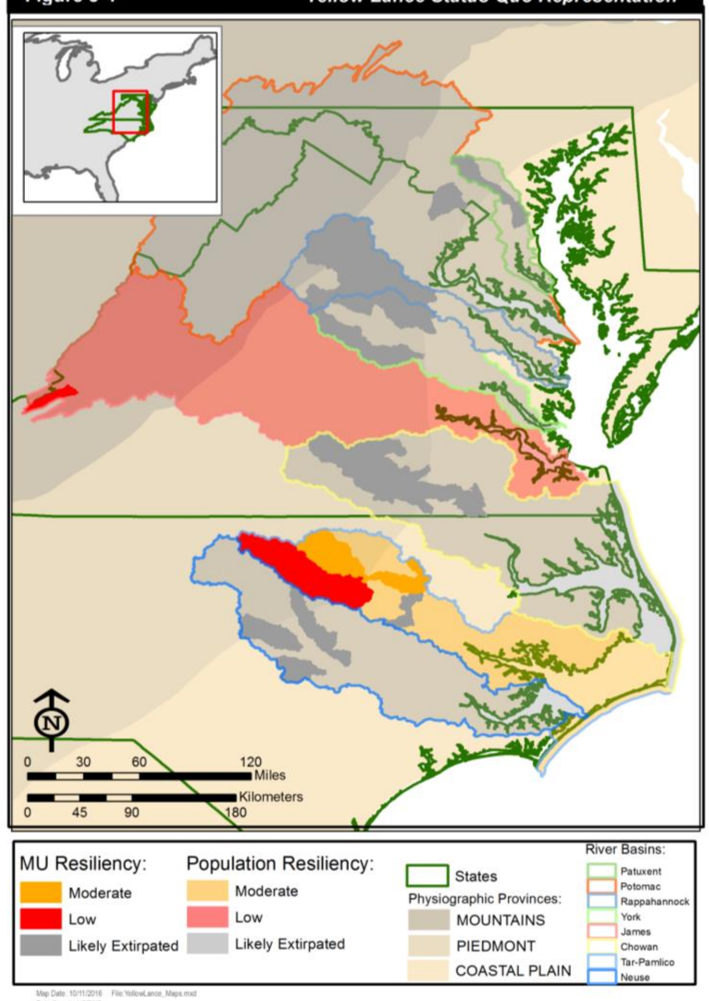
Table 5-2 Yellow Lance Resiliency under Scenario 1 - Status Quo

	Population Factors				Habitat Elements					
Population/ Management Unit	MU Occupancy	Abundance	Reproduction	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Patuxent	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
Potomac	Ø	Ø	Ø	Ø	Very Low	Moderate	Very Low	Low	Low	Ø
Rappahannock	Ø	Ø	Ø	Ø	Low	High	Low	Low	Low	Ø
York	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
James										**Low**
Johns Creek	Moderate	Low	Low	Low	Moderate	High	High	High	High	Low
Chowan										Ø
Nottoway	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
Meherrin	Ø	Ø	Ø	Ø	Low	Moderate	High	Low	Moderate	Ø
Tar										**Moderate**
Upper/Middle Tar	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lower Tar	Ø	Ø	Ø	Ø	Low	Moderate	Moderate	Low	Low	Ø
Fishing Ck Subbasin	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Moderate	Moderate
Sandy Swift Ck	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Neuse										Ø
Middle Neuse Tribs	Ø	Ø	Ø	Ø	Very Low	Very Low	Low	Low	Low	Ø

5.2.2 Representation

Given our measures of representation, including Physiographic, Latitudinal and River Basin Variability, we predicted that the Yellow Lance will have limited representation at the end of the predictive time horizon. Under the Status Quo Scenario, the species is expected to lose 75% of its known River Basin Variability with populations remaining only in the James and Tar River basins. Physiographic Variability is also expected to decline in the Mountains (75%), Piedmont (84%), and Coastal Plain (80%). As for Latitudinal Variability, the species' northernmost occurrence is expected to move south from the Patuxent (under current conditions) to the James (under predicted future conditions), and the species' southernmost occurrence is expected to move north from the Neuse (under current conditions) to the Tar (under predicted future conditions), thus further contracting species distribution (Figure 5-4).

Figure 5-4 Yellow Lance Status Quo Representation



5.2.3 Redundancy

Under the Status Quo Scenario, we predicted that the number of resilient Yellow Lance populations will decline considerably with likely extirpation in eight of twelve currently extant MUs; only the Tar Population retains more than one moderately resilient MU (Table 5-2). This expected loss in both the number and distribution of resilient populations is likely to make the species vulnerable to stochastic disturbance events.

5.3 Scenario 2 – Pessimistic

Factors that negatively influence Yellow Lance populations (see Chapter 4) get worse under the Pessimistic Scenario (Table 5-1). Reflecting Climate Model RCP8.5 (Wayne 2013, p.11), effects of climate change are expected to be magnified beyond what is experienced in the Status Quo Scenario. Effects are predicted to result in extreme heat (Figure 5-5), more storms and flooding, and exacerbated drought conditions (IPCC 2013, p.7). Based on the results of the

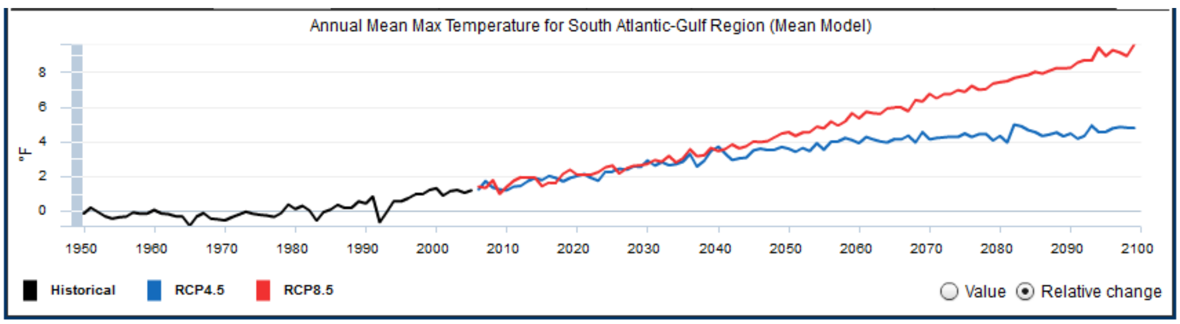


Figure 5-5 Time Series of Annual Mean Maximum Temperature under RCP8.5 (shown in red) (NCCV 2016)

SLEUTH BAU model (Terando et al. 2014, entire), urbanization in Yellow Lance watersheds could expand to triple the amount of developed area resulting in large increases of impervious surface cover and, potentially, consumptive water use. Increased urbanization and climate change impacts are likely to result in increased impacts to water quality, flow, and habitat connectivity, and we predict that there is limited capacity for species restoration under this scenario.

- Patuxent – High urbanization rates are predicted to result in up to 200% increased developed area within the basin in the next 50 years, or double of what is currently occurring (NLCD 2011; Table 5-1). This is predicted to further degrade habitat conditions, especially through water quality stressors and instream habitat unsuitability (see Section 4.1), thus the species is not expected to persist under the Pessimistic Scenario.
- Potomac – Like many of the watersheds in the vicinity of the Washington DC, high urbanization rates under the Pessimistic Scenario (Table 5-1) are predicted to deteriorate water quality conditions, flow conditions will be reduced through consumptive use, and riparian and instream habitat protections will be compromised by impacts from urban sprawl (see Section 4.1), thus resulting in low habitat conditions that are unsuitable for the species existence. The species is expected to remain extirpated from the Potomac under the Pessimistic Scenario.

- Rappahannock – Under the Pessimistic Scenario, urban sprawl will likely affect water quality and habitat conditions in many of the lower areas of the MU (see Section 4-1), and based on the current low condition of Yellow Lance in the Rappahannock basin, the species response to the synergistic impacts is predicted to result in extirpation.
- York – Given the low current condition in the York MU, further declines in habitat conditions (Table 5-3) are expected to have continued negative effects, thus resulting in the inability of the species to respond and adapt to such conditions.
- James – Habitat conditions in the Johns Creek MU are predicted to decline only slightly under a Pessimistic Scenario, due primarily to climate-induced changes; the reduced habitat conditions will not sustain a robust population. Therefore, the overall condition of the species in the Pessimistic Scenario would remain low.
- Chowan – The Chowan Population is composed of the Meherrin (currently extirpated) and the Nottoway (currently extant) MUs. The Pessimistic Scenario does not involve human intervention that would repopulate extirpated MUs, so the Meherrin is predicted to remain extirpated, while the Nottoway is predicted to experience a decline in habitat conditions (Table 5-3) that will subsequently negatively influence Yellow Lance habitat availability, and is predicted to result in loss of the species from this basin.
- Tar – Climate change is predicted to result in an increase in the number and duration of droughts in the Tar Basin (see Section 4-3; Table 5-1). Low flows combined basic effluent treatment in the Upper Tar basin is likely to make the Upper/Middle Tar MU uninhabitable for the Yellow Lance. Conversely, while the habitat conditions in the Fishing Creek and Sandy/Swift MUs are predicted to decline under more extreme climate and urbanization futures, the species is expected to persist, but reduced to low resiliency.
- Neuse - High urbanization rates (up to 200% in 50-years, or double of what is currently occurring) is predicted to further degrade habitat conditions, especially through water quality stressors and instream habitat unsuitability (see Section 4-1), thus the species is not expected to persist in this MU under the Pessimistic Scenario.

5.3.1 Resiliency

The Pessimistic Scenario projects the condition of the Yellow Lance populations under a more extreme climate and urbanization future, with increased impacts to habitat conditions resulting in a reduced species response. Habitat conditions are only expected to be able to support the continued survival of two currently extant populations, the James and the Tar (Table 5-3). We predict that no highly or moderately resilient populations will remain at the end of the predictive time horizon, thus the remaining three MUs (Johns Creek, Sandy/Swift, and Fishing Creek Subbasin) are predicted to have low resiliency. All other MUs are predicted to either become or remain extirpated from their current/historic range. Similar to Status Quo Scenario, six of the eight populations of Yellow Lance are predicted to become extirpated in 50 years; however, the population conditions in the Pessimistic Scenario are expected to be lower than those predicted for the Status Quo Scenario (Table 5-2, Table 5-3).

Table 5-3 Yellow Lance Resiliency under Scenario 2 - Pessimistic

	Population Factors				Habitat Elements					
Population/ Management Unit	MU Occupancy	Abundance	Reproduction	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Patuxent	Ø	Ø	Ø	Ø	Very Low	Moderate	Low	Very Low	Low	Ø
Potomac	Ø	Ø	Ø	Ø	Very Low	Low	Very Low	Very Low	Very Low	Ø
Rappahannock	Ø	Ø	Ø	Ø	Low	Moderate	Very Low	Very Low	Very Low	Ø
York	Ø	Ø	Ø	Ø	Low	Moderate	Low	Very Low	Low	Ø
James										**Low**
Johns Creek	Low	Low	Low	Low	Moderate	High	Moderate	Moderate	Moderate	Low
Chowan										Ø
Nottoway	Ø	Ø	Ø	Ø	Low	Very Low	Low	Very Low	Low	Ø
Meherrin	Ø	Ø	Ø	Ø	Low	Low	Low	Low	Low	Ø
Tar										**Low**
Upper/Middle Tar	Ø	Ø	Ø	Ø	Very Low	Very Low	Low	Very Low	Very Low	Ø
Lower Tar	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
Fishing Ck Subbasin	Low	Low	Low	Low	Moderate	Low	Low	Low	Low	Low
Sandy Swift Ck	Moderate	Low	Low	Low	Moderate	Low	Moderate	Moderate	Moderate	Low
Neuse										Ø
Middle Neuse Tribs	Ø	Ø	Ø	Ø	Very Low	Very Low	Low	Very Low	Very Low	Ø

5.3.2 Representation

We predicted that the Yellow Lance will have very limited representation in the form of Physiographic, Latitudinal, and River Basin variability. The species is expected to lose 75% of its known River Basin Variability, retaining representation in only in the James and Tar River Basins. The species is also expected to retain minimal Physiographic Variability in the Piedmont (9%), the Mountains (25%), and the Coastal Plain (20%). At the population level, only two populations (James and Tar) are expected to remain representative at the end of the predictive time horizon (Figure 5-6).

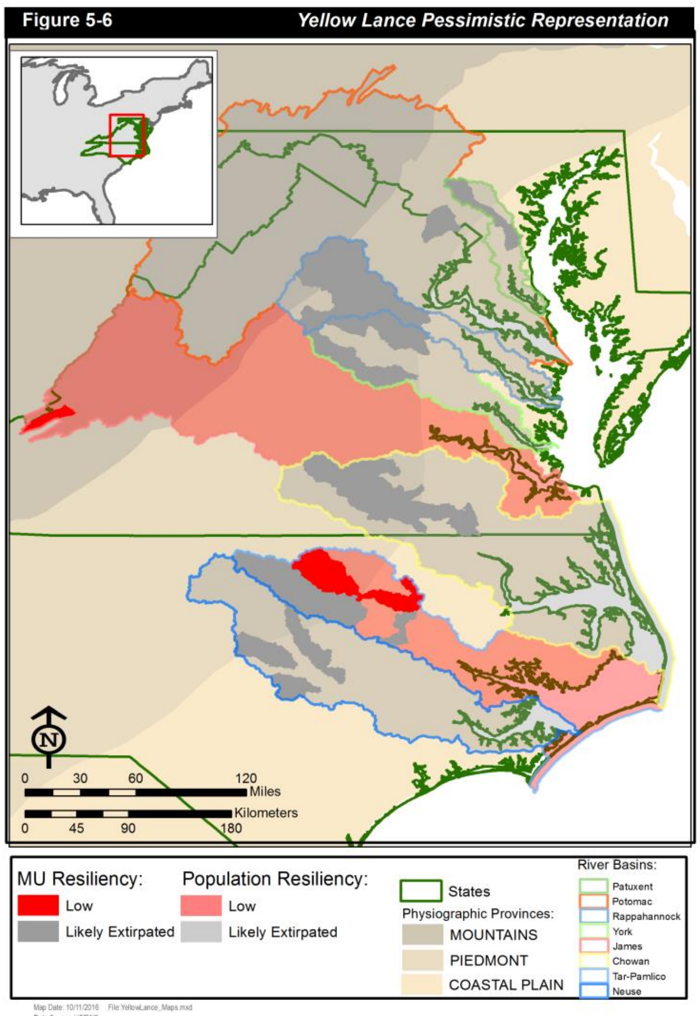


Figure 5-6 Yellow Lance Pessimistic Representation

5.3.3 Redundancy

Under the Pessimistic scenario, it is predicted that the Yellow Lance will lose redundancy, with likely extirpation in nine of the twelve MUs, and only two populations (James and Tar) are predicted to be extant, though in relatively poor condition, at the end of the 50 year time horizon.

5.4 Scenario 3 - Optimistic

Factors that influence population and habitat conditions of Yellow Lance are expected to be somewhat improved given the Optimistic Scenario. Reflecting Climate Model RCP2.6 (Wayne 2013, p.11), climate change effects are predicted to be minimal under this scenario, so effects of increased temperatures, storms, and droughts are not reflected in Optimistic predictions as they were in Status Quo and Pessimistic scenario predictions. Urbanization is also predicted to have less of impact in this scenario as reflected by effects that are slightly lower than BAU model predictions (Table 5-1). Because water quality, flow, and habitat impacts are predicted to be less severe in this scenario as compared to others, it is expected that the species will maintain or have a slightly positive response. While the capacity for species restoration was kept at current levels for this scenario, predicted responses to targeted conservation activities were more positive based on the predicted habitat conditions under this scenario.

- Patuxent – Even a best case is predicted to result in increased urbanization from the sprawl of Baltimore and Washington DC (Table 5-1), ultimately resulting in low water quality and instream habitat conditions (see Section 4-1). Moderate flow conditions and overall habitat connectivity, coupled with targeted species restoration, are predicted to result in low to moderate habitat conditions which will allow the species to persist, but at low levels at the end of 50 years (Table 5-4).
- Potomac – Despite potential habitat improvements under an Optimistic Scenario, there are no interventions in this scenario (e.g., reintroductions) that would result in the repopulation of this currently presumed extirpated basin.
- Rappahannock – Under the Optimistic Scenario, water quality conditions are predicted to improve via reduced sedimentation and better stormwater controls, thus the instream and riparian habitat conditions are expected to hold in moderate condition (Table 5-4). Targeted species restoration is predicted to promote a more optimistic response to impacts therefore the species is likely to persist at the end of our predicted time horizon.
- York – Water quality, flow, and habitat conditions are predicted to remain in moderate condition under the optimistic future, thus enabling the species to persist at low levels.
- James – Both habitat and population conditions are predicted to remain resilient under the Optimistic Scenario, and potential targeted species restoration is likely to improve the species adaptive capacity in the Johns Creek MU.
- Chowan – Given minimal climate change effects and lower levels of urbanization, water quality, flow, and habitat conditions are predicted to remain in moderate condition under the optimistic future. A “best case” species response to these conditions will likely enable the species to persist, but only in the Nottoway MU, as species restoration in the Meherrin MU is not likely under this scenario.
- Tar – Given the Optimistic Scenario, both urbanization and climate-induced impacts are expected to be minimal (Table 5-1). As such, habitat conditions, including water quality, flows, and instream and riparian habitat, are predicted to enable persistence at high levels in the Sandy/Swift and Fishing Creek Subbasin MUs. Further, current species restoration efforts in this scenario will be targeted to the highest condition areas to improve overall resiliency, especially in the Fishing Creek Subbasin.

- Neuse – Targeted species restoration efforts in the few areas least affected by urbanization, coupled with optimal species response, are predicted to enable the persistence of the species out to 50 years, albeit at low levels.

5.4.1 Resiliency

The Optimistic Scenario projects the condition of the Yellow Lance populations if the current risks will be slightly improved by the end of the predictive time horizon. Because of the more optimistic lens, considerably more populations are predicted to remain extant (Table 5-4). Specifically, the Tar River Population is predicted to be moderately resilient under the Optimistic Scenario with the Sandy/Swift and Fishing Creek MUs in high condition. The Rappahannock population is also predicted to be moderately resilient, while five other MUs are predicted to be characterized by low resiliency. No extirpations that have not already occurred are predicted under the Optimistic Scenario, thus only the Potomac population is lost from historic levels of representation.

Table 5-4 Yellow Lance Resiliency under Scenario 3 - Optimistic

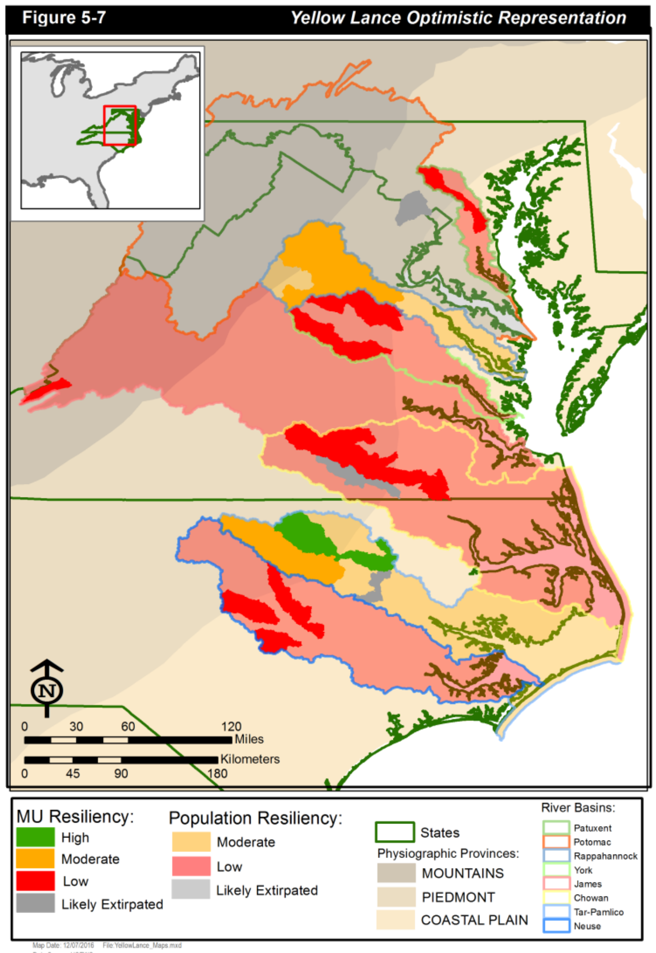
	Population Factors				Habitat Elements					
Population/ Management Unit	**MU Occupancy**	**Abundance**	**Reproduction**	**Combined Population Factors**	**Water Quality**	**Water Quantity**	**Connectivity**	**Instream Habitat (Substrate)**	**Combined Habitat Elements**	**Overall**
Patuxent	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate	**Low**
Potomac	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	**Ø**
Rappahannock	Moderate	Moderate	Low	Moderate	Moderate	High	Moderate	Moderate	Moderate	**Moderate**
York	Low	Low	Low	Low	Moderate	High	Low	Moderate	Moderate	**Low**
James										**Low**
Johns Creek	High	Low	Low	Low	High	High	High	High	High	Low
Chowan										**Low**
Nottoway	Low	Moderate	Low	Low	Low	Moderate	Low	Moderate	Moderate	Low
Meherrin	Ø	Ø	Ø	Ø	Moderate	Moderate	High	Moderate	Moderate	Ø
Tar										**Moderate**
Upper/Middle Tar	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Lower Tar	Ø	Ø	Ø	Ø	Moderate	Moderate	High	Moderate	Moderate	Ø
Fishing Ck Subbasin	High	High	Moderate	High	High	Moderate	High	High	High	High
Sandy Swift Ck	High	High	High	High	High	Moderate	High	High	High	High
Neuse										**Low**
Middle Neuse Tribs	Low	Low	Low	Low	Low	Very Low	Moderate	Moderate	Low	Low

5.4.2 Representation

Under the Optimistic Scenario, it is predicted that the Yellow Lance will retain current levels of representation. As such, the species will continue to retain 87% of its known River Basin Variability (i.e., it will continue to remain representative in all river basins except the Potomac). The species is predicted to retain limited Physiographic Variability in the Coastal Plain (30%) and moderate variability in the Piedmont (44%) and in the Mountains (50%).
At the population level, two populations (Rapphannock and Tar) are predicted to have moderate resiliency, while the remaining five populations (Patuxent, York, James, Chowan and Neuse) are predicted to have low resiliency (Figure 5-7).

5.4.3 Redundancy

Under the Optimistic Scenario, it is predicted that the Yellow Lance will maintain existing levels of redundancy, with varying resiliency in nine of twelve MUs. Only the Rappahannock and Tar populations are predicted to have multiple, moderately resilient MUs. Scaling up to the population level, this leaves the species with seven of the eight (historically) populations.



5.5 Scenario 4 – Opportunistic

Under the Opportunistic Scenario, those landscape-level factors (e.g., development and climate change) that are having an influence on populations of Yellow Lance get moderately worse, reflecting Climate Change Model RCP4.5 or RCP6 (Wayne 2013, p.11) and SLEUTH BAU (Terando et al. 2014; Table 5-1). Effects of climate change are expected to be moderate, resulting in some increased impacts from heat, storms, and droughts (IPCC 2013, p.7). Urbanization in this scenario reflects the moderate BAU SLEUTH levels, indicating approximately double the amount of developed area compared to current levels. Overall, it is expected that the synergistic impacts of changes in water quality, flow, and habitat connectivity will negatively affect the Yellow Lance. However, in this scenario, species restoration is targeted in areas that are less heavily impacted, ultimately resulting in a patchy distribution of a few resilient populations across the species range.

- Patuxent – Moderate urbanization in this watershed will likely lead to degraded water quality and habitat connectivity (Table 5-5), thus habitat conditions are predicted to become unsuitable for Yellow Lance.
- Potomac – Species restoration is not likely in this highly urbanized watershed, therefore the species is expected to remain extirpated from this basin.
- Rappahannock – Water quality, flows, and overall habitat conditions are predicted to be moderate at the end of the 50 year time horizon under the Opportunistic Scenario (Table 5-5); therefore, the less impacted areas of the watershed are likely to remain suitable for Yellow Lance, and targeted species restoration in these areas is likely.
- York – This basin is predicted to continue to be characterized by degraded habitat conditions leading to a low likelihood of species persistence.
- James – Habitat conditions remain high and the population continues in low condition under the opportunistic scenario.
- Chowan – the moderate climate future will likely affect habitat conditions in the Nottoway MU, thus the species is expected to persist at low levels into the future. The Meherrin MU will remain unoccupied.
- Tar – under the opportunistic scenario, there will be moderate climate-induced impacts resulting in continued drought issues in the Upper Tar and potential storm related windthrow issues in the Sandy/Swift MU. Habitat in the lower Tar is not expected to sustain the species, however moderate habitat conditions will likely sustain a moderately resilient population condition for the species into the future.
- Neuse – impacts from urbanization, including declining water quality from stormwater runoff and decreased flows from consumptive use, along with minimal development restrictions will lead to species extirpation under the Opportunistic Scenario.

5.5.1 Resiliency

The Opportunistic Scenario projects the condition of the Yellow Lance populations if the risks continue at moderately increased levels compared to what they are now. Under this scenario, the remaining extant populations occur in areas where habitat conditions support continued reproduction and survival of the species, at varying levels. None of the populations are expected to have high resiliency under this scenario. Only the Fishing Creek and Sandy/Swift MUs retain moderate resiliency, whereas the Johns Creek, Rappahannock, Nottoway, and Upper/Middle Tar MUs retain low resiliency. At the population level, only one population (Tar) retains moderate resiliency. Under this scenario, it is predicted that four of the eight populations of Yellow Lance will become extirpated in 50 years.

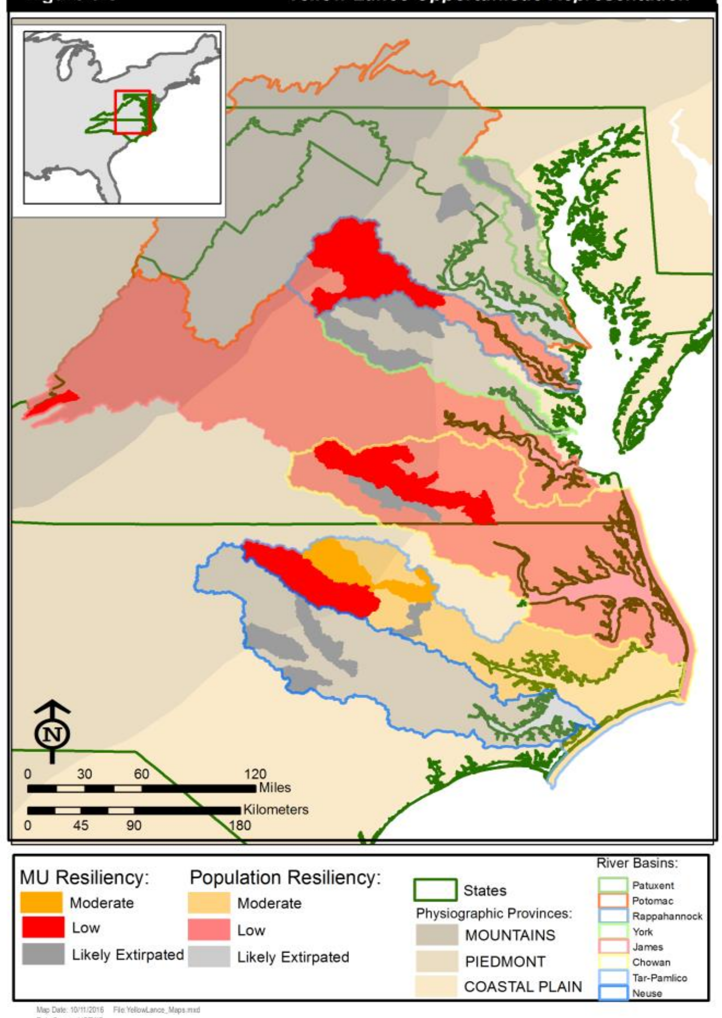
Table 5-5 Yellow Lance Resiliency under Scenario 4 - Opportunistic

	Population Factors				Habitat Elements					
Population/ Management Unit	MU Occupancy	Abundance	Reproduction	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Patuxent	Ø	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø
Potomac	Ø	Ø	Ø	Ø	Very Low	Moderate	Very Low	Low	Low	Ø
Rappahannock	Low	Moderate	Low	Low	Moderate	High	Low	Moderate	Moderate	Low
York	Ø	Ø	Ø	Ø	Low	High	Low	Low	Low	Ø
James										**Low**
Johns Creek	Moderate	Low	Low	Low	High	High	High	High	High	Low
Chowan										**Low**
Nottoway	Low	Moderate	Low	Low	Low	Low	Low	Moderate	Low	Low
Meherrin	Ø	Ø	Ø	Ø	Low	Moderate	High	Low	Moderate	Ø
Tar										**Moderate**
Upper/Middle Tar	Low	Moderate	Low	Low	Low	Moderate	Moderate	Low	Low	Low
Lower Tar	Ø	Ø	Ø	Ø	Low	Moderate	Moderate	Low	Low	Ø
Fishing Ck Subbasin	High	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	Moderate	Moderate
Sandy Swift Ck	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Neuse										Ø
Middle Neuse Tribs	Ø	Ø	Ø	Ø	Very Low	Very Low	Low	Low	Low	Ø

5.5.2 Representation

Under the Opportunistic Scenario, it is predicted that the Yellow Lance will have reduced representation. The species will only retain 50% of its known River Basin variability, remaining in the Rappahannock, James, Chowan and Tar River basins. The species also retains limited Physiographic variability in the Piedmont (31%) and Coastal Plain (20%) and moderate variability in the Mountains (50%). At the population level, only the Tar Population retains moderate condition representation, whereas the Rappahannock, James, and Chowan retain low condition representation under the Opportunistic Scenario (Figure 5-8).

Figure 5-8 ***Yellow Lance Opportunistic Representation***



5.5.3 Redundancy

Under the Opportunistic scenario, it is predicted that the Yellow Lance will have reduced levels of redundancy, with likely extirpation in six of the twelve MUs, and only the Tar Population is predicted to have multiple moderately resilient MUs into the future. This expected loss in both the number and distribution of resilient populations is likely to make the species vulnerable to stochastic disturbance events.

5.6 Status Assessment Summary

Future Viability Summary

The goal of this assessment was to describe the viability of the Yellow Lance in terms of resiliency, representation, and redundancy by using the best science available at the time of the analysis. To capture the uncertainty associated with the degree and extent of potential future risks and their impacts on species' needs, each of the 3Rs were assessed using four plausible future scenarios (Status Quo, Pessimistic, Optimistic, and Opportunistic). These scenarios were based, in part, on the results of urbanization (Terando et. al. 2014) and climate models (IPCC 2013) that predict changes in habitat used by the Yellow Lance. The results of the predictive analysis describe a range of possible conditions in terms of the number and distribution of Yellow Lance populations (Table 5-6). It is important to note that not all scenarios have the same probability of occurrence at any one time step. To account for this, a discretized range of probabilities (Table 5-7) were used to describe the likelihood of scenario occurrence at a 50 year time-step based on professional judgment (Table 5-8). (Note: the range of likelihoods in Table 5-7 was based on IPCC guidance (Mastrandea et al. 2011) and has been accepted and is understood relatively well by and in the scientific community).

Table 5-6 Summary of Current and Future Scenario Outcomes

		Future Scenarios of Population Conditions			
Populations: Management Units	Current	#1 Status Quo	#2 Pessimistic	#3 Optimistic	#4 Opportunistic
Patuxent	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
Potomac	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Rappahannock	Low	Likely Extirpated	Likely Extirpated	Moderate	Low
York	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
James: Johns Creek	Low	Low	Low	Low	Low
Chowan: Nottoway	Low	Likely Extirpated	Likely Extirpated	Low	Low
Chowan: Meherrin	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Tar: Upper/Middle Tar	High	Low	Likely Extirpated	Moderate	Low
Tar: Lower Tar	Presumed Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated	Likely Extirpated
Tar: Fishing Ck	Moderate	Moderate	Low	High	Moderate
Tar: Sandy-Swift	High	Moderate	Low	High	Moderate
Neuse: Middle Neuse	Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated

Table 5-7 Explanation of confidence terminologies used to estimate the likelihood of scenario (after IPCC guidance, Mastrandrea et al. 2011).

Confidence Terminology	Explanation
Very likely	We are **greater than 90% sure** that this scenario will occur.
Likely	We are **70-90% sure** that this scenario will occur.
As Likely As Not	We are **40-70% sure** that this scenario will occur.
Unlikely	We are **10-40% sure** that this scenario will occur.
Very unlikely	We are **less than 10% sure** that this scenario will occur.

Table 5-8 Likelihood of Scenario occurrence at 50 years

	#1 Status Quo	#2 Pessimistic	#3 Optimistic	#4 Opportunistic
Likelihood of Scenario Occurring at 50 Years	Very Likely	Likely	As Likely As Not	As Likely As Not

An important assumption of the predictive analysis was that future population resiliency is largely dependent on water quality, water flow, riparian, and instream habitat conditions. Our assessment predicted that at least seven (of 8) currently extant Yellow Lance populations would experience negative changes to these important habitat requisites. Predicted viability varied amongst scenarios and is summarized below and in Table 5-6.

Given Scenario 1, the "Status Quo" option, a substantial loss of resiliency, representation, and redundancy is expected. Under this scenario, we predicted that no MUs would remain in high condition, two in moderate condition, two in low condition, and the remaining MUs would be likely extirpated. Redundancy would be reduced with likely extirpation in eight of twelve currently extant MUs; only the Tar Population retains more than one moderately resilient MU. Representation would be reduced, with only two (25%) of the former river basins occupied, and with reduced variability in the Mountains, Piedmont, and Coastal Plain. This scenario is very likely at the 50 year time-step (Tables 5-7, 5-8).

Given Scenario 2, the "Pessimistic" option, we predicted a near complete loss of resiliency, representation, and redundancy. Redundancy would be reduced to two populations, and the resiliency of those populations is expected to be low. Nearly all MUs were predicted to be extirpated, and, of the remaining three MUs, all would be in low condition. All three measures of representation are predicted to decline under this scenario, leaving remaining Yellow Lance populations underrepresented in River Basin, Latitudinal, and Physiographic variability. Nearly all Piedmont representation is predicted to be lost. This scenario is likely at the 50 year time-step (Tables 5-7, 5-8).

Given Scenario 3, the "Optimistic" option, we predicted slightly higher levels of resiliency, representation, and redundancy than was estimated for current condition. Two MUs are predicted to be in high condition, two in moderate condition, five in low condition, and the three currently presumed extirpated MUs would remain extirpated. Despite predictions of population persistence for all populations, only the Tar Population is expected to retain a high level of resiliency. Existing levels of representation are predicted to remain unchanged under this scenario. This scenario is as likely as not at the 50 year time-step (Tables 5-7, 5-8), primarily because it will take many years for effects of management actions to be realized on the landscape.

Given Scenario 4, the "Opportunistic" option, we predicted reduced levels of resiliency, representation, and redundancy. No MUs would be in high condition, two would be in moderate condition, four in low condition, and six would be likely extirpated. Redundancy would be reduced by half with six of twelve MUs predicted to be extirpated. Representation is predicted to be reduced with only four (50%) of the former eight river basins occupied, and with reduced variability in the Mountains, Piedmont, and Coastal Plain. This scenario is likely at the 50 year time-step (Tables 5-7, 5-8).

Current Viability Summary

The historical range of the Yellow Lance included streams and rivers in the Atlantic Slope drainages from the Patuxent River Basin south to the Neuse River Basin with the documented historical distribution in 12 MUs within eight former populations. The Yellow Lance is presumed extirpated from 25% (3) of the historically occupied MUs. Of the remaining nine occupied MUs, 17% are estimated to have high resiliency, 8% moderate resiliency, and 67% low resiliency. Scaling up from the MU to the population level, one of eight former populations (the Tar Population) was estimated to have moderate resiliency, while the remaining six extant populations (Patuxent, Rappahannock, York, James, Chowan, and Neuse populations) were characterized by low resiliency. The Potomac Population is presumed to be extirpated thus eliminating 13% of the species' historical range. 86% of streams that remain part of the current species' range are estimated to be in low or very low condition, potentially putting the Yellow Lance at risk of extirpation. Once known to occupy streams in three physiographic regions, the species has also lost substantial physiographic representation. An estimated 50% loss has occurred in Mountain watersheds, an estimated 56% loss has occurred in Piedmont watersheds, and an estimated 70% loss has occurred in Coastal Plain watersheds.

Overall Summary

Estimates of current and future resiliency for Yellow Lance are low, as are estimates for representation and redundancy. The Yellow Lance faces a variety of threats from declines in water quality, loss of stream flow, riparian and instream fragmentation, and deterioration of instream habitats. These threats, which are expected to be exacerbated by urbanization and climate change, were important factors in our assessment of the future viability of the Yellow Lance. Given current and future decreases in resiliency, populations become more vulnerable to extirpation from stochastic events, in turn, resulting in concurrent losses in representation and redundancy. Predictions of Yellow Lance habitat conditions and population factors suggest possible extirpation in up to five of seven currently extant populations. The two populations predicted to remain extant are expected to be characterized by low occupancy and abundance.

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APPENDIX A - US Museum of Natural History – Lance Specimen Photos
(provided by Matt Ashton, MD DNR)

Specimens from Maryland Localities:


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution


U. S. Nat. Mus. Coll. Mollusca.
Smithsonian Institution

Specimens from Virginia localities:


U. S. Nat. Mus. 182249 Coll. Mollusca.
Unio
lanceolatus Lea
Lexington
Virginia


U. S. N. M. 770206 Coll. Moll.
Elliptio
lanceolatus
So. Anna R./or Little River
Virginia Ex. M Riddick


U. S. Nat. Mus. 182249 Coll. Mollusca.
Unio
lanceolatus Lea
Lexington
Virginia


711396
U. S. N. M. 711396 Coll. Moll.
South Anna River[at Rt.738]
Virginia Ex. M Riddick


U. S. Nat. Mus. 182249 Coll. Mollusca.
Unio
lanceolatus Lea
Lexington
Virginia


U. S. Nat. Mus. 102249 Coll. Mollusca.
Smithsonian Institution.
Unio
lanceolatus Lea.
Lexington
Virginia


USNM 837348 VOUCHER
ELLIPTIO LANCEOLATA
(LEA, 1828)
LOUISA COUNTY, SOUTH
ANNA RIVER
VIRGINIA DRY
SEE REMARKS!
YORK RIVER
STA.
RT. 522; 37 52 --N 077
52 --W;
ACC.307412


USNM 837348 VOUCHER
ELLIPTIO LANCEOLATA
(LEA, 1828)
LOUISA COUNTY, SOUTH
ANNA RIVER
VIRGINIA DRY
SEE REMARKS!
YORK RIVER
STA.
RT. 522; 37 52 --N 077
52 --W;
ACC.307412


USNM 837348 VOUCHER
ELLIPTIO LANCEOLATA
(LEA, 1828)
LOUISA COUNTY, SOUTH
ANNA RIVER
VIRGINIA DRY
SEE REMARKS!
YORK RIVER
STA.
RT. 522; 37 52 --N 077
52 --W;
ACC.307412


USNM 837348 VOUCHER
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(LEA, 1828)
LOUISA COUNTY, SOUTH
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VIRGINIA DRY
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52 --W;
ACC.307412


USNM 837348 VOUCHER
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52 --W;
ACC.307412


USNM 837348 VOUCHER
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LOUISA COUNTY, SOUTH
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VIRGINIA DRY
SEE REMARKS!
YORK RIVER
STA.
RT. 522; 37 52 --N 077
52 --W;
ACC.307412


U. S. N. M.
Coll. Moll.
Virginia


USNM 837348 VOUCHER
ELLIPTIO LANCEOLATA
(LEA, 1828)
LOUISA COUNTY, SOUTH
ANNA RIVER
VIRGINIA DRY
SEE REMARKS!
YORK RIVER
STA.
RT. 522; 37 52 --N 077
52 --W;
ACC.307412


U. S. N. M. 424176 Coll. Moll.
Elliptio lanceolatus
21 Lea
Mountain Run, Orange Co.
Va. W. F. Webb
Institution.


U. S. N. M.
Coll. Moll.
Virginia


U. S. N. M. 424176 Coll. Moll.
Elliptio lanceolatus
21 Lea
Mountain Run, Orange Co.
Va. W. F. Webb
Institution.


U.S.N.M. 434176 Coll. Moll.
Elliptio lanceolatus
21 Lea
Mountain Run, Orange Co
Va. W. F. Webb


U.S.N.M. 594182 Virginia
Elliptio ♂
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington, J.P.E. Morrison!


U.S.N.M. 594182 Virginia
Elliptio ♂
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington, J.P.E. Morrison!


U.S.N.M. 594182 Virginia
Elliptio ♂
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington, J.P.E. Morrison!


U.S.N.M. 594182 Virginia
Elliptio ♂
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington, J.P.E. Morrison!


U.S.N.M. 594182 Virginia
Elliptio ♂
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington, J.P.E. Morrison!

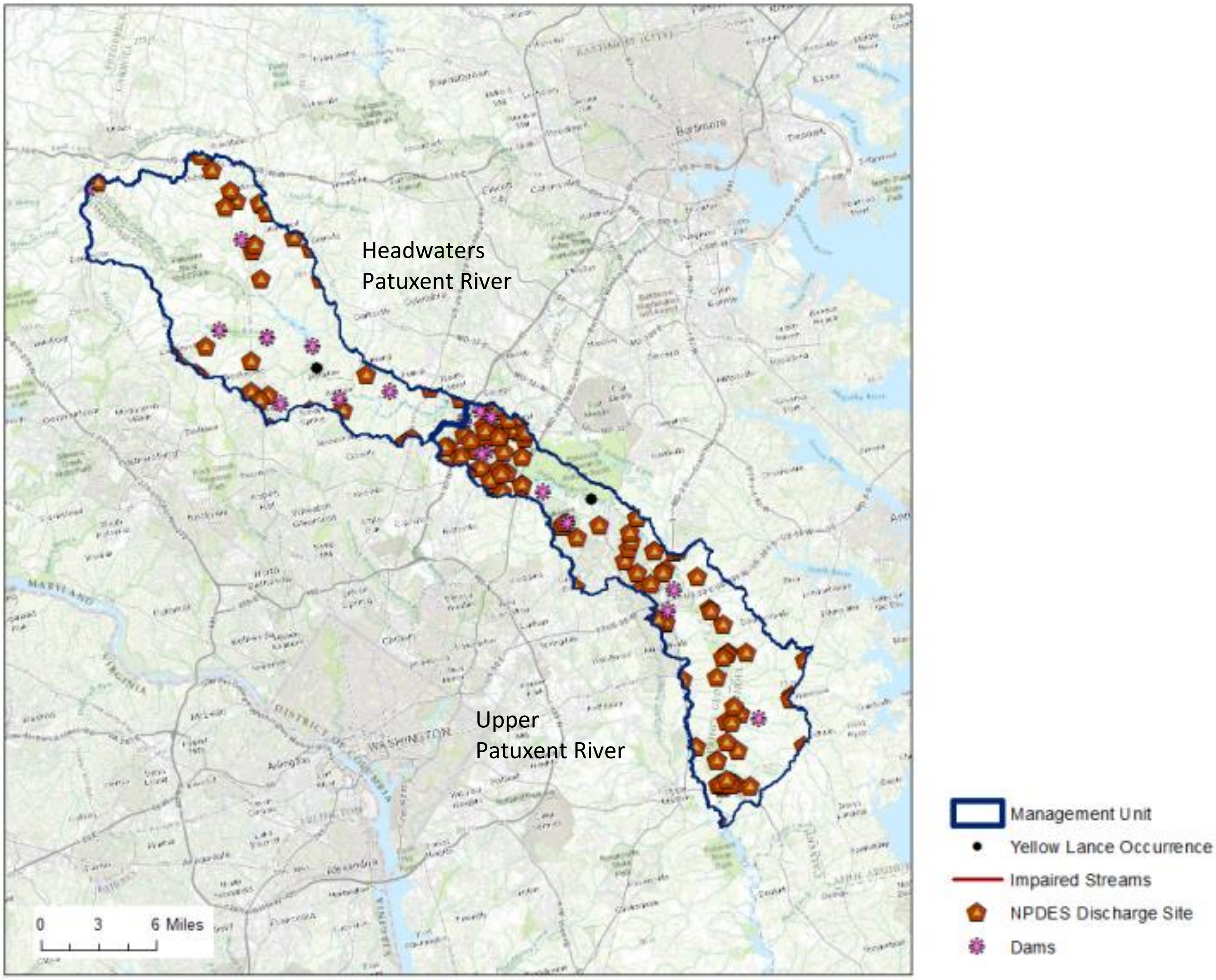

U.S.N.M. 594182 Virginia
Elliptio
lanceolatus Lea
Rappahannock R: 10-28-1945
Remington. (nn) J.P.E. Morrison!

APPENDIX B – YELLOW LANCE DISTRIBUTION INFORMATION

(Note: survey data were acquired through data use agreements with state agency and Natural Heritage Programs)

Patuxent River Population
Consists of one MU: Hawlings-Patuxent Rivers

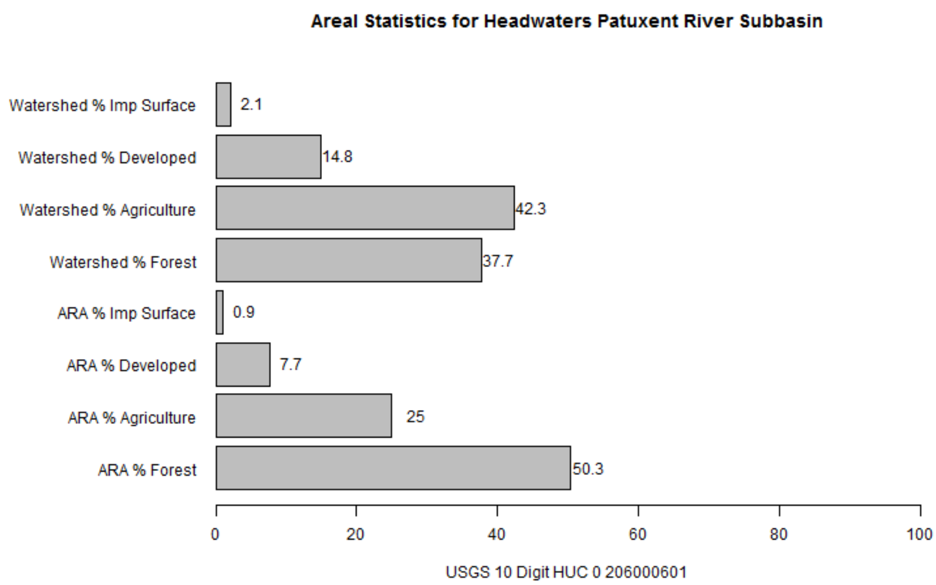
Patuxent River Management Unit

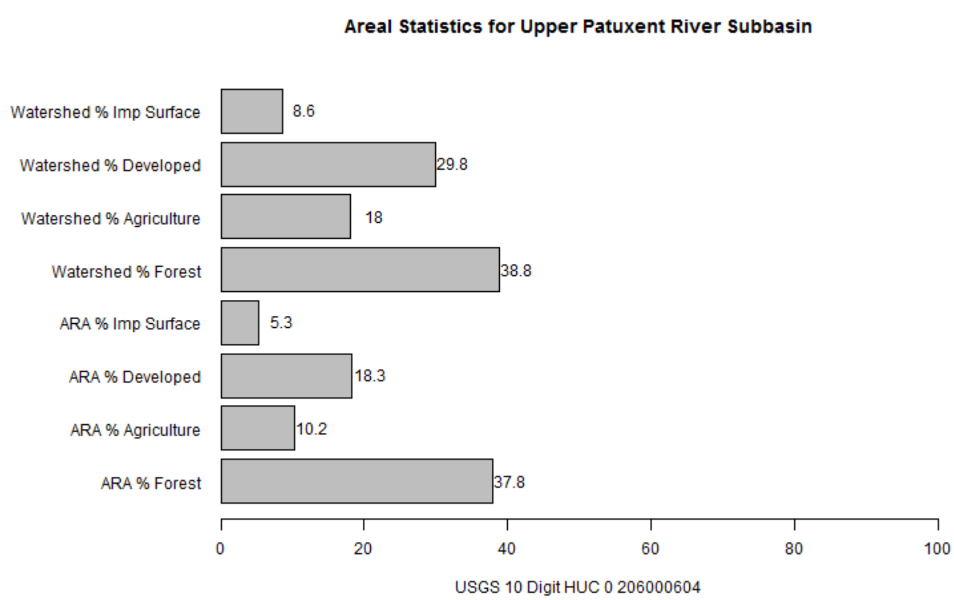


Survey Summary: This MU consists of two HUC10 watersheds: Headwaters Patuxent River and Upper Patuxent River. In 1913, a Yellow Lance specimen was collected from the Patuxent River eight miles below Laurel, MD. In1952, four valves from two specimens were collected in the Hawlings River, a tributary to the Patuxent River. In 2015, a live Yellow Lance was collected from the Hawlings River, approximately 2 miles upstream of the 1952 site. Although specimens have not yet been confirmed (and thus, not mapped or considered in this analysis), the Canadian Museum of Nature has two specimens (one per site) that were collected in 1964 from Cattail Creek and the Little Patuxent River, within the Patuxent River drainage.

Water Quality Information: In 2011, portions of the upper Patuxent River watershed were listed as impaired for aquatic life and wildlife due to Total Suspended Solids (note: impaired streams do not show up on map above because GIS layers were unavailable at time of report release). The biostressor analysis indicated that excess sediment was a major stressor affecting the biological integrity of the watershed (MDE 2016). In 2014, portions of the watershed were also listed as impaired for aquatic life and wildlife due to chlorides and sulfates (MDE 2016). There are 146 non-major NPDES discharges and three major (including Maryland City WRF and Bowie WWTP) NPDES discharges in the MU. This river is also fragmented by two water supply reservoirs, one with dual use as a hydroelectric facility.

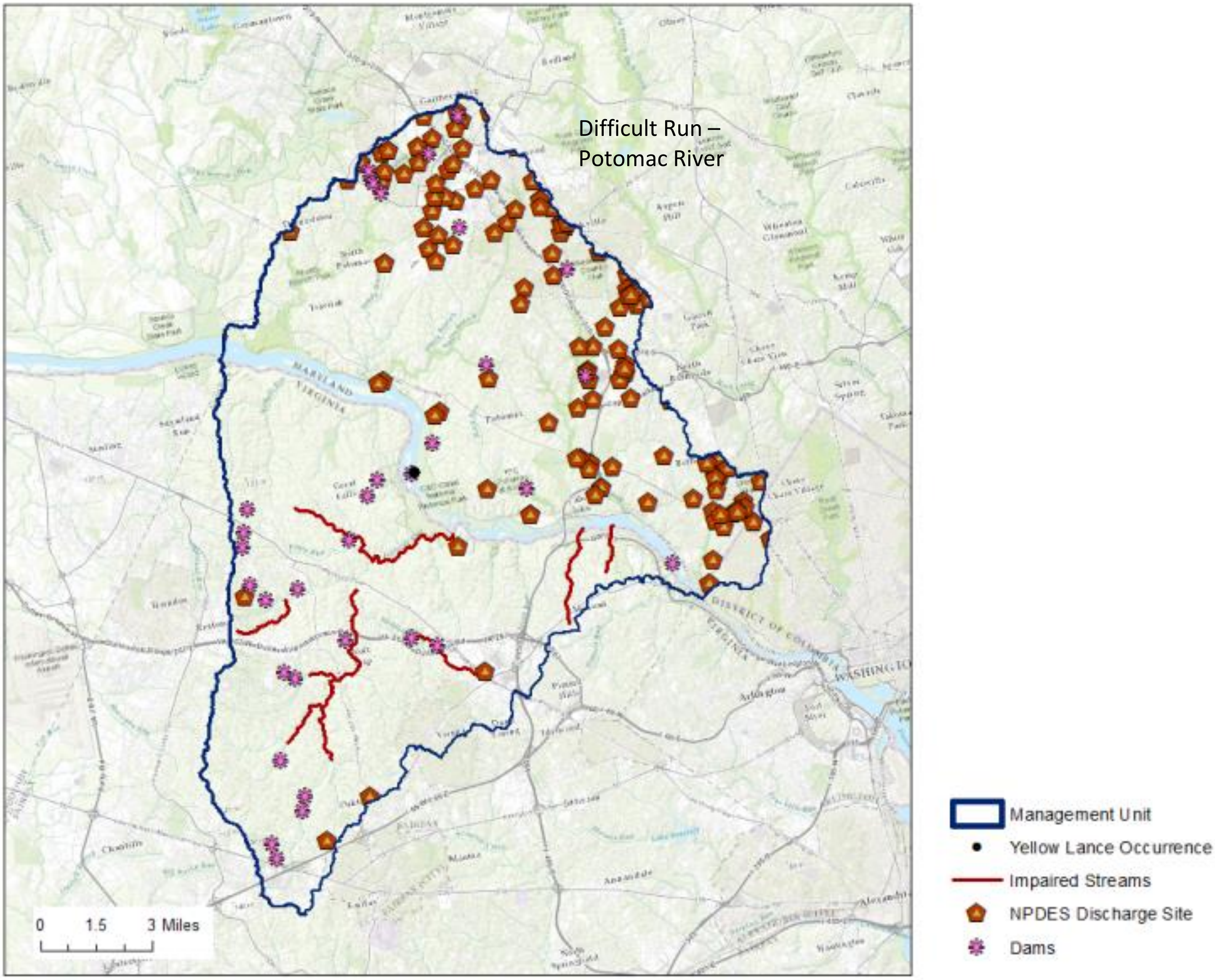
Land Use Land Cover Summary Statistics:





Potomac River Population
Consists of one MU: Potomac River

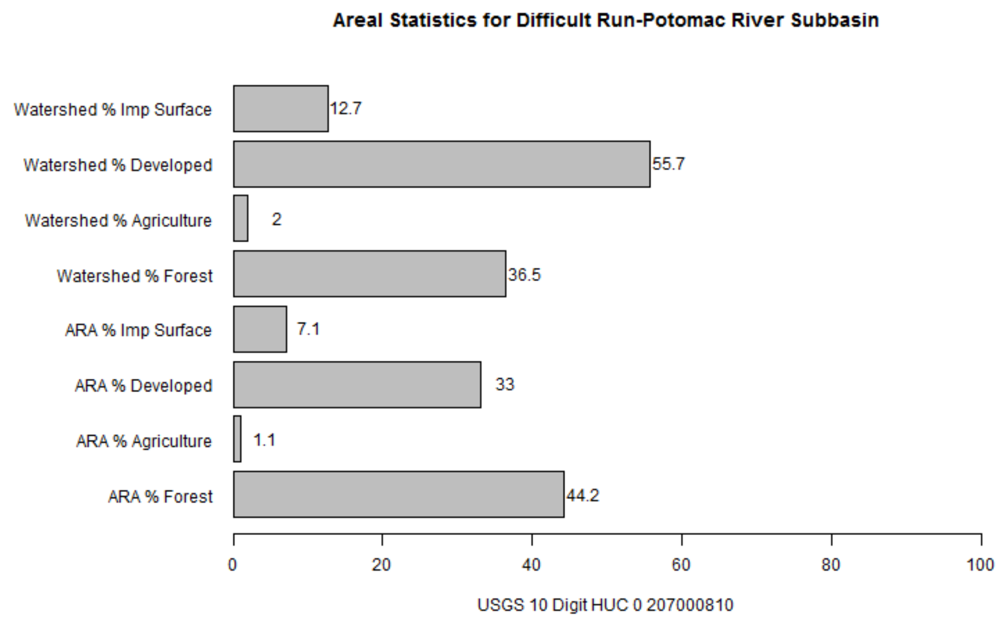
Potomac River Management Unit



Survey Summary: This MU consists of one HUC10 watershed: Difficult Run-Potomac. Pre-1970s record (NMNS #42792) in the Potomac River near Washington D.C. Two individuals reported from 2004 survey.

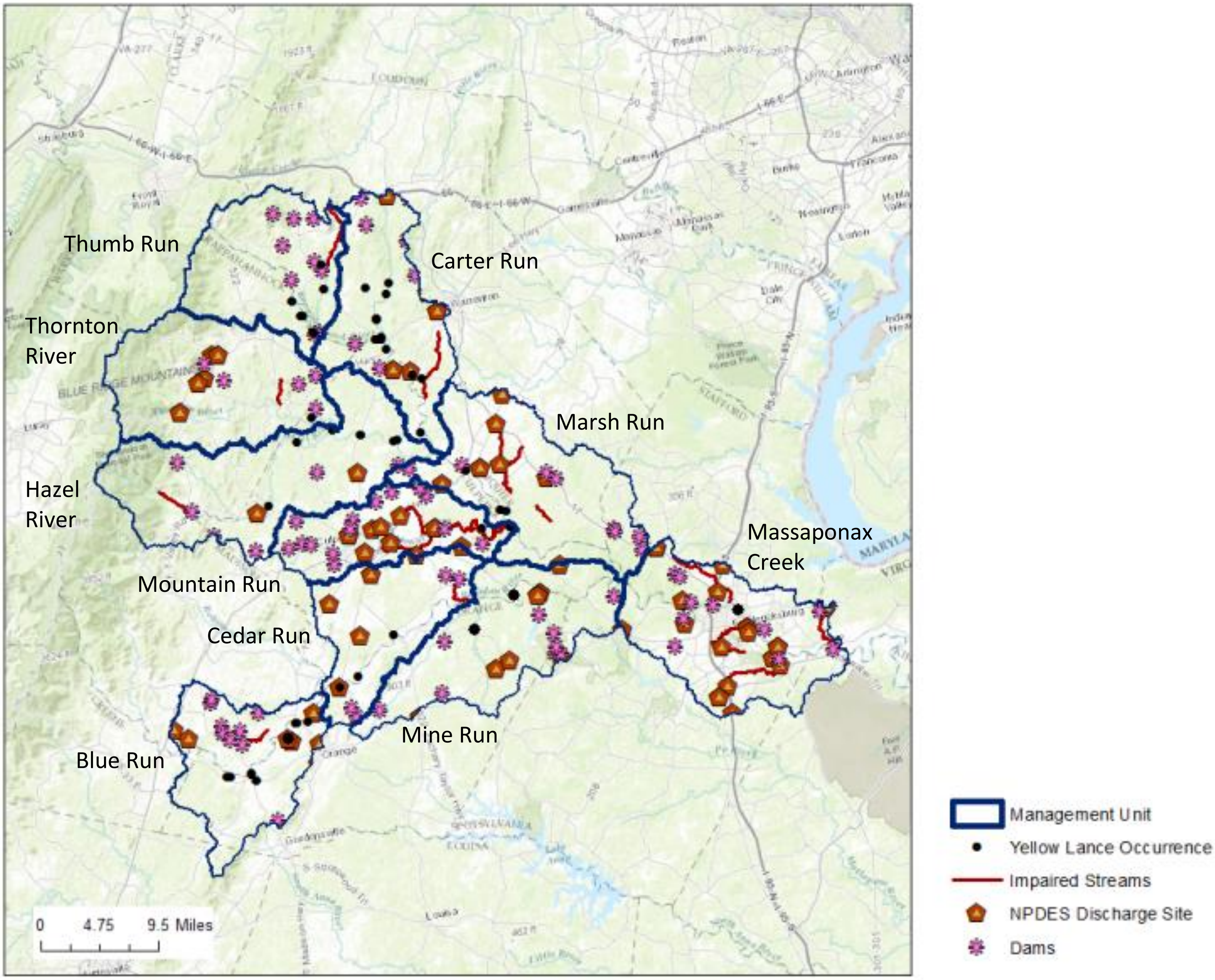
Water Quality Information: Based on 2012 data from Virginia, there are 12 stream reaches, totaling ~23 miles that are impaired for aquatic life in the Virginia portion of the Difficult Run-Potomac watershed. Impairment is indicated by low benthic-macroinvertebrate bioassessment scores, E.coli, PCP in fish tissue, and Heptachlor epoxide, which is from urban runoff. There are 137 non-major NPDES discharges in the MU and 2 major NPDES discharges into this portion of the Potomac watershed. Mining and agriculture in the upper basin, as well as urban sewage and runoff in the lower basin have caused severe eutrophication problems and overall deterioration of water quality.

Land Use Land Cover Summary Statistics:



Rappahannock River Population
Consists of one MU: Rappahannock River Subbasin

Rappahannock River Subbasin Management Unit

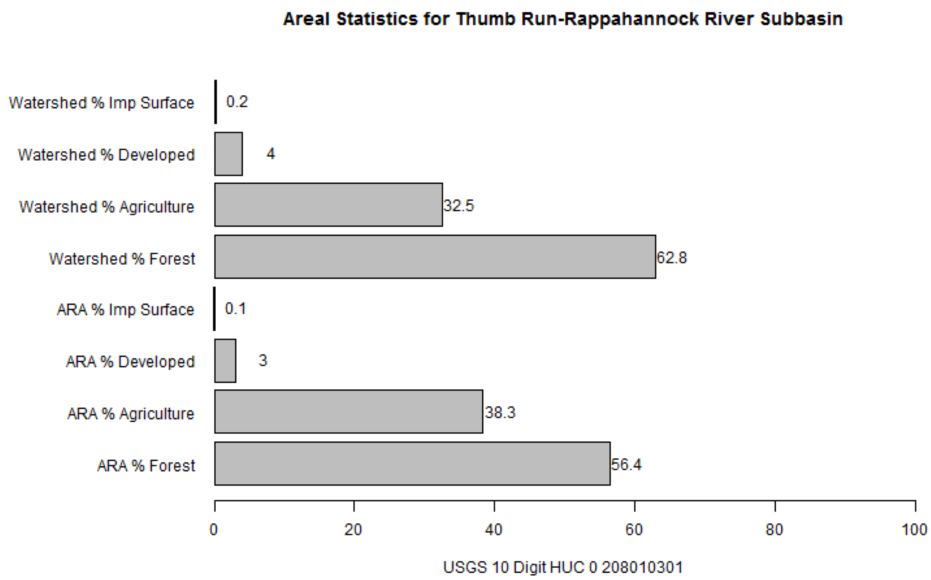


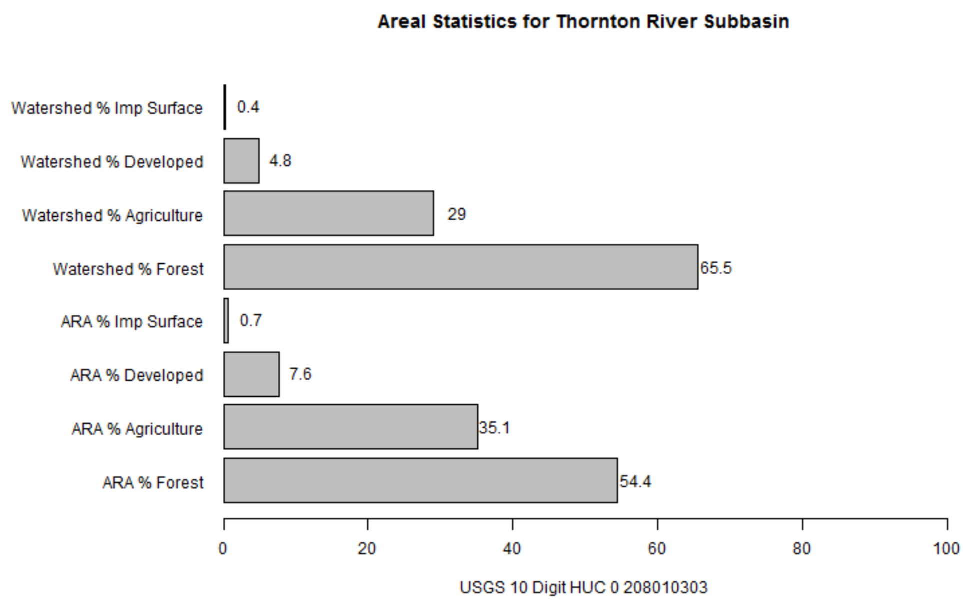
Survey Summary: This MU includes several tributaries – Blue Run, Great Run, Marsh Run, Thumb Run, and the Rapidan and Rappahannock rivers in ten HUC10 watersheds (Thumb Run, Thornton River, Hazel River, Mountain Run, Cedar Run, Blue Run, Mine Run, Carter Run, Marsh Run, and Massaponax Creek). Many surveys have documented the presence of Yellow Lance, with an occasional observation of upwards of 50 individuals. The species was first seen in the late 1980s, and has been observed most recently in 2011 in the Rappahannock River, although very few individuals were seen during that survey. 10 individuals were observed in Hungry Run in 2011. Reproduction and recruitment were documented in the MU in 2007.

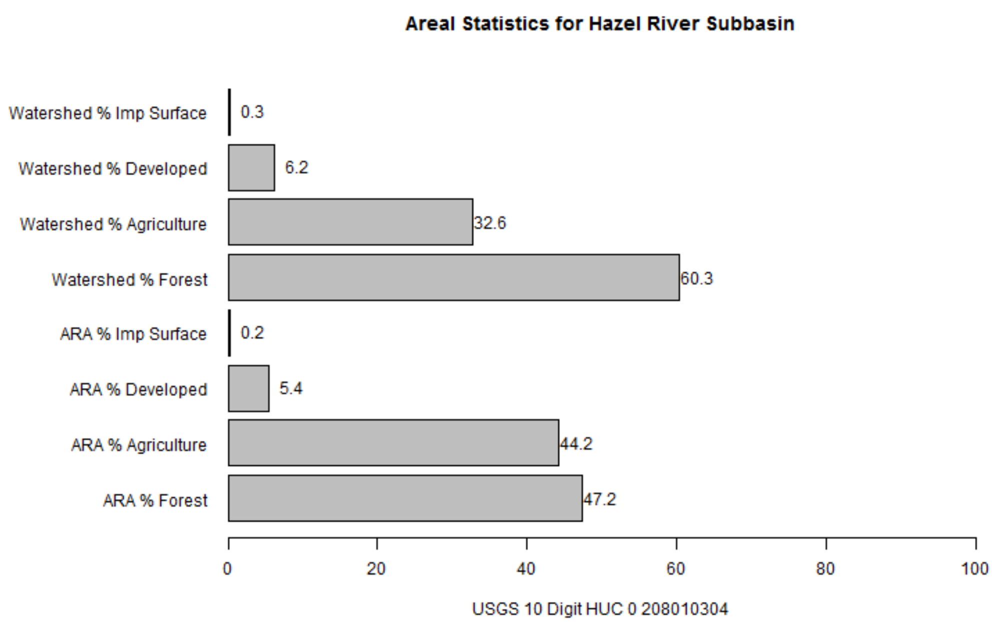
[NOTE: Because Johnson (1970) synonymized many lance species, many of the records in Virginia basins are unconfirmed, and possible misidentifications. Survey and distribution information for Yellow Lance reported here are only those records that have been confirmed by VDGIF staff with species expertise.]

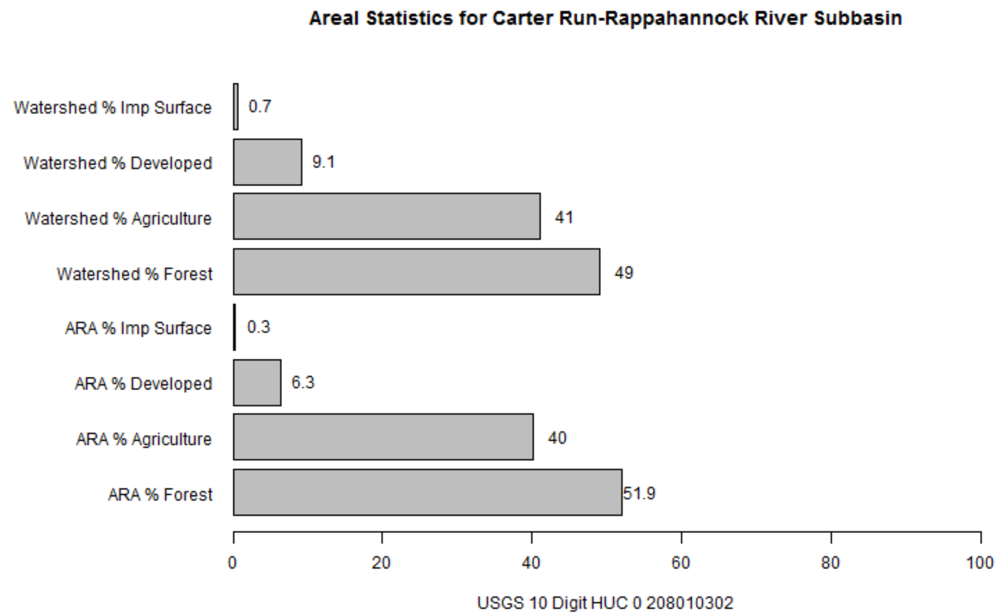
Water Quality Information: Based on 2012 data, there are 20 stream reaches, totaling ~77 miles that are impaired for aquatic life in the Rappahannock River watershed. Impairment is indicated by low benthic-macroinvertebrate bioassessment scores, pH and temperature issues, and E.coli; several of these can be attributed to septic systems or nonpoint source runoff into streams. There are 93 non-major NPDES discharges in the MU and 11 major NPDES discharges, including several city and package WWTPs.

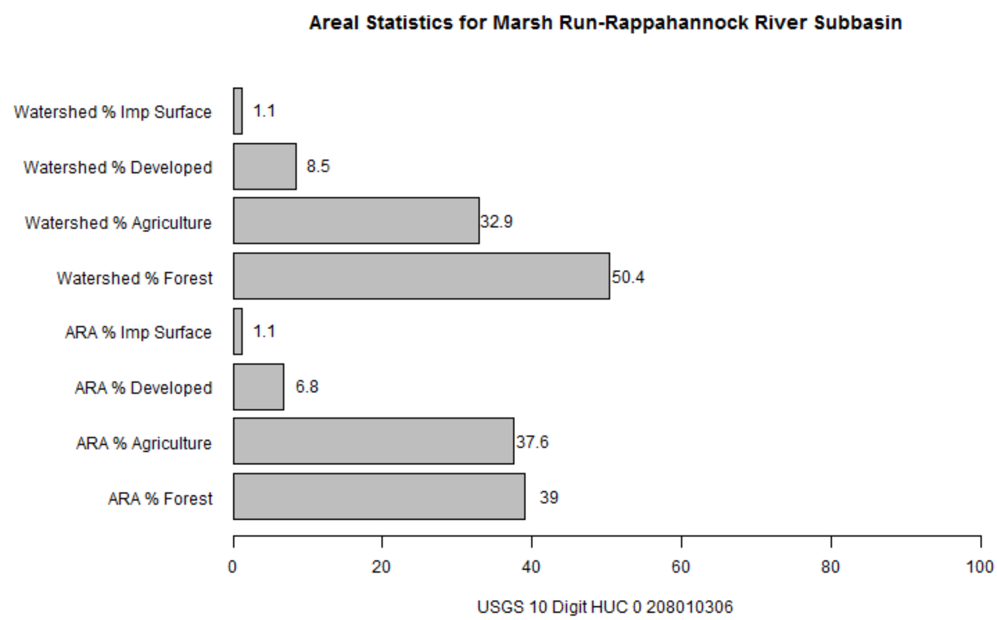
Land Use Land Cover Summary Statistics:

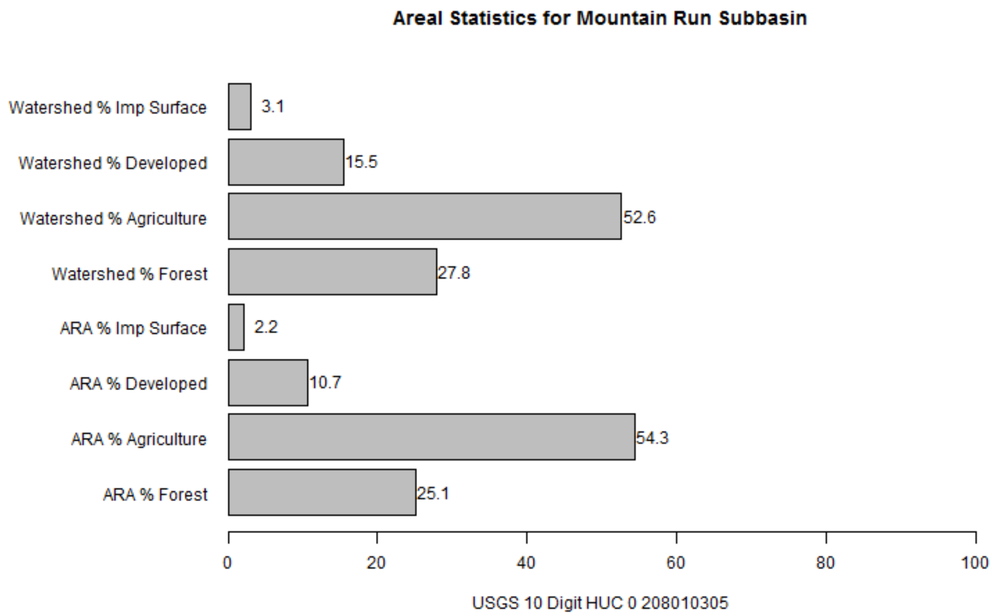


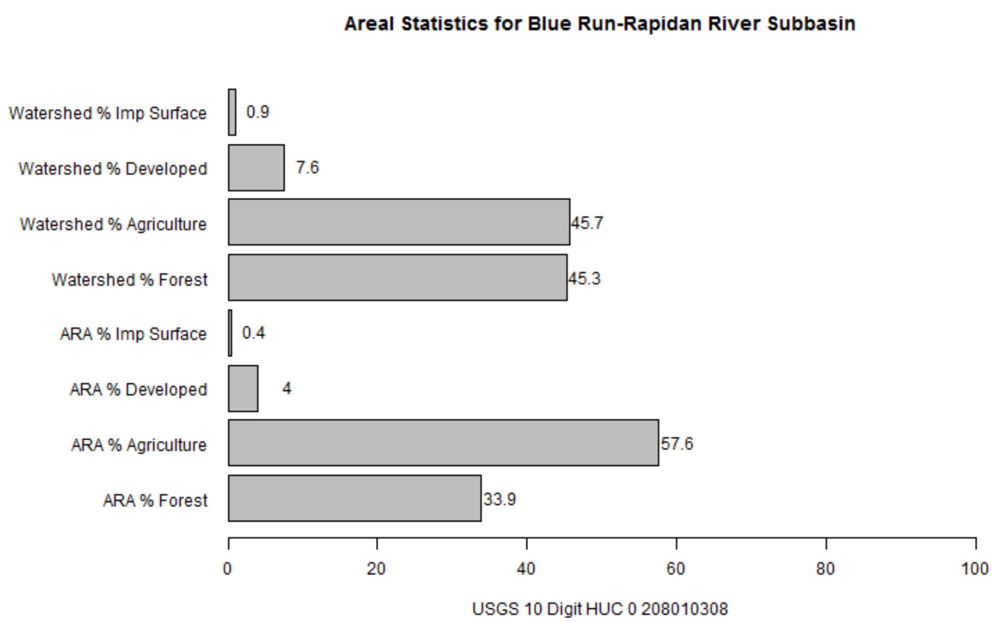

Areal Statistics for Thornton River Subbasin
Watershed % Imp Surface
0.4
Watershed % Developed
4.8
Watershed % Agriculture
29
Watershed % Forest
65.5
ARA % Imp Surface
0.7
ARA % Developed
7.6
ARA % Agriculture
35.1
ARA % Forest
54.4
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010303


Areal Statistics for Hazel River Subbasin
Watershed % Imp Surface
0.3
Watershed % Developed
6.2
Watershed % Agriculture
32.6
Watershed % Forest
60.3
ARA % Imp Surface
0.2
ARA % Developed
5.4
ARA % Agriculture
44.2
ARA % Forest
47.2
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010304

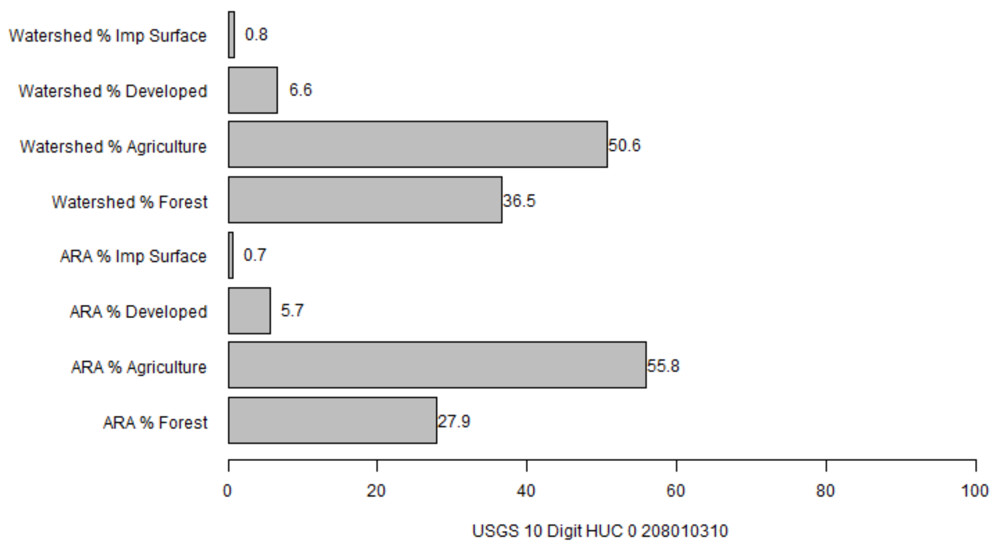

Areal Statistics for Carter Run-Rappahannock River Subbasin
Watershed % Imp Surface
0.7
Watershed % Developed
9.1
Watershed % Agriculture
41
Watershed % Forest
49
ARA % Imp Surface
0.3
ARA % Developed
6.3
ARA % Agriculture
40
ARA % Forest
51.9
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010302


Areal Statistics for Marsh Run-Rappahannock River Subbasin
Watershed % Imp Surface
1.1
Watershed % Developed
8.5
Watershed % Agriculture
32.9
Watershed % Forest
50.4
ARA % Imp Surface
1.1
ARA % Developed
6.8
ARA % Agriculture
37.6
ARA % Forest
39
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010306

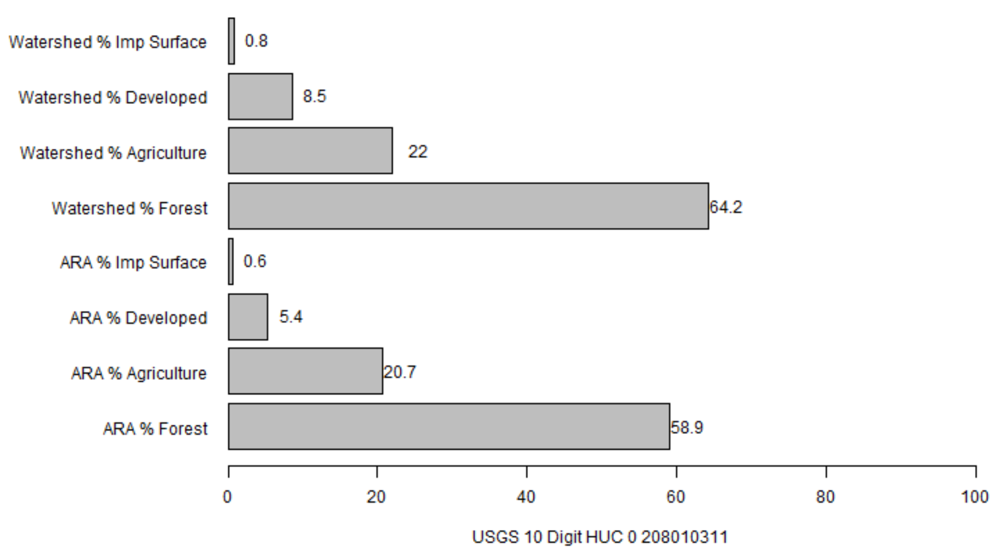

Areal Statistics for Mountain Run Subbasin
Watershed % Imp Surface
3.1
Watershed % Developed
15.5
Watershed % Agriculture
52.6
Watershed % Forest
27.8
ARA % Imp Surface
2.2
ARA % Developed
10.7
ARA % Agriculture
54.3
ARA % Forest
25.1
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010305

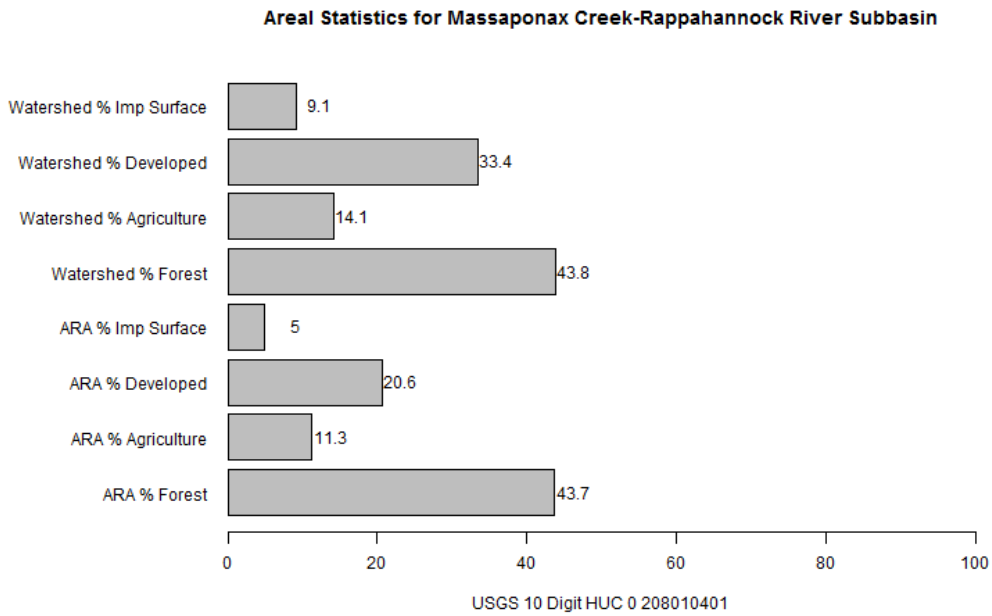

Areal Statistics for Blue Run-Rapidan River Subbasin
Watershed % Imp Surface
0.9
Watershed % Developed
7.6
Watershed % Agriculture
45.7
Watershed % Forest
45.3
ARA % Imp Surface
0.4
ARA % Developed
4
ARA % Agriculture
57.6
ARA % Forest
33.9
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010308

Areal Statistics for Cedar Run-Rapidan River Subbasin



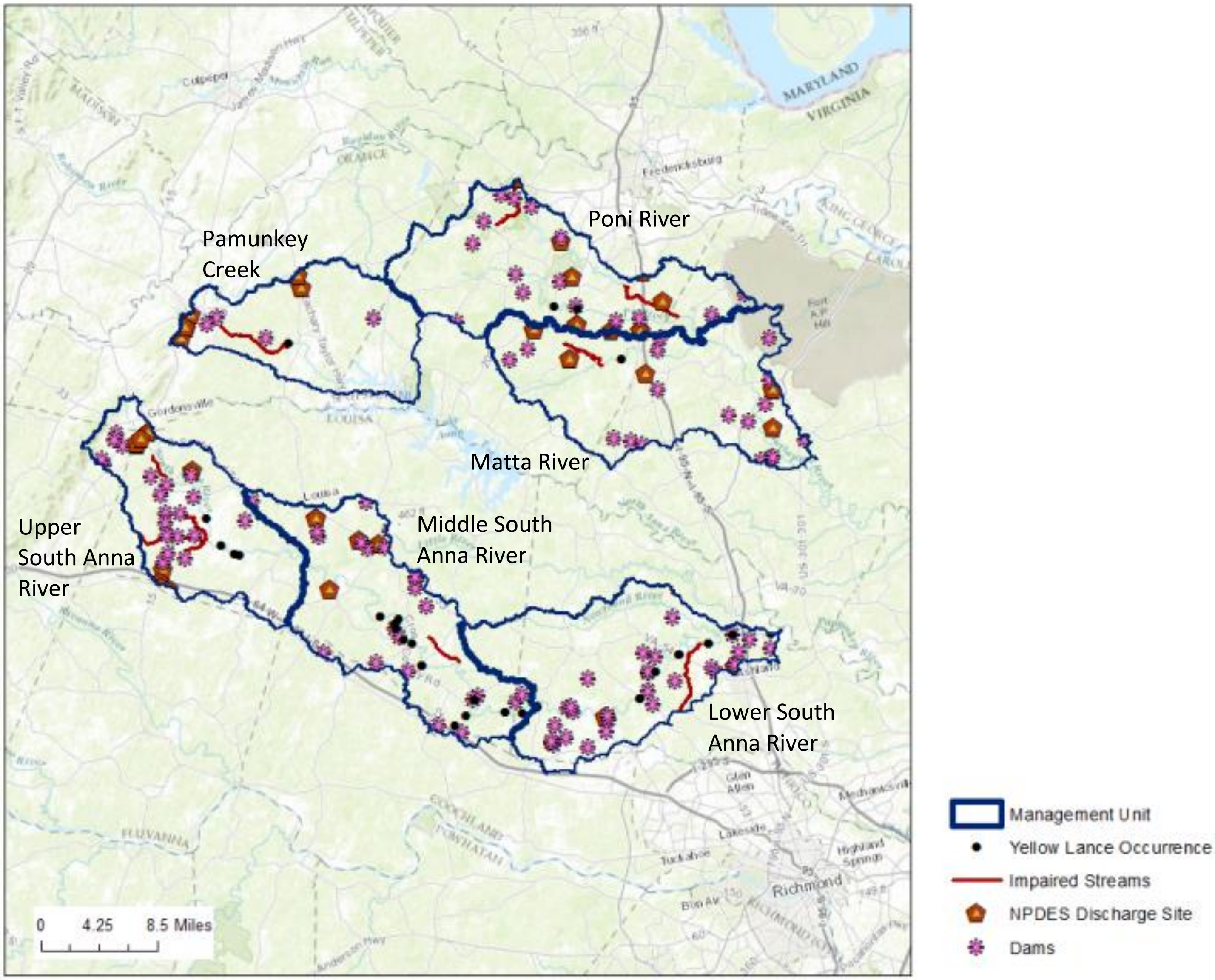
Areal Statistics for Mine Run-Rapidan River Subbasin




Areal Statistics for Massaponax Creek-Rappahannock River Subbasin
Watershed % Imp Surface
9.1
Watershed % Developed
33.4
Watershed % Agriculture
14.1
Watershed % Forest
43.8
ARA % Imp Surface
5
ARA % Developed
20.6
ARA % Agriculture
11.3
ARA % Forest
43.7
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010401

York River Population
Consists of one MU: Mattaponi-South Anna River (York MU)

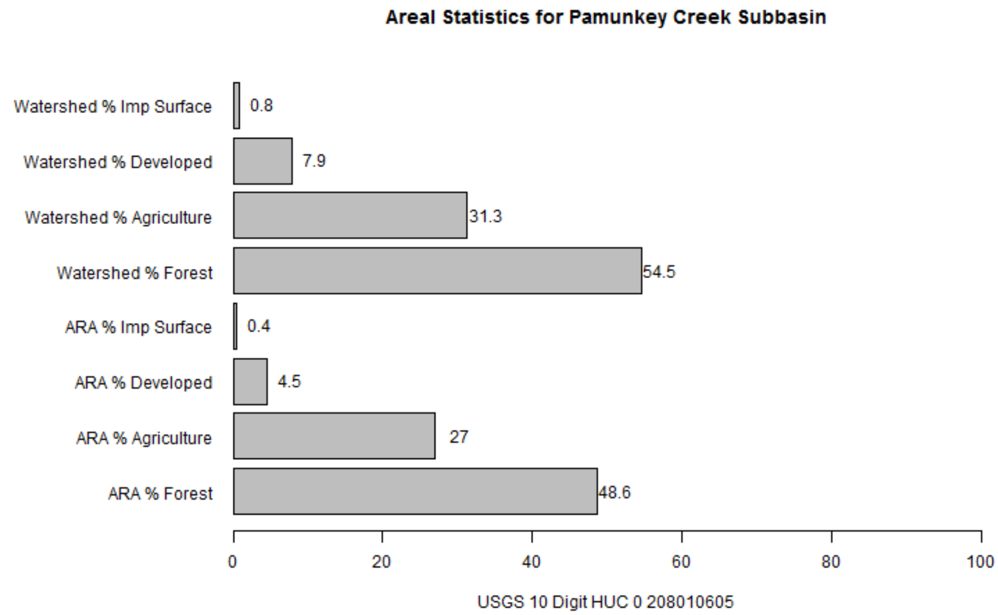
York River Management Unit

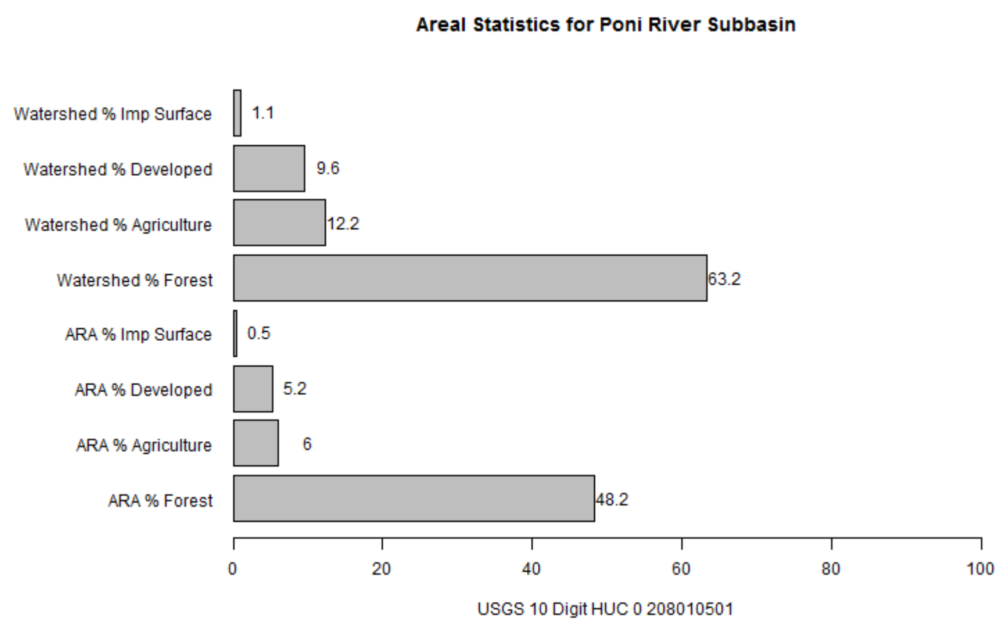


Survey Summary: This MU consists of 6 HUC10 watersheds: Pamunkey Creek, Matta River, Poni River, Upper South Anna River, Middle South Anna River, and Lower South Anna River. Several surveys document the presence of Yellow Lance in this MU – presumably first seen in 1973, and as recent as 2007 in the South Anna River. Abundance is described as "rare" and no information exists on reproduction or recruitment.

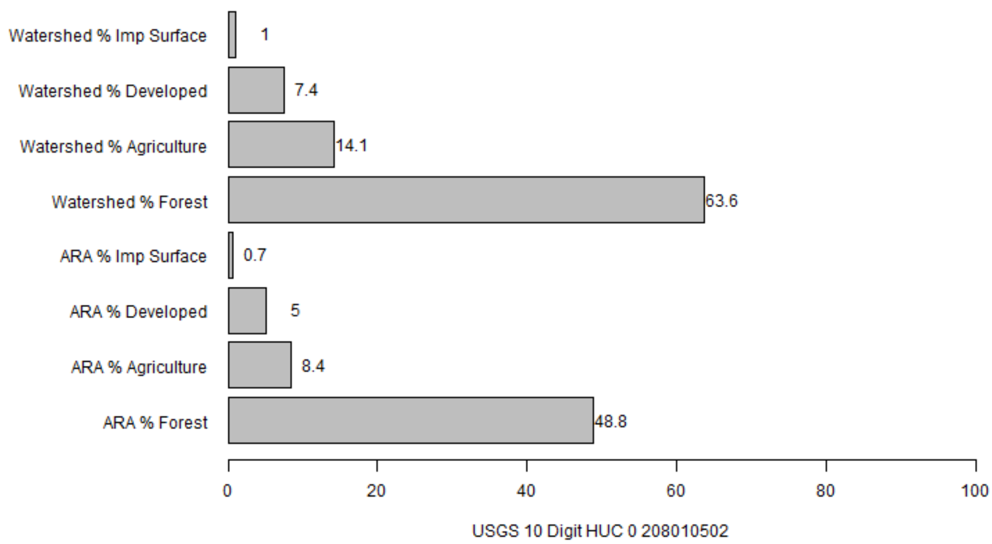
Water Quality Information: Based on 2012 data, there are 13 stream reaches, totaling ~44 miles that are impaired for aquatic life in the Po/South Anna River watersheds. Causes of impairment are indicated by low benthic-macroinvertebrate bioassessment scores, low dissolved oxygen, pH, and E.coli. There are 50 non-major and one major NPDES discharges in the MU, including the Ashland WWTP.

Land Use Land Cover Summary Statistics:

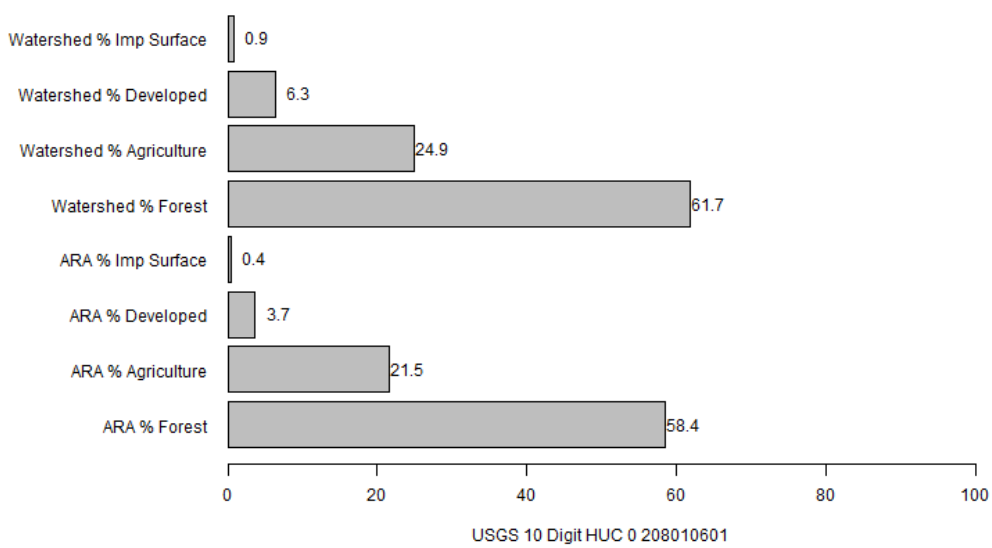


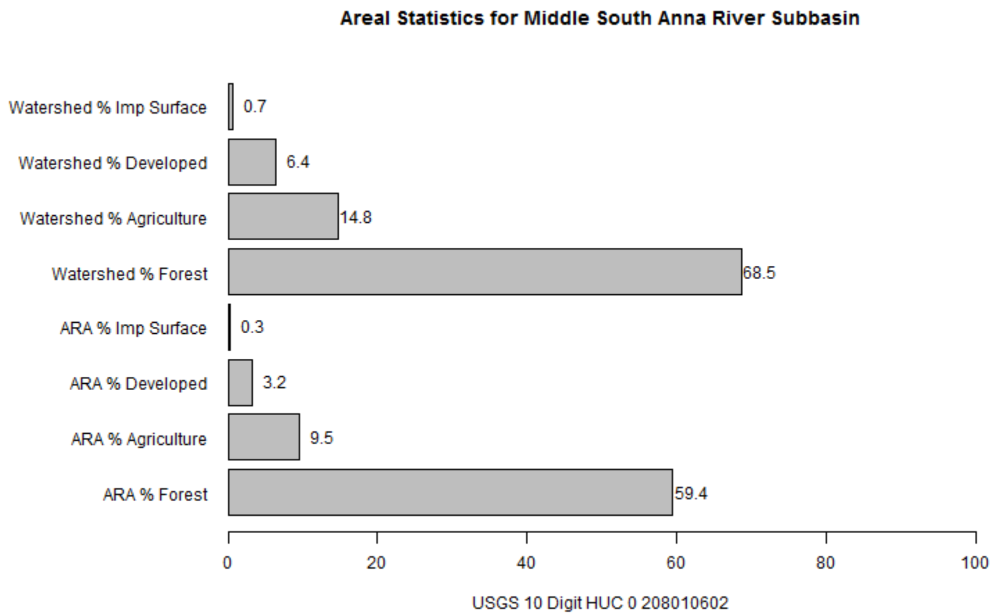


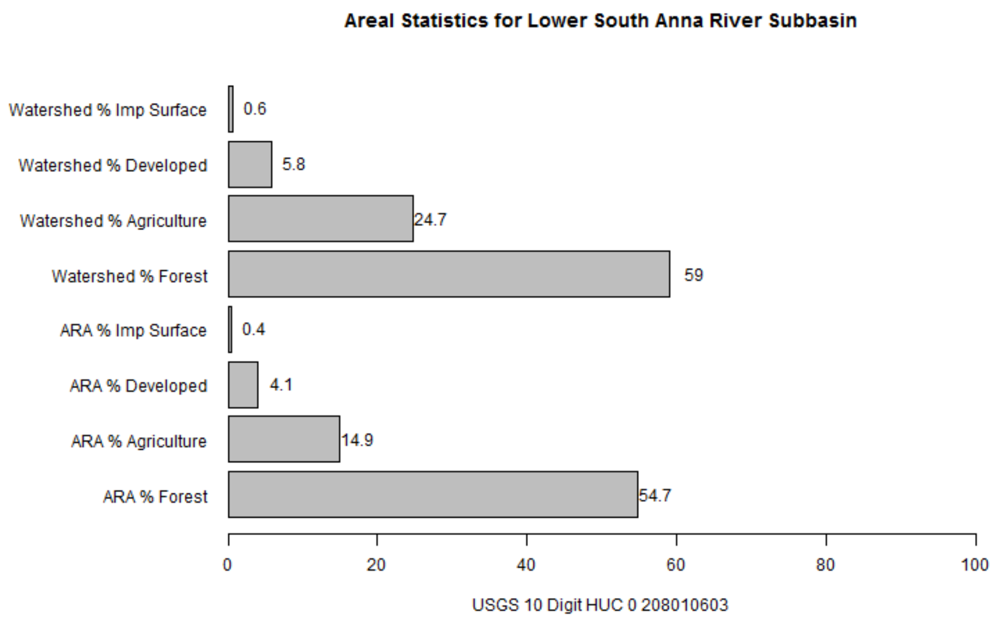
Areal Statistics for Matta River-Mattaponi River Subbasin



Areal Statistics for Upper South Anna River Subbasin

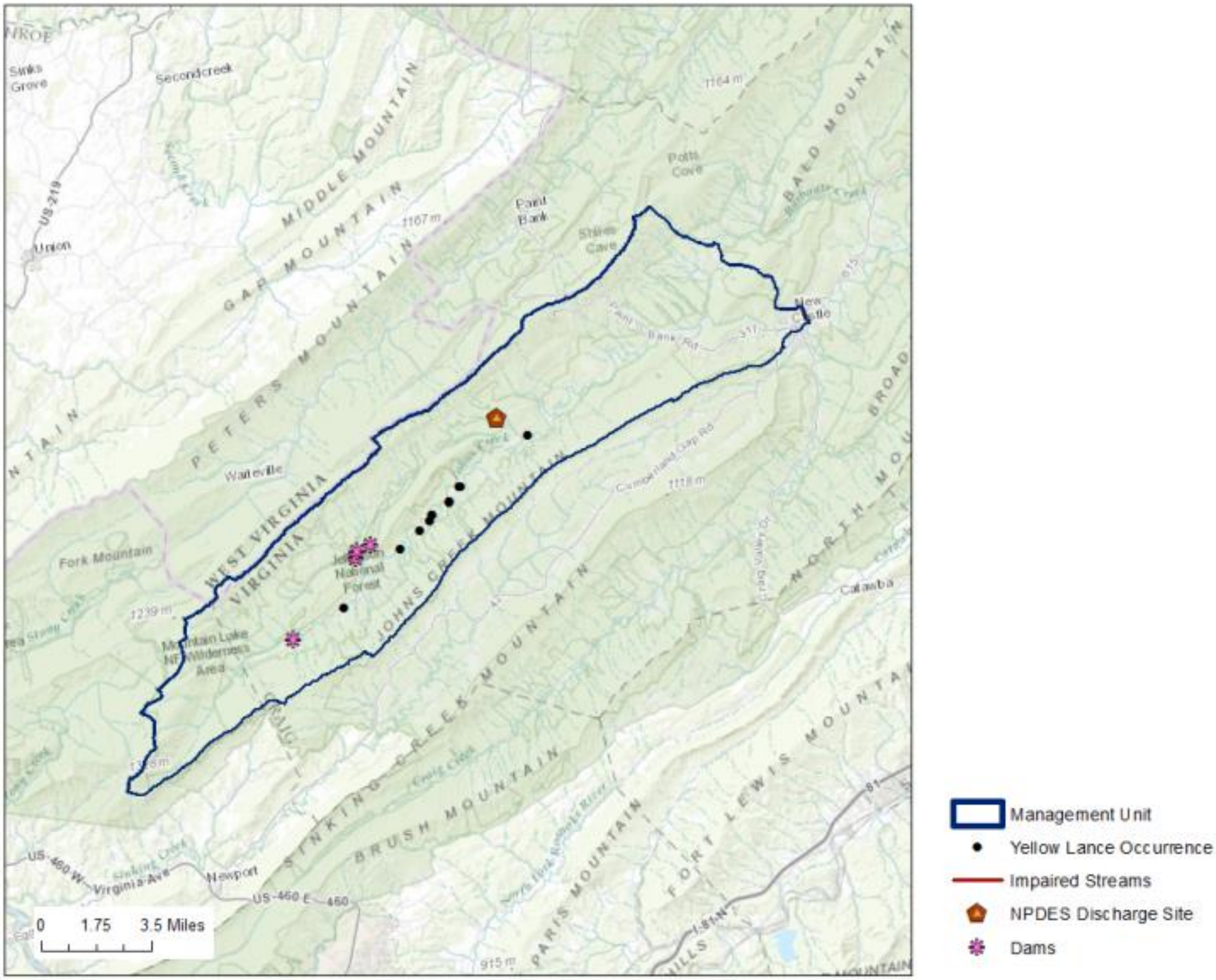



Areal Statistics for Middle South Anna River Subbasin
Watershed % Imp Surface
Watershed % Developed
Watershed % Agriculture
Watershed % Forest
ARA % Imp Surface
ARA % Developed
ARA % Agriculture
ARA % Forest
0.7
6.4
14.8
68.5
0.3
3.2
9.5
59.4
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010602


Areal Statistics for Lower South Anna River Subbasin
Watershed % Imp Surface
Watershed % Developed
Watershed % Agriculture
Watershed % Forest
ARA % Imp Surface
ARA % Developed
ARA % Agriculture
ARA % Forest
0.6
5.8
24.7
59
0.4
4.1
14.9
54.7
0
20
40
60
80
100
USGS 10 Digit HUC 0 208010603

James River Population
Consists of one MU: Johns Creek

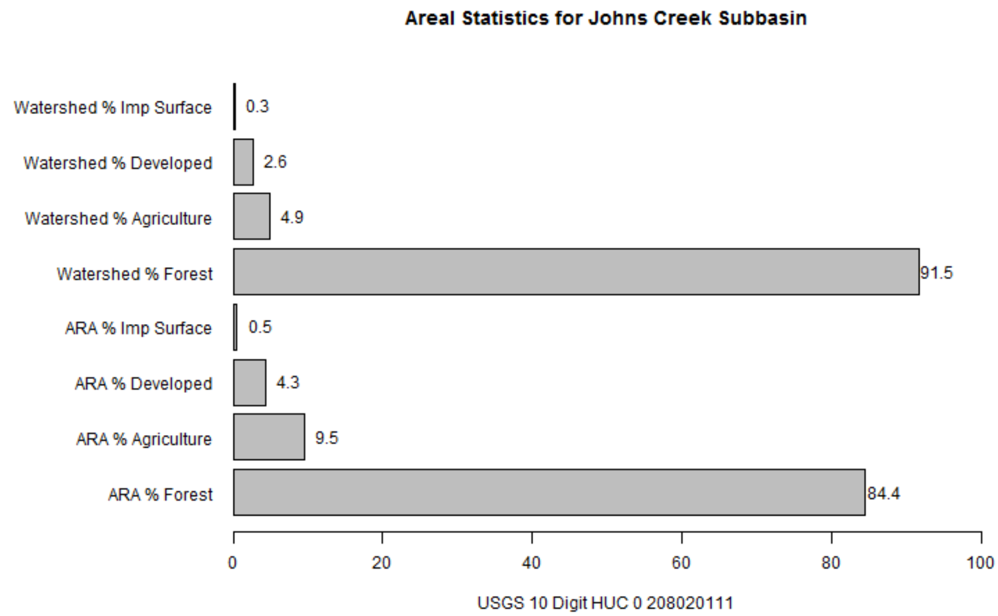
James River (Johns Creek) Management Unit



Survey Summary: The only confirmed records of Yellow Lance in the James basin exist in Johns Creek (see NOTE in Rappahannock Survey Summary above). The species was first seen in 1984, and last observed in 2009. Most survey efforts documented less than a handful of specimens although one 2004 effort found 31. VDOT indicates that repeat surveys have found fewer individuals of Yellow Lance with each survey effort. Abundances have been described as “rare” or “uncommon” and reproduction has been documented.

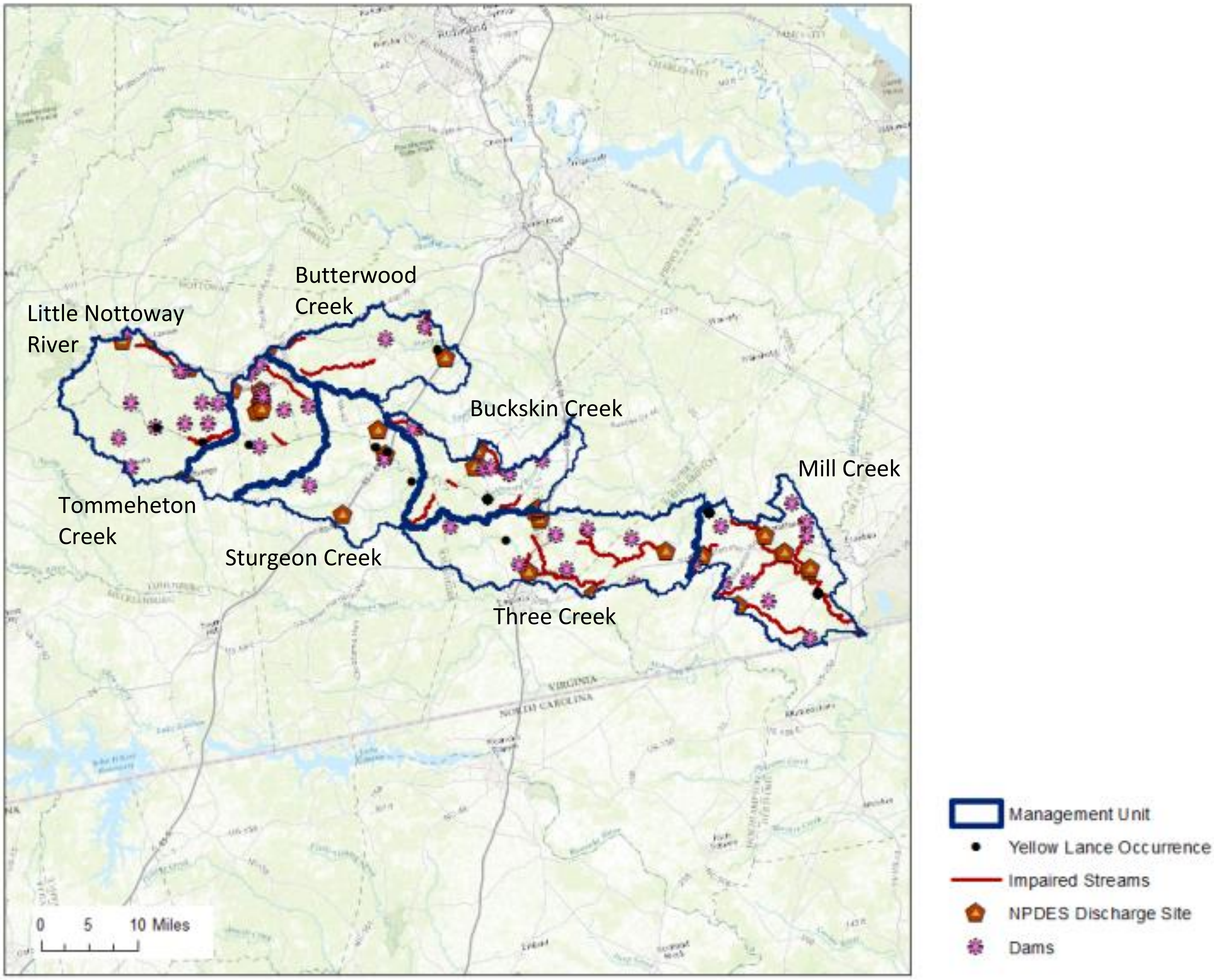
Water Quality Information: Based on 2012 data, there are no impaired stream reaches in the Johns Creek watershed. There is one non-major NPDES discharge in the MU.

Land Use Land Cover Summary Statistics:



Chowan River Population
Consists of two MUs: Nottoway River; Meherrin River

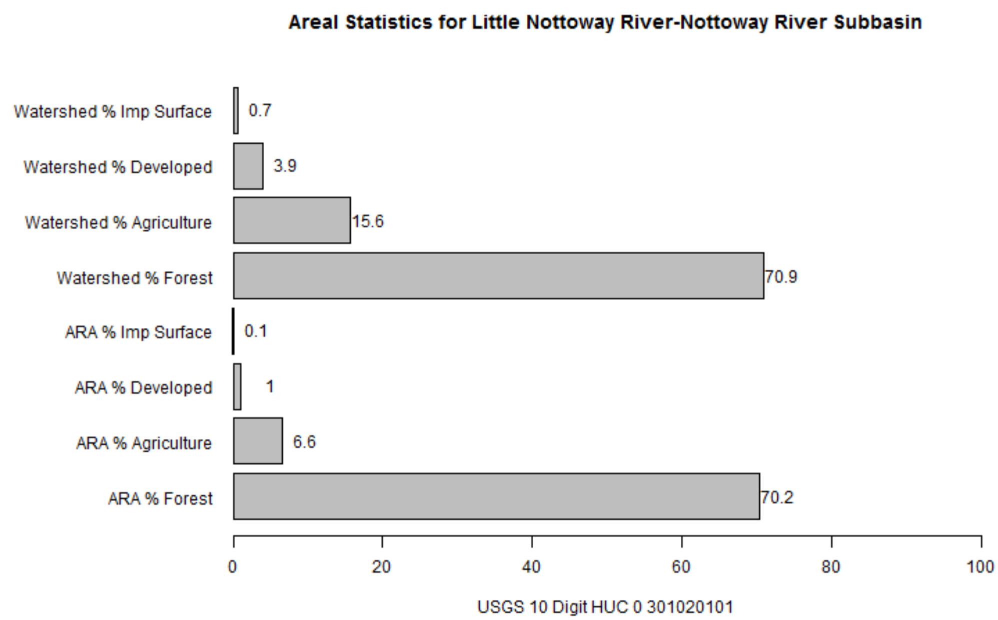
Nottoway River Management Unit

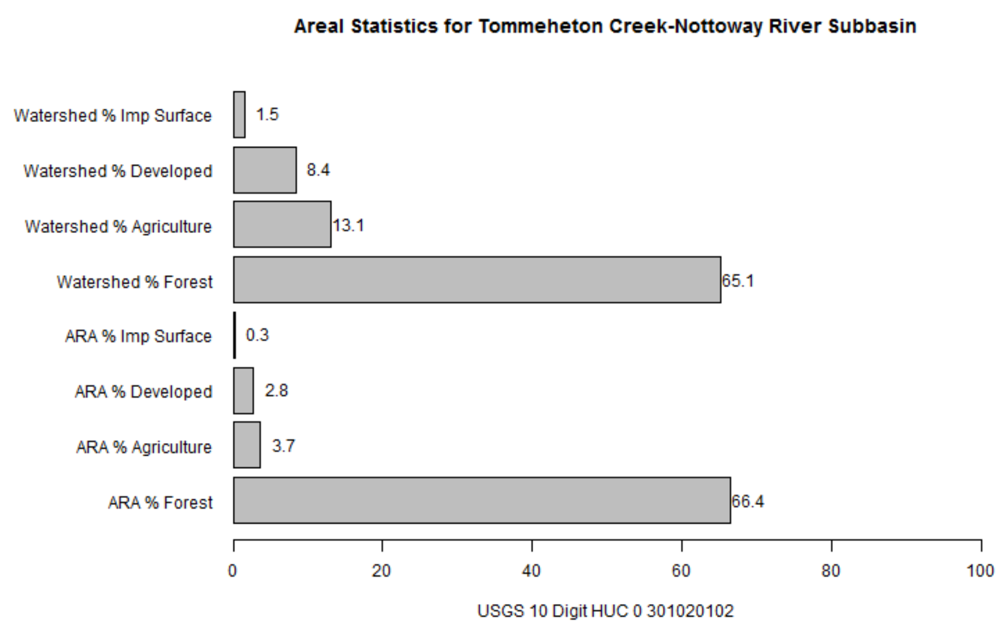


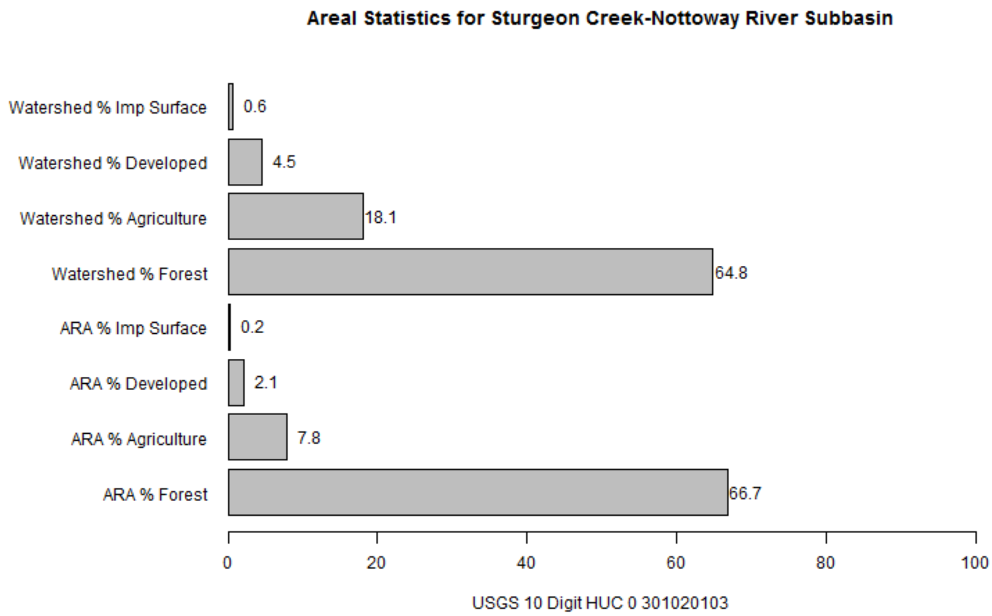
Survey Summary: This MU consists of 7 HUC10 watersheds: Little Nottoway River, Tommeheton Creek, Sturgeon Creek, Butterwood Creek, Buckskin Creek, Three Creek, and Mill Creek. Several surveys in the Nottoway River basin have noted the presence of "Yellow Lance" (one with as many as 781 individuals, although the exact identity of each specimen was not confirmed – see NOTE in Rappahannock Survey Summary above). The species has been seen as recently as 2011 in the Nottoway River, albeit in extremely low numbers. There is no information on reproduction or recruitment in this MU.

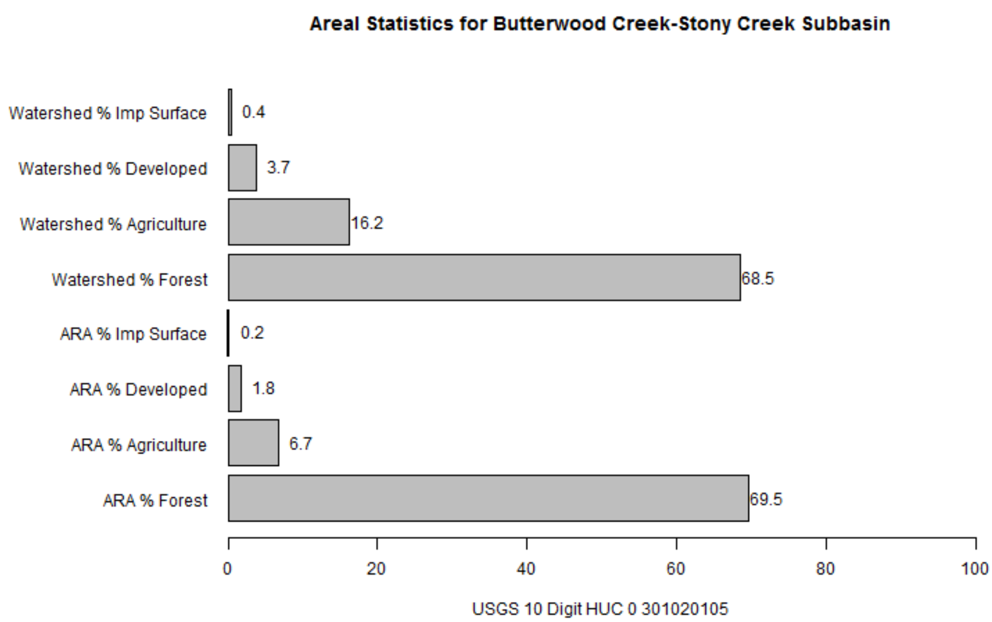
Water Quality Information: Based on the 2012 data, there are there are 29 stream reaches, totaling ~155 miles that are impaired for aquatic life in the Nottoway River watersheds. Causes of impairment are indicated by low benthic-macroinvertebrate bioassessment scores, low dissolved oxygen, pH, and E.coli, and sources are from urban stormwater and natural conditions. There are 32 non-major and four major NPDES discharges in the MU.

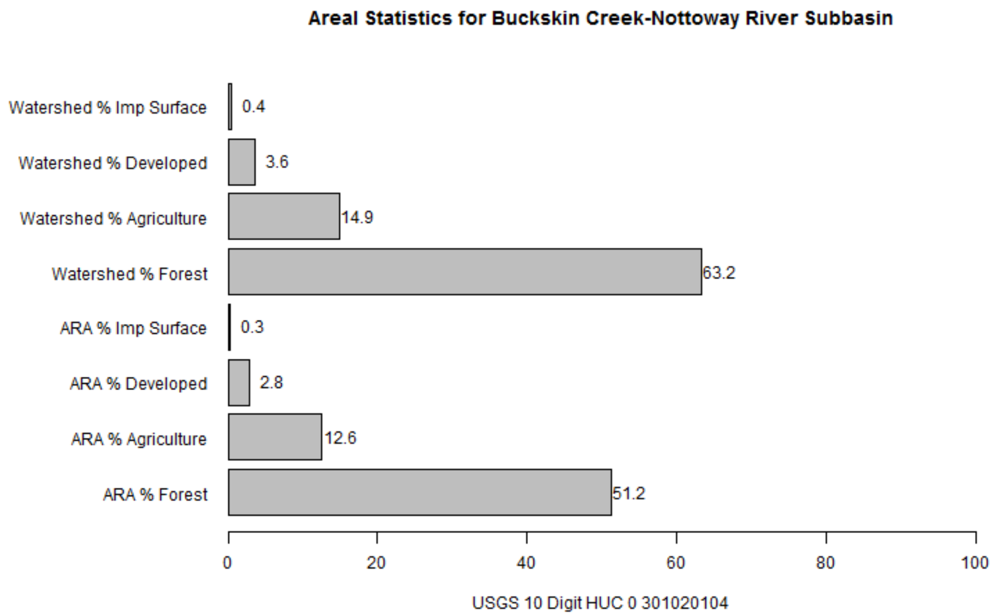
Land Use Land Cover Summary Statistics:

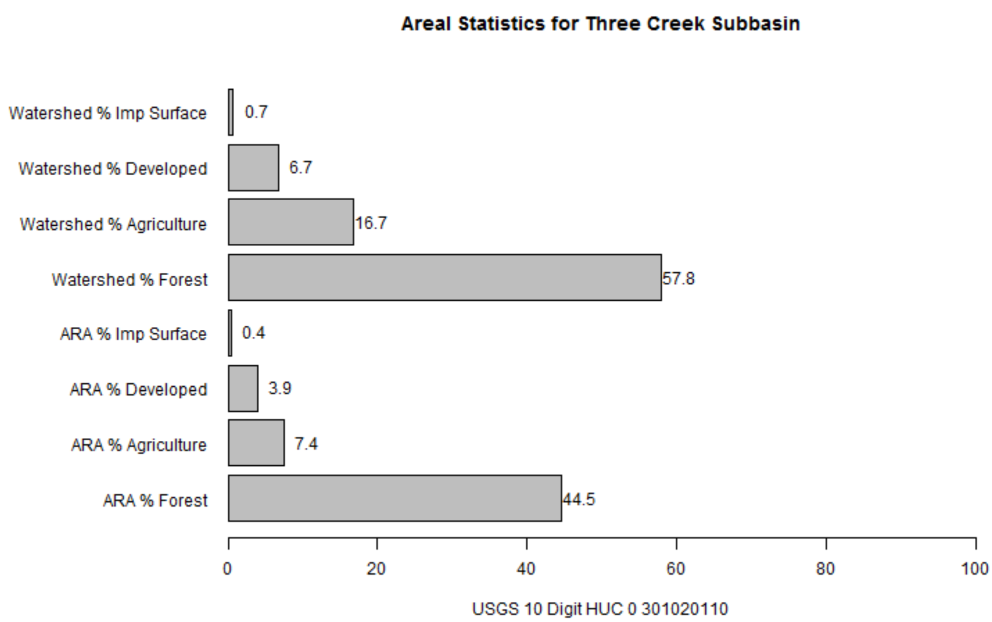


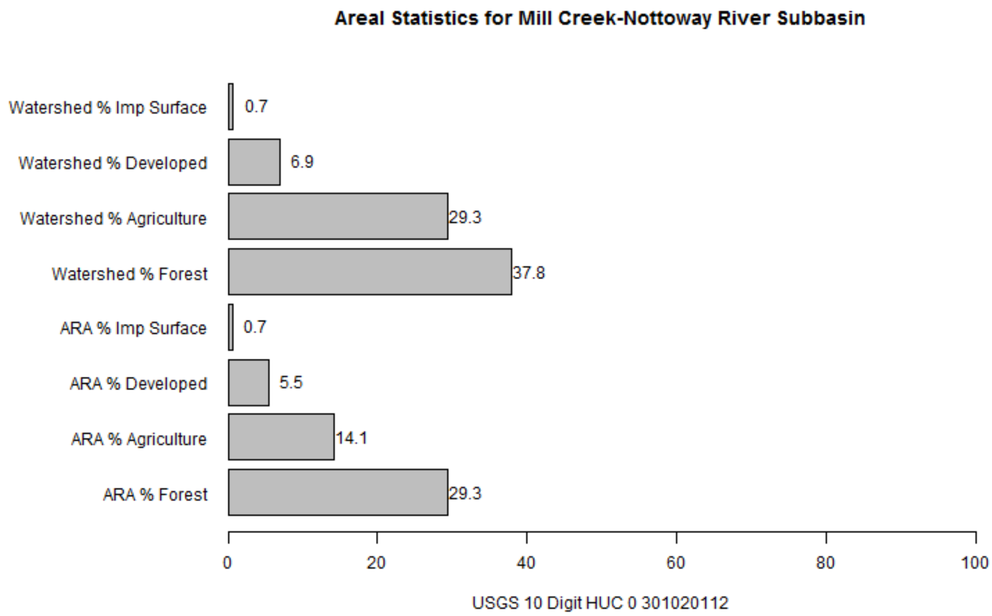



Areal Statistics for Sturgeon Creek-Nottoway River Subbasin
Watershed % Imp Surface
0.6
Watershed % Developed
4.5
Watershed % Agriculture
18.1
Watershed % Forest
64.8
ARA % Imp Surface
0.2
ARA % Developed
2.1
ARA % Agriculture
7.8
ARA % Forest
66.7
0
20
40
60
80
100
USGS 10 Digit HUC 0 301020103

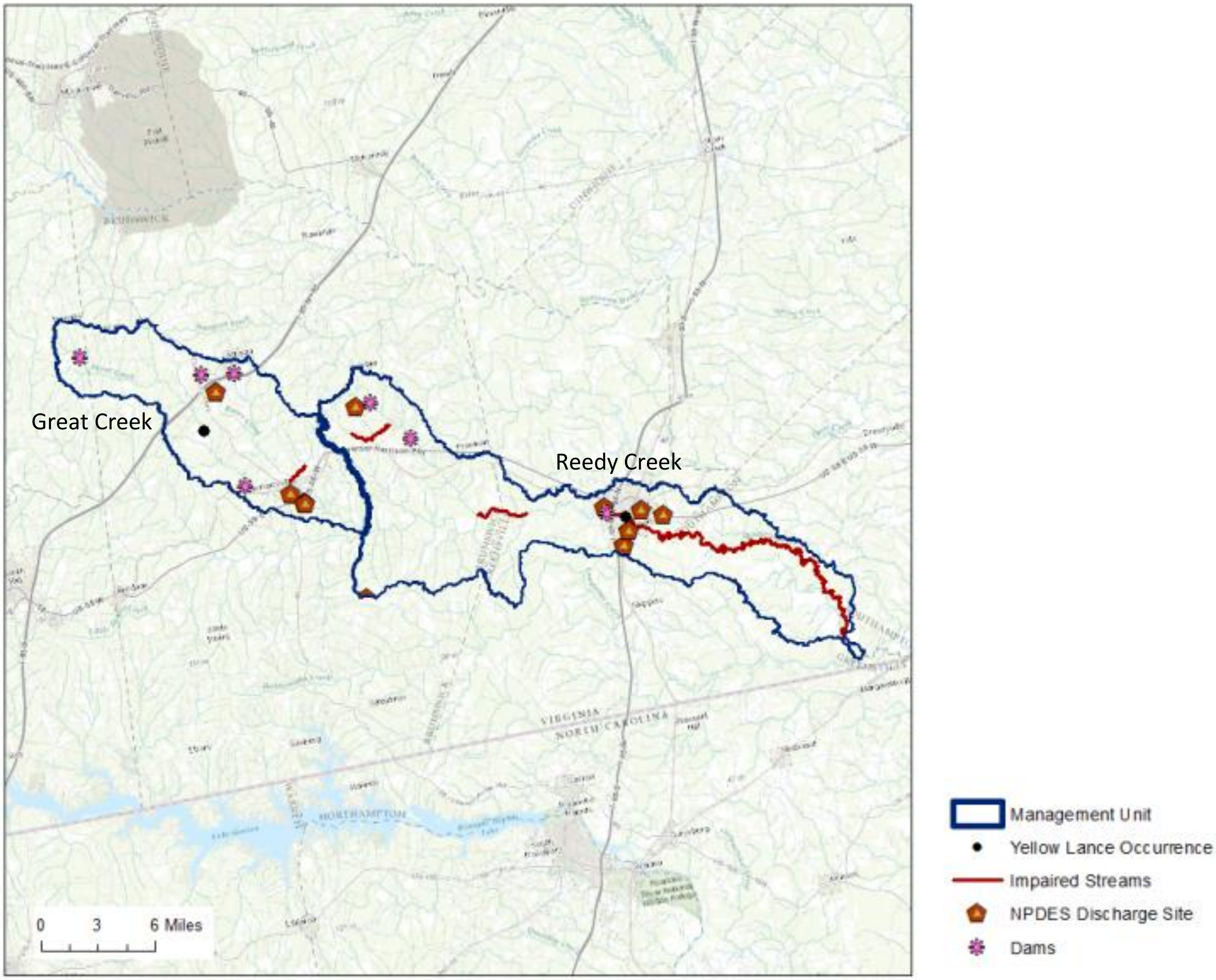

Areal Statistics for Butterwood Creek-Stony Creek Subbasin
Watershed % Imp Surface
0.4
Watershed % Developed
3.7
Watershed % Agriculture
16.2
Watershed % Forest
68.5
ARA % Imp Surface
0.2
ARA % Developed
1.8
ARA % Agriculture
6.7
ARA % Forest
69.5
0
20
40
60
80
100
USGS 10 Digit HUC 0 301020105


Areal Statistics for Buckskin Creek-Nottoway River Subbasin
Watershed % Imp Surface
0.4
Watershed % Developed
3.6
Watershed % Agriculture
14.9
Watershed % Forest
63.2
ARA % Imp Surface
0.3
ARA % Developed
2.8
ARA % Agriculture
12.6
ARA % Forest
51.2
0
20
40
60
80
100
USGS 10 Digit HUC 0 301020104


Areal Statistics for Three Creek Subbasin
Watershed % Imp Surface
0.7
Watershed % Developed
6.7
Watershed % Agriculture
16.7
Watershed % Forest
57.8
ARA % Imp Surface
0.4
ARA % Developed
3.9
ARA % Agriculture
7.4
ARA % Forest
44.5
0
20
40
60
80
100
USGS 10 Digit HUC 0 301020110


Areal Statistics for Mill Creek-Nottoway River Subbasin
Watershed % Imp Surface
0.7
Watershed % Developed
6.9
Watershed % Agriculture
29.3
Watershed % Forest
37.8
ARA % Imp Surface
0.7
ARA % Developed
5.5
ARA % Agriculture
14.1
ARA % Forest
29.3
0
20
40
60
80
100
USGS 10 Digit HUC 0 301020112

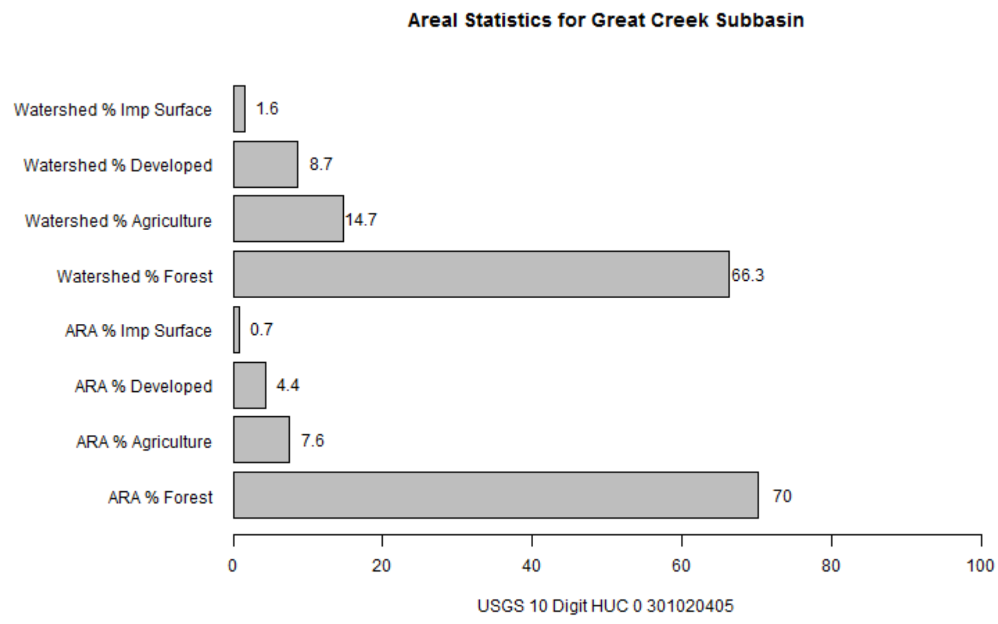
Meherrin River Management Unit

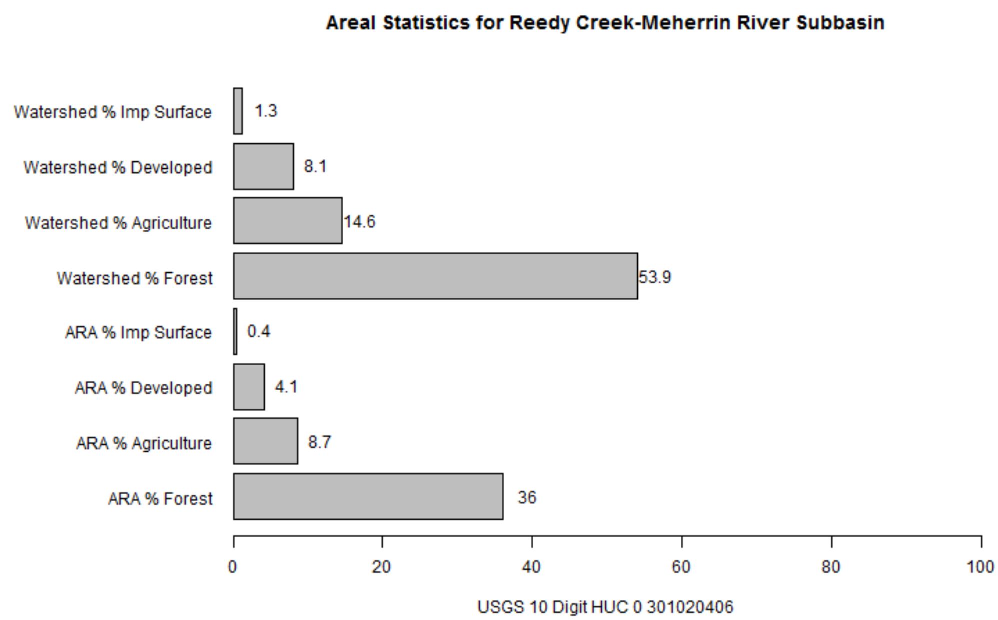


Survey Summary: This MU consists of two HUC10 watersheds: Great Creek and Reedy Creek. The VA Natural Heritage database has one record of a Yellow Lance in the Meherrin River, found during a survey in 1990 and another found in Great Creek in 1994.

Water Quality Information: Based on the 2012 data, there are there are four stream reaches, totaling ~34 miles that are impaired for aquatic life in the Meherrin River watersheds. Indicators of impairment are low benthic-macroinvertebrate bioassessment scores, low dissolved oxygen, pH, and E.coli. There are 16 non-major and 2 major NPDES discharges in the MU.

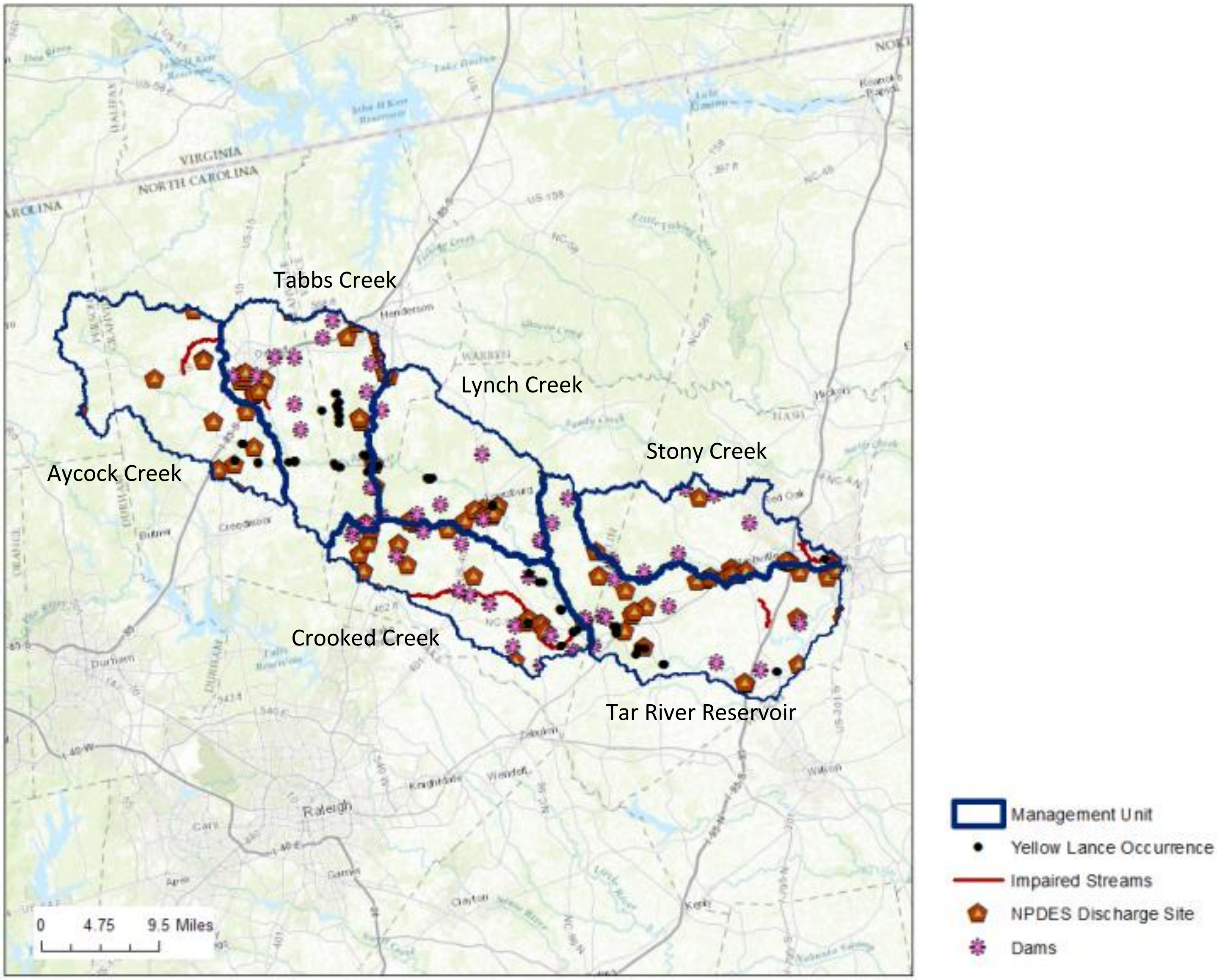
Land Use Land Cover Summary Statistics:





Tar River Population
Consists of four MUs: Upper/Middle Tar River; Lower Tar River; Sandy-Swift Creek; Fishing Creek Subbasin

Upper/Middle Tar River Management Unit

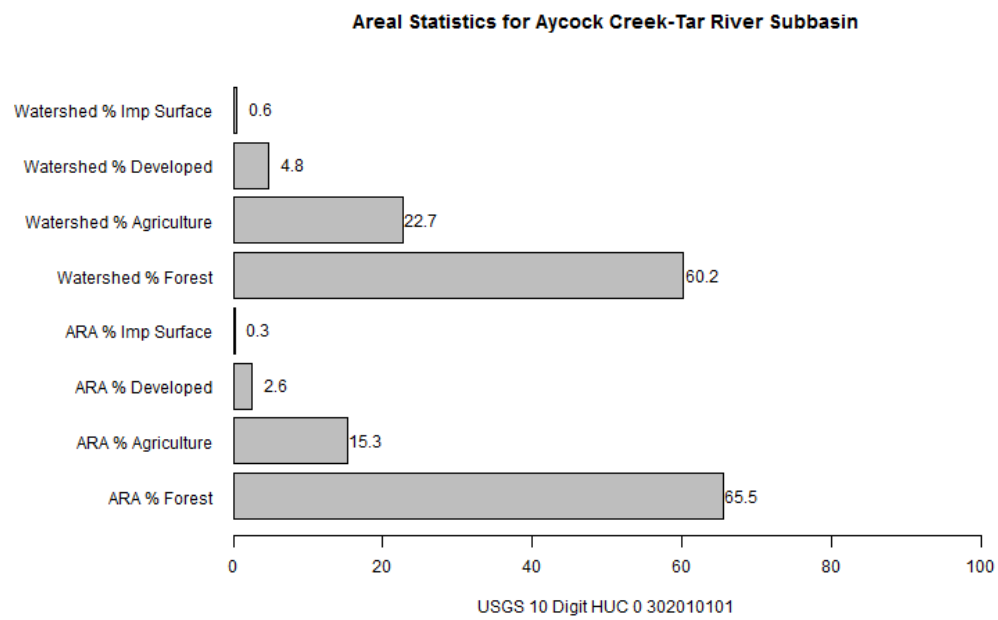


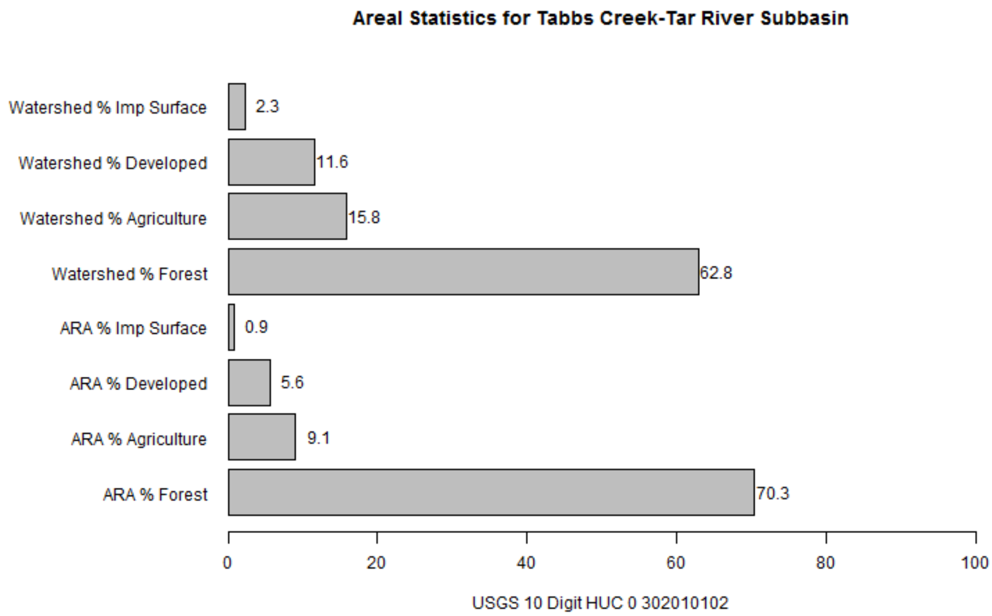
Survey Summary: This MU includes the tributaries Fox Creek, Crooked Creek, Ruin and Tabbs Creek, as well as the mainstem of the upper and middle Tar River in six HUC10 watersheds (Aycock Creek, Tabbs Creek, Lynch Creek, Crooked Creek, Stony Creek, and Tar River Reservoir). Many surveys efforts have documented the presence of Yellow Lance over the years; the species was first seen in 1966 and it has been documented as recently as 2016 in the Tar River. Recent abundances have been described as “rare” or “uncommon” – where one survey in the 1990 documented upwards of 100 live individuals (Tar River sites), most other surveys have documented 25 to 31 individuals, and most recently (2014), 25 live individuals (Tar

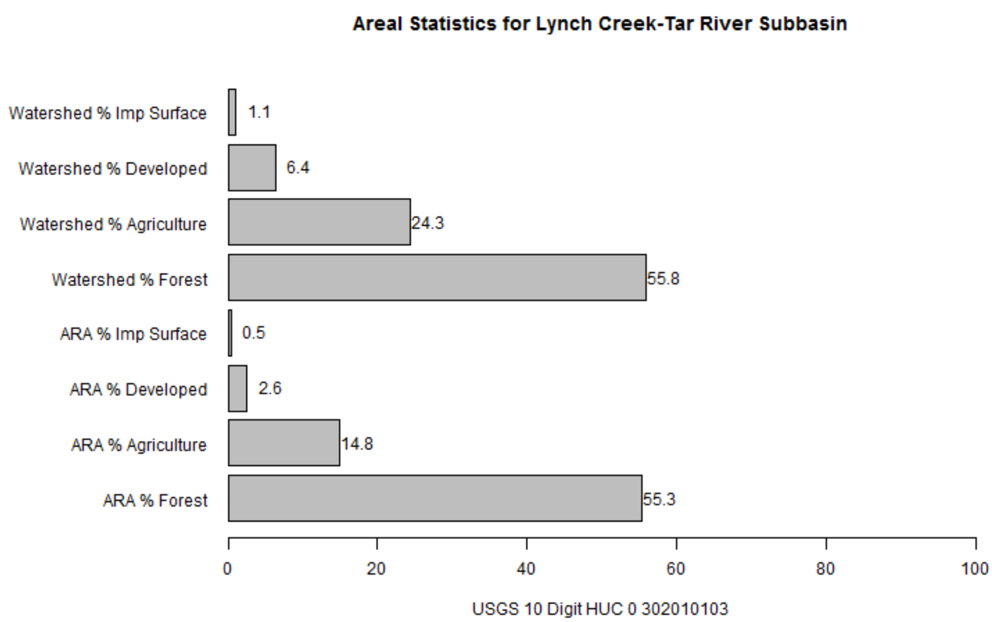
River sites). Tributary sites do not have the same abundances as mainstem sites – the most collected during a given survey was six in Fox Creek (1993). Reproduction and recruitment have been confirmed as recently as 2015 (Tar River sites).

Water Quality Information: Based on 2014 data, there are seven impaired stream reaches totaling ~38 miles in this MU. Indicators of impairment are low DO and low benthic-macroinvertebrate assessment scores, and the entire basin is classified as Nutrient Sensitive Waters (NCDEQ 2016, pp.115-117). There are 102 non-major NPDES discharges, including several package WWTPs and biosolids facilities, and 3 major (Oxford WWTP, Louisburg WWTP, and Franklin County WWTP) NPDES discharges in this MU.

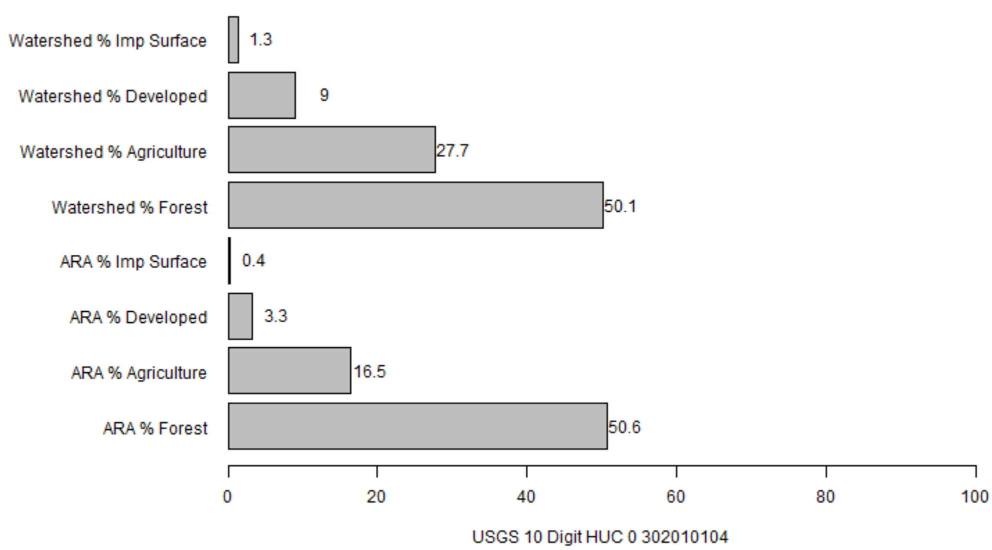
Land Use Land Cover Summary Statistics:



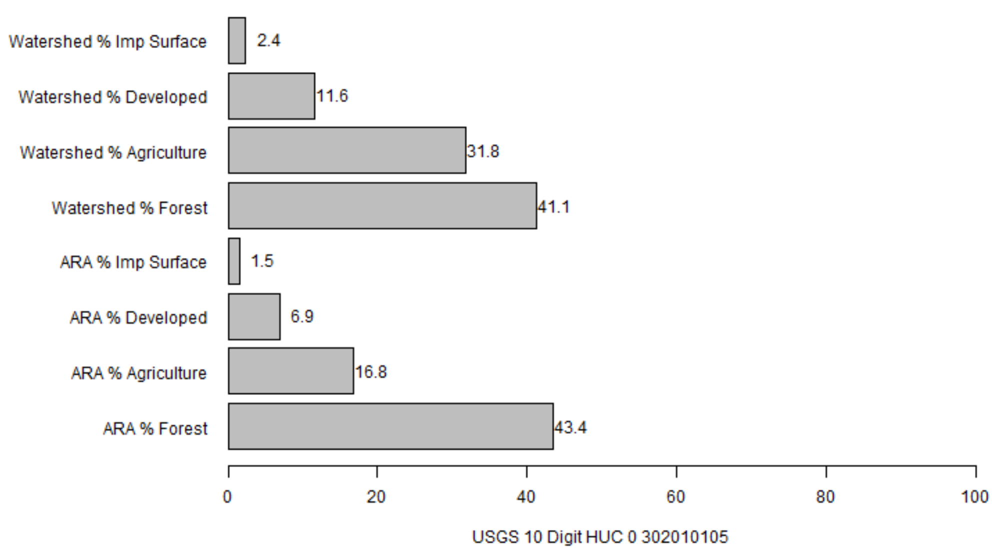

Areal Statistics for Tabbs Creek-Tar River Subbasin
Watershed % Imp Surface
2.3
Watershed % Developed
11.6
Watershed % Agriculture
15.8
Watershed % Forest
62.8
ARA % Imp Surface
0.9
ARA % Developed
5.6
ARA % Agriculture
9.1
ARA % Forest
70.3
0
20
40
60
80
100
USGS 10 Digit HUC 0 302010102

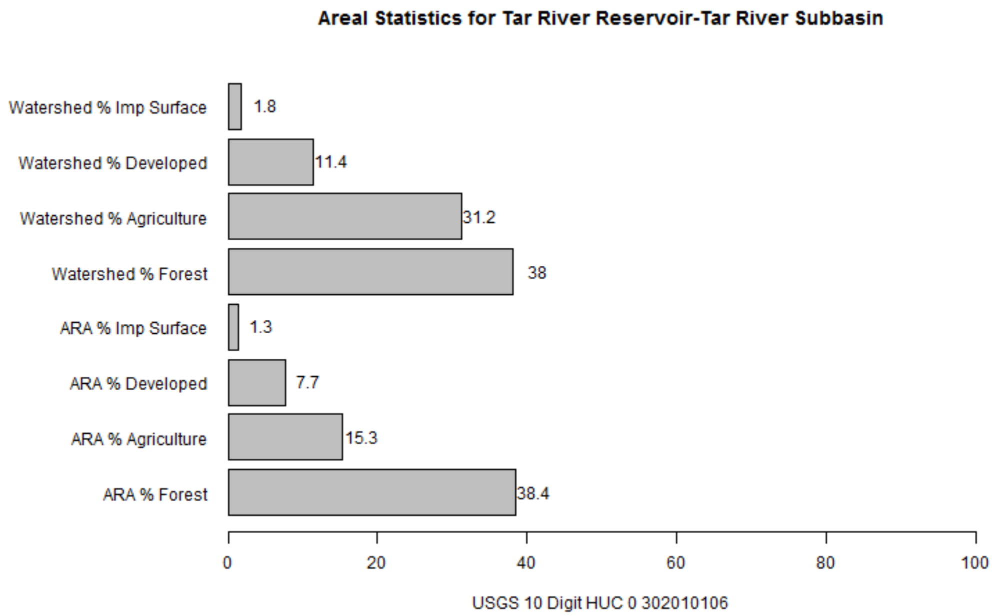

Areal Statistics for Lynch Creek-Tar River Subbasin
Watershed % Imp Surface
1.1
Watershed % Developed
6.4
Watershed % Agriculture
24.3
Watershed % Forest
55.8
ARA % Imp Surface
0.5
ARA % Developed
2.6
ARA % Agriculture
14.8
ARA % Forest
55.3
0
20
40
60
80
100
USGS 10 Digit HUC 0 302010103

Areal Statistics for Crooked Creek-Tar River Subbasin

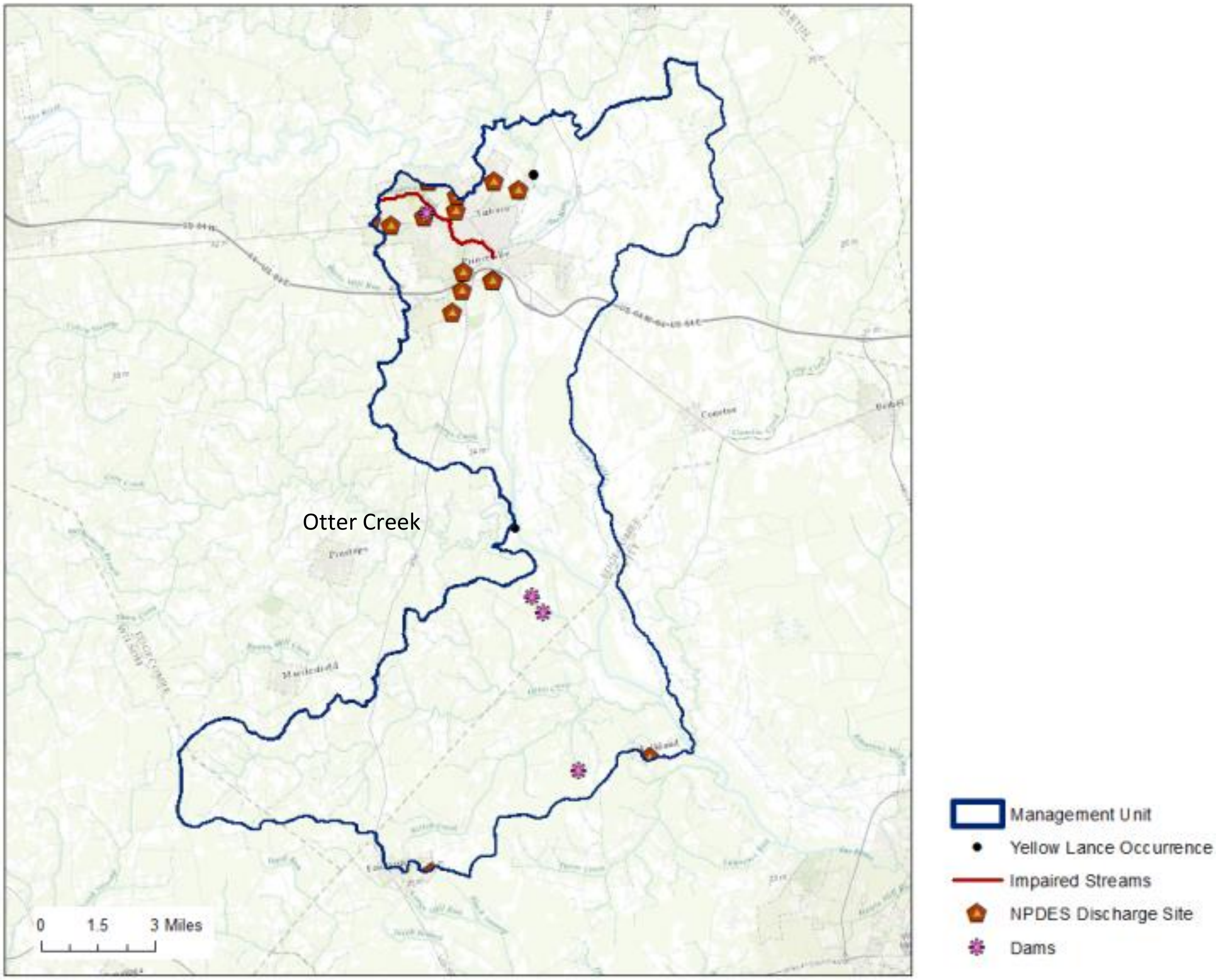


Areal Statistics for Stony Creek Subbasin




Areal Statistics for Tar River Reservoir-Tar River Subbasin
Watershed % Imp Surface
1.8
Watershed % Developed
11.4
Watershed % Agriculture
31.2
Watershed % Forest
38
ARA % Imp Surface
1.3
ARA % Developed
7.7
ARA % Agriculture
15.3
ARA % Forest
38.4
0
20
40
60
80
100
USGS 10 Digit HUC 0 302010106

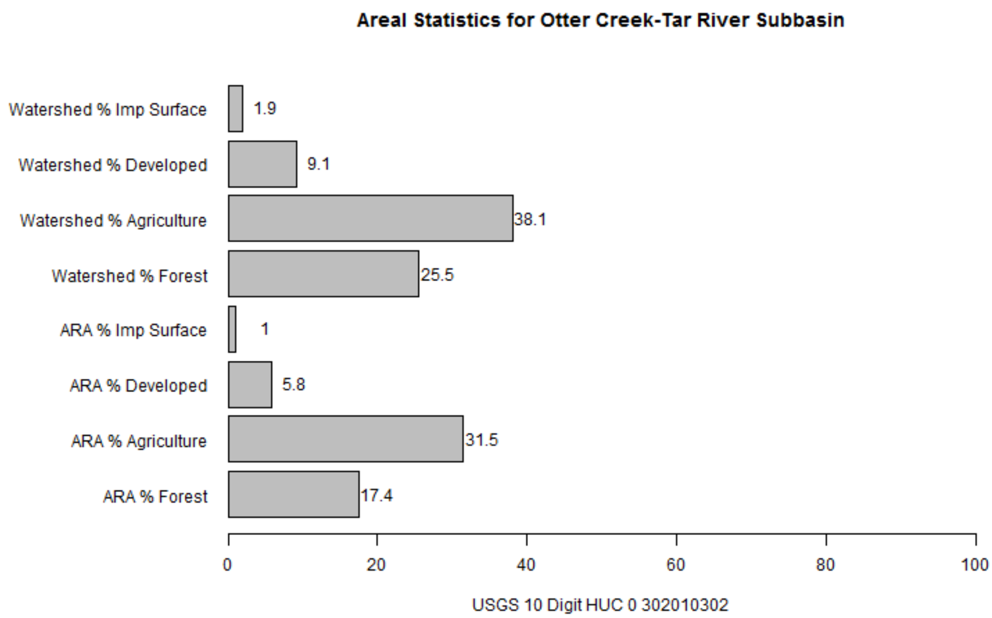
Lower Tar River Management Unit



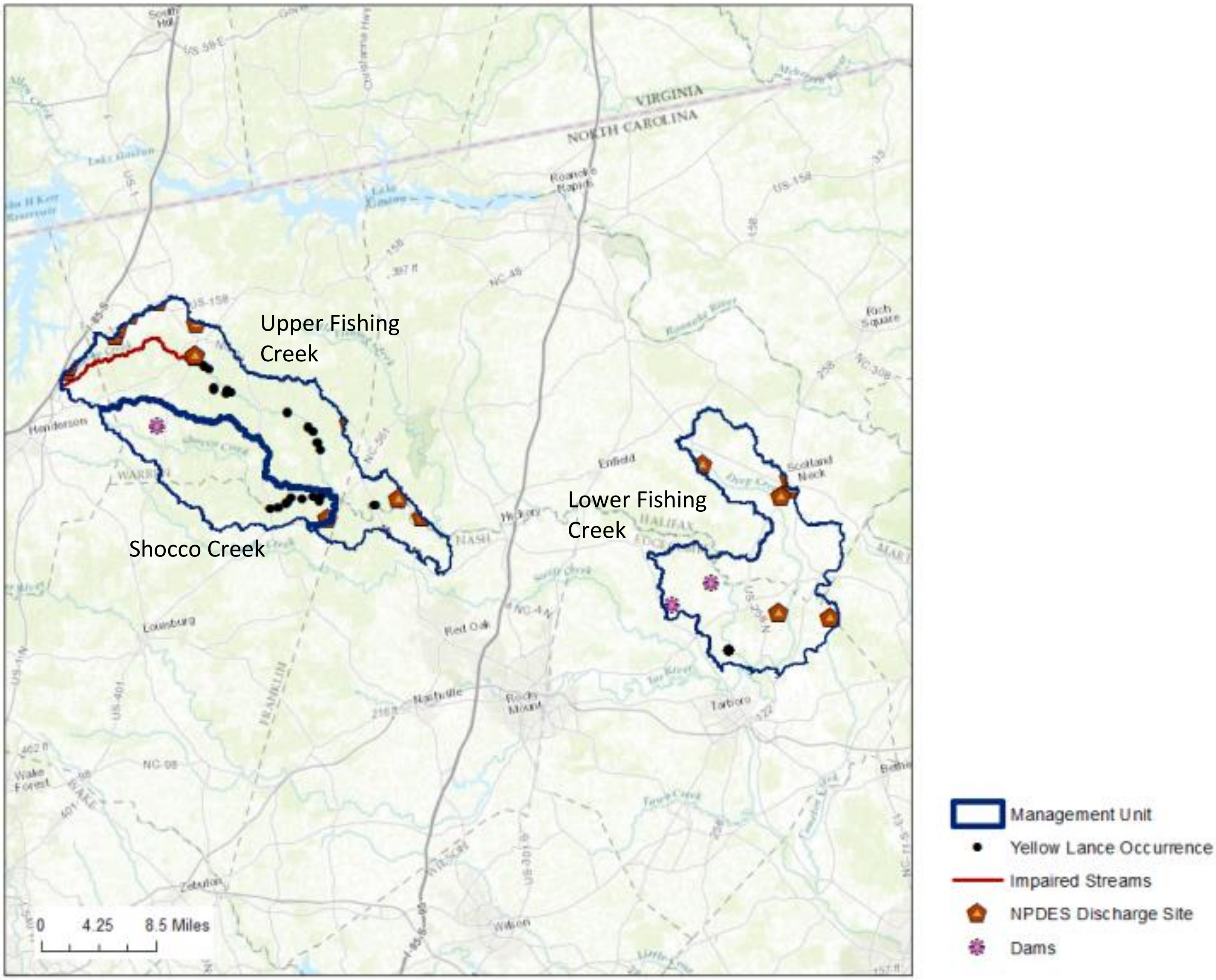
Survey Summary: The Yellow Lance was first documented from this MU (consisting of one HUC10 watershed: Otter Creek) in 1966 (H.Athearn collection) with 18 shells; two surveys in 1987 documented two live specimens.

Water Quality Information: Based on the 2014 data, there are one impaired stream reach totaling ~4 miles in this MU. Causes are indicated by very low benthic-macroinvertebrate assessment scores, and the entire basin is classified as Nutrient Sensitive Waters. There are 16 non-major and one major (Tarboro WWTP) NPDES discharges in this MU.

Land Use Land Cover Summary Statistics:



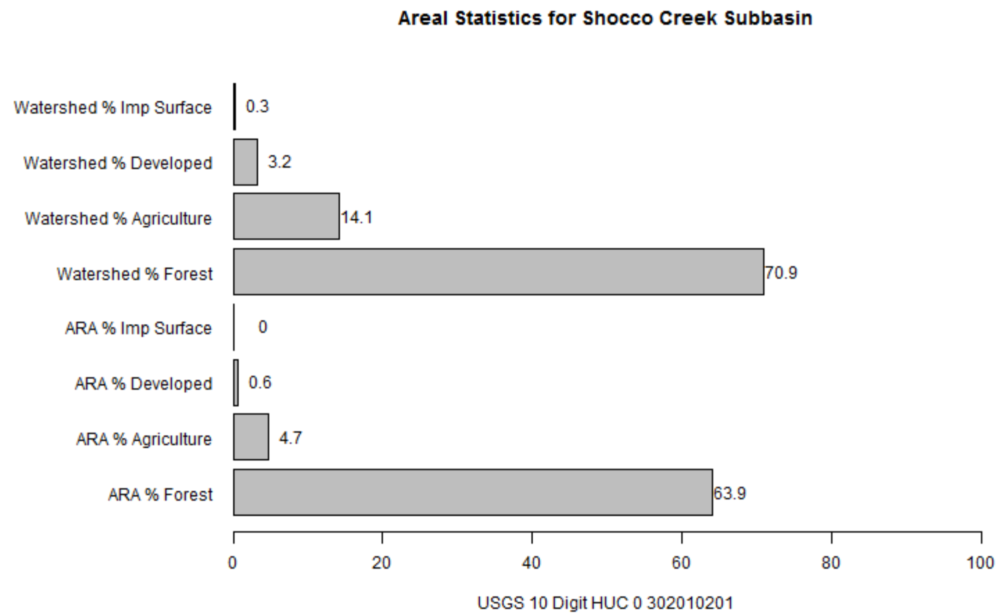
Fishing Creek Subbasin Management Unit

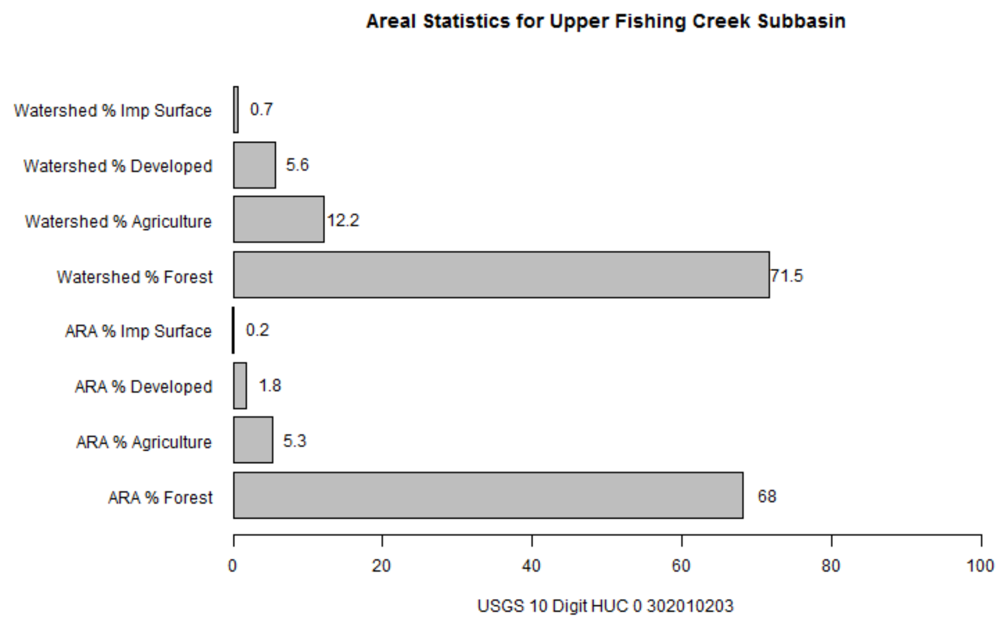


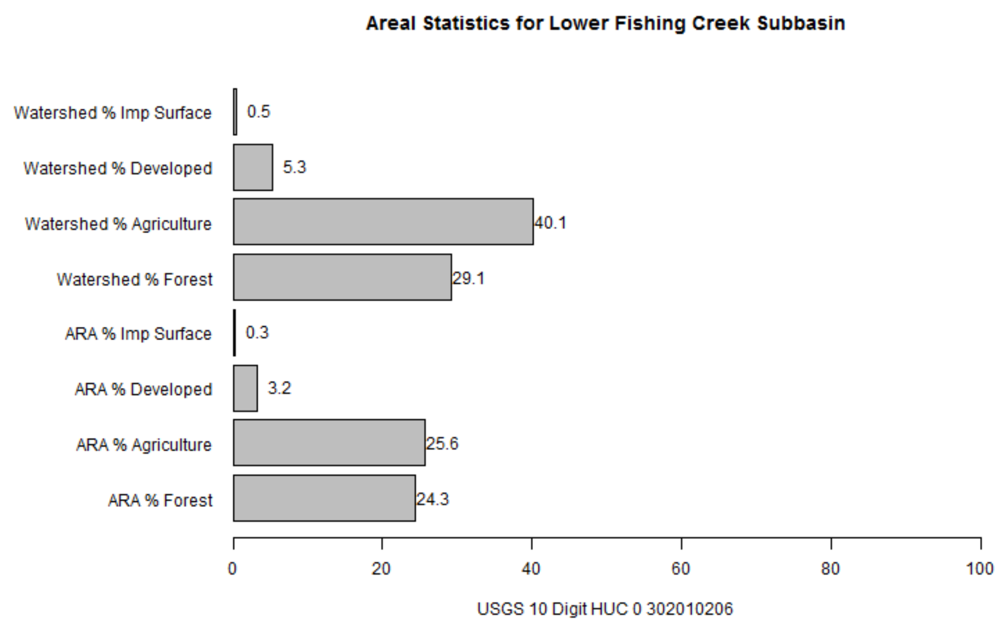
Survey Summary: This MU consists of three HUC10 watersheds: Shocco Creek, Upper Fishing Creek and Lower Fishing Creek. The Yellow Lance has been documented via many surveys in both Shocco Creek and Fishing Creek, and a couple of surveys in Richneck Creek. The species was first seen in 1983, and has been seen as recently as 2016. Most surveys describe abundances as "rare" with usually less than a handful observed in each effort; the most seen was nine live individuals in Fishing Creek (1994, 2004, and 2005). Recruitment was observed in 2015..

Water Quality Information: Based on 2014 data, there is one impaired stream reach totaling ~14 miles in this MU. Cause of impairment is due to low DO. There are 23 non-major and one major (Warrenton WWTP) NPDES discharges in this MU.

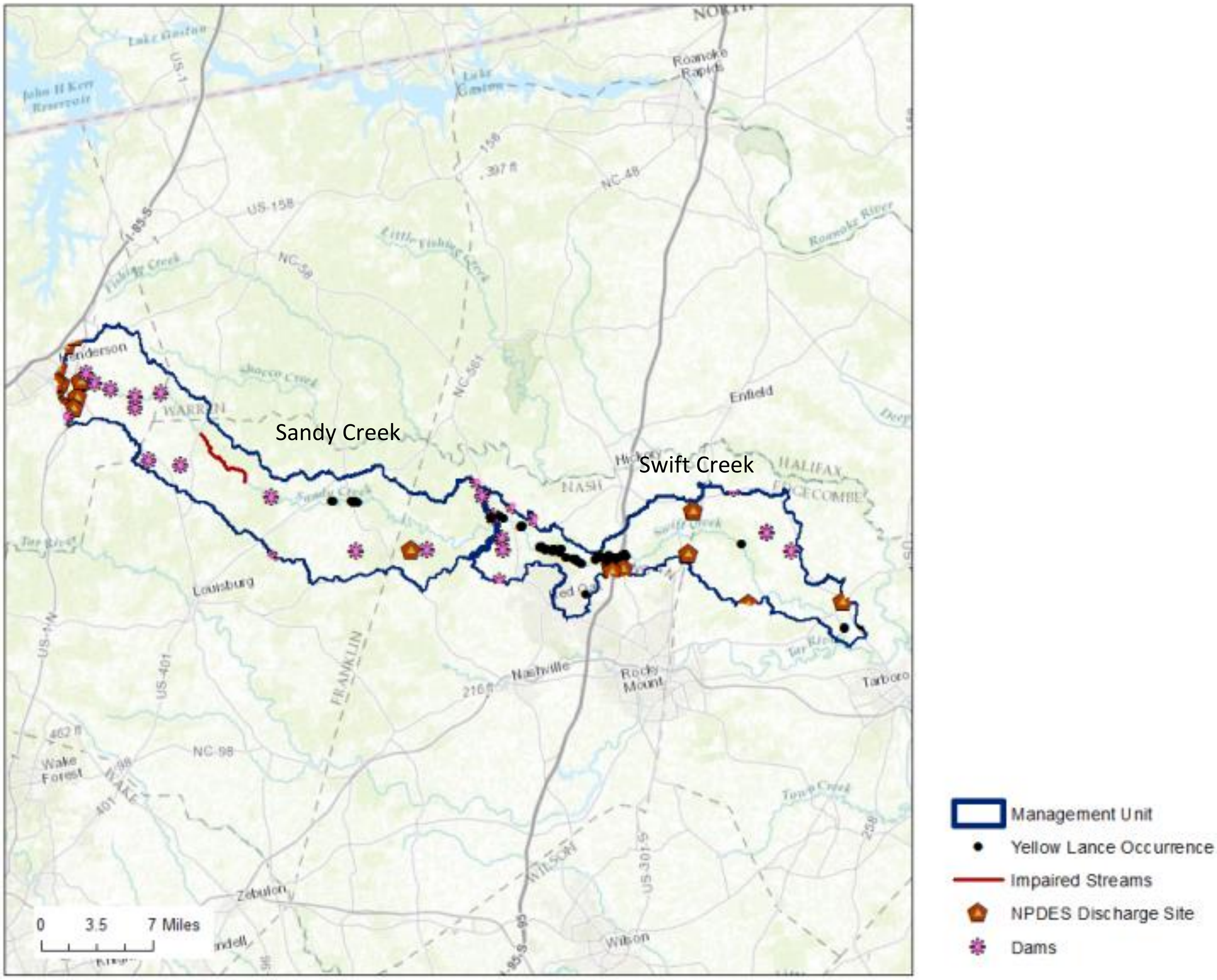
Land Use Land Cover Summary Statistics:






Areal Statistics for Lower Fishing Creek Subbasin
Watershed % Imp Surface
0.5
Watershed % Developed
5.3
Watershed % Agriculture
40.1
Watershed % Forest
29.1
ARA % Imp Surface
0.3
ARA % Developed
3.2
ARA % Agriculture
25.6
ARA % Forest
24.3
0
20
40
60
80
100
USGS 10 Digit HUC 0 302010206

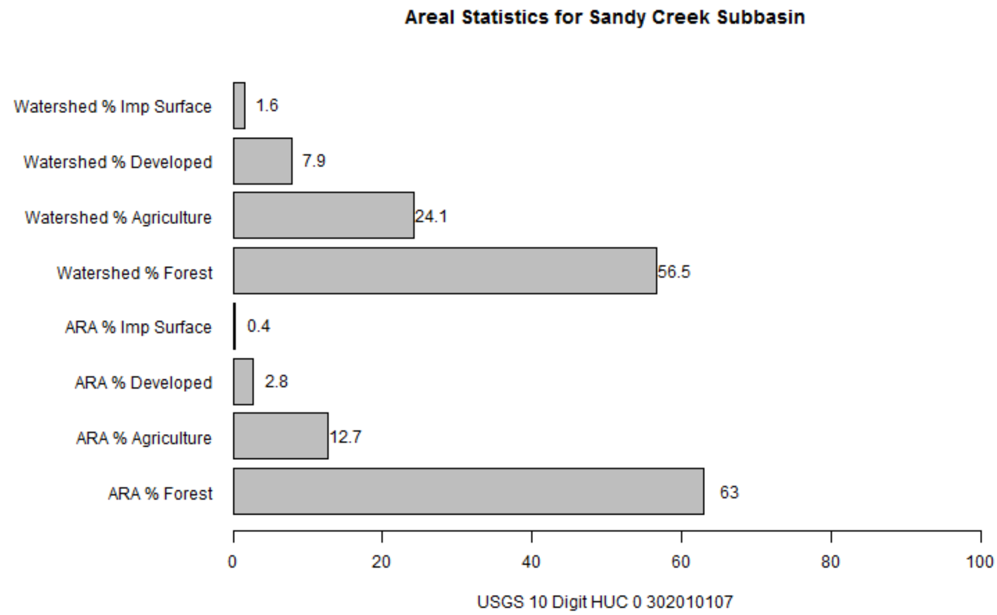
Sandy-Swift Creek Management Unit

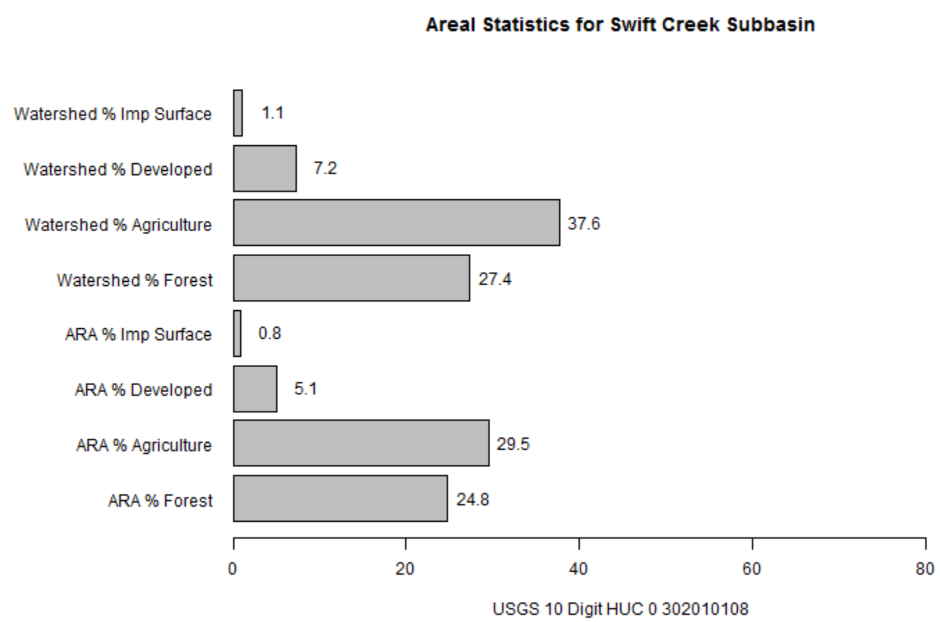


Survey Summary: This MU consists of two HUC10 watersheds: Sandy Creek and Swift Creek. Many surveys in this system have documented the presence of Yellow Lance; it was first seen in 1988, and most recently in 2016. Abundances have usually been described as "rare/uncommon" to "common". During one survey in 1996, 50 live individuals were observed, however surveys from 2010-2014 found fewer than 5 individuals per effort; more recent surveys in 2015 and 2016 documented 53 and 45 live individuals, respectively. Recruitment was documented in 2016.

Water Quality Information: Water Quality Information: Based on 2014 data, there is one impaired stream reach totaling ~5 miles in this MU. Cause of impairment is due to low benthic-macroinvertebrate assessment score. There are 21 non-major NPDES discharges in this MU. The entire Sandy Creek HUC and the upper portion of the Swift Creek HUC are designated as an ORW Special Management Strategy Area, which is a classification intended to protect unique and special waters having excellent water quality and being of exceptional or national ecological or recreational significance (NCDEQ 2016).

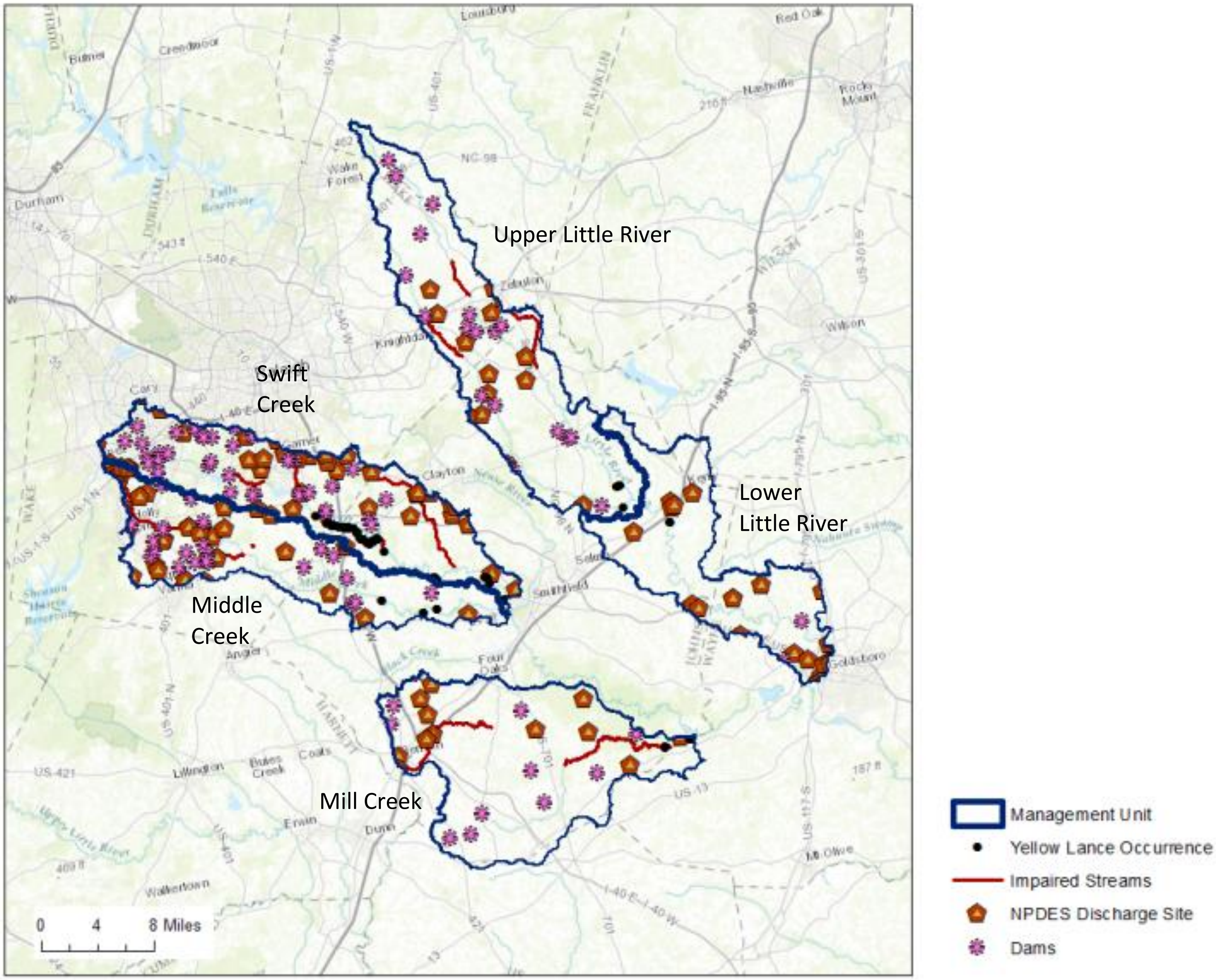
Land Use Land Cover Summary Statistics:





Neuse River Population
Consists of one MU: Middle Neuse Tributaries

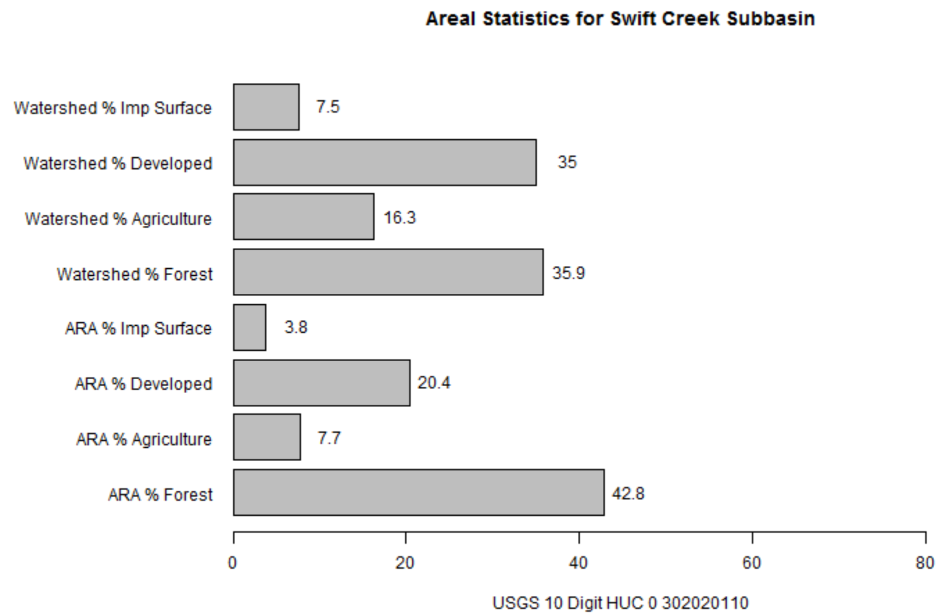
Middle Neuse Tributaries Management Unit

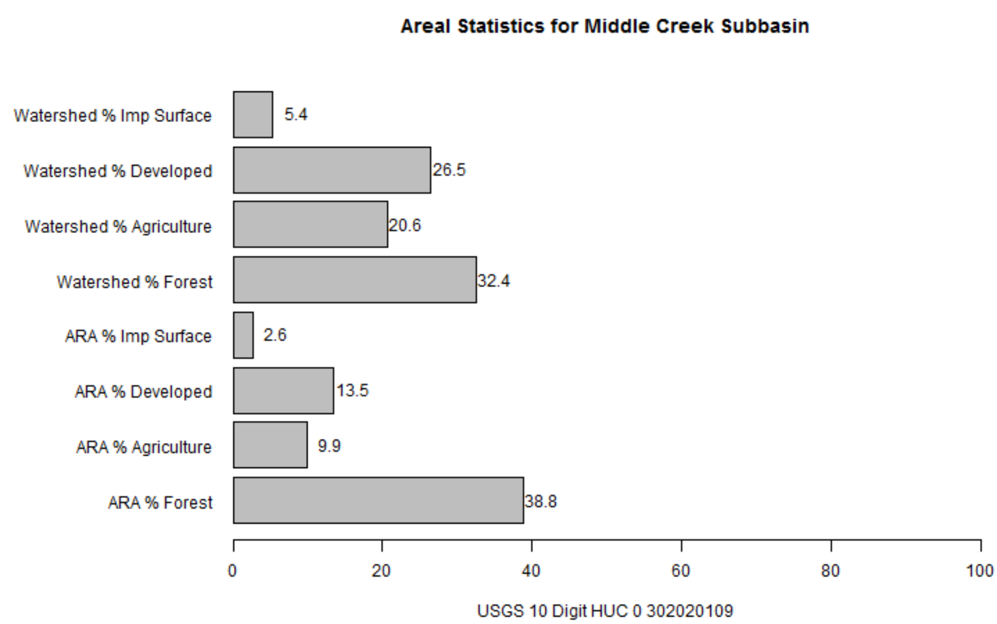


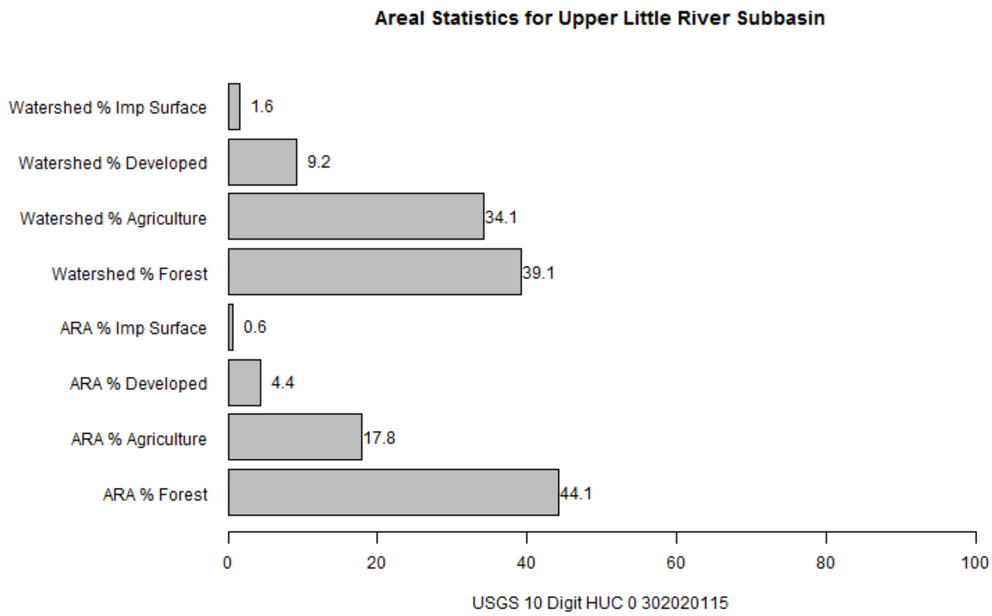
Survey Summary: This MU includes the tributaries Swift, Middle, and Mill Creek and the Little River in five HUC10 watersheds (Upper and Lower Little River, Swift Creek, Middle Creek, and Mill Creek). The Yellow Lance was first seen in 1991, and most recently in 2015. Most surveys report very low numbers observed (usually only one live individual or just shell material), although one effort in 1994 documented 18 live individuals. There is no information about reproduction or recruitment for this MU. Despite many survey attempts, the species was last seen in the Little River in 2009, and only one individual has been seen in Swift Creek in 2015.

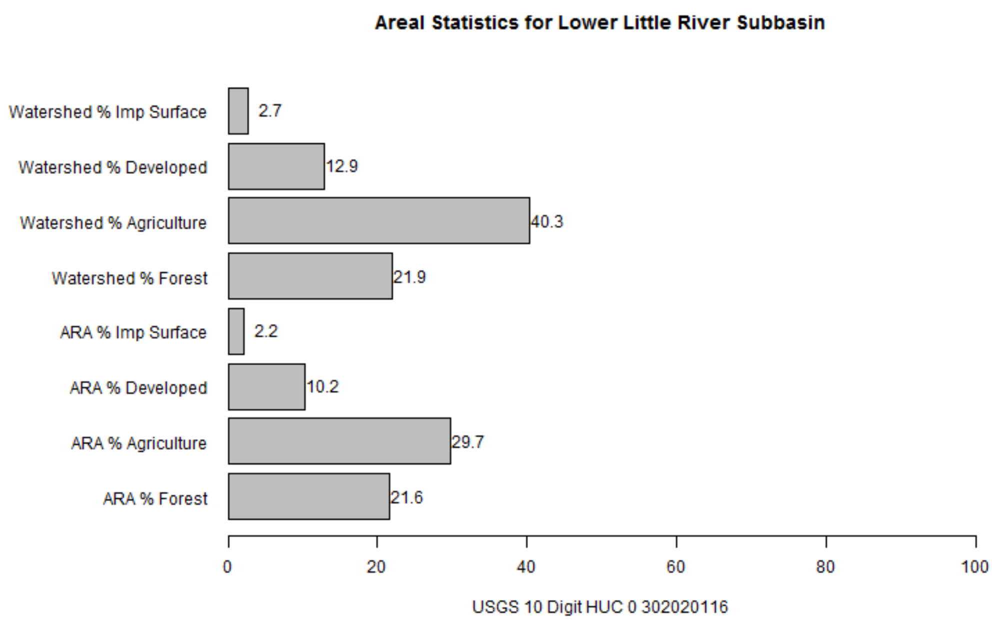
Water Quality Information: Based on the 2014 data, there are 15 impaired stream reaches totaling ~94 miles in this MU. There are many indicators of impairment, including low benthic-macroinvertebrate assessment scores, low pH, poor fish community scores, and low DO. There are 124 non-major and 6 major (Apex WRF, Central Johnston county WWTP, Cary WWTP, City of Raleigh, Dempsey Benton WTP, and Terrible Creek WWTP) NPDES discharges in this MU.

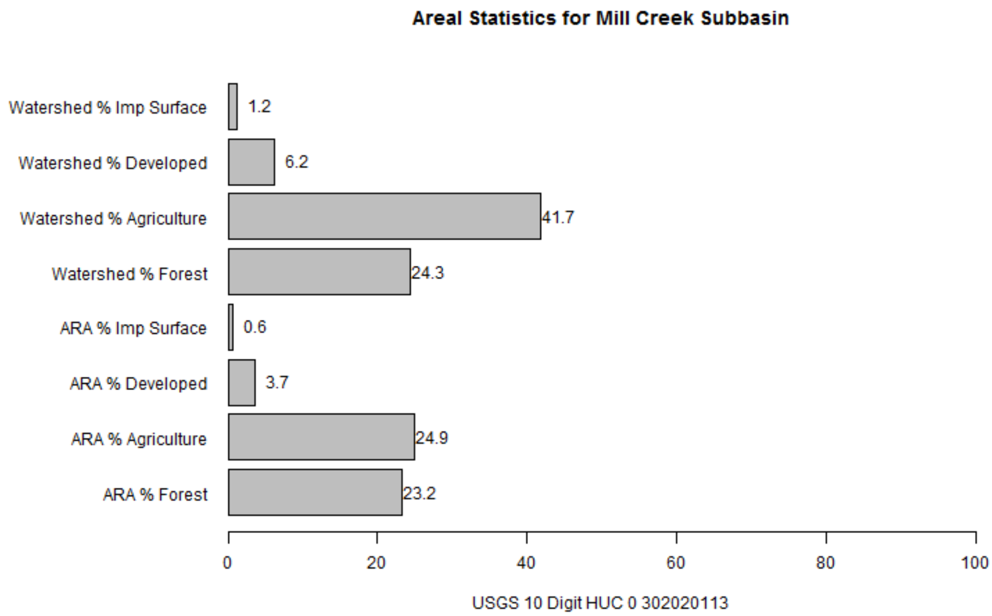
Land Use Land Cover Information:



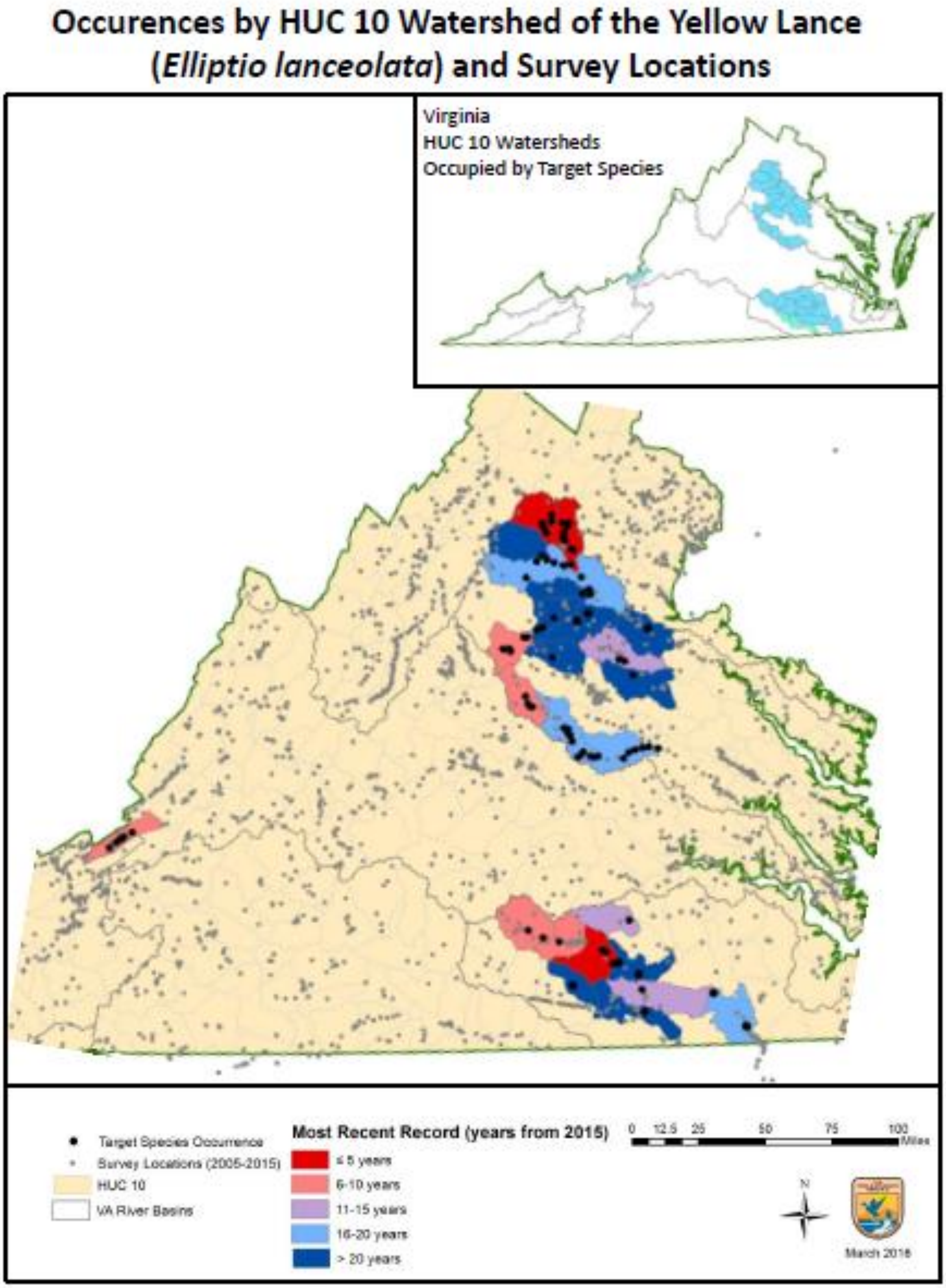



Areal Statistics for Upper Little River Subbasin
Watershed % Imp Surface
1.6
Watershed % Developed
9.2
Watershed % Agriculture
34.1
Watershed % Forest
39.1
ARA % Imp Surface
0.6
ARA % Developed
4.4
ARA % Agriculture
17.8
ARA % Forest
44.1
0
20
40
60
80
100
USGS 10 Digit HUC 0 302020115

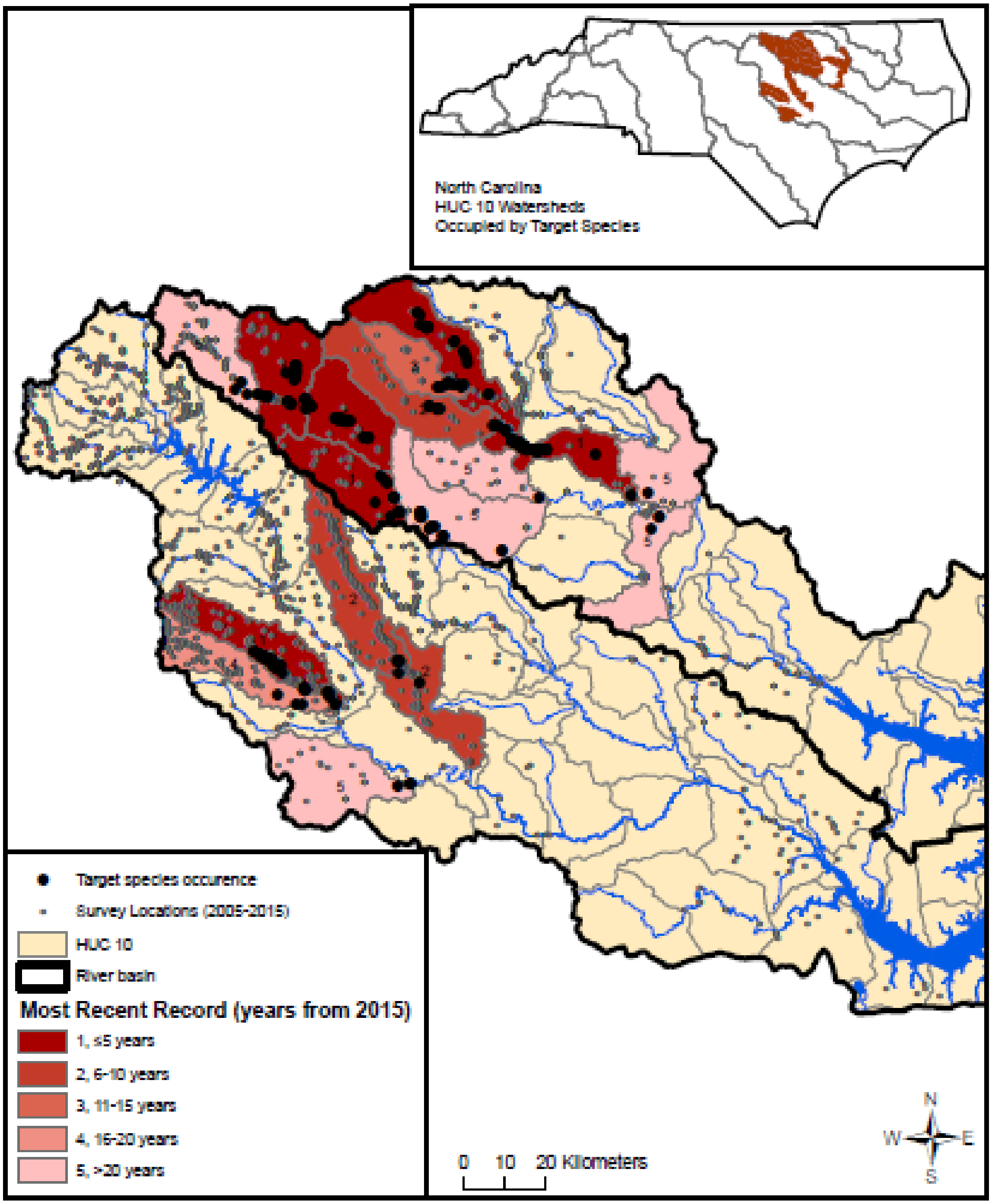

Areal Statistics for Lower Little River Subbasin
Watershed % Imp Surface
2.7
Watershed % Developed
12.9
Watershed % Agriculture
40.3
Watershed % Forest
21.9
ARA % Imp Surface
2.2
ARA % Developed
10.2
ARA % Agriculture
29.7
ARA % Forest
21.6
0
20
40
60
80
100
USGS 10 Digit HUC 0 302020116


Areal Statistics for Mill Creek Subbasin
Watershed % Imp Surface
1.2
Watershed % Developed
6.2
Watershed % Agriculture
41.7
Watershed % Forest
24.3
ARA % Imp Surface
0.6
ARA % Developed
3.7
ARA % Agriculture
24.9
ARA % Forest
23.2
0
20
40
60
80
100
USGS 10 Digit HUC 0 302020113

APPENDIX C – VA and NC Yellow Lance "Heat Maps"



Occurrences by HUC 10 Watershed of the Yellow Lance (*Elliptio lanceolata*) and Survey Locations



Map created by: Tyler Black, Ph.D., 1/8/2016
Data sources: NC Wildlife Resources Commission and NC Museum of Natural Sciences

APPENDIX D – Data for Population Factors & Habitat Elements (Data sources: Population Factor survey data from state resource agency and Natural Heritage databases; Habitat Element data from publicly available state water quality and transportation databases and National Land Cover Database)

Population/ Management Unit	# of Historically Occupied MUs	# of Currently Occupied MUs	# Historically Occupied HUC10s	# Currently Occupied HUC10s	% Decline	MU Occupancy Condition	Approx Pop Size (Abundance) or #live/#shell	Total Number of Live Individuals Observed 2005-2015	Year Last Seen	Approx Abundance Condition	Reproduction/ Recruitment	% sites with evidence of recent reproduction	Reproduction Condition	Current Condition - Population Factors
Patuxent	**1**	**1**	**2**	**1**	**50**	**M**	**1/3**	**1**	**2015**	**VL**	**N**	**N**	**Ø**	**Very Low**
Potomac	**1**	**0**	**1**	**0**	**100**	**Ø**	**0/1**	**0**	**1970**	**Ø**	**N**	**N**	**Ø**	**Ø**
Rappahannock	**1**	**1**	**10**	**3**	**70**	**L**	**537/53**	**53**	**2011**	**M**	**Y**	**<25%**	**L**	**Low**
York	**1**	**1**	**6**	**1**	**83**	**VL**	**71/35**	**5**	**2007**	**VL**	**N**	**N**	**Ø**	**Very Low**
James	**1**	**1**	**1**	**1**	**0**	**H**		**0**	**2009**	**L**			**VL**	**Low**
Johns Creek			1	1	0	H	63/0	5	2009	L	N	N	VL	Low
Chowan	**2**	**1**	**9**	**3**	**67**	**L**		**5**	**2011**	**VL**			**L**	**Low**
Nottoway			7	3	57	L	1684/20	5	2011	VL	Y	<25%	L	Low
Meherrin			2	0	100	Ø	2/0	0	1994	VL	N	N	Ø	Ø
Tar	**4**	**3**	**12**	**8**	**33**	**M**				**M**			**H**	**Moderate**
Upper/Middle Tar			6	4	33	M	507/81	120	2016	H	Y	55%	H	High
Lower Tar			1	0	100	Ø	2/16	0	1987	L	N	N	Ø	Ø
Fishing Ck Subbasin			3	2	33	M	76/13	26	2016	L	Y	30%	M	Moderate
Sandy Swift Ck			2	2	0	H	351/2143	125	2016	H	Y	60%	H	High
Neuse	**1**	**1**	**5**	**3**	**40**	**M**				**L**			**VL**	**Low**
Middle Neuse Tribs			5	3	40	M	85/69	30	2015	L	N	N	VL	Low

			Water Quality				Water Quantity			Connectivity				Instream Habitat			
Population/ Management Unit	Size of MU (km2)	Size of MU (mi2)	Impaired Stream Miles	Major NPDES	Minor NPDES	Overall Water Quality Condition	Known Flow Issues?	Consecutive Drought Years	Overall Water Quantity Condition	# of Dams	Actual # Road Crossings	Average # Road Crossings per HUC10	Overall Connectivity Condition	Avg ARA % Forest	Avg Watershed % Imp Surface	Overall Instream Habitat (Substrate) Condition - combine ARA Forest + Watershed Impervious Surface	**Current Habitat Condition**
Patuxent	654	253	?	3	146	**L**	?	2007-2008	**H**	20	571	286	**M**	44	5.4	**L**	**M**
Potomac	403	156	23	2	137	**L**	Y	2007-2008	**M**	33	919	919	**L**	44	12.7	**L**	**L**
Rappahannock	3621	1398	77	11	93	**L**	?	2007-2008	**H**	78	3223	322	**L**	44	1.7	**M**	**M**
York	2420	934	44	1	50	**M**	?	2007-2008	**H**	107	1406	234	**L**	53	0.8	**M**	**M**
James						**H**	?		**H**				**H**			**H**	**H**
Johns Creek	272	105	0	0	1	H	N	2007-2008	H	4	240	240	H	84	0.3	H	**H**
Chowan						**M**			**M**				**M**			**M**	**M**
Nottoway	2862	1105	155	4	32	L	?	2007, 2008, 2009, 2010	M	43	3094	442	L	57	0.7	M	M
Meherrin	621	240	34	2	16	M	?	2007, 2008, 2009, 2010	M	7	676	338	H	53	1.4	M	M
Tar						**M**			**L**				**M**			**M**	**M**
Upper/Middle Tar	2403	928	38	3	102	L	Y	2005-2010	L	52	1723	287	M	54	1.6	M	M
Lower Tar	324	125	4	1	16	M	N	2005-2010	M	4	244	244	H	17	1.9	L	M
Fishing Ck Subbasin	1052	406	14	1	23	M	N	2005-2010	M	3	420	140	H	52	0.5	M	M
Sandy Swift Ck	705	272	5	0	21	H	Y	2005-2010	L	25	431	216	M	44	1.3	M	M
Neuse						**L**			**L**				**L**			**L**	**L**
Middle Neuse Tribs	2052	792	94	6	124	L	Y	2005-2012	L	89	2308	462	L	34	3.7	L	L