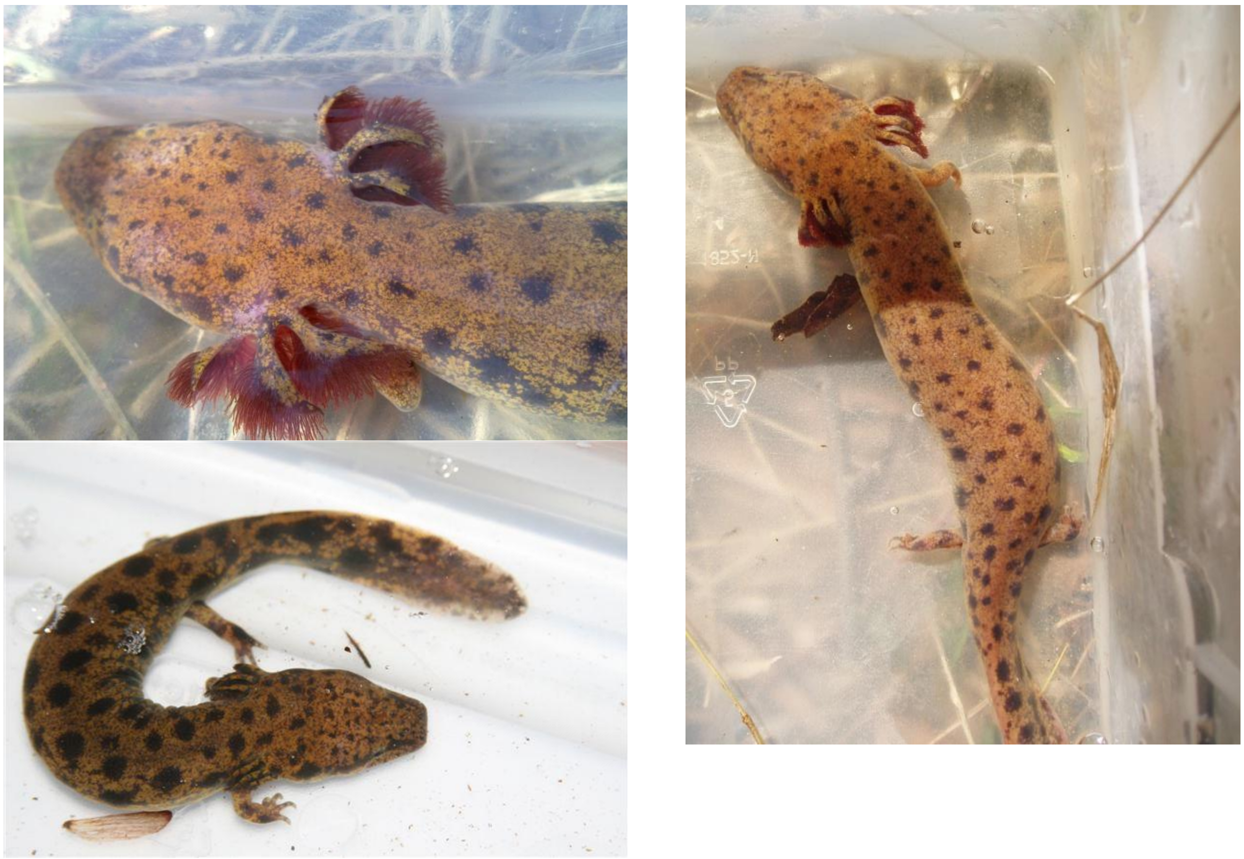
Species Status Assessment Report for the Neuse River Waterdog (*Necturus lewisi*) Version 1.1



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

This document was prepared by Sarah McRae (USFWS-Raleigh Field Office) with assistance from Erin Rivenbark (USFWS-Region 4), Beth Forbus (USFWS-HQ), and the Neuse River Waterdog SSA Technical Advisory Team (Jeff Beane-NC Museum of Natural Sciences, Jeff Hall-NC Wildlife Resources Commission, Jeff Humphries-NC Wildlife Resources Commission, Judith Ratcliffe-NC Natural Heritage Program, and Alvin Braswell-retired).
Valuable peer review of a draft of this document were provided by Jessica Homyack (Weyerhaeuser Company). We appreciate the time and effort of those dedicated to learning and implementing the SSA Framework, which resulted in a more robust assessment and final report.

Suggested reference:

U.S. Fish and Wildlife Service. 2018. Species status assessment report for the Neuse River Waterdog (*Necturus lewisi*). Version 1.1. November, 2018. Atlanta, GA.

Summary of Version Updates

The change from version 1.0 (May 2017) and 1.1 (November 2018) was minor and did not change the SSA Analysis for Neuse River Waterdog. The change was:

1) Removed mention of SmithEnvironment Blog in Section 4.6 under Regulatory Reform in North Carolina.

Species Status Assessment Report For
Neuse River Waterdog (*Necturus lewisi*)
Prepared by the
U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

This species status assessment (SSA) reports the results of the comprehensive status review for the Neuse River Waterdog (*Necturus lewisi* (Brimley 1924)), documenting the species' historical condition and providing estimates of current and future condition under a range of different scenarios. The Neuse River Waterdog is a permanently aquatic salamander species endemic to the Tar-Pamlico and Neuse River drainages in North Carolina. The species occurs in riffles, runs, and pools in medium to large streams and rivers with moderate gradient in both the Piedmont and Coastal Plain physiographic regions.

The SSA process can be categorized into three sequential stages. During the first stage, we used the principles of resiliency, redundancy, and representation (together, the 3Rs) to evaluate individual waterdog 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 Neuse River Waterdog, 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 three river basins that Neuse River Waterdogs have historically occupied (i.e., Tar-Pamlico, Neuse, and Trent 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 Neuse River Waterdog 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 Neuse River Waterdog has limited resiliency, with one population in moderate condition, and two populations in low condition.

Redundancy describes the ability of the species to withstand catastrophic disturbance events; for the Neuse River Waterdog, we considered whether the distribution of resilient populations was sufficient for minimizing the potential loss of the species from such an event. The Neuse River Waterdog historically has a narrow endemic range in the Tar-Pamlico River and the Neuse River (including the Trent River) basins in North Carolina, but both the number and distribution of waterdogs occupying that historical range has declined over the past 40 years.

Representation characterizes a species' adaptive potential by assessing geographic, genetic, ecological, and niche variability. The Neuse River Waterdog 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 medium streams to large rivers in two physiographic provinces, in the Piedmont and into the Coastal Plain. Some of the representation of the Neuse River Waterdog has been lost; physiographic variability has been lost with 13% loss in the Coastal Plain and 43% loss in the Piedmont.

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 Neuse River Waterdog abundance and distribution has declined, with the species currently occupying approximately 73% of its historical range. Many of the remaining populations are fragmented, occupying fewer reaches than were historically occupied, with losses in the headwaters of each basin. 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 suitability. The effects of climate change have begun to be realized in current Neuse River Waterdog range and may have contributed to habitat degradation.

Current Viability Summary

The historical range of the Neuse River Waterdog included 3^{rd} and 4^{th} order streams and rivers in the Tar, Neuse, and Trent drainages, with documented historical distribution in 9 MUs within three populations. The Neuse River Waterdog is extant in all identified MUs, however within those MUs it is presumed extirpated from 35% (14/40) of the historically occupied HUCs. Of the nine occupied MUs, two (22%) are estimated to have high resiliency, three (33%) moderate resiliency, and four (45%) low resiliency. Scaling up from the MU to the population level, one of three populations (the Tar Population) is estimated to have moderate resiliency, and two (the Neuse and Trent populations) are estimated to have low resiliency. 60% of streams that were once part of the species' range are estimated to be in low or very low condition or likely extirpated. The species is known to occupy streams in two physiographic regions, however it has lost physiographic representation with an estimated 43% loss in Piedmont watersheds and an estimated 13% loss in Coastal Plain watersheds.

Future Viability

To assess the future condition of the Neuse River Waterdog, 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 Neuse River Waterdog.

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 Neuse River Waterdog 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 loss of resiliency, representation, and redundancy is expected. Under this scenario, we predicted that no Management Units (MU) would remain in high condition, two in moderate condition, four in low condition, and three MUs would be likely extirpated. Redundancy would be reduced to four MUs in the Tar Population and two in the Neuse Population. Representation would also be reduced, primarily with reduced variability in the Piedmont and Coastal Plain.

Given Scenario 2, the "Pessimistic" option, we predicted substantial losses of resiliency, representation, and redundancy. Redundancy would be reduced to four MUs in one population, and the resiliency of that population is expected to be low. Several (5) MUs were predicted to be extirpated, and, of the remaining four MUs, all would be in low condition. All measures of representation are predicted to decline under this scenario, leaving remaining Neuse River Waterdog populations underrepresented in River Basin and Physiographic variability.

Given Scenario 3, the "Optimistic" option, we predicted slightly higher levels of resiliency, representation, and redundancy than was estimated under the Status Quo or Pessimistic options. Three MUs would be in high condition, one in moderate condition, and the remaining five would be in low condition. Despite predictions of population persistence in the Neuse and Trent River Basins, these populations are expected to retain only low levels of resiliency, thus levels of representation are also predicted to decline under this scenario.

Given Scenario 4, the "Opportunistic" option, we predicted reduced levels of resiliency, representation, and redundancy. One MU would be in high condition, three would be in moderate condition, three in low condition, and two would be likely extirpated. Redundancy would be reduced with the loss of the Trent Population. Under the Opportunistic Scenario, representation is predicted to be reduced with 67% of formerly occupied river basins remaining occupied and with reduced variability in the Piedmont and Coastal Plain Physiographic Regions.

Table ES-1. Summary results of the Neuse River Waterdog 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 gravels and bedrock • Abundant cover • Multiple occupied management units per population	• 3 populations known to be extant • Population status: 1 moderate resiliency 2 low resiliency	Projections based on future scenarios in 50 years: • Status Quo: Threats continue on current trajectory and species maintains current level of response. One population is expected to be extirpated; remaining populations has reduced resiliency • Pessimistic: higher level of threats and reduced species response. Two populations are expected to be extirpated; remaining population has low resiliency • Optimistic: minimal level of threats and optimistic species response. All populations persist; one population maintains high resiliency condition • Opportunistic: moderate level of threats and selective species response. One population is expected to be extirpated; remaining two 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 smaller streams and larger rivers, and between physiographic provinces	Compared to historical distribution: • All river basin variability retained, however two populations are in low condition • Reduced physiographic variability in Piedmont and Coastal Plain	Projections based on future scenarios in 50 years: • Status Quo: 33% of river basin variability lost; losses in physiographic variability in Piedmont (63%), substantial loss in the Coastal Plain (17%) • Pessimistic: 67% river basin variability lost; considerable losses in physiographic variability in Piedmont (75%) and Coastal Plain (58%) • Optimistic: River basin variability maintained; maintain physiographic variability in Coastal Plain (87%) and in the Piedmont (57%) • Opportunistic: 33% of river basin variability lost; losses in physiographic variability in Piedmont (44%) and substantial loss in the Coastal Plain (17%)
Redundancy (number and distribution of populations to withstand catastrophic events)	• Multiple populations in each area of representation	• 5 MUs occupied in Tar Population • 3 MUs occupied in Neuse Population Compared to historical redundancy: • 18% (3/17 HUC10s) loss in Tar Population • 30% (6/20 HUC10s) loss in Neuse Population • 67% (2/3 HUC10s) loss in Trent Population • Overall loss of 27% redundancy across range (29 out of 40 HUCs currently occupied)	Projections based on future scenarios in 50 years: • Status Quo: only one population (Tar) retains resilient redundancy; 3 of 9 MUs likely extirpated • Pessimistic: no resilient redundancy; 5 of 9 MUs likely extirpated • Optimistic: two populations retain redundancy; no MUs predicted to be extirpated • Opportunistic: only one population (Tar) retains redundancy; 2 of 9 MUs likely extirpated

Table ES-2. Future scenario and condition category descriptions for each of four scenarios used to predict Neuse River Waterdog 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. Predicted Neuse River Waterdog population conditions under each of 4 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
Tar: Upper Tar	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
Tar: Middle Tar	Moderate	Low	Low	High	Moderate
Tar: Lower Tar	High	Moderate	Low	High	Moderate
Tar: Sandy-Swift	High	Moderate	Low	High	High
Tar: Fishing Ck	Low	Low	Low	Moderate	Moderate
Neuse: Upper Neuse	Low	Likely Extirpated	Likely Extirpated	Low	Low
Neuse: Middle Neuse	Low	Low	Likely Extirpated	Low	Low
Neuse: Lower Neuse	Moderate	Low	Likely Extirpated	Low	Low
Trent	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated

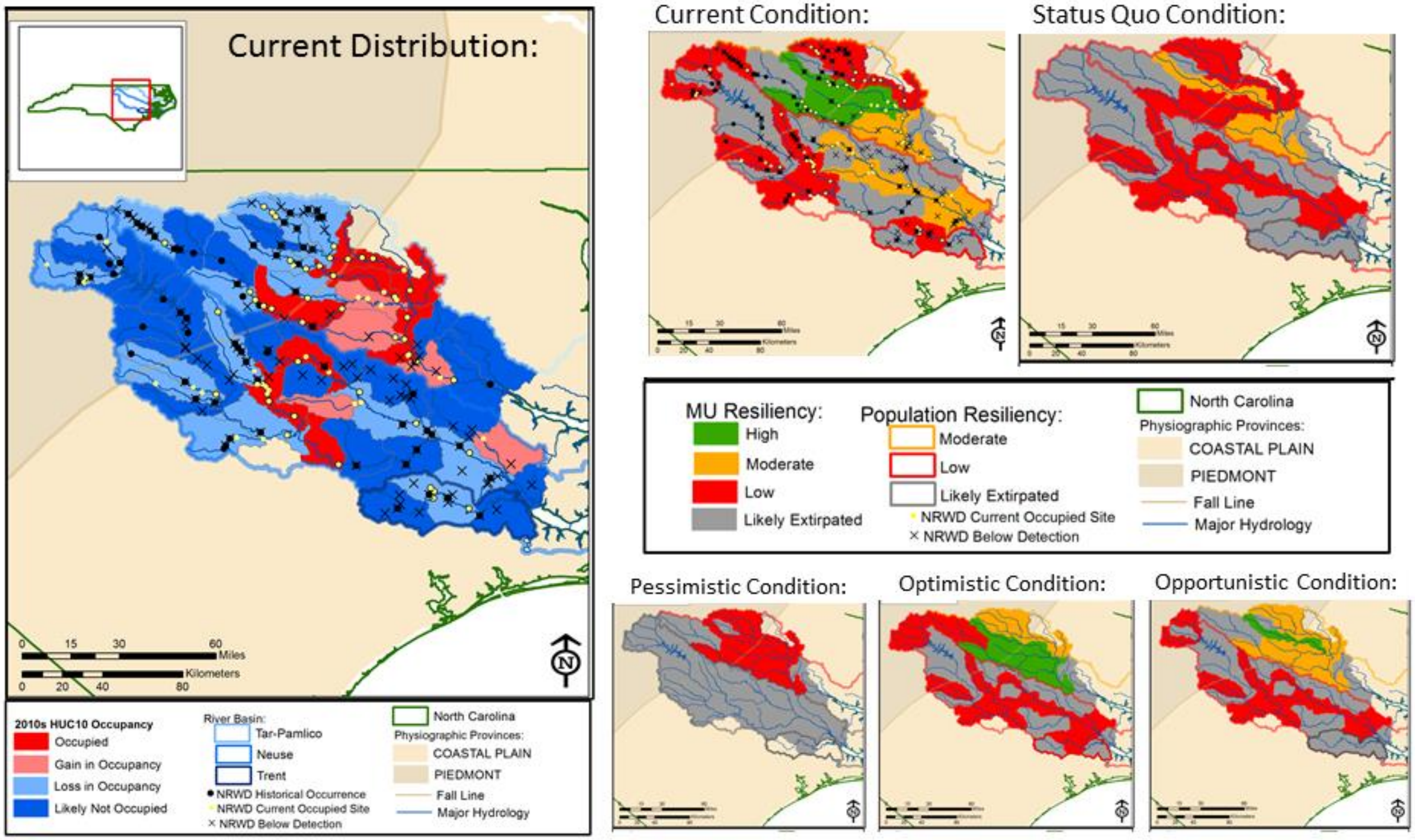

Figure ES-1 Maps of current distribution, current condition, and predicted Neuse River Waterdog population conditions under each scenario (see Table ES-3)

Overall Summary

Estimates of current and future resiliency for Neuse River Waterdog are moderate to low, as are estimates for representation and redundancy. The Neuse River Waterdog faces a variety of risks from declines in water quality, loss of stream flow, riparian and instream fragmentation, and deterioration of instream habitats. These risks, which are expected to be exacerbated by urbanization and climate change, were important factors in our assessment of the future viability of the Neuse River Waterdog. Given losses of resiliency, populations become more vulnerable to extirpation, in turn, resulting in concurrent losses in representation and redundancy. Predictions of Neuse River Waterdog habitat conditions and population factors suggest possible extirpation in two of three currently extant populations. The one population predicted to remain extant (Tar) is expected to be characterized by low occupancy and abundance under a pessimistic future.

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CHAPTER 1 - INTRODUCTION

The Neuse River Waterdog is a permanently aquatic salamander that is endemic to the Atlantic Slope drainages of the Tar-Pamlico and Neuse River basins 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.723).

The Species Status Assessment (SSA) framework (USFWS 2016, 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 (should the species warrant listing under the Act).

Because the Neuse River Waterdog 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 prudent and determinable, where to propose designating critical habitat. Importantly, the SSA Report is not a decisional document by the Service, rather; it provides a review of available information strictly related to the biological status of the Neuse River Waterdog. 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 2016, entire; Wolf et al. 2015, entire).

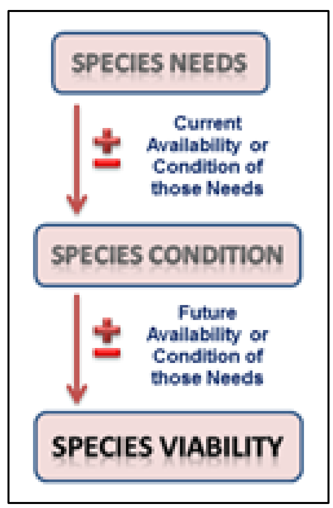


Figure 1-1 Species Status Assessment Framework

- 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.

- 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 Neuse River Waterdog, 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 demographic risks, threats, and limiting factors in the context of determining viability and extinction risk for the species.

This SSA Report includes: (1) a description of Neuse River Waterdog 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); (4) a synopsis of the factors characterized in earlier chapters as a means of examining the future biological status of the species (Chapter 5); and (5) a summary (Chapter 6). This document is a compilation of the best available scientific and commercial information (and associated uncertainties regarding that information) used to assess the viability of the Neuse River Waterdog.

CHAPTER 2 - INDIVIDUAL NEEDS:
LIFE HISTORY AND BIOLOGY

In this section, we provide basic biological information about the Neuse River Waterdog, including its taxonomic history and morphological description, and life history traits such as reproduction and nesting, diet, age, growth, population structure, and habitat. 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 Neuse River Waterdog, refer to Brimleyana, the Journal of the North Carolina Museum of Natural History, Number 10, published in 1985.

2.1 Taxonomy

The Neuse River Waterdog (*Necturus lewisi*) is one of three species of *Necturus* in North Carolina. In 1924, Brimley described the Neuse River Waterdog as a subspecies of *N. maculosus* (Brimley 1924, p.167), primarily because of the "spotted larvae". The type specimen (USNM 73848) was taken from the Neuse River near Raleigh by F.B. Lewis in 1921. In 1937, Viosca elevated it to a full species (Viosca 1937, p.138), primarily based on the ventral spotting pattern. Brode (1970, pp.5288-5289) suggested that *N.* lewisi (as *N. maculosus lewisi*) and *N. maculosus* (as *N. maculosus maculosus*) formed an intergrading series of populations. However, in 1980, Ashton et al. (pp.43-46) compared electrophoretic data for *N. maculosus*, *N. punctatus*, and *N. lewisi*, and determined that each is a distinct species.

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

Phylum: Chordata
Class: Amphibia
Order: Caudata
Family: Proteidae
Genus: *Necturus*
Species: *Necturus lewisi*

2.2 Description

Neuse River Waterdogs are from an ancient lineage of permanently aquatic salamanders in the genus *Necturus*. Adult Neuse River Waterdogs have been described by Bishop (1943, p.32), Brimley (1924, p.167), Cahn and Shumway (1926, p.106-107), Viosca (1937, p.138), and Hecht (1958, p.15), while the first accurate descriptions and illustrations of hatchlings and larvae were documented by Ashton and Braswell (1979, pp. 15-22).

Hatchlings are light brown in color with dark lines from each nostril through the eye to the gills, with a white patch behind the eye and above the line (Ashton and Braswell 1979, p.17; Figure 2-1). Their heads are round compared to the square, elongated heads of the adults. Hatchlings have melanophores scattered on the gills, upper surfaces of the legs, lower jaw, and parts of the head, with concentrations highest on the tail, making the tail darker than the head and trunk (Ashton and Braswell 1979, p.17). Hatchlings have developed forelimbs, with three complete toes and the fourth, inner toe is only a bud and the hindlimbs are pressed close to the lower tail fin and not fully developed (Ashton and Braswell 1979, p.17).

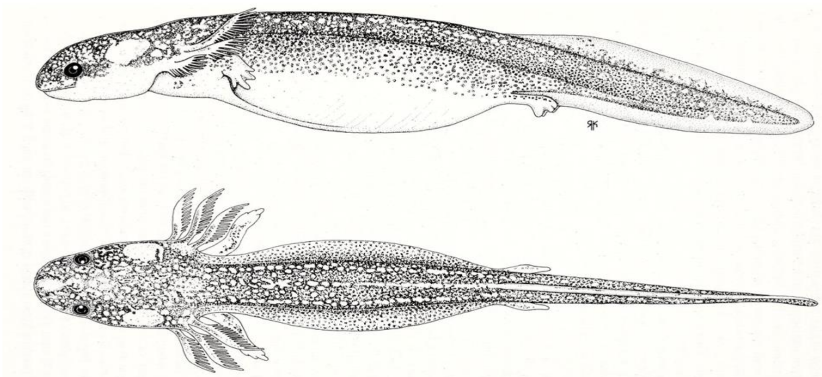


Figure 2-1 Neuse River Waterdog hatchling (from Ashton and Braswell 1979).

Most post-hatchling larvae have a broad, light tan, dorsal stripe from the snout to the tail, and along the dorsal region are small, poorly defined, dark spots (Ashton and Braswell 1979, p.20; Figure 2-2). The underside of the larvae is white, or has a faint network of lines. A major difference between the larvae of *N. lewisi* and other members of the genus *Necturus* is the difference in pigmentation - *N. maculosus* has a dark dorsal stripe bordered on each side by a thin, light stripe and dark sides, and *N. punctatus* are uniformly grayish brown with no striping pattern.

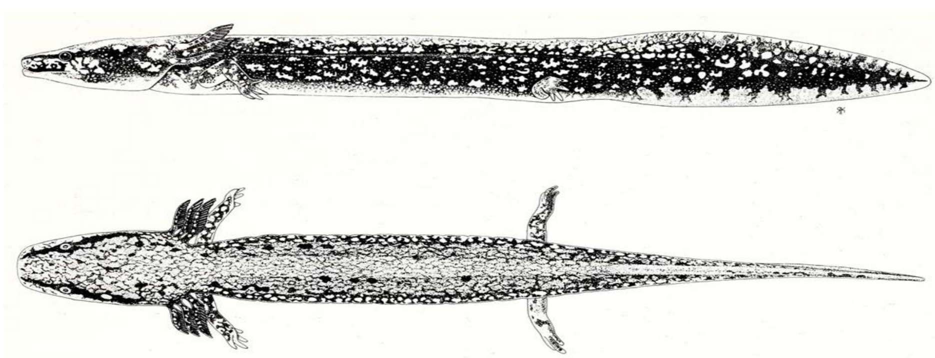


Figure 2-2 Neuse River Waterdog post-hatchling larvae (from Ashton and Braswell 1979).

Figure 2-3 A young Neuse River Waterdog from the Little River, Johnston County, NC (credit: Jeff Beane)

Adults lose the striped pattern (Figure 2-3), and the side melanophores decrease in intensity while the dorsal melanophores increase in intensity and definition, on top of a reddish brown skin (Ashton and Braswell 1979, p.20; Figure 2-4). The underside is brown/grey and also has dark spots but smaller than those on the back. Adults have a set of external bushy dark red gills. Their tail is laterally compressed, and each foot has four toes (as referenced in Lai 2011, p. 3). Adults can be up to 11 inches long.

Figure 2-4 Adult Neuse River Waterdog (credit: NCWRC).

2.3 Reproduction

Neuse River Waterdogs reach sexual maturity at around 5.5-6.5 years, or at a length of 102 mm (~4 inches) SVL (snout-vent length) for males and 100 mm SVL for females (Fedak, 1971). The sexes are similar in appearance and can be distinguished only by the shape and structure of the cloacal area.

Neuse River Waterdogs breed once per year, with mating in the fall/winter and spawning in the spring (Pudney et al. 1985, p.54). After courtship, the male will deposit a packet of sperm which the female places into her vent, thus fertilization occurs internally (Pudney et al. 1985, p.54). During the spring (May-June), females will lay a clutch of ~25-90 eggs in a rudimentary nest, under large rocks in moderate currents (Cooper and Ashton 1985, p.5). Ashton (1985, p.95) noted that nest sites were often found under large bedrock outcrops or large boulders with sand and gravel beneath them, often placed there by the waterdogs. Females guard the nest (Braswell 2005, p.868).

2.4 Movement and Home Range of Adults

The species is cold-adapted, and is much more active in colder seasons and when water is near-freezing. Braswell and Ashton (1985, p.29) documented activity decreasing after the water temperature rises above 18ºC, possibly because of increased predatory fish activity, nest guarding, and also a greater supply of prey items that reduce foraging activities. In winter at a monitored site with tagged animals, most (85%) time is spent under large granite rocks or in burrows in the bank, and in early spring they move into leaf beds that are formed over mud banks on the low-energy sides of riffles and where leaves were intact or only slightly decomposed so many potential food invertebrates are present in the leaf litter (Ashton 1985, pp.95-96). Activity is also stimulated by rising water and higher turbidity, likely because of the "cover" turbidity provides, as well as an increase in terrestrial food items produced by runoff and rising water (Braswell and Ashton 1985, p.29). Overall, movements increase during the spring and fall, and decline during the winter and summer (Ashton 1985, p.93). There is no evidence of migrational movement for the species.

Home ranges of waterdogs often overlap, regardless of the sex or season. Males have a larger home range of ~73 m^2 compared to ~17 m^2 for females (Ashton 1985, p.93). Waterdogs do defend a territory, usually referred to as a home retreat area in a burrow or under a rock (Ashton 1985, p.96).

2.5 Diet

Neuse River Waterdogs use both olfactory and visual cues to detect prey (Ashton 1985, p.83). Both adults and larvae are opportunistic feeders (Braswell and Ashton 1985, p.13), and most commonly waterdogs lie in wait for a small organism to swim or float by (Ashton 1985, p.97). However, Neuse River Waterdogs also use other feeding techniques when they are active at night, often leaving their retreats to actively search of food.

Larvae eat a variety of small aquatic arthropods (primarily ostracods and copepods), and adults eat larger aquatic arthropods and also any aquatic and terrestrial invertebrates (including hellgrammites, mayflies, caddisflies, crayfish, beetles, caterpillars, snails, spiders, earthworms, centipedes, millipedes, slugs) and some vertebrates (including small fish like darters and pirate perch) (Bury 1980, p.16; Braswell and Ashton 1985, p.23). All prey are ingested whole, and larger items are sometimes regurgitated and then re-swallowed.

2.6 Age and Growth

Longevity of Neuse River Waterdogs is not known, however its close relative *N. maculosus* may live for 30+ years (McDaniel et al. 2009, p.182). Like many long-lived animals, breeding is delayed until a minimum body size is reached and they tend to grow slowly. Generation time for Neuse River Waterdogs is between 10-15 years (A.Braswell, pers. comm. to S.McRae on 3/20/2017).

2.7 Habitat

The Neuse River Waterdog is endemic to the Neuse and Tar drainages of North Carolina. They are distributed from larger headwater streams in the Piedmont to coastal streams up to the point of saltwater intrusion, and none have been found in lakes or ponds (Braswell and Ashton 1985, p.13). Braswell and Ashton (1985, p.13) noted that waterdogs are usually found in streams wider than 15m (although some have been observed in smaller creeks (S.McRae, USFWS, pers. obs.), deeper than 100cm, and with a main channel flow rate greater than 10cm/sec. Further, these stream salamanders need clean, flowing water characterized by high dissolved oxygen concentrations (Brimley 1924, p.168; Braswell and Ashton 1985, p.13; Ashton 1985, p.103).

The preferred habitats vary with the season, temperature, dissolved oxygen content, flow rate and precipitation (Ashton 1985, p.103), however the waterdogs do maintain home retreat areas under rocks, in burrows, or under substantial cover in backwater or eddy areas.

Table 2.1 Life history and resource needs of the Neuse River Waterdog.

Life Stage	Resources and/or circumstances needed for INDIVIDUALS to complete each life stage	Resource Function (BFSD*)	Information Source
Egg/Embryo - May-June	• Clean, flowing water with moderate current (~10-50cm/sec) • Sexually mature males and females (~6 years old) • Appropriate spawning temperatures (8ºC-22ºC) • Nest sites (large flat rocks with gravel bottoms) • Adequate flow for oxygenation (7-9ppm DO)	B	- Pudney et al. 1985, p.54 - Cooper and Ashton 1985, p.5 - Braswell and Ashton 1985, p.21 - Ashton 1985, p.95
Hatchling - late summer	• Clean, non-turbid, flowing water (~10-50cm/sec) • Adequate food availability	B, S	- Cooper and Ashton 1985, p.5
Post-hatchling Larvae - 1 to 2 inches long	• Clean, flowing water (~10-50cm/sec) • Adequate food availability (opportunistic feeding; primarily invertebrates)	F, S	- Ashton 1985, p.95
Juveniles - Up to 5.5 to 6.5 years; 2 to 4 inches long	• Clean, flowing water (~10-50cm/sec) • Adequate food availability (primarily invertebrates) • Cover (large rocks/boulders, outcrops, burrows) for retreat areas	F, S	- Ashton 1985, p.95 - Braswell 2005, p.867
Adults - 6 to 30+ years - 5 to 9 inches long	• Clean, flowing water deeper than 100cm with flows 10-50cm/sec • Streams >15m wide • High dissolved oxygen (7-9ppm) • Appropriate substrate (hard clay bottom with leaf litter, gravel, cobble) • Little to no siltation • Adequate food availability (aquatic and terrestrial invertebrates) • Cover (large rocks/boulders, outcrops, burrows) for retreat areas	F, S, D	- Braswell and Ashton 1985, p.13,22,28 - Ashton 1985, p.95 - Braswell 2005, p.868

*B= Breeding, F=Feeding, S=Sheltering, D=Dispersal

CHAPTER 3 – POPULATION AND SPECIES NEEDS AND CURRENT CONDITION

In this chapter we consider the Neuse River Waterdog's historical distribution, its current distribution, and the factors that contribute 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 Neuse River Waterdog resiliency, representation, and redundancy. Through the lens of the 3Rs, we then estimate the current condition of Neuse River Waterdog populations.

3.1 Historical Range and Distribution

The Neuse River Waterdog is endemic to the Tar-Pamlico and Neuse River basins in North Carolina. Its historical distribution includes two physiographic provinces (Piedmont and Coastal Plain) comprising all major tributary systems of the Tar and Neuse, including the Trent River Basin (Cooper and Ashton 1985, p.1; Figures 3-1 and 3-2). Because of salt water influence, the habitats in the Trent River system are isolated from the Neuse River and its tributaries; therefore, we consider the Trent River system as a separate basin (i.e., population), even though it is technically part of the larger Neuse River Basin.

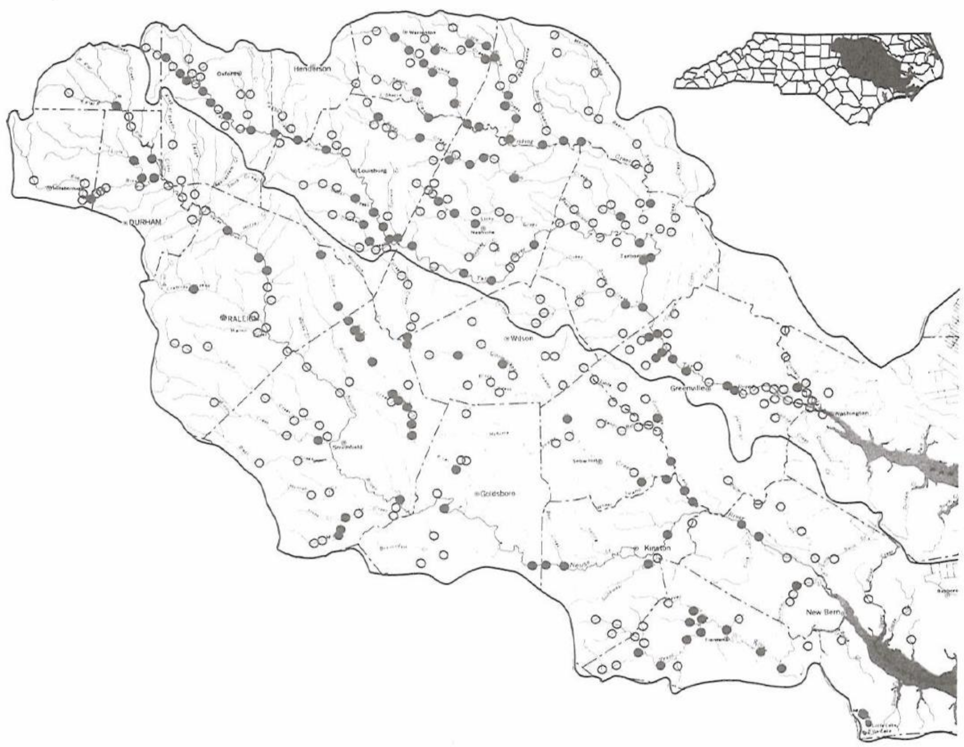


Fig. 1. Sites sampled for *Necturus lewisi*, 1978 through 1981, Neuse and Tar River drainages. Solid dots are positive sites, hollow dots are negative sites. Inset shows location of Neuse and Tar River drainages in North Carolina.

Figure 3-1 Survey locations for Neuse River Waterdog (from Braswell and Ashton 1985, p.19).

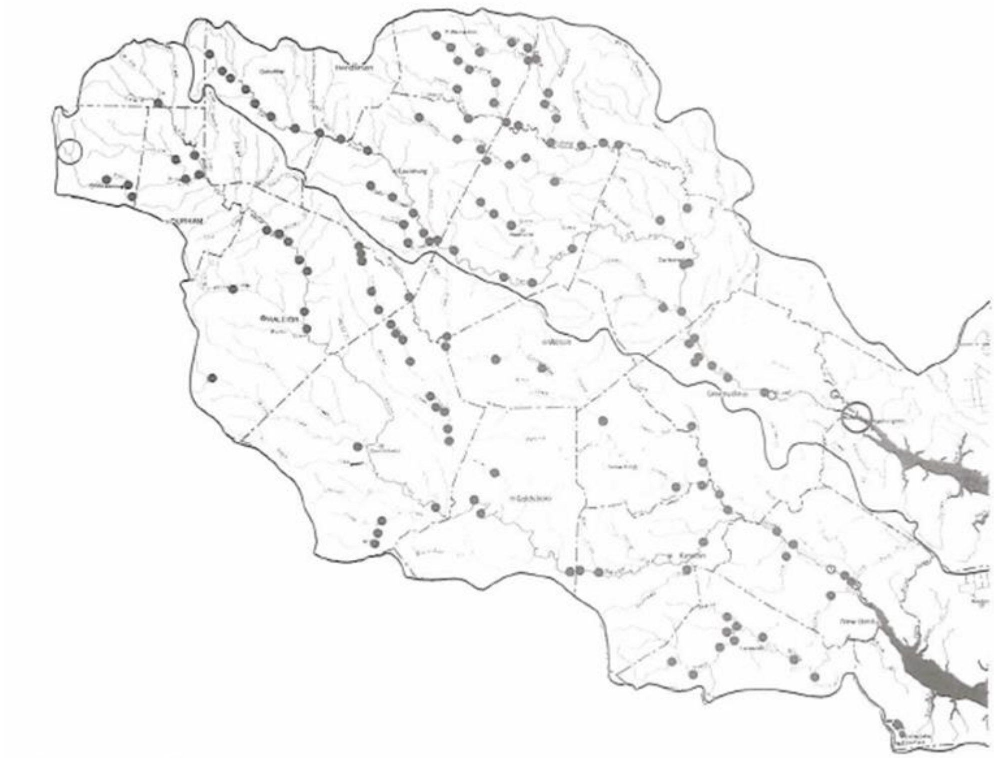


Fig. 2. All known records for *Necturus lewisi*. Solid dots are localities supported by voucher specimens; small hollow dots are sight records believed valid; and large hollow circles are localities supported by voucher specimens with imprecise locality data.

Figure 3-2 Historical distribution of the Neuse River Waterdog (from Braswell and Ashton 1985, p.20).

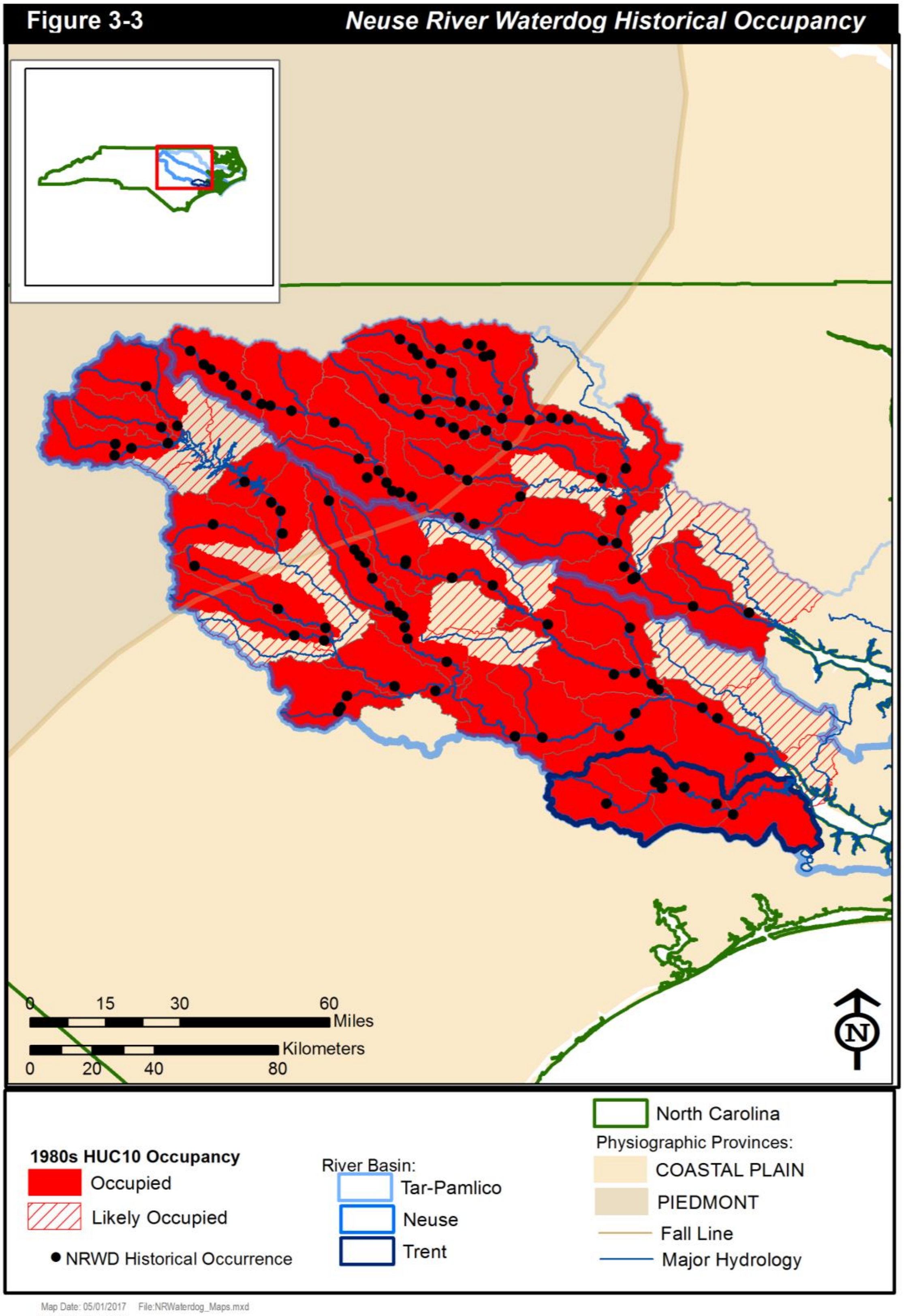
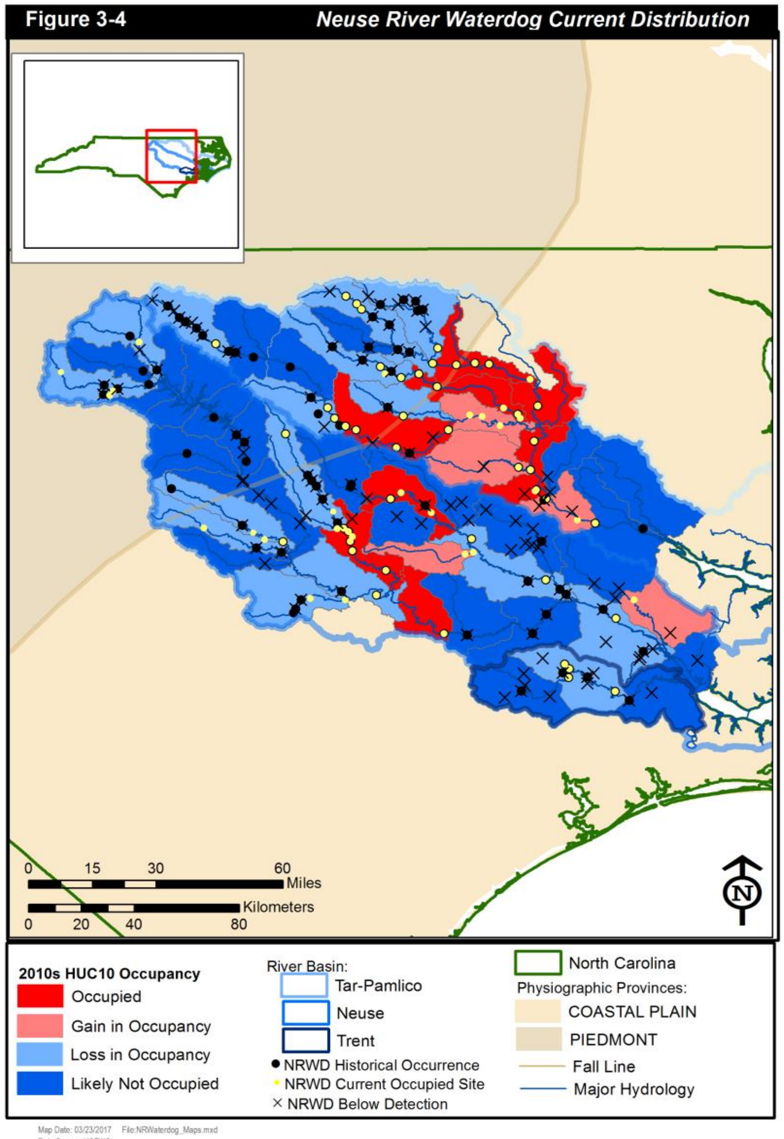


Figure 3-3
Neuse River Waterdog Historical Occupancy
0 15 30 60 Miles
0 20 40 80 Kilometers
N
1980s HUC10 Occupancy
Occupied
Likely Occupied
NRWD Historical Occurrence
River Basin:
Tar-Pamlico
Neuse
Trent
North Carolina
Physiographic Provinces:
COASTAL PLAIN
PIEDMONT
Fall Line
Major Hydrology
Map Date: 05/01/2017 File:NRWaterdog_Maps.mxd
Data Source: USFWS

3.2 Current Range and Distribution

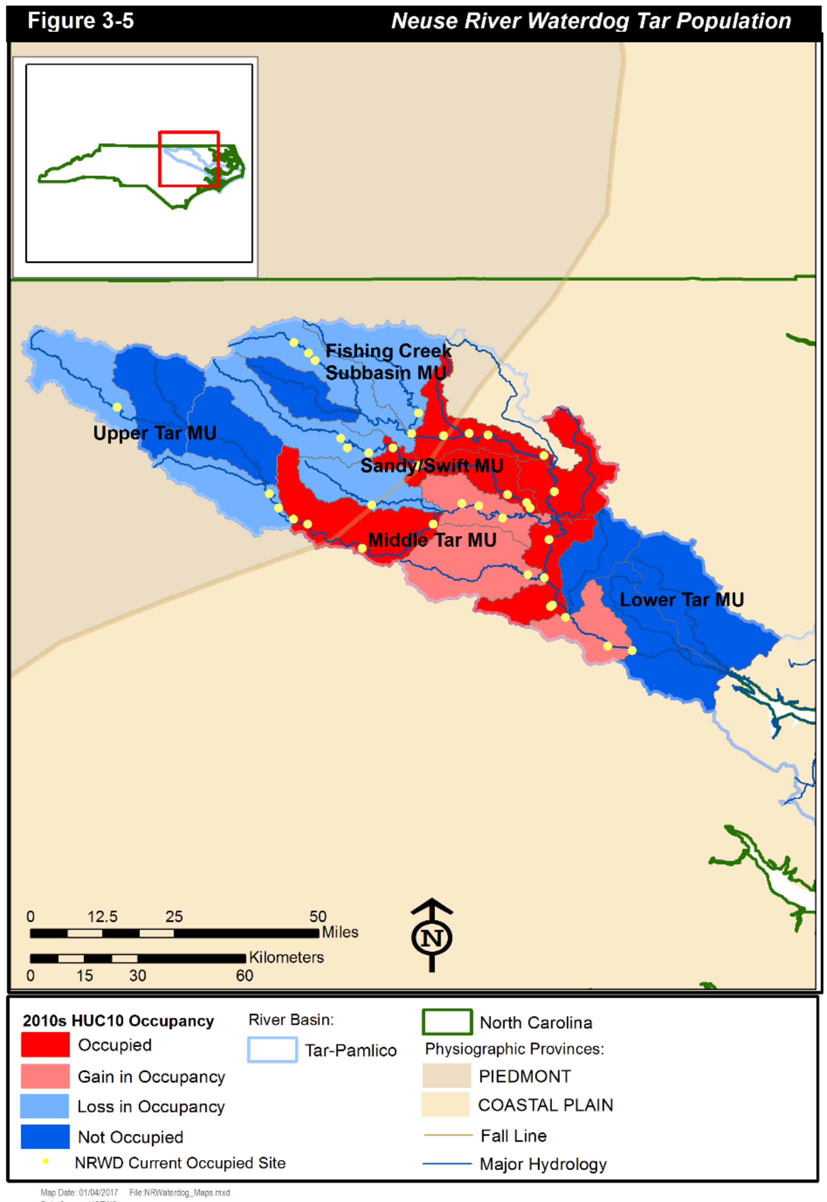
For the purposes of this assessment, populations were delineated using the river basins that Neuse River Waterdogs have historically occupied. This includes the Tar, the Neuse, and the Trent River basins, and from here forward, we will use these terms to refer to populations (e.g., the Tar Population).



Of the three historical Neuse River Waterdog populations, all have observations in the last 10 years (Figure 3-4). 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). Range-wide species occurrence data were used to create "occurrence heat maps" that categorize HUC10 watersheds based on occupancy. These heat maps display recent observed occurrences in red, newly occupied HUC10s in pink, recently presumed losses in HUC10 occurrence in light blue, and presumed extirpated occurrences are displayed in dark blue (Figure 3-4). Documented species occurrences are included to show distribution within HUC10s and the NC Wildlife Resources Commission has documented sites where the Neuse River Waterdog is below detection ("X" in Figure 3-4), based on their most recent comprehensive surveys (NCWRC 2015). Throughout this section, heat maps are used to characterize the historical and current distribution of Neuse River Waterdog among MUs for each of the three populations.

3.2.1 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 2016d). 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 2016d). 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 2016d).

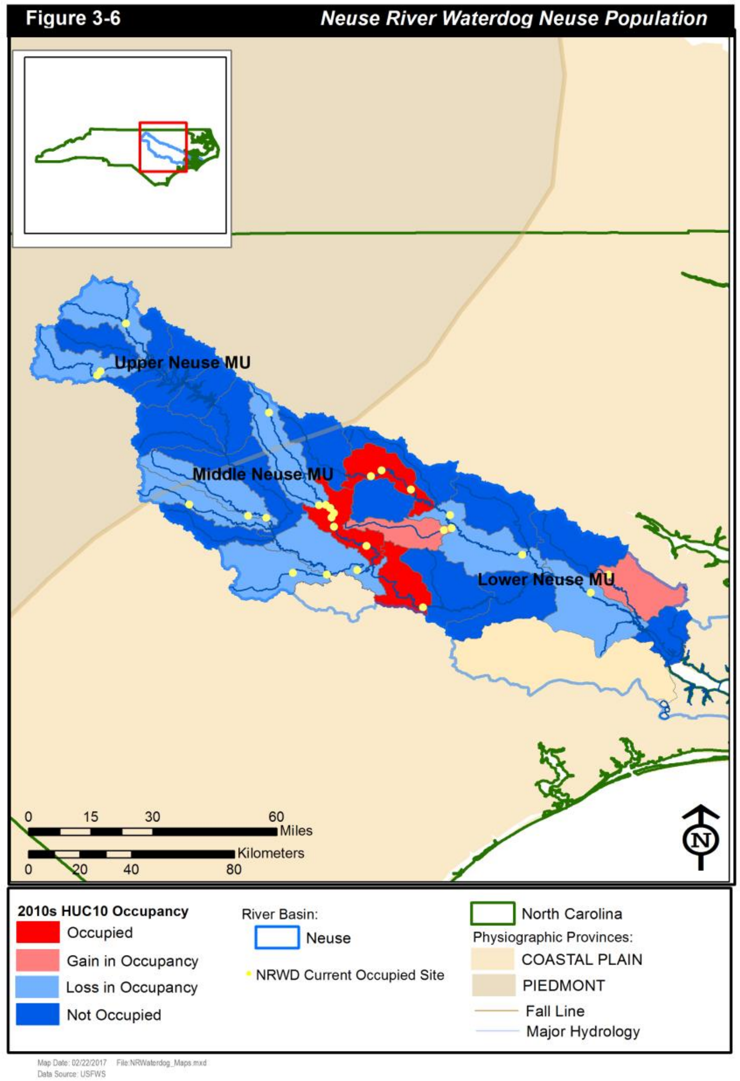


The Tar population consists of five MUs, herafter referred to as the Upper Tar MU, Middle Tar MU, Lower Tar MU, Fishing Creek Subbasin MU, and Sandy-Swift Creek MU. The species was first documented in the Tar River Basin in 1971, and it has been documented as recently as 2016 in Fishing Creek and Swift Creek (Appendix A). Four out of the five MUs have experienced losses in occupancy based on survey results from 2010-2016 (Figure 3-5).

3.2.2 Neuse River Population

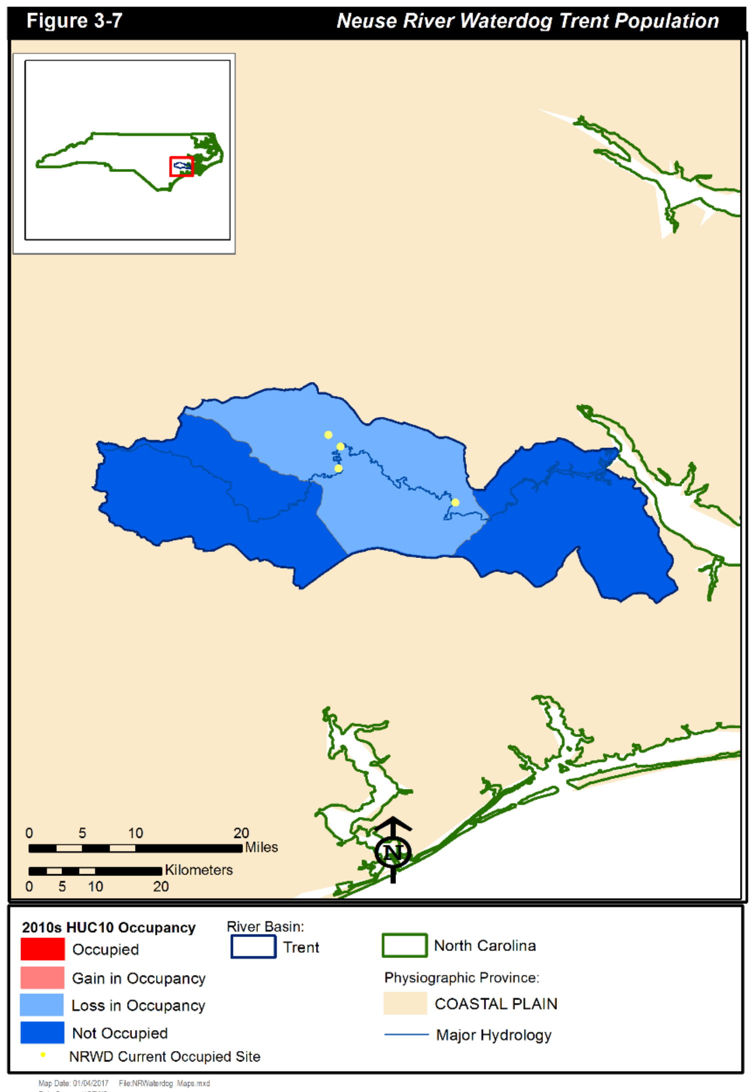
Basin Overview: The Neuse River basin is contained completely within the state of North Carolina and has a drainage area of approximately 6,062mi^2 with over 3,400 miles of rivers and streams (NCDEQ 2016c). The headwaters of the Neuse River originate in the Piedmont of central North Carolina in Person 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 Creeks and the Eno, Little, and Trent Rivers (although the Trent River is considered a separate population – see below). 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 2016c). In addition, more than 400 permitted point source sites discharge wastewater into streams and rivers in the basin (NCDEQ 2016c 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 human population (NCDEQ 2016c), and increased development pressure has increased stormwater runoff, contributing to the basin's pollution and flow issues. The Neuse population consists of three MUs, herafter referred to as the Upper Neuse MU, Middle Neuse MU, and Lower Neuse MU. The species was first documented in the Neuse River Basin in 1921, and it has been documented as recently as 2016 in the Little River (Appendix A). All three MUs have experienced losses in occupancy based on survey results from 2010-2016 (Figure 3-6).

Figure 3-6 Neuse River Waterdog Neuse Population



3.2.3 Trent River Population

Basin Overview: Technically the Trent River basin is within the greater Neuse River basin. The Trent River basin is contained completely within the state of North Carolina and has a drainage area of approximately 540mi^2 with over 1,400 miles of rivers and streams. The headwaters of the Trent River originate in the Coastal Plain of eastern North Carolina in Lenoir and Jones counties, and then the river flows southeast until it reaches confluence with the Neuse River and the tidal waters near New Bern where it empties into the Pamlico Sound. A major tributary is Tuckahoe Swamp. Like the Tar River basin, the Neuse River basin (including the Trent 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 2016c). In addition, 12 permitted point source sites discharge wastewater into streams and rivers in the basin. Based on the 2011 National Land Cover Data, the Trent River basin's has approximately 6% developed area, 20% agriculture, 35% wetlands, 5% grassland, and 34% forest. The watershed is mostly rural, and the Croatan National Forest covers a large portion of the lower watershed. Development and population growth are centered around New Bern.



The Trent population consists of one MU, herafter referred to as the Trent MU. The species was first documented in the Trent River Basin in 1979, and it has been documented as recently as 2012 (Appendix A). This MU has experienced losses in occupancy based on survey results from 2010-2016 (Figure 3-7).

3.3 Needs of the Neuse River Waterdog

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 3-8). Using various time frames and the current and projected levels of the 3Rs, we thereby describe the species' level of viability over time.

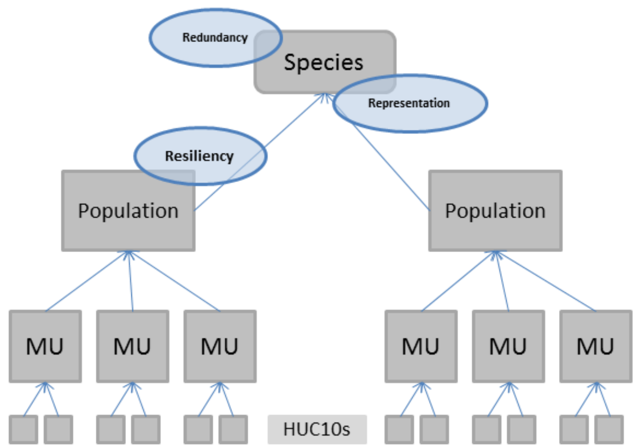


Figure 3-8 Resiliency is measured at the population level, representation is measured at the species and, possibly, population level, and redundancy is measured at the species level (after Fig 4, USFWS 2016). MU=Management Unit; HUC10 = Hydrologic Unit

3.3.1 Neuse River Waterdog MU Resiliency

As previously described, Neuse River Waterdog populations were delineated at the river basin level, while MUs were defined at the finer geographic-level of 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). 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 assess this metric. Given the hierarchical nature of the relationship between MUs, populations, and species (Figure 3-6), 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 3R SSA Framework; thus, for the Neuse River Waterdog to be viable, some proportion of MUs must be resilient enough to withstand stochastic events. Stochastic events that have the potential to affect waterdog populations include high flow events, droughts, pollutant discharge failures, and sediment pulses. Given the data available, the metrics that were used to assess resiliency were categorized as population factors (MU occupancy over time and Site occupancy over time) and habitat elements (water quality, water quantity, habitat connectivity, and instream substrate) (Appendix A). In the next section, we discuss the methods used to estimate resiliency metrics, and we explore potential causal relationships between resiliency and waterdog habitat requisites (see Figure 3-7).

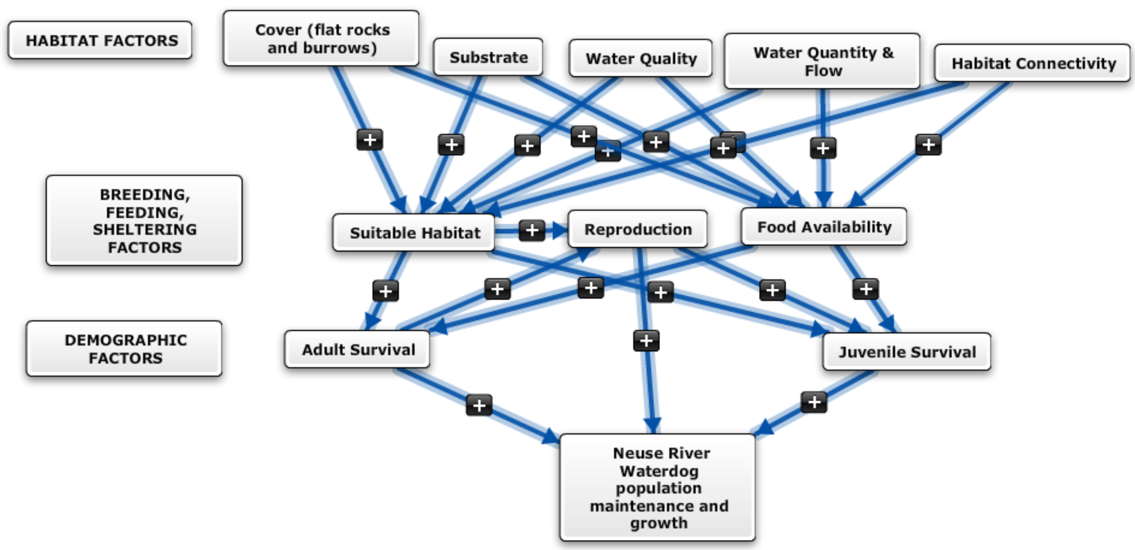


Figure 3-9 Neuse River Waterdog Ecology: Influence diagram illustrating how habitat factors influence breeding, feeding, and sheltering factors, which in turn affect demographic factors that ultimately drive waterdog population growth and maintenance. Diagram was developed by a group of waterdog experts and substantiated from literature.

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 (Figures 3-3 and 3-4). Neuse River Waterdog presence was compiled from survey data made available by the North Carolina Wildlife Resources Commission. Historical surveys were conducted by Braswell and Ashton (1985, pp.15-18). Recent (2010s) surveys repeated methods from Braswell and Ashton, and involved setting 10 minnow traps baited with chicken livers in appropriate waterdog habitat at each site. Traps were deployed during winter months (December-February) for a maximum of five days/four nights and checked daily. If waterdogs were present in traps, specimens were measured, sexed, and tail clipped, returned to stream, and all traps were pulled.

Site Occupancy – A resilient site will be one that maintains Neuse River Waterdog occupancy over time. Based on the information available for surveys done in the late 1970s-early 1980s and repeat surveys done in the 2010s, we examined changes in site occupancy. For this analysis we considered changes in number of occupied sites as well as changes in the overall percentage of sites that were occupied over time. In the earlier surveys, the range of the species was not known, therefore many sites (360+) were surveyed, and only ~30% of the sites were found to be positive for waterdog occurrence (Figure 3-1). The more recent surveys were targeted, based on known positive locations from the 1980s effort. Detection probability was approximately 82% (J.Humphries, NCWRC, email to S.McRae, USFWS, on March 21, 2017).

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 Neuse River Waterdog, breeding, feeding, and sheltering needs such as appropriate nest sites, adequate food delivery, and suitable stable habitat are all needs influenced by water quality, water quantity, and suitable in-stream (substrate) habitat and habitat connectivity (Figure 3-8). See Chapter 4 for further discussion about the many factors that influence the condition of these habitat elements.

<u>Water Quality</u> - Clean, non-polluted water is essential to the survival of the Neuse River Waterdog. Streams that have non-altered thermal regimes, average pH, low salinity, and negligible chemical pollution provide suitable habitat for the persistence of waterdog populations. As required by section 303(d) of the Clean Water Act, all waters that do not meet standards for the designated use of the particular waterbody (e.g., to support/protect aquatic life) are placed on the Impaired Streams List. Note that not all streams throughout every river basin are monitored, therefore it is possible that there are more miles of impaired streams than actually reported. 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, and high levels of fecal coliform bacteria. As with many waterdogs, the Neuse River Waterdog is sensitive to changes in water quality parameters such as DO, pH, and pollutants (see Chapter 2 for more information). For this assessment, the number and miles of impaired stream reaches (as designated by the NC Division of Water Resources), as well as the number of National Pollutant Discharge Elimination System (NPDES) point discharges were used to characterize water quality within a given MU.

<u>Water Quantity</u> – Optimal habitats for Neuse River Waterdogs are perennial streams with continuous, year-round flow. Because a lotic environment is a critical need for the Neuse River Waterdog, perturbations that disrupt natural discharge regimes have a potential negative influence on Neuse River Waterdog resilience metrics. Neuse River Waterdog habitat must have adequate flow to deliver oxygen, provide optimal water temperatures, enable movement, and deliver prey items, as well as to carry away waste materials and remove fine sediments from the bottom substrate. 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).

Figure 3-10 Fish kill on the Neuse River (credit: T.Graves)

While waterdogs 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, aquatic species including salamanders can become stressed during the low flow times of year, either because they have to tolerate less than ideal conditions where water remains, or they are unable to find refuge and ultimately die (Turner 2004, p.6; Figure 3-10). 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.

To understand whether Neuse River Waterdog 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 waterdogs were exposed to consecutive droughts (Figure 3-11).

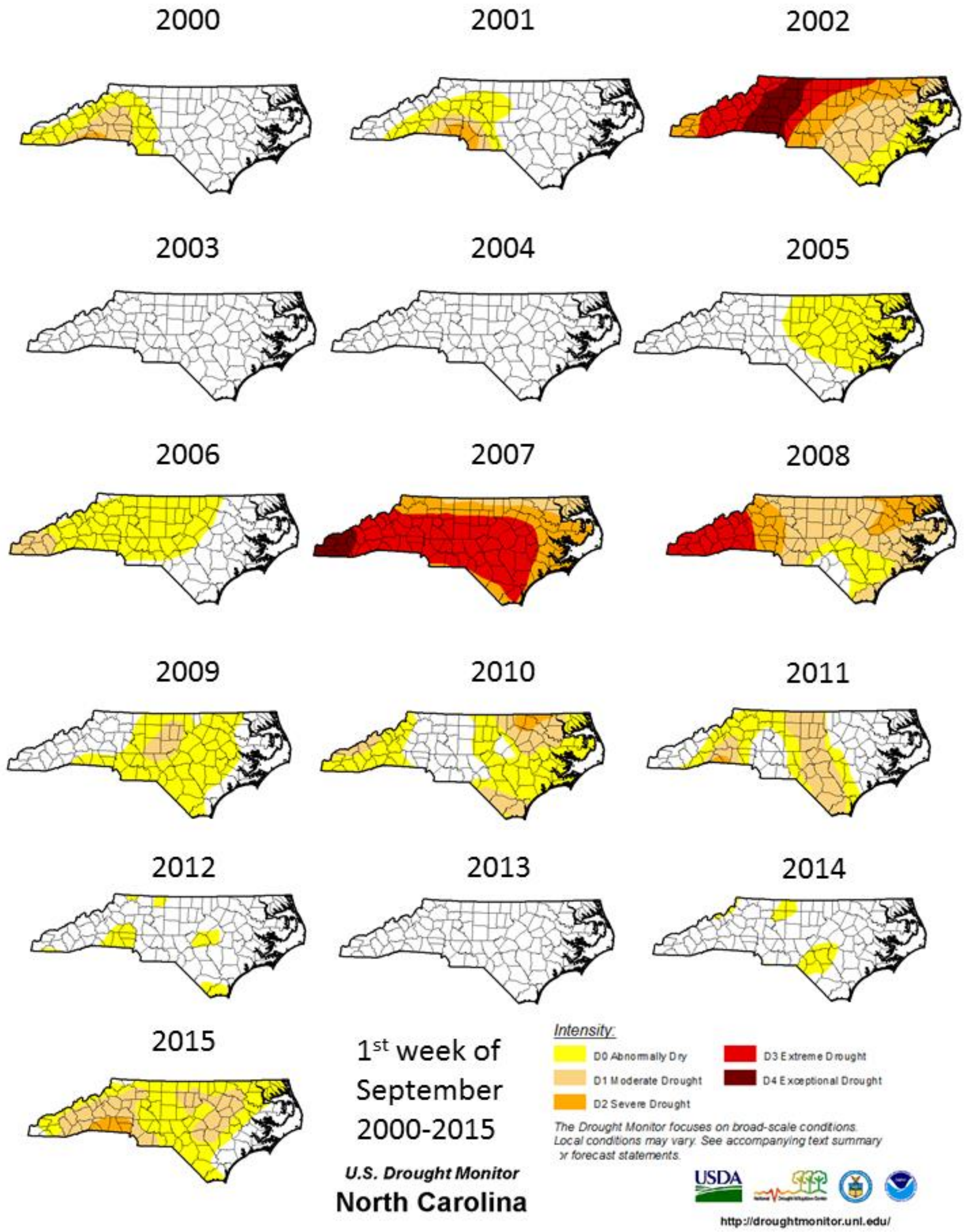


Figure 3-11 North Carolina Drought Monitor annual images for 1st week in September

Substrate and Cover – For sheltering, Neuse River Waterdogs need cover under flat rocks or in burrows. For breeding, the Neuse River Waterdog also requires cover for nest sites – this is usually in the form of flat rocks or logs (Braswell and Ashton 1985, p.13,22,28). In addition, the Neuse River Waterdog requires predominantly silt-free stable gravel and cobble substrates as optimal in-stream bottom habitat, and also stable root mats in coastal plain areas. Riparian condition strongly influences the composition and stability of substrates that aquatic species 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 waterdogs 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 et al. 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 waterdogs, fragmentation can result in loss of access to quality habitat for one or more life stages, such as preventing movement among habitats, thus potentially impacting overall distributions. Barriers to movement can cause isolated or patchy distributions of aquatic salamanders which may limit both genetic exchange and recolonization (e.g., after a high flow, scouring event) (Cartwright and Wolfe 2016, p.136). To assess the influence of factors affecting Neuse River Waterdog habitat connectivity, 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 Neuse River Waterdog habitat (see Section 4.1 below).

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 Neuse River Waterdog can be described in terms of River Basin Variability and Physiographic Variability. Below we examine these aspects of the historical and current distribution of the Neuse River Waterdog and identify potential causal effects for changes in representation over time.

River Basin Variability – The Neuse River Waterdog has likely maintained ecological representation based on continued persistence in all three river basins. Despite losses at the HUC10 scale (see Table 3-2), each of the three populations remain occupied.

Physiographic Variability – The Neuse River Waterdog is found in two physiographic provinces – the eastern Piedmont and Coastal Plain; the majority of extant Neuse River Waterdog occurrences are found in the Coastal Plain (see Figure 3-4). Monitoring data indicate declines in occurrence in both physiographic regions; a 13% decline in occurrence was estimated in the Coastal Plain and a 43% decline in the Piedmont (Figure 3-12). The species has declined considerably from its once much larger presence in the Piedmont, and nearly every historically occupied Piedmont HUC10 has experienced a decline (Figure 3-13). Of the 16 historically occupied Piedmont HUC10s, 7 are no longer occupied, and 9 have experienced loss.

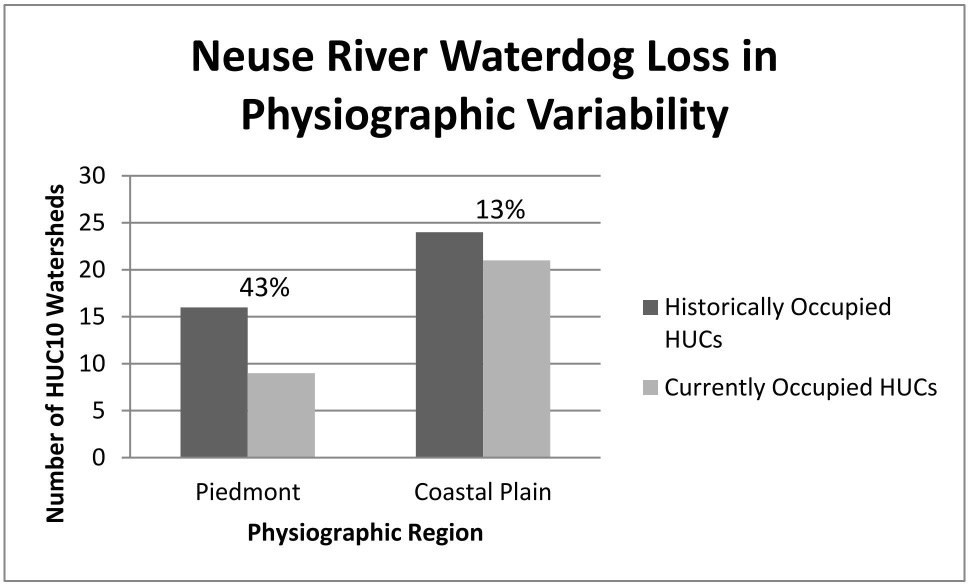
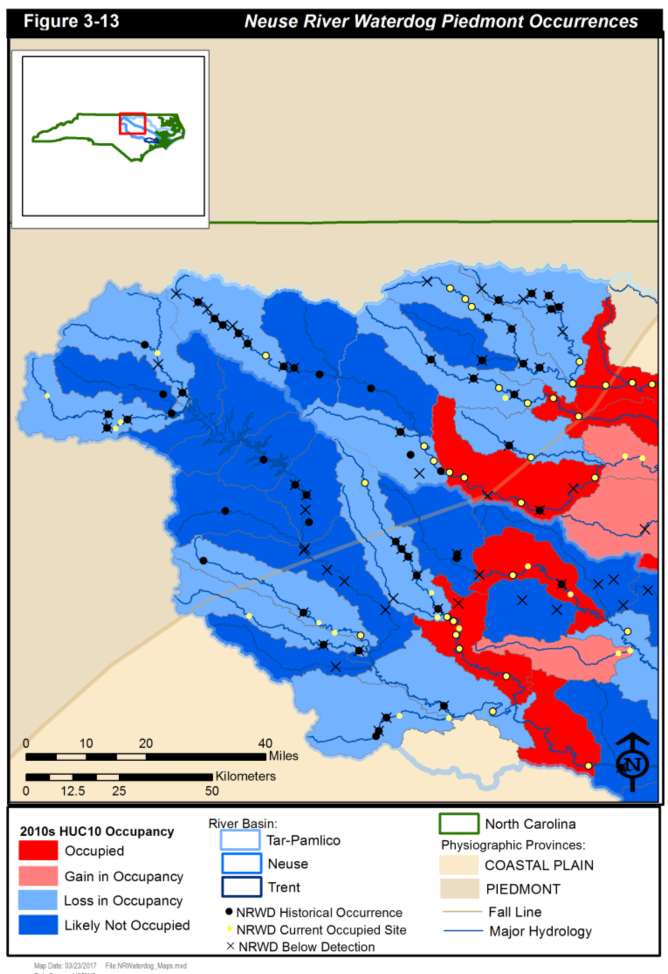


Figure 3-12 Change in physiographic variability for Neuse River Waterdog. Percentages are the proportion lost from historically occupied HUC10s to currently occupied HUC10s.



Summary

As evaluated through the lens of river basin and physiographic province, the contemporary distribution of Neuse River Waterdog 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.

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 Neuse River Waterdog 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 Neuse River Waterdog populations were once much more broadly distributed throughout their historical range (Figures 3-1 and 3-2). However, several factors, including impoundments (e.g., Falls Reservoir, Milburnie Dam, and Buckhorn Reservoir), unsuitable water quality (e.g., the Neuse River downstream from the City of Raleigh's wastewater treatment plant discharge) have resulted in population fragmentation (see Chapter 4), making repopulation of extirpated locations unlikely without human intervention.

We assessed Neuse River Waterdog redundancy by first evaluating site occupancy within each of the hydrologic units (i.e., HUC10s) that constitute MUs (Appendix A), and then we evaluated occupancy at the MU and ultimately the population level. This assessment revealed a decline in the number of sites occupied in all MUs except for one (Sandy-Swift). At the population level, the Tar Population experienced an estimated 31% decline in site occupancy, the Neuse Population experienced an estimated 40% decline, and the Trent Population experienced an estimated 50% decline (Figure 3-14; Appendix A).

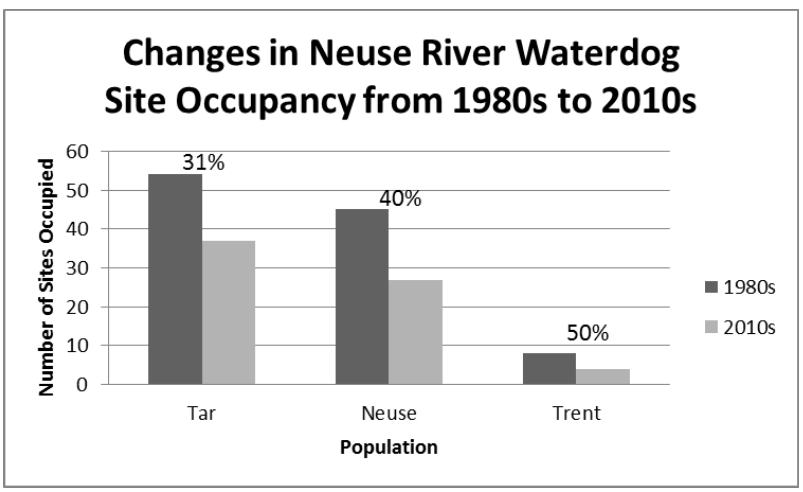


Figure 3-14 Changes in NRWD site occupancy from surveys in 1980s to surveys in 2010s. Percentages indicate declines.

Of the 40 HUC10s historically occupied by Neuse River Waterdog, 29 (73%) are currently occupied (Table 3-2). Note that current occupancy was defined as the observation of at least one Neuse River Waterdog during surveys conducted from 2010 to 2016, and some HUCs have only one confirmed site of occurrence (Figure 3-4). Of those 29 HUC10s that were counted as occupied, 19 (66%) have more than one site occupied during the current sample period (Table 3-2). At the level of MUs, seven have experienced an estimated 17-67% decline, one (Sandy-Swift) has experienced no decline, and one (Middle Tar) increased (Table 3-2).

Table 3-2 NRWD occupancy changes over time. Historical occupancy represents detections that occurred from 1979 to 1980, while current occupancy represents a sample period from 2010 to 2016. 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 Occupied HUC10s	# Currently Occupied HUC10s	% Decline	# Current HUC10s with Multiple Sites Occupied
Tar	**17**	**14**	**18**	
Upper Tar	3	1	67	0
Middle Tar	3	4	+33	3
Lower Tar	4	3	25	2
Sandy-Swift	2	2	0	2
Fishing Ck Subbasin	5	4	20	3
Neuse	**20**	**14**	**30**	
Upper Neuse	4	2	50	1
Middle Neuse	10	7	30	4
Lower Neuse	6	5	17	3
Trent	**3**	**1**	**67**	1
Totals	40	29		19

3.4 Current Conditions

The results of surveys conducted since 2010 suggest that the currently occupied range of the Neuse River Waterdog includes nine MUs from three populations in the Tar, Neuse, and Trent River basins in North Carolina, however all MUs have experienced declines in site occupancy. The species has experienced declines throughout its range, but most notably in the Piedmont and the southern portion of its range, including a large portion of the Neuse River basin and the Trent River basin. 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 Neuse River Waterdog

Entity	**Status/Rank**	Reference
NatureServe	G2N2 (Imperiled)	NatureServe 2015
IUCN	NT (Near Threatened)	IUCN 2001
North Carolina	Special Concern/S2 (Imperiled)	NCWRC 2014; NCNHP 2014

3.4.1 Current Population Resiliency

Methodology

To summarize the overall current conditions of Neuse River Waterdog MUs, we sorted them into five categories (high, moderate, low, very low and 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 two population factors (MU Occupancy and Site Occupancy) 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 two population factors and four habitat elements, respectively.

For example, for the Middle Tar MU, given the categorical scale of: High – Moderate – Low – Very Low – ø (see Table 3-4), the overall Current Population Condition is estimated to be *Moderate*; the *High* MU Occupancy condition combined with the *Moderate* Site Occupancy condition together is *Moderate*; the Site Occupancy has greater weight because of the finer resolution at the site scale (Figure 3-14; Appendix A).

Population/ Management Unit	MU Occupancy		Site Occupancy	**Current Condition - Population Factors**
Tar/Middle Tar	**H**	**+**	**M**	
		↓		
		M	→	**Moderate**

Figure 3-14 Current Population Condition calculation is determined by combining the two population factors (MU Occupancy Condition, Site Occupancy Condition).

Note: If MU Occupancy is estimated to be ø, this extirpated condition supersedes all other category rankings and is assigned as the Population Condition.

For the Habitat Elements, the scale included the following categories: High – Moderate – Low – Very Low. For example, for the Upper Tar MU, the overall Current Habitat Condition was determined by first combining the *High* Instream Habitat Condition with the *Low* Water Quantity Condition to get *Moderate*; when this *Moderate* was then combined with the *Moderate* Connectivity Condition and *Moderate* Instream Habitat Condition, the three *Moderate* ranks combine to get an overall Current Habitat Condition of *Moderate* (Figure 3-15):

Population/ Management Unit	Overall Instream Habitat (Substrate) Condition		Overall Water Quantity Condition	Overall Connectivity Condition		Overall Water Quality Condition	**Current Habitat Condition**
Tar/Upper Tar	**H**	**+**	**L**	**M**		**M**	
		↓					
		M	+	M	+	M	
				M		→	**Moderate**

Figure 3-15 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 Neuse River Waterdog condition (Table 3-5), we weighed population factors (direct measures greater than habitat elements (indirect measures) when estimating the summary Current Condition. Table 3-6 displays the presumed ranges of probabilities of persistence of a population with a given current condition category over 30-45 years (about 3 generations of the Neuse River Waterdog). These ranges were not calculated; instead they serve to communicate what the experts mean when describing the current condition of a population. Because the "high" condition category does not represent a reference condition (i.e., a condition that implies the absence of significant human disturbance or alteration), the probability of persistence for "high" condition was determined to be 40-70% (Table 3-6).

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

	Population Factors		Habitat Elements			
Condition Category	**MU Occupancy**	**Site Occupancy**	**Water Quality**	**Water Quantity**	**Connectivity**	**Instream Habitat (Substrate)**
High	<10% decline or a positive increase in occupied HUC10s over time	<10% decline in site occupancy over time	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	Very little (if any) known habitat fragmentation issues (<10 dams per MU; avg # of Road Crossings <300 per MU)	Predominantly natural (>70% forested) ARA; <6% impervious surfaces in HUC10 watershed
Moderate	11-30% decline in occupied HUC10s over time	11-30% decline in site occupancy over time	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	Some habitat fragmentation issues (10-30 dams per MU; Avg # of Road Crossings 300-500 per MU)	20-70% forested ARA; 6-15% impervious surfaces in HUC10 watershed
Low	31-70% decline in occupied HUC10s over time	31-70% decline in site occupancy over time	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	Habitat severely fragmented (30+ dams in MU; 500+ Avg Road Crossings per MU)	<20% forested ARA; >15% impervious surfaces in HUC10 watershed
Very Low	>70% decline in occupied HUC10s over time	>70% decline in site occupancy over time	Impairment or contaminant at levels that cannot support species survival	Flow conditions do not support species survival	Habitat extremely fragmented and unable to support species survival	Instream habitat unable to support species survival
Ø	Total Loss	Total Loss	N/A	N/A	N/A	N/A

Table 3-5 Resiliency of the Neuse River Waterdog populations. See Table 3-4 for condition categories. Data for categorization are found in Appendix A.

	Population Factors			Habitat Elements					
Population/ Management Unit	**MU Occupancy**	**Site Occupancy**	**Combined Population Factors**	**Water Quality**	**Water Quantity**	**Connectivity**	**Instream Habitat (Substrate)**	**Combined Habitat Elements**	**Overall**
Tar									**Moderate**
Upper Tar	Very Low	Very Low	Very Low	Moderate	Low	Moderate	High	Moderate	Very Low
Middle Tar	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Lower Tar	Moderate	High	High	Moderate	Moderate	Moderate	Low	Moderate	High
Sandy-Swift	High	High	High	High	Low	Moderate	Moderate	Moderate	High
Fishing Ck Subbasin	Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Neuse									**Low**
Upper Neuse	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Low
Middle Neuse	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lower Neuse	Moderate	Moderate	Moderate	Low	Moderate	Low	Low	Low	Moderate
Trent									**Very Low**
Trent	Very Low	Very Low	Very Low	High	Moderate	High	Low	Moderate	Very Low

Table 3-6 Presumed probability of persistence for current condition categories.

Likelihood of Persistence:	**High**	**Moderate**	**Low**	**Very Low**	**Ø**
Range of Presumed Probability of **Persistence** over 30-45 years (~3 generations*)	50-70%	30-50%	10-30%	<10%	0%
* Generation time for NRWD is ~10-15 years					

Combined habitat elements, representing overall habitat condition, were moderate in seven MUs, and low in two MUs (Table 3-5). Combined population factors were estimated to be high for two MUs, moderate for two MUs, low for three MUs, and very low for two MUs (Table 3-5). Figure 3-16 shows the MU resiliency mapped on the landscape.

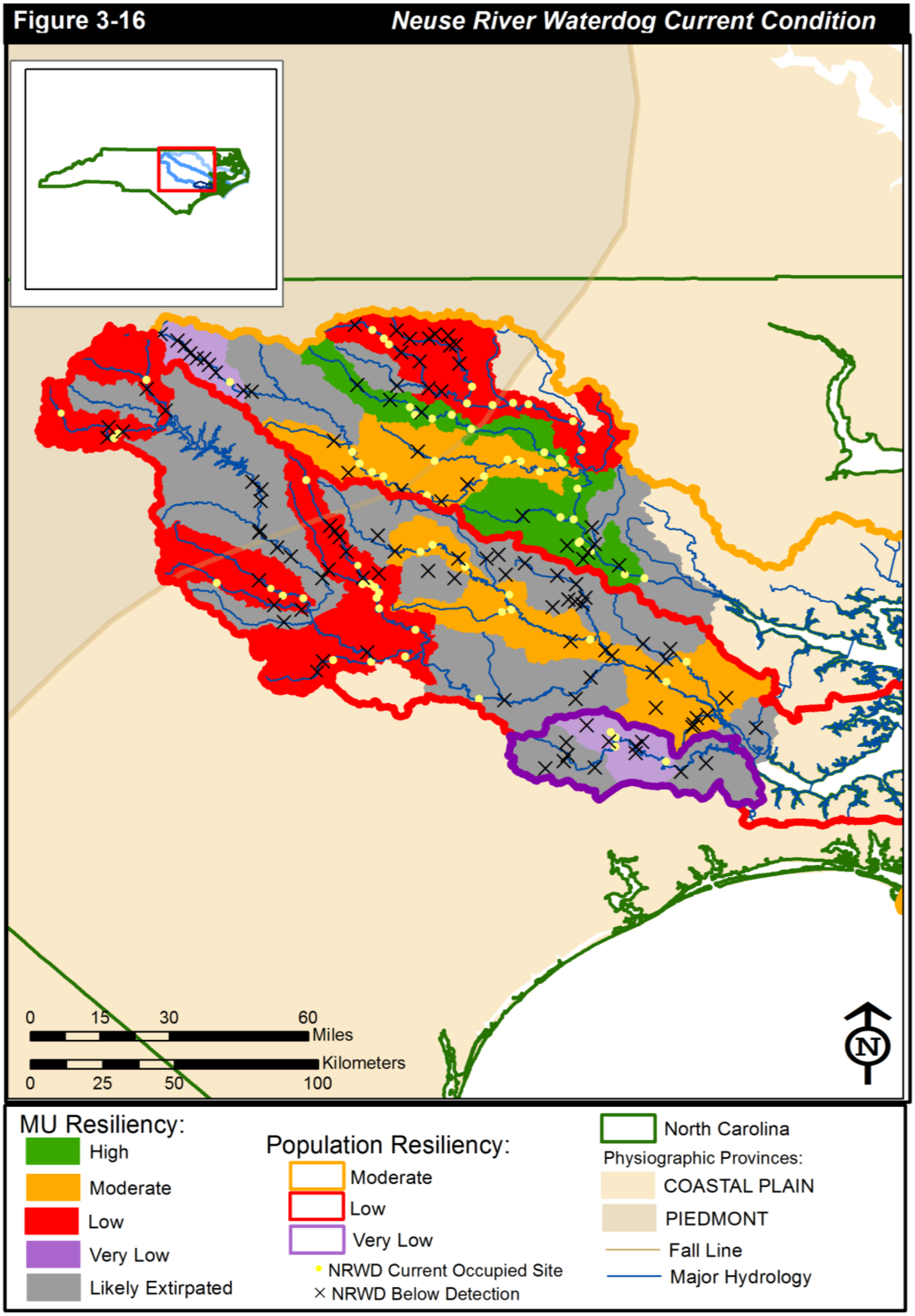
At the population level, the overall current condition (= resiliency) was estimated to be moderate for the Tar Population, low for the Neuse population, and very low for the Trent population (Table 3-5, Figure 3-16).

3.4.2 Current Species Representation

We estimated that the Neuse River Waterdog currently has moderate adaptive potential, primarily due to ecological representation in three river basins and two physiographic regions (Figure 3-16). The species retains nearly all of its known River Basin variability, however, the variability is reduced compared to historical distribution for all three populations. In addition, compared to historical occupancy, the species currently retains moderate Physiographic Variability in the Coastal Plain (87%) and in the Piedmont (67%), however the Piedmont has experienced significant declines in occupancy, with nearly half of the MUs losing species occurrence.

3.4.3 Current Species Redundancy

The range of the Neuse River Waterdog has always been very narrow – limited to the Tar and Neuse River drainages (with the Trent River considered functionally a separate drainage). Within the identified representation areas (i.e. river basins), the species retains redundancy in terms of occupied HUC10s within the Tar River population (82%) and the Neuse River population (70%), however 67% of redundancy has been lost in the Trent River population (Figure, 3-16, Table 3-2). Overall, the species has lost 27% (11 out of 40 historically occupied HUC10s) of its redundancy across its narrow, endemic range.



Map Date: 05/30/2017 File:NRWaterdog_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 Neuse River Waterdog needs for long term viability. Aquatic systems face a multitude of natural and anthropogenic threats and stressors (Neves et al. 1997, p.44). The North Carolina State Wildlife Action Plan has identified several factors that have impacts on Neuse River Waterdog habitats (Table 4-1). Generally, the factors can be categorized as either environmental stressors (e.g., development, agriculture practices, or forest conversion and management), systematic changes (e.g., climate change, invasive species, barriers, regulatory frameworks), or conservation management practices (Figure 4-1).

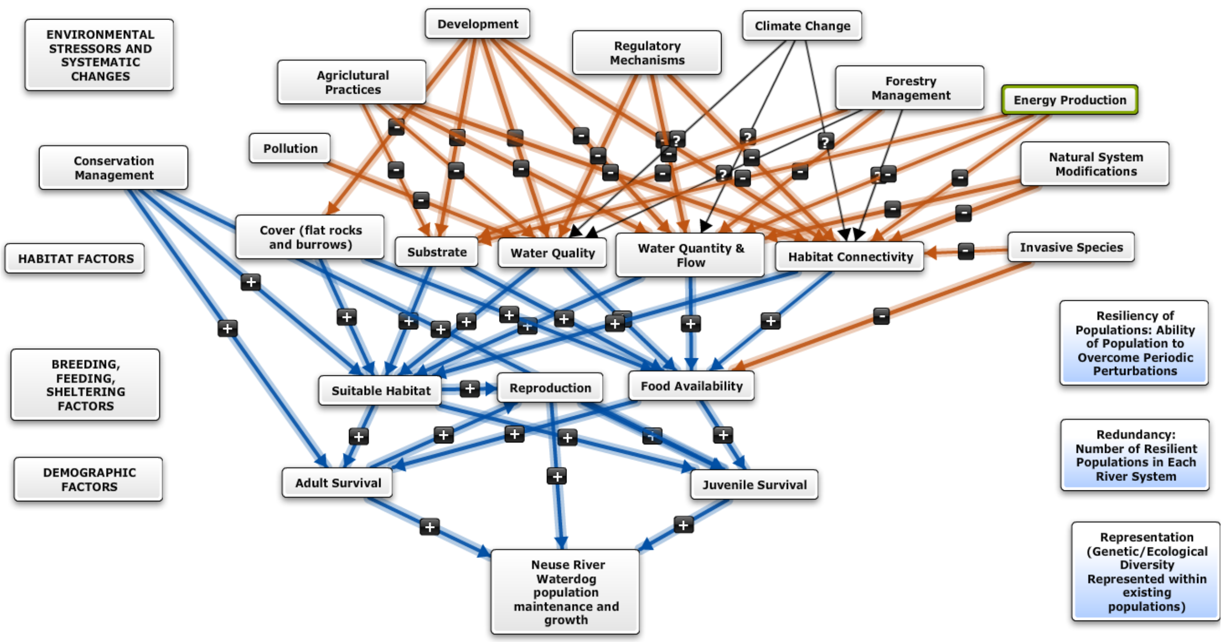


Figure 4-1 Influence diagram illustrating how environmental stressors and systematic changes influence habitat factors which in turn influence breeding, feeding, and sheltering needs of the species; in turn, these affect demographic factors which ultimately influence waterdog population growth and maintenance.

Current and potential future effects, along with current expected distribution, determine present viability and, therefore, vulnerability to extinction. Detailed information is provided for those factors that experts deemed important (Figure 4-1), including those factors that ranked as "high" as Wildlife Action Plan Conservation Concerns for the Neuse River Waterdog (Table 4-1), with the addition of information about regulatory frameworks. Those factors that are not known to have effects on Neuse River Waterdog populations, such as overutilization for commercial and scientific purposes and disease, are not discussed in this SSA report.

Table 4-1 Threats to Neuse River Waterdog from the North Carolina State Wildlife Action Plan (SWAP), including Conservation Concern Score and Scope and Severity categorizations for each threat (NCWRC 2015, Chapter 5).

SWAP Metric:	Conservation Concern Score	Scope*	Severity**
Development	LOW	RESTRICTED	SLIGHT
Agriculture & Forestry	LOW	RESTRICTED	MODERATE
Energy & Mining	HIGH	LARGE	SERIOUS
Transportation	LOW	SMALL	SLIGHT
Biological Resource Use	LOW	SMALL	SLIGHT
Human Intrusions & Disturbance	LOW	SMALL	SLIGHT
Natural System Modifications	LOW	RESTRICTED	MODERATE
Invasives	HIGH	LARGE	SERIOUS
Pollution	HIGH	LARGE	SERIOUS
Climate Change	LOW	SMALL	SLIGHT
Disease & Pathogens	LOW	SMALL	SLIGHT

***SCOPE**
(a) Pervasive Affects all or most (71-100%) of the total population or occurrences
(b) Large Affects much (31-70%) of the total population or occurrences
(c) Restricted Affects some (11-30%) of the total population or occurrences
(d) Small Affects a small (1-10%) proportion of the total population or occurrences
(e) Unknown There is insufficient information to determine the scope of threats
(f) None

****SEVERITY**
(a) Extreme Likely to destroy or eliminate occurrences, or reduce the population 71-100%
(b) Serious Likely to seriously degrade/reduce affected occurrences or habitat or reduce the population 31-70%
(c) Moderate Likely to moderately degrade/reduce affected occurrences or habitat or reduce the population 11-30%
(d) Slight Likely to only slightly degrade/reduce affected occurrences or habitat, or reduce the population 1-10%
(e) Unknown There is insufficient information to determine the severity of threats
(f) None

4.1 Development & Pollution

We use the term "development" to refer to urbanization of the landscape, including (but not necessarily limited to) land conversion for urban and commercial development, infrastructure (roads, bridges, utilities) development, and urban water uses (water supply reservoirs, wastewater treatment, etc.). The effects of urbanization 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 slow seepage 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 as runoff to local streams (Figure 4-2).

This results in degradation of stream habitats in three important ways (USGS 2014, p.2-5):

1. Water Quantity: Storm drains deliver large volumes of water to streams much faster than would occur naturally, resulting in flooding and bank erosion. Species living in the streams become stressed, displaced, or killed by the fast moving water and the debris and sediment carried in it.
2. Water Quality: Pollutants (gasoline or oil drips, fertilizers, etc) accumulate on impervious surfaces and are 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.

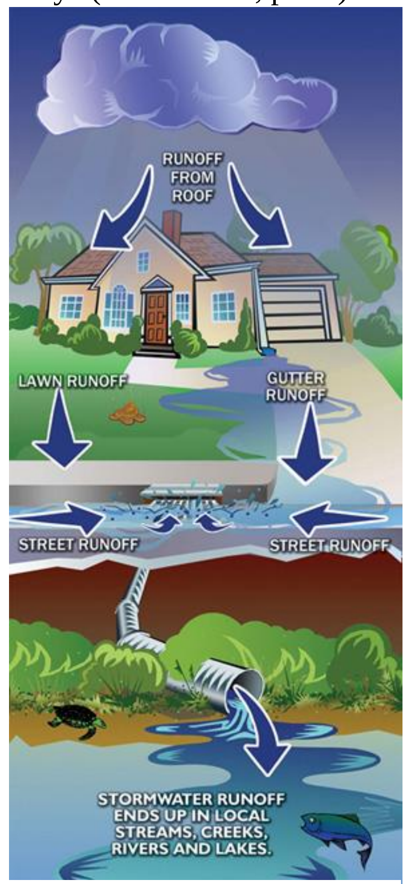


Figure 4-2 Rain becomes stormwater runoff to local streams (Credit: NCDENR)

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, salinity, and turbidity which in turn alters the water chemistry potentially making it inhospitable for aquatic biota (Figure 4-3.).

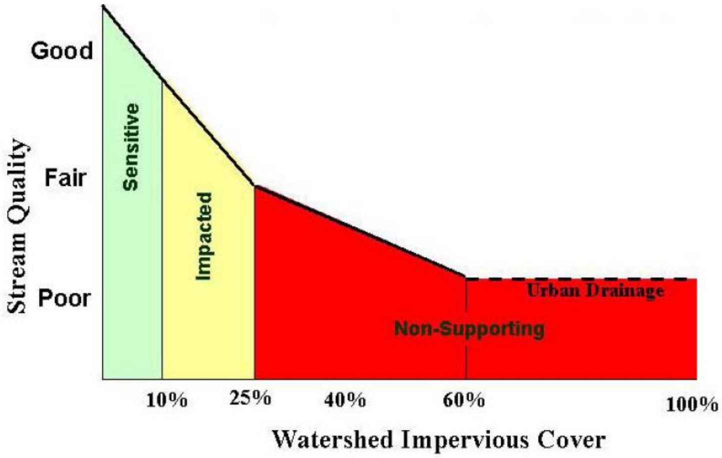


Figure 4-3. Stream Quality is adversely impacted by increased impervious surfaces (from CWP 2003, p.2)

Waterdogs prefer clean water with permanent flow and are not tolerant of siltation and turbidity (Ashton 1985, entire). Benthic critters such as the waterdog have disproportionate rates of imperilment and extirpation because stream bottoms are often the first habitats affected by pollution (Midway et al. 2010, p.325). Furthermore, the Neuse River Waterdog could be considered an “intolerant” species, meaning the species is most affected by environmental perturbations (Ashton 1985, p.104-105).

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 ultimately reduces feeding, spawning, and living spaces of the Neuse River Waterdog and other aquatic biota living in the streams (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).

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 component 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). These changes affect stream-dwelling organisms such as the Neuse River Waterdog by displacing them from once preferred, but now polluted habitats, as well as increasing exposure and assimilation of pollutants that can result in growth defects, decreased immune response, and even death. In addition, a major impact of road development is improperly constructed culverts at stream crossings. 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 such as Neuse River Waterdogs 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 four significant Neuse River Waterdog 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 instream habitat).

4.2 Agricultural Practices

Nutrient and Chemical Pollution

Farming operations can contribute to nutrient pollution when not properly managed (USEPA 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 in the proper amount, 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. 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. Agricultural pesticide use can also have detrimental effects, and studies have shown the species to have low to moderate levels of pesticide contamination from a variety of sources, including insect control (Aktar et al. 2009, p.5).

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, thus potentially resulting in dewatering of channels and displacement of aquatic salamanders.

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 US ACE 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 (E.Wells (USFWS) email to S.McRae (USFWS) on 5/13/2016).

Confined Animal Feeding Operations
Confined Animal Feeding Operations (CAFOs) and feedlots can cause degradation of aquatic ecosystems, primarily because of manure management issues (Burkholder et al. 2007, p.308). CAFOs hold tens of thousands of animals and produce a large amount of waste which enters the environment either by being discharged directly into streams or constructed ditches, stored in open lagoons, or applied to fields in wet or dry form (as referenced by Buckner et al. 2002, Mallin and Cahoon 2003, and Orlando 2004 in CBD 2010, p.18). CAFO wastes contain nutrients, pharmaceuticals, and hormones, and cause eutrophication of waterways, toxic blooms of algae and dinoflagellates, and endocrine disruption in downstream wildlife (Mallin and Cahoon 2003, p.369; Orlando et al. 2004, p.353; Burkholder et al. 2007, pp.308-309; Harden 2015, p.2).

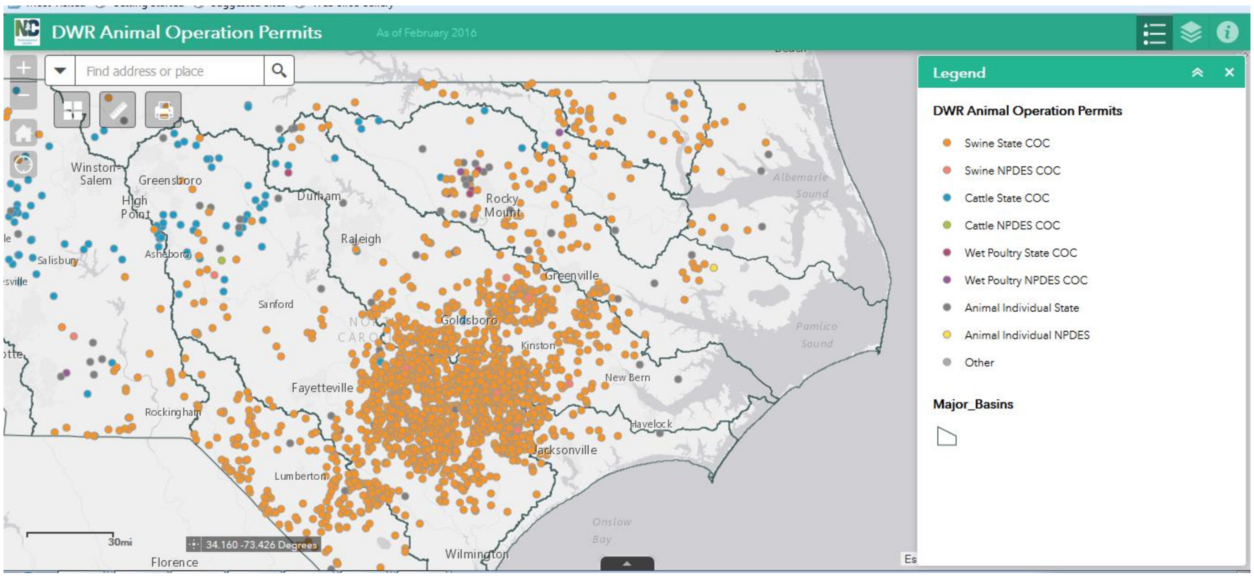


Figure 4-7 CAFO locations in eastern North Carolina from the NC Division of Water Resources website (accessed: 11/22/2016)

Table 4-2 Annual CAFO wet and dry waste production in Tar and Neuse watersheds (CBD 2017)

Watershed	# of waste lagoons	gallons/year of wet waste	# of poultry barns	tons/year of dry waste
Upper Tar	75	10,354,302	270	39,657
Lower Tar	63	216,533,254	89	7,698
Upper Neuse	276	504,942,335	424	67,410
Middle Neuse	245	585,350,859	347	39,048

The number of CAFOs in the southeast has increased drastically since 1990 as livestock production has undergone extensive industrialization (Mallin and Cahoon 2003, p.371). North Carolina is now the nation's second largest pork producer (as referenced in CBD 2010, p.18; Harden 2015, p.4). As shown in Figure 4-7, poultry CAFOs are also abundant in North Carolina, and there are many swine CAFOs in the North Carolina Coastal Plain, including streams where Neuse River Waterdogs are known to occur. More than 1 million gallons of wet waste and more than 150,000 tons of dry waste are created each year (Table 4-2) in watersheds where Neuse River Waterdog is known to occur.

4.3 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 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), and are thus a critical component to characterizing overall instream habitat (see Section 3.3.1). Specifically, forested riparian areas serve a role as (USFWS 2006, p.6):

Table 4-3 Range of buffer widths for specific riparian functional values (from USFWS 2006, p.22)

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

- 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 4-3; May et al. 1999, p.485) 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 (NCFS 2016, p.1), 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, including North Carolina. 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.107). 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).

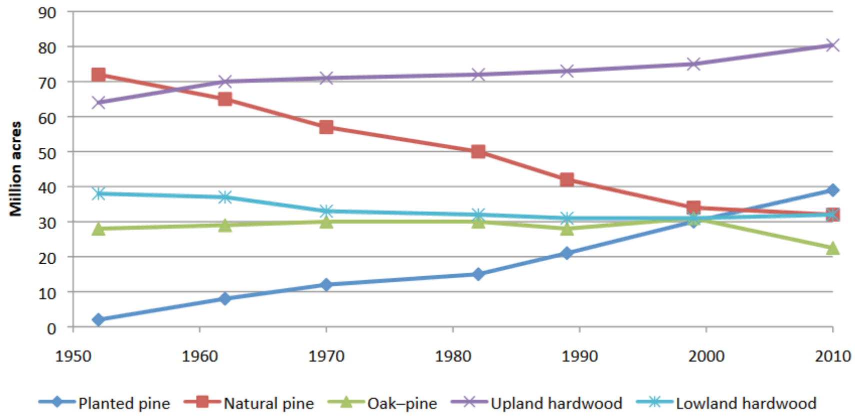


Figure 4-8 Historical trends in forest area by broad management type, showing an increase in planted pine over the past half-century (from Wear and Greis 2012, p.13)

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; Sun et al. 2011, p.253), 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). Aquatic species 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 aquatic species 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 (NCFS 2016, p.1; 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 4-4; NCASI 2015, pp.3-4).

Table 4-4. 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		Average Implementation Rate (from SGSF 2012)
	SGSF (2012)[1]	NASF (2015)[2]	
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.

Overall BMP implementation rates for the Neuse River Basin since 2000 are 90-95%, and for the Tar River Basin since 2000 are 90-91% (NCFS 2016, pp.6-7). FPG compliance rates for both the Neuse and Tar River basins are 97% for Harvest Operations and 99% for other forest management (NCFS 2016, pp.6-7). While FPGs and BMPs are widely adhered to (Table 4-4), there are instances of non-compliance (19 times in the Neuse and 32 times in the Tar in the past 10 years (NCFS 2016, pp.6-7)) as well as some practices that may not rise to a level of threat minimization that is adequate for the sensitive species (e.g., freshwater mussels, fish, amphibians) 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).

4.4 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 (NCANSMP 2015, pp.8-9). There are many areas across 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.

The flathead catfish is an invasive species that may have an impact on Neuse River Waterdog distribution. The Flathead Catfish is an apex predator, known to influence native fish populations, including predation on benthic fishes (NC ANSMPC 2015, p.75), and it occurs in both the Neuse and Tar River basins. It is not known whether or not these fish prey on waterdogs, but it is speculated that Neuse River Waterdog inactivity during warmer months is in part due to the avoidance of large, predatory fishes (Braswell 2005, p.870).

Excessive aquatic plant growth, particularly from Hydrilla, can cause many types of impacts to aquatic systems and have become an issue in the Neuse River Basin. The dense mats of hydrilla in the upper Neuse River Basin likely impact waterdog movement and foraging during the summer months. It has also been noted that privet, a terrestrial invasive plant species, can create dense stands that may be problematic to the stream food webs, ultimately affecting waterdog resource needs (J.Hall, NCWRC, email to S.McRae, USFWS, March 20, 2017).

4.5 Dams and Barriers (Natural System Modifications)

Extinction/extirpation of North American freshwater biota can be traced to impoundment and inundation of riffle habitats in all major river basins of the central and eastern United States (NCWRC 2015, 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 a many impacts on stream ecosystems. Reductions in the diversity and abundance of aquatic species are primarily attributed to habitat shifts causes by impoundment (Neves et al. 1997, p.63):

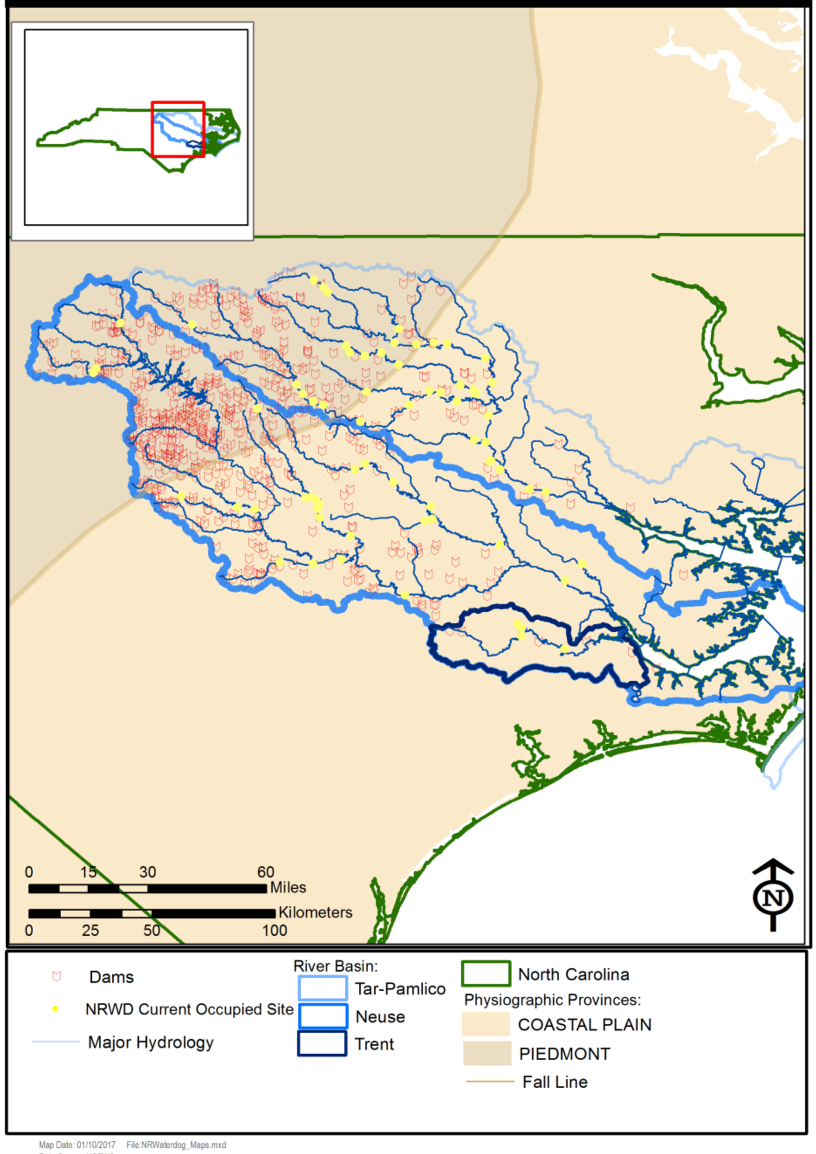
- Upstream of dams – the change from flowing to impounded waters, increased depths, increased buildup of sediments, decreased dissolved oxygen (DO), and the drastic alteration in resident amphibian populations inevitably can threaten the survival and reproductive success of many aquatic species, including waterdogs.
- Downstream of dams – fluctuations in flow regimes, minimal releases and scouring flows, seasonal dissolved oxygen depletion, reduced water temperatures, and changes in aquatic species assemblages can also threaten the survival and reproduction of many aquatic species.

Neuse River Waterdogs have specific preferences for size, depth, flow, and temperature of the streams they inhabit (Table 2-1), and a dam's impact on the flow regime and alteration of the physical and chemical water quality (including DO and temperature) can lead to negative impacts on the species (CBD 2017, p.3).

Dams have also been identified as causing genetic segregation/isolation in river systems – aquatic amphibians can no longer move freely through different habitats and may become genetically isolated from other salamander populations throughout the river.

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 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 segregation of the aquatic species inhabiting the streams.

Figure 4-9 ***Dam Distribution in Tar/Neuse Basins***



4.6 Energy Production and Mining

As indicated in the NCSWAP (NCWRC 2015, pp.687-698), the Energy Production and Mining Threat Category addresses threats from production of nonbiological resources related to exploring for, developing, and producing energy and mining resources (e.g., oil and gas, coal and gold mining, and rock, sand, and phosphate mining) as well as renewable energy resources (e.g., hydropower, solar power, wind power, geothermal power, and biofuels). Of these energy resources, the Neuse River Waterdog faces impacts from oil and gas production, coal power, hydropower, and the use of biofuels.

Potential impacts to Neuse River Waterdog from oil and gas extraction are numerous; they include water quality and water quantity impacts, riparian habitat fragmentation and conversion, increased sand mining, and increased road and utility corridors (NCWRC 2015, p.691). While oil and gas extraction does not currently and will not likely occur in the Tar River Basin (due to lack of subsurface shale deposits), impacts from shale gas extraction could occur in the Neuse

River Basin, and impacts from establishing travel and utility corridors, as well as the potential use of natural resources (primarily water and sand) for hydraulic fracturing, and handling and disposing of waste and byproducts, including possible spills and unintentional discharges could occur throughout the range of the Neuse River Waterdog (NCWRC 2015, p.691). Future impacts from oil and gas exploration and production are certain, as North Carolina has recently become the 34th state in the country to allow fracking operations to drill for natural gas (Patsy 2015, p.1).

Coal mined from other states is used for energy production in North Carolina. As referenced in the NC SWAP, fish and wildlife damage from exposure to coal ash slurry ranges from physiological, developmental, and behavioral toxicity to major population and community-level changes (NCWRC 2015, p.690). Coal-combustion residue contamination of aquatic habitats can result in the accumulation of metals and trace elements in larval amphibians, including arsenic, cadmium, chromium, copper, mercury, lead, selenium, and vanadium, potentially leading to developmental, behavioral, and physiological effects (Rowe et al. 2002, entire).

As recently as October 2016, Neuse River Waterdogs in the Neuse River were exposed to coal ash slurry when Hurricane Matthew caused inundation of coal ash storage ponds (Figure 4-10). Furthermore, coal-fired power plants pump large volumes of water to produce electricity and aquatic organisms such as larval waterdogs can be entrained or impinged unless measures are sufficient to keep organisms from being impacted. After water is used for electricity production, it is returned to surface waters but the temperature can be considerably higher than the temperature of the receiving waterbody, thus altering the natural thermal regime and potentially altering the aquatic community composition (NCWRC 2015, p.690).

Figure 4-10 Hurricane Matthew: rising waters from Neuse River inundate coal ash storage pond near Goldsboro, NC (credit: Travis Graves, lower Neuse Riverkeeper)

Hydropower as a domestic energy source is becoming more prevalent in North Carolina, including areas where the Neuse River Waterdog occurs. In 2015, the US Army Corps of Engineers applied to create a hydropower operation on the Falls Lake dam in Wake County (USACE 2015, p.1). A recent study by Standt and Doyle (2013, entire), looked at the potential of micro-hydropower development at numerous low-head dams in the Cape Fear and Neuse River basins (Figure 4-11).

Hydropower dams have similar impacts as other impoundments: streams and rivers impounded by dams are changed from lotic systems to lentic systems, fragmenting habitats and disrupting movements and migrations of fish and other aquatic organisms like the Neuse River Waterdog (NCWRC 2015, p.693). Downstream water quality can also suffer from low dissolved oxygen (DO) levels and altered temperatures (lower water temperatures if water is released from near the bottom of the reservoir). In addition, hydropower generation can significantly change flow regimes downstream of hydropower dams, and can affect other riverine processes, such as bedload and sediment transport, nutrient cycling, and woody debris transport (NCWRC 2015, p.693).

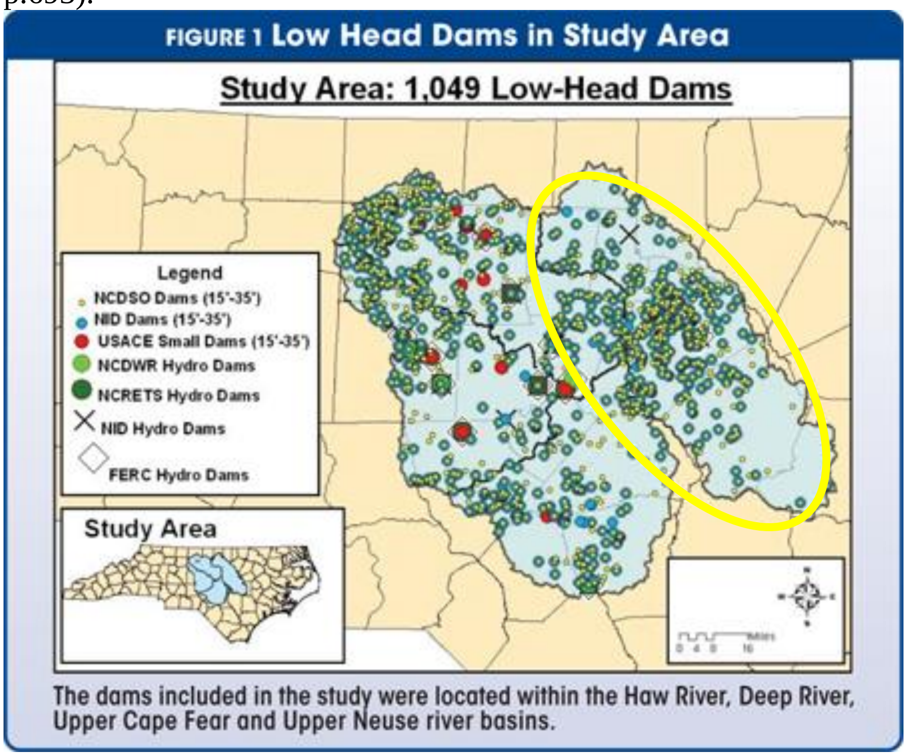


Figure 4-11 Mico-hydropower production possible locations; Neuse River Basin circled to show area of overlap with Neuse River Waterdog range (from Sandt and Doyle 2013)

Finally, biofuel production involves biomass resources, including organic matter from a variety of wood materials and energy crops that can be gasified (NCWRC 2015, p.688). Biomass production often involves intensive management that uses fertilizers and pesticides that can runoff into nearby waterways, as well as monocultures of high-yield nonnative cultivars that replace native forests (NCWRC 2015, p.688). Similar to agriculture and forest management (see Sections 4.2 and 4.3), these impacts can change the dynamics in the aquatic system, impacting foraging and sheltering functions for species such as the Neuse River Waterdog.

4.7 Regulatory Mechanisms

State Endangered Species Law

North Carolina has state-level legislation modeled after the federal Endangered Species Act: the North Carolina Endangered Species Act was enacted in 1987. Animal species that are protected by the state laws are regulated by the state wildlife agency, the North Carolina Wildlife Resources Commission. The state endangered species protection law allow the state wildlife agency to identify, document, and protect any animal species that is considered rare or in danger of extinction. Illegal activities include take, transport, export, process, sell, offer for sale, or ship species, and the penalty for doing so is a misdemeanor crime, usually inciting a fine of no more than $1,000 or imprisonment not to exceed a year (Pellerito 2002, entire), however it has been identified in the NC Administrative code that the replacement cost of any endangered species is $4,960 (15A NCAC 10B .0117). There are no mechanisms for recovery, consultation, or critical habitat designation other than where recommendations, not requirements, can be made for lands to be protected or acquired (Pellerito 2002, entire; George and Snape 2010, p.346).

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. North Carolina had buffer requirements in specific watersheds, including the Tar-Pamlico and Neuse, however, as described below, the NC Legislature enacted a Regulatory Reform effort, including "Riparian Buffer Reform" that allowed for the amendment of the buffer rules to allow/exempt development (see Session Law 2012-200, Section 8 and Session Law 2015-246, Section 13.1, G.S. 143-214.23A (NCDEQ 2016a, entire)).

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/water features are issued by the U.S. 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 as what is 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 Water Quality Program

Current State regulations regarding pollutants are designed to be protective of aquatic organisms; however, Neuse River Waterdogs may be more susceptible to some pollutants than the test organisms commonly used in bioassays. Despite existing authorities such as the Clean Water Act, pollutants continue to impair the water quality throughout the current range of the Neuse River Waterdog. 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 Neuse River Waterdog. In the past six years (since 2010), there have been several changes to state regulations, known as "Regulatory Reform" and in 2016, the changes are described in legislation titled: "Regulatory Reduction Act." These changes in Session Laws, House and Senate Bills, and enacted Legislation have far reach and the most recent reforms have affected significant environmental programs and protections, including:

- disinvestment in data collection on rare and endangered species by significant funding reductions to the state's Natural Heritage Program (SL2015-241, Sections 14.4,14.30(a) and (r1) and (ggg) and (nnn1));
- 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 review. 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 2016b, 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 and Tar-Pamlico river basins (SL2015-246, Section 13.1);
- 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 (SL2014-90, Part II);
- reduction of CWA 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 (SL2014-120, Section 54(b));
- 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 SL2013-413). The result of these regulatory changes could impact aquatic species such as the Neuse River Waterdog, 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.

4.8 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

Figure 4-12 Drought conditions resulting in dry channels are becoming more prevalent in the Upper Tar River Basin (credit: S.McRae)

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.

- Streamflow is becoming more variable in many parts of the Southeast and dry years are becoming drier…As climate change influences temperature and precipitation, drought conditions are likely to become more prevalent (SECSC 2017, p.2).
- 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.

Effects of drought have been seen in the upper Tar River Basin (Figures 3-11 and 4-12), once occupied by Neuse River Waterdog (Figure 3-4).

4.9 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 in North Carolina. Land Trusts are targeting key parcels for acquisition, federal, state, and University biologists are surveying and monitoring species occurrences, and recently there has been increased interest in efforts to ramp up captive propagation and species population restoration via augmentation, expansion, and reintroduction efforts.

4.10 Summary

Of the past, current, and future influences on what the Neuse River Waterdog needs for long term viability, the largest factors affecting the future viability of the species relate to habitat degradation from stressors influencing water quality, water quantity, instream habitat, and habitat connectivity (Table 4-5). 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 Neuse River Waterdog 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 Neuse River Waterdog MUs and populations, and the viability of the species overall.

Table 4-5 Summary of Factors affecting Neuse River Waterdog viability and whether they influence Habitat Elements

		Habitat Element			
		Water Quality	Water Quantity	Connectivity	Substrate & Cover
Factor	Development	x	x	x	x
	Agricultural Practices	x	x	x	x
	Forest Management	x	x	x	x
	Invasive Species	x		x	x
	Dams and Barriers	x	x	x	x
	Energy Production	x	x	x	x
	Regulatory Mechanisms	x	x	x	x
	Climate Change	x	x	x	
	Conservation Measures	x	x	x	x

CHAPTER 5 – FUTURE CONDITIONS

Thus far, we have considered Neuse River Waterdog 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 Neuse River Waterdog.

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 Neuse River Waterdog 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 Neuse River Waterdog 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), and as mentioned above, is in line with the Southeast being the fastest growing region in the country.

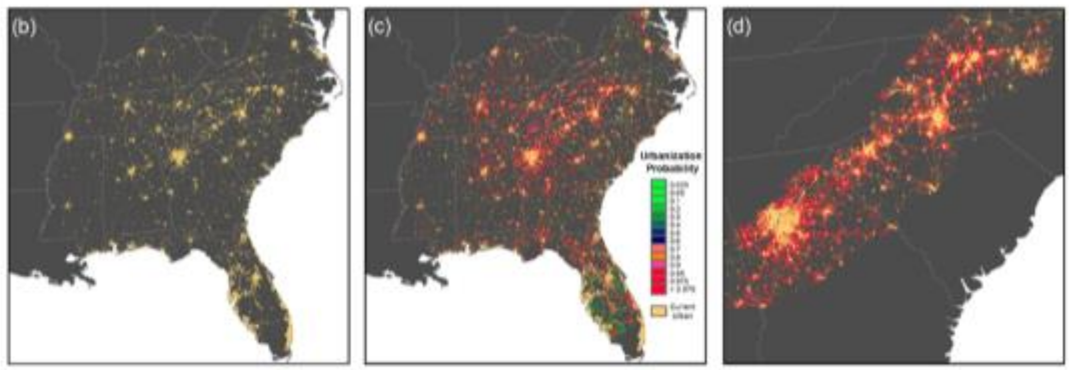


Figure 5-1 "Business-as-usual" urbanization scenario for the Southeast US from Terando et al. 2014, p.3. Red areas are the urban extent as classified by their methodology. (b) is the initial urban land cover in 2009; (c) is the projected urban land cover in 2060; and (d) is the projected urban land cover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

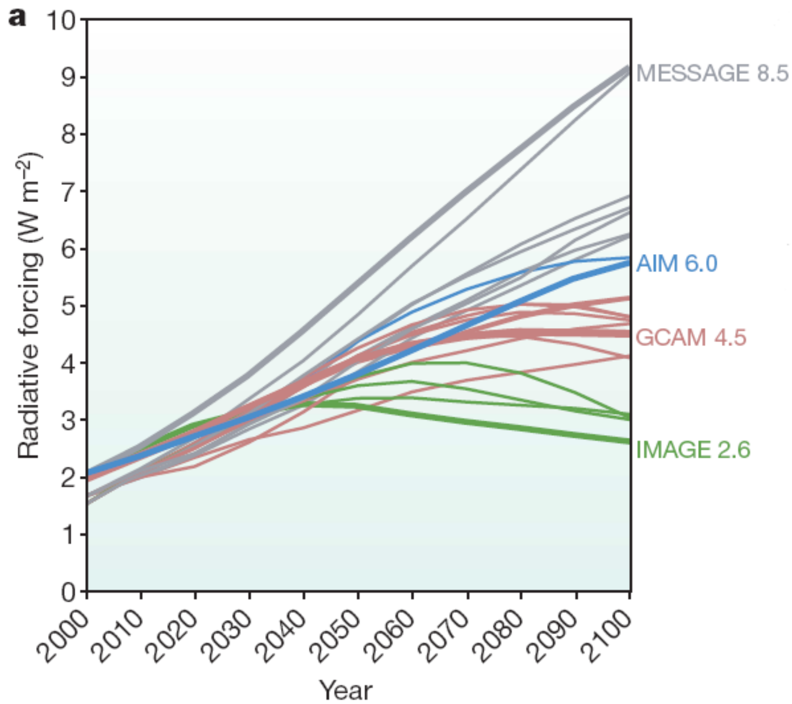


Figure 5-2 Changes in radiative forcing relative to pre-industrial conditions. Bold colored lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing (from Moss et al., 2010).

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 Neuse River Waterdog.

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 2015, p.5-48; Table 4-1), climate change is seen as a "low" threat to the Neuse River Waterdog, with Unknown to Large Scope (affecting up to 70% of the total population or occurrences) and Unknown to Moderate Severity (likely to only slightly degrade/reduce affected occurrences or habitat, or reduce the population by up to 30%). 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 Neuse River Waterdog 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

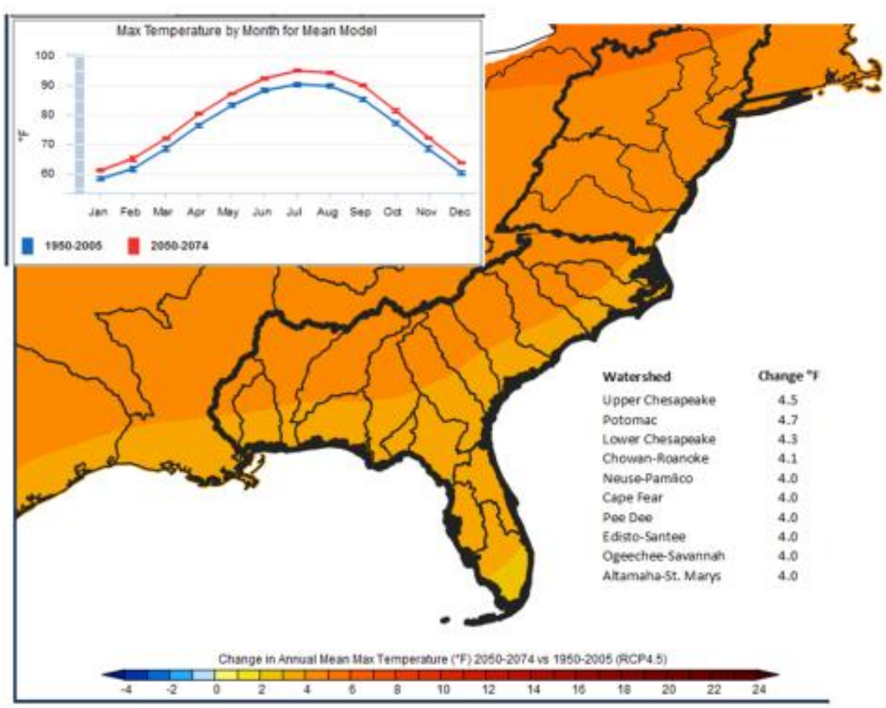


Figure 5-3 Predicted change in annual mean maximum air temperature under RCP4.5 (NCCV 2016)

5.1.1 The Scenarios

The Neuse River Waterdog has declined in overall distribution and abundance. The species currently occupies approximately 73% of its historical range with many remaining populations being small and fragmented, occupying sporadic reaches compared to previous historical occurrences, 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 Neuse River Waterdog occurs, resulting in higher air temperatures and increased evaporation, and changing precipitation patterns such that water levels rangewide have already reached historic lows (SECSC 2017, p.2; NCILT 2012, p.6). These low water levels put the populations at elevated risk for habitat loss, especially in the headwater areas.

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 Neuse River Waterdog, 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 flow loss, water quality impairment, or connectivity issues may occur, and how the species might respond, we have forecasted what the Neuse River Waterdog 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 Neuse River Waterdog. 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 Neuse River Waterdog 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 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 that may occur. MUs in moderate condition were defined as having lower resiliency than those in high condition but are still expected to persist beyond 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 Neuse River Waterdog were assumed to remain on trend 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. Described below are how factors affecting populations, such as water quality, flow, and riparian cover are expected to change under the Status Quo Scenario. Given predicted habitat conditions and current population factors (i.e., initial conditions), we then forecast Neuse River Waterdog viability using the 3R framework.

- Tar – Continued climate induced changes that reduce flows (NCILT 2012, p.27) are predicted to affect habitat in the Upper Tar MU, causing likely extirpation of the species in the MU; continuation of reduced water quality through utilization of basic effluent treatment technologies and reduced riparian habitat protections (see Section 4.2; Table 5-2) are predicted to result in degraded habitat conditions throughout the Middle Tar MU, thus reducing the viability of the species in this MU. Both the Fishing Creek Subbasin and Sandy/Swift Creek MUs will likely maintain moderate habitat conditions in the Status Quo Scenario, but lower occupancy currently seen in the Fishing Creek watershed is predicted to continue while moderate population conditions in Sandy/Swift are projected to continue into the future. The Lower Tar MU is predicted to have slightly lower habitat conditions, thus decreasing the species resiliency in this MU under the Status Quo Scenario.
- Neuse – Urbanization in the Upper and Middle portions of the basin is predicted to result in continued declines in water quality from runoff (see Section 4-1) and wastewater effluent issues. 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 resulting in more road crossings. All of these factors contribute to declining instream habitat for the species, contributing to likely extirpation in the Upper Neuse MU and low resiliency in the Middle Neuse MU. Habitat conditions in the Lower Neuse are also predicted to decline, thus reducing the condition of the species in this MU (Table 5-2).
- Trent – Habitat conditions in the Trent are predicted to decline, this leading to likely extirpation under the Status Quo Scenario.

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 Neuse River Waterdog reproduction and survival. Two of the Tar MUs (Lower Tar MU and Sandy/Swift MU) are predicted to remain moderately resilient, while the Middle Tar MU, Fishing Creek Subbasin MU, Middle Neuse MU, and Lower Neuse MU were predicted to have low resiliency at the end of the predictive time horizon. All other MUs were predicted to become extirpated.

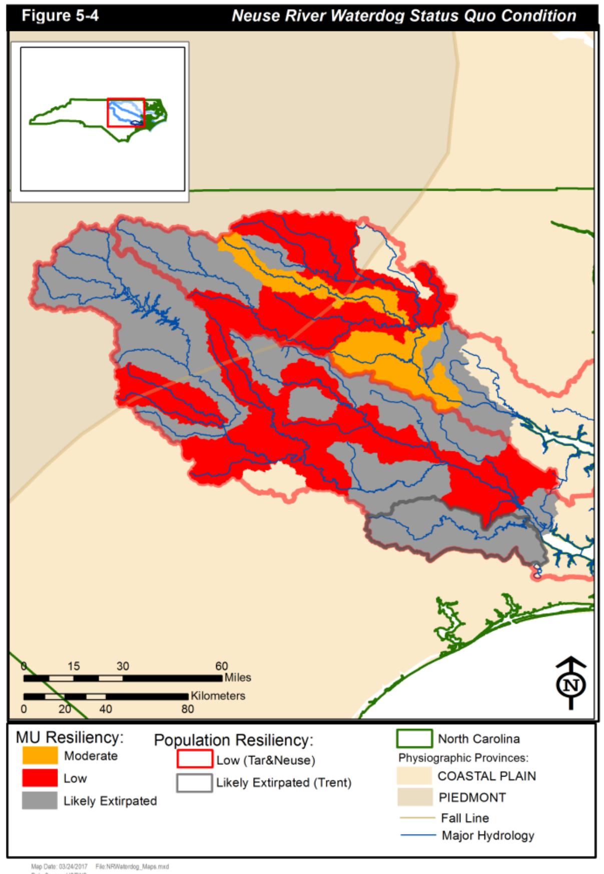
Scaling up to the population level, both the Tar and Neuse populations are expected to have low resiliency under the Status Quo Scenario. The Trent Population is predicted to become extirpated.

Table 5-2 Neuse River Waterdog Resiliency under Scenario 1 - Status Quo

	Population Factors			Habitat Elements					
Population/ Management Unit	MU Occupancy	Site Occupancy	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Tar									**Low**
Upper Tar	Ø	Ø	Ø	Moderate	VLow	Moderate	Low	Moderate	Ø
Middle Tar	Low	Low	Low	Low	Moderate	Moderate	Low	Low	Low
Lower Tar	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low	Low	Moderate
Sandy-Swift	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Fishing Ck Subbasin	Moderate	Low	Low	Moderate	Low	Moderate	Moderate	Moderate	Low
Neuse									**Low**
Upper Neuse	Ø	Ø	Ø	Low	Low	Low	Low	Low	Ø
Middle Neuse	Moderate	Low	Low	VLow	VLow	Low	Low	Low	Low
Lower Neuse	Moderate	Low	Low	VLow	Moderate	VLow	Low	Low	Low
Trent									**Ø**
Trent	Ø	Ø	Ø	Low	Moderate	Moderate	Low	Low	Ø

5.2.2 Representation

Figure 5-4 Neuse River Waterdog Status Quo Condition



Given our measures of representation, including Physiographic and River Basin Variability, we predicted that the Neuse River Waterdog will have reduced representation at the end of the predictive time horizon (Figure 5-4). Under the Status Quo Scenario, while the species maintains most of its known River Basin Variability the Physiographic Variability is expected to decline in both the Piedmont (63%) and in the Coastal Plain (17%).

5.2.3 Redundancy

Under the Status Quo Scenario, we predicted that the number of resilient Neuse River Waterdog populations will decline considerably with likely extirpation in three of nine MUs and low resiliency in four of nine MUs. This expected reduction in both the number and distribution of resilient populations is likely to make the species vulnerable to catastrophic disturbance events.

5.3 Scenario 2 – Pessimistic

Factors that negatively influence Neuse River Waterdog 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

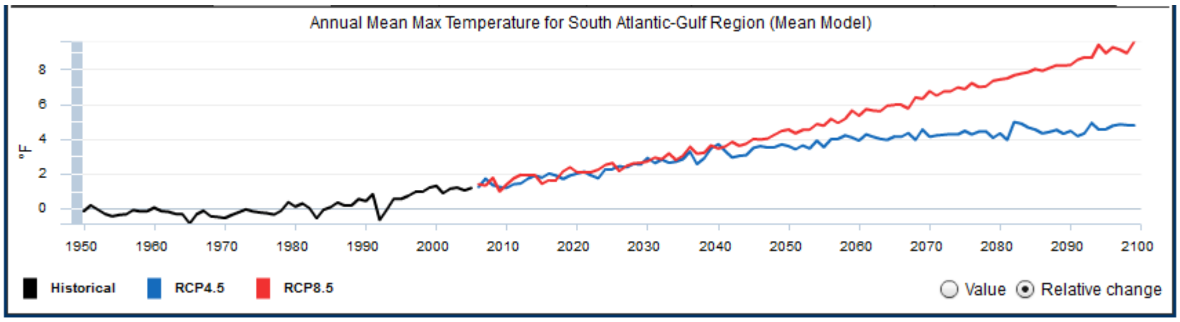


Figure 5-5 Time Series of Annual Mean Maximum Temperature under RCP8.5 (shown in red) (NCCV 2016)

SLEUTH BAU model (Terando et al. 2014, entire), urbanization in Neuse River Waterdog 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.

- Tar – Climate change is predicted to result in an increase in the number and duration of droughts in the Tar Basin (see Section 4-7; Table 5-1). Low flows in the Upper Tar Basin will create uninhabitable conditions for the waterdogs, therefore they are predicted to be likely extirpated in the Upper Tar MU. Increased urbanization and basic effluent treatment in the Middle Tar basin are predicted to reduce habitat quality, with predicted low resiliency of waterdogs in this MU. Similarly, the habitat conditions in the Fishing Creek Subbasin, Sandy/Swift, and Lower Tar MUs are predicted to decline under more extreme climate and urbanization futures, and the species is expected to persist, but reduced to low resiliency.
- Neuse - High urbanization rates (up to 200% in 50-years, or double current rate) 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 river basin under the Pessimistic Scenario.
- Trent – Habitat conditions in the Trent are predicted to decline, this leading to likely extirpation under the Pessimistic Scenario.

5.3.1 Resiliency

The Pessimistic Scenario projects the condition of the Neuse River Waterdog 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 one currently extant population, 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 four MUs (Middle Tar, Lower Tar, 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. Two of three populations of Neuse River Waterdog are predicted to become extirpated in 50 years (Table 5-3).

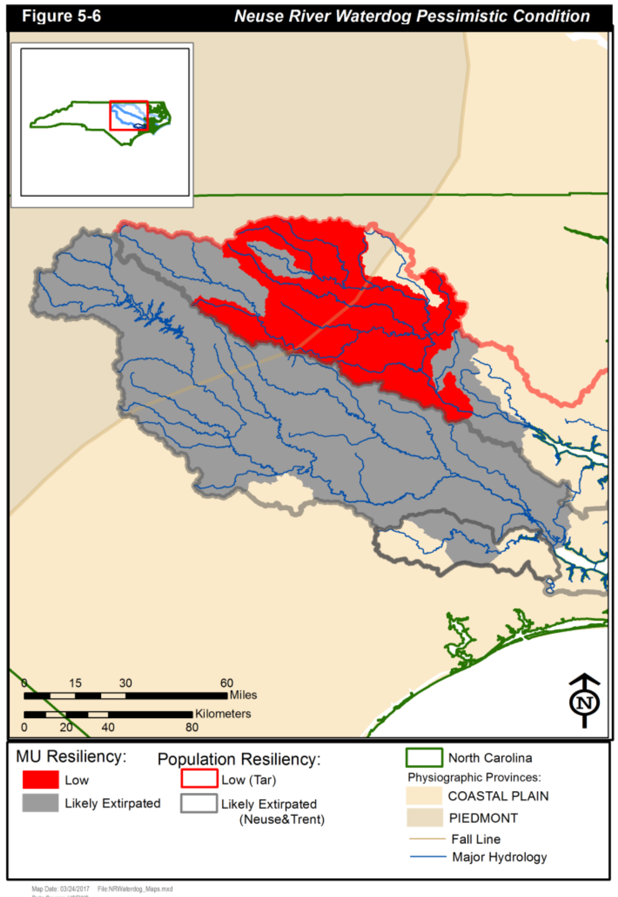
Table 5-3 Neuse River Waterdog Resiliency under Scenario 2 - Pessimistic

	Population Factors			Habitat Elements					
Population/ Management Unit	**MU Occupancy**	**Site Occupancy**	**Combined Population Factors**	**Water Quality**	**Water Quantity**	**Connectivity**	**Instream Habitat (Substrate)**	**Combined Habitat Elements**	**Overall**
Tar									**Low**
Upper Tar	Ø	Ø	Ø	VLow	Low	Moderate	Low	Low	Ø
Middle Tar	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lower Tar	Moderate	Low	Low	VLow	Moderate	Low	Low	Low	Low
Sandy-Swift	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate	Low
Fishing Ck Subbasin	Moderate	Low	Low	Low	Moderate	Low	Moderate	Moderate	Low
Neuse									**Ø**
Upper Neuse	Ø	Ø	Ø	Low	Low	VLow	Low	Low	Ø
Middle Neuse	Ø	Ø	Ø	VLow	VLow	VLow	Vlow	VLow	Ø
Lower Neuse	Ø	Ø	Ø	VLow	Low	Low	Low	VLow	Ø
Trent									**Ø**
Trent	Ø	Ø	Ø	Low	Moderate	Low	Low	Low	Ø

5.3.2 Representation

We predicted that the Neuse River Waterdog will have limited representation in the form Physiographic and River Basin variability under the Pessimistic Scenario. The species is expected to lose 67% of its known River Basin Variability, retaining representation in only in the Tar River Basin. The species is also expected to lose Physiographic Variability in the Piedmont (75%) and the Coastal Plain (58%). At the population level, only one population (Tar) is expected to be extant, albeit in low condition, at the end of the predictive time horizon (Figure 5-6).

Figure 5-6 Neuse River Waterdog Pessimistic Condition



5.3.3 Redundancy

Under the Pessimistic Scenario, it is predicted that the Neuse River Waterdog will lose significant redundancy, with likely extirpation in five of the nine MUs, and only one population (Tar) is 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 Neuse River Waterdog 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. Targeted permanent protection of riparian areas is a potential conservation activity that could benefit the Neuse River Waterdog across its range, and current efforts are considered successful as part of the Optimistic 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 Middle Tar, Lower Tar, and Sandy/Swift Creek MUs and at moderate levels in the Fishing Creek Subbasin MU. It is also predicted that the waterdogs will maintain current (low) levels of resiliency in the Upper Tar MU. Conservation efforts in the Fishing Creek Subbasin and Sandy-Swift Creek benefit the species.
- Neuse – Despite an ameliorated climate future and lower levels of urbanization, the habitat conditions in the Neuse River Basin are predicted to decline slightly, thus resulting in low resiliency condition of the Neuse River Waterdog throughout the basin.
- Trent – Under the Optimistic Scenario, habitat conditions are predicted to remain similar to current conditions, thus likely maintaining the waterdog population in low condition in this basin.

5.4.1 Resiliency

The Optimistic Scenario projects the condition of the Neuse River Waterdog populations if the current risks will be slightly improved by the end of the predictive time horizon. Because of the more optimistic lens, more MUs are predicted to remain extant than the Status Quo or Pessimistic Scenarios (Table 5-4). Specifically, the Tar River population is predicted to be highly resilient under the Optimistic Scenario with the Middle Tar, Lower Tar, and Sandy/Swift MUs in high condition and the Fishing Creek Subbasin MU in moderate condition (Figure 5-7; Note that all HUCs that are currently likely extirpated are also predicted to be likely extirpated in the future). Despite a more optimistic future, we predict that both the Neuse River and Trent populations will be in low condition (Figure 5-7).

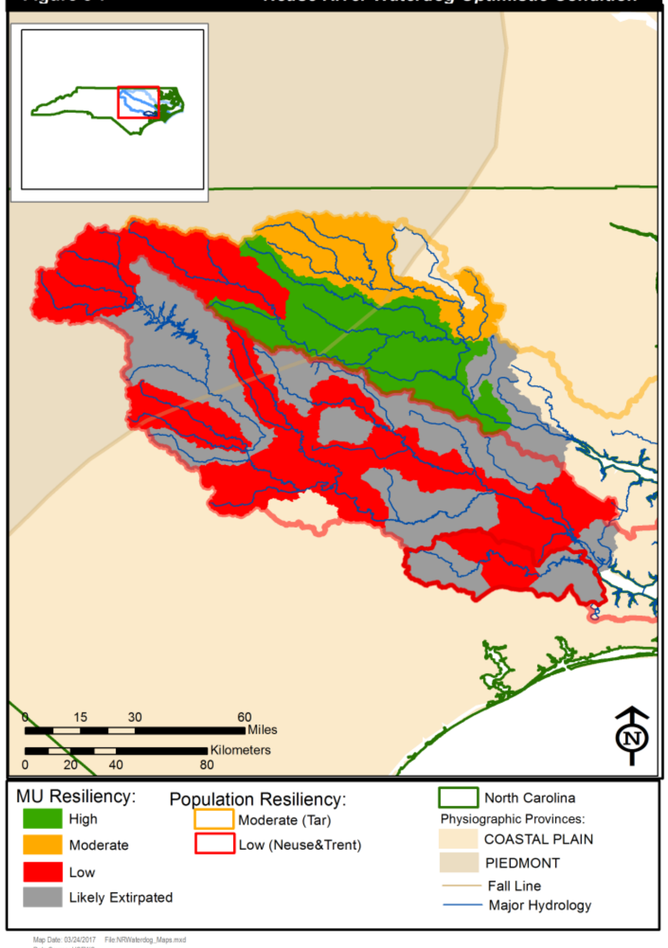
Table 5-4 Neuse River Waterdog Resiliency under Scenario 3 - Optimistic

	Population Factors			Habitat Elements					
Population/ Management Unit	MU Occupancy	Site Occupancy	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Tar									**Moderate**
Upper Tar	Low	Low	Low	Moderate	Low	Moderate	Moderate	Moderate	Low
Middle Tar	High	High	High	Moderate	Moderate	Low	Moderate	Moderate	High
Lower Tar	High	High	High	Low	Moderate	Moderate	Low	Low	High
Sandy-Swift	High	High	High	Moderate	Moderate	Moderate	Moderate	Moderate	High
Fishing Ck Subbasin	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Neuse									**Low**
Upper Neuse	Moderate	Low	Low	Moderate	Low	Moderate	Moderate	Moderate	Low
Middle Neuse	Moderate	Low	Low	Low	VLow	Moderate	Moderate	Low	Low
Lower Neuse	Moderate	Low	Low	Low	Moderate	Low	Low	Low	Low
Trent									**Low**
Trent	Moderate	Low	Low	High	Moderate	High	Moderate	Moderate	Low

5.4.2 Representation

Under the Optimistic Scenario, it is predicted that the Neuse River Waterdog will retain current levels of representation. As such, the species will continue to retain all of its known River Basin Variability. The species is predicted to retain Physiographic Variability in the Coastal Plain (87%) and the Piedmont (57%).

Figure 5-7 ***Neuse River Waterdog Optimistic Condition***



5.4.3 Redundancy

Under the Optimistic Scenario, it is predicted that the Neuse River Waterdog will maintain existing levels of redundancy however resiliency of the Neuse and Trent populations is predicted to be low. The species will have moderate and high resiliency in four of nine MUs.

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 Neuse River Waterdog get moderately worse, reflecting Climate Change Model RCP4.5 (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 Neuse River Waterdog, although current land conservation efforts will benefit the species in some watersheds.

- Tar – Under the Opportunistic Scenario, there will be moderate climate-induced impacts creating continued drought issues in the Upper Tar, resulting in predicted extirpation of the species in this MU. Habitat conditions in the Middle and Lower Tar are predicted to decline, thus reducing resiliency of the waterdogs in both MUs over the predictive time horizon. Targeted conservation efforts in the Fishing Creek Subbasin and Sandy-Swift Creek are predicted to enable the species to continue to persist in moderate and high condition, respectively.
- Neuse – Impacts from urbanization, including declining water quality from stormwater runoff and decreased flows from consumptive use, along with minimal development restrictions will continue to degrade habitat condition under the Opportunistic Scenario. Additionally, this scenario predicts declines in habitat connectivity by maintaining existing dam infrastructure and population-growth resulting in more road crossings. All of these factors contribute to declining instream habitat for the species, thus the Neuse River Waterdog is predicted to persist in low condition under the Opportunistic Scenario.
- Trent - Habitat conditions in the Trent are predicted to decline, this leading to likely extirpation under the Opportunistic Scenario.

5.5.1 Resiliency

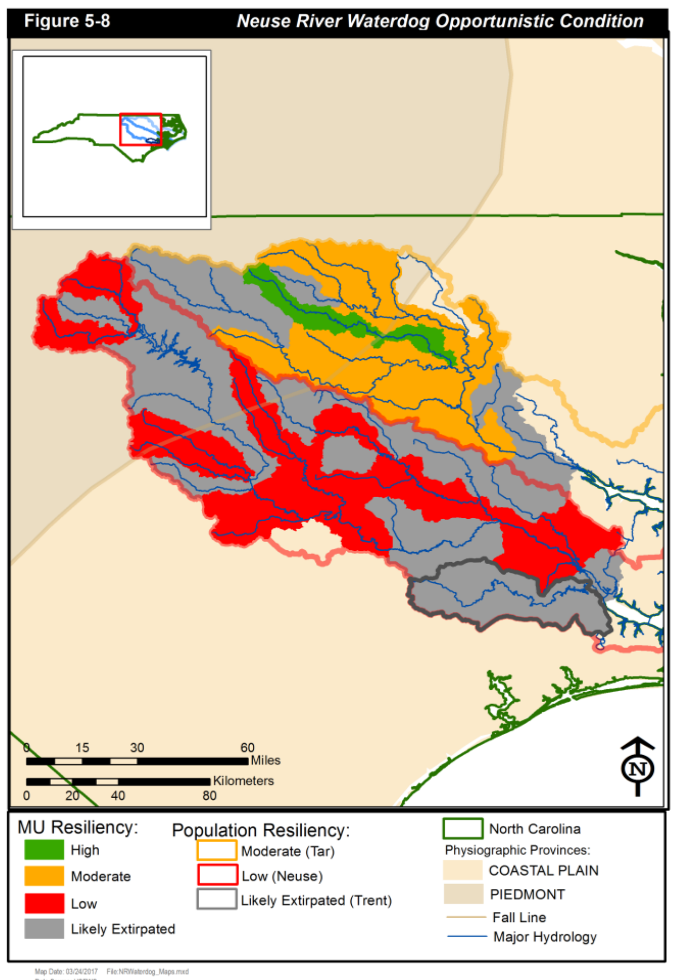
The Opportunistic Scenario projects the condition of the Neuse River Waterdog populations if the risks continue at moderately increased levels compared to what they are now. Under this scenario, the remaining extant populations occur in areas where habitat conditions support continued reproduction and survival of the species, at varying levels. Only the Sandy-Swift Creek MU is expected to have high resiliency under this scenario. The Middle Tar, Lower Tar, and Fishing Creek Subbasin MUs retain moderate resiliency, whereas all three Neuse MUs are predicted to have low resiliency. The Upper Tar MU and Trent MU/Population are expected to be extirpated. At the population level, only one population (Tar) retains moderate resiliency and one population (Neuse) retains low resiliency at the end of the predictive time horizon.

Table 5-5 Neuse River Waterdog Resiliency under Scenario 4 - Opportunistic

	Population Factors			Habitat Elements					
Population/ Management Unit	MU Occupancy	Site Occupancy	Combined Population Factors	Water Quality	Water Quantity	Connectivity	Instream Habitat (Substrate)	Combined Habitat Elements	Overall
Tar									**Moderate**
Upper Tar	Ø	Ø	Ø	Low	Low	Moderate	Moderate	Low	Ø
Middle Tar	Moderate	Moderate	Moderate	VLow	Moderate	Low	Low	Low	Moderate
Lower Tar	Moderate	Moderate	Moderate	Low	Moderate	Low	Low	Low	Moderate
Sandy-Swift	High	High	High	Moderate	Moderate	Moderate	Moderate	Moderate	High
Fishing Ck Subbasin	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Neuse									**Low**
Upper Neuse	Moderate	Low	Low	Moderate	Low	Moderate	Low	Low	Low
Middle Neuse	Low	Low	Low	VLow	VLow	Low	Low	Low	Low
Lower Neuse	Low	Low	Low	Low	Moderate	Low	Low	Low	Low
Trent									**Ø**
Trent	Ø	Ø	Ø	Moderate	Moderate	High	Low	Moderate	Ø

5.5.2 Representation

Under the Opportunistic Scenario, it is predicted that the Neuse River Waterdog will have reduced representation. The species will retain 67% of its known River Basin variability, remaining moderately resilient in the Tar River Basin. The species also retains limited resiliency Physiographic variability in the Coastal Plain (83%) and moderate variability in the Piedmont (56%). At the population level, one population (Tar) retains moderate condition representation (Figure 5-8).



5.5.3 Redundancy

Under the Opportunistic scenario, it is predicted that the Neuse River Waterdog will have reduced levels of redundancy, with likely extirpation in two of the nine MUs, persisting in low condition in all three MUs of the Neuse River Basin. Redundancy is reduced to 3 MUs within one population (Tar), thus making the species susceptible to catastrophic events.

CHAPTER 6 – STATUS ASSESSMENT SUMMARY

Current Viability Summary

The historical range of the Neuse River Waterdog included 3rd and 4th order streams and rivers in the Tar, Neuse, and Trent drainages, with documented historical distribution in 9 MUs within three populations. The Neuse River Waterdog is currently extant in all identified MUs, however within those MUs it is presumed extirpated from 35% (14) of the historically occupied HUCs. Of the nine occupied MUs, two (22%) are estimated to have high resiliency, two (22%) moderate resiliency, and five (56%) low resiliency. Scaling up from the MU to the population level, one of three populations (the Tar Population) is estimated to have moderate resiliency, and two (the Neuse and Trent population) are characterized by low resiliency. 60% of streams that were once part of the species' range are estimated to be in low condition or likely extirpated. The species is known to occupy streams in two physiographic regions, however it has lost physiographic representation with an estimated 43% loss in Piedmont watersheds and an estimated 13% loss in Coastal Plain watersheds.

Future Viability Summary

The goal of this assessment was to describe the viability of the Neuse River Waterdog in terms of resiliency, representation, and redundancy by using the best science available at the time of the analysis (the 3Rs). 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 Neuse River Waterdog. The results of the predictive analysis describe a range of possible conditions in terms of the number and distribution of Neuse River Waterdog populations (Table 6-1). While the future projections were made using a 50-year predictive time horizon, after the analysis the experts noted that that not all scenario outcomes have the same likelihood of occurrence at any one time step. To account for this, a discretized range of probabilities (Table 6-2) was used to describe the likelihood of scenario outcome at 10, 25, and 50 year time-steps (Table 6-3). (Note: the range of likelihoods in Table 6-2 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 6-1 Summary of Current and Future Scenario Outcomes

Populations: Management Units	Current	Future Scenarios of Population Conditions: #1 Status Quo	#2 Pessimistic	#3 Optimistic	#4 Opportunistic
Tar: Upper Tar	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated
Tar: Middle Tar	Moderate	Low	Low	High	Moderate
Tar: Lower Tar	High	Moderate	Low	High	Moderate
Tar: Sandy-Swift	High	Moderate	Low	High	High
Tar: Fishing Ck	Low	Low	Low	Moderate	Moderate
Neuse: Upper Neuse	Low	Likely Extirpated	Likely Extirpated	Low	Low
Neuse: Middle Neuse	Low	Low	Likely Extirpated	Low	Low
Neuse: Lower Neuse	Moderate	Low	Likely Extirpated	Low	Low
Trent	Very Low	Likely Extirpated	Likely Extirpated	Low	Likely Extirpated

Table 6-2 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 the outcome of this scenario will occur.
Likely	We are **70-90% sure** that the outcome of this scenario will occur.
As Likely As Not	We are **40-70% sure** that the outcome of this scenario will occur.
Unlikely	We are **10-40% sure** that the outcome of this scenario will occur.
Very unlikely	We are **less than 10% sure** that the outcome of this scenario will occur.

Table 6-3 Likelihood of Scenario Outcome at 10, 25, and 50 years

Likelihood of Scenario Outcome Occurring at:	#1 Status Quo	#2 Pessimistic	#3 Optimistic	#4 Opportunistic
10 Years	As Likely As Not	Unlikely	As Likely As Not	Likely
25 Years	Likely	As Likely As Not	Unlikely	As Likely As Not
50 Years	Likely	Likely	Unlikely	Unlikely

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 all currently extant Neuse River Waterdog populations would experience negative changes to these important habitat requisites. Predicted viability varied among scenarios and is summarized below and in Table 6-1.

Given Scenario 1, the "Status Quo" option, a loss of resiliency, representation, and redundancy is expected. Under this scenario, we predicted that no Management Units (MU) would remain in high condition, two in moderate condition, four in low condition, and three MUs would be likely extirpated. Redundancy would be reduced to four MUs in the Tar Population and two in the Neuse Population. Representation would also be reduced, primarily with reduced variability in the Piedmont and Coastal Plain. The scenario outcome is as likely as not at the 10 year time-step, and likely at both the 25 and 50 year time-steps (Tables 6-2 and 6-3).

Given Scenario 2, the "Pessimistic" option, we predicted substantial losses of resiliency, representation, and redundancy. Redundancy would be reduced to four MUs in one population, and the resiliency of that population is expected to be low. Several (5) MUs were predicted to be extirpated, and, of the remaining four MUs, all would be in low condition. All measures of representation are predicted to decline under this scenario, leaving remaining Neuse River Waterdog populations underrepresented in River Basin and Physiographic variability. The scenario outcome is unlikely at the 10 year time-step, as likely as not at the 25 year time-step, and likely at the 50 year time-step (Tables 6-2 and 6-3).

Given Scenario 3, the "Optimistic" option, we predicted slightly higher levels of resiliency, representation, and redundancy than was estimated under the Status Quo or Pessimistic options. Three MUs would be in high condition, one in moderate condition, and the remaining five would be in low condition. Despite predictions of population persistence in the Neuse and Trent River Basins, these populations are expected to retain low levels of resiliency. Existing levels of representation are predicted to decline under this scenario. This scenario is as likely as not at the 10 year time-step (Tables 6-2, 6-3), primarily because we will hopefully be able to hold the line in the Tar and Trent basins but expect continued decline in the Neuse. Over time it will be difficult to maintain the conditions predicted by the Optimistic Scenario, therefore the likelihood of scenario outcome is as unlikely at both the 25 and 50 year time-steps (Table 5-8, 5-9).

Given Scenario 4, the "Opportunistic" option, we predicted reduced levels of resiliency, representation, and redundancy. One MU would be in high condition, three would be in moderate condition, three in low condition, and two would be likely extirpated. Redundancy would be reduced with the loss of the Trent Population. Under the Opportunistic Scenario, representation is predicted to be reduced with 67% of formerly occupied river basins remaining occupied and with reduced variability in the Piedmont and Coastal Plain Physiographic Regions. The scenario outcome is likely at the 10 year time-step, as likely as not at the 25 year time-step, and unlikely at the 50 year time-step (Tables 6-2, 6-3).

Overall Summary

Estimates of current and future resiliency for Neuse River Waterdog are moderate to low, as are estimates for representation and redundancy. The Neuse River Waterdog faces a variety of risks from declines in water quality, loss of stream flow, riparian and instream fragmentation, and deterioration of instream habitats. These risks, which are expected to be exacerbated by urbanization and climate change, were important factors in our assessment of the future viability of the Neuse River Waterdog. Given losses of resiliency, populations become more vulnerable to extirpation, in turn, resulting in concurrent losses in representation and redundancy. Predictions of Neuse River Waterdog habitat conditions and population factors suggest possible extirpation in two of three currently extant populations. The one population predicted to remain extant (Tar) is expected to be characterized by low occupancy and abundance in the future.

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Appendix A – Data for Population Factors and Habitat Elements

Population/ Management Unit	# of Historically Occupied MUs	# of Currently Occupied MUs	# Historically Occupied HUC10s	# Currently Occupied HUC10s	% Decline	MU Occupancy Condition	# Historically Occupied Sites	# Currently Occupied Sites	% Decline	# Historically Surveyed Locations	# Current Surveyed Locations	% Historically Positive Site Occupancy	% Current Positive Site Occupancy	Change in % occupancy	Site Occupancy Condition	Current Condition - Population Factors
Tar	**5**	**5**	**17**	**14**	**18**	**M**	**54**	**37**	**31**	**192**	**77**	**28**	**48**	**20**	**M**	**M**
Upper Tar			3	1	67	VL	10	1	90	30	11	33	9	**-24**	VL	VL
Middle Tar			3	4	+33	H	12	10	17	45	16	27	63	**36**	M	M
Lower Tar			4	3	25	M	8	8	0	46	15	17	53	**36**	H	H
Sandy-Swift			2	2	0	H	6	8	+33	20	11	30	73	**43**	H	H
Fishing Ck Subbasin			5	4	20	M	18	10	44	51	24	35	42	**6**	L	L
Neuse	**3**	**3**	**20**	**14**	**30**	**L**	**45**	**27**	**40**	**149**	**87**	**30**	**31**	**1**	**L**	**L**
Upper Neuse			4	2	50	L	7	3	57	25	9	28	33	**5**	L	L
Middle Neuse			10	7	30	L	24	15	38	63	37	38	41	**2**	L	L
Lower Neuse			6	5	17	M	14	9	36	61	41	23	22	**-1**	M	M
Trent	**1**	**1**	**3**	**1**	**67**	**VL**	**8**	**4**	**50**	**23**	**16**	**35**	**25**	**-10**	**L**	**VL**

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 (NC layer)	# of Dams (NID)	# of Barriers in Top 20% NACP/CFPP /SEACAP Ranking	Actual # of Road Crossings	Average # of Road Crossings	Overall Connectivity Condition	Avg ARA % Forest	Avg Watershed % Imp Surface	Overall Instream Habitat (Substrate) Condition - combine ARA Forest + Watershed Impervious Surface	Current Habitat Condition
Tar						**M**			**M**						**M**			**M**	**M**
Upper Tar	1228	474	8	2	51	M	Y - dry channels	2007, 2008, 2009, 2010	L	67	20	51	879	293	M	64	1.3	H	M
Middle Tar	1447	559	36	2	90	M	none	2007, 2008, 2009, 2010	M	81	36	53	144	286	M	39	2.7	M	M
Lower Tar	2487	960	29	3	99	M	none	2007, 2008, 2009, 2010	M	27	20	14	2028	338	M	20	2.2	L	M
Sandy Swift Ck	705	272	5	0	21	H	Y - windthrow blockages	2007, 2008, 2009, 2010	L	31	25	22	431	216	M	44	1.3	M	M
Fishing Ck Subbasin	1855	716	14	1	33	M	Y - beavers	2007, 2008, 2009, 2010	M	25	16	20	801	160	M	51	0.5	M	M
Neuse						**L**			**L**						**L**			**L**	**L**
Upper Neuse	1998	771	55	3	640	L	none	2007, 2008, 2009, 2010	M	143	99	99	2150	430	L	59	4.2	M	M
Middle Neuse	4714	1820	273	12	443	L	Y	2007, 2008, 2009, 2010	L	418	285	302	6594	550	L	31	5.6	L	L
Lower Neuse	4835	1867	55	9	195	L	none	2007, 2008, 2009, 2010	M	47	33	41	3895	325	L	19	1.8	L	L
Trent						**H**			**M**						**H**			**L**	**M**
Trent	1402	541	18	0	12	H	none	2007, 2008, 2009, 2010	M	8	6	5	690	230	H	19	1	L	M