Recovery Plan
for the Neuse River Waterdog (*Necturus lewisi*)

Photo by Melissa McGaw, NC Wildlife Resources Commission

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For:
Southeast Region
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Atlanta, Georgia
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Regional Director, US Fish and Wildlife Service

PURPOSE AND DISCLAIMER

This document presents the U.S. Fish and Wildlife Service's (Service) plan for the conservation of the Neuse River waterdog. The recovery plan is the second part of the Service's 3-part recovery planning framework including the statutorily required elements pursuant to section 4(f) of the Endangered Species Act (Act). This recovery plan is informed by the first part of the framework, a Species Status Assessment (SSA) that delivers foundational science for informing decisions related to the Act and includes an analysis of the best available scientific and commercial information regarding a species' life history, biology, and current and future conditions that characterizes the species' viability (i.e., ability to sustain populations in the wild over time) and extinction risk. Complimenting the recovery plan, we have also prepared a separate Recovery Implementation Strategy (RIS) the third part of the framework. The RIS is an easily updateable operational plan that describes the on-the-ground recovery activities needed to complete the recovery actions contained in the recovery plan.

Recovery plans describe the envisioned recovered state when a listed species should no longer meet the Act's definitions of a threatened species or endangered species and include a recovery strategy, recovery criteria, recovery actions, and the estimates of time and cost needed to achieve it. Plans are published by the Service and are often prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in plan formulation, other than the Service. They represent the official position of the Service only after they have been approved and signed by the Regional Director. Recovery plans are guiding and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and completion of recovery actions.

ACKNOWLEDGMENTS

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Recommended Citation and Electronic Availability

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INTRODUCTION

This Recovery Plan describes criteria for determining when the Neuse River waterdog (*Necturus lewisi*) should be considered for removal from the List of Endangered and Threatened Wildlife (50 CFR 17.11). It also lists specific actions that will be necessary to meet those criteria and estimates the time and costs for implementing recovery actions. A RIS has been developed as an operational document that details specific activities for implementing the recovery plan actions. Brief descriptions of the species' status, habitat requirements, and limiting factors are included. A detailed discussion of these and other topics pertinent to the recovery of the Neuse River waterdog can be found in the SSA (Service 2021). The RIS and SSA are finalized separately from the Recovery Plan, and they will be updated routinely.

Species Status

The Neuse River waterdog is a large, aquatic salamander that was listed as threatened on July 9, 2021 (86 FR 30688). The Service also designated 779 river miles (1,254 river km) of critical habitat across its range (Figure 1). It is assigned a recovery priority number of 11C, reflecting a moderate degree of threat, low recovery potential, and the potential for conflict with construction or development projects, or other forms of economic activity within its range. The degree of threat is moderate because the species is not facing immediate extinction, but populations have declined and threats to its habitat are ongoing. For recovery potential, biological and ecological limiting factors of the Neuse River waterdog and its threats are fairly well understood. However, because threats to the species and habitat are pervasive and difficult to alleviate (i.e., watershed-level effects that degrade habitat and water quality), its recovery potential is considered low without strategic management of stressors.

The Neuse River waterdog is endemic to medium to large streams and rivers in the Neuse and Tar-Pamlico River basins across the Piedmont and Coastal Plain physiographic regions of North Carolina (Figure 1). The 2021 SSA and the listing rule recognized documented historical occurrences spanning 40 HUC-10 watersheds (i.e., 10-digit hydrologic units) of the Neuse and Tar-Pamlico basins (Service 2021). However, additional occurrences (1919-1980) beyond those incorporated into the first SSA and listing rule indicate that the species' historical range included 43 HUC-10 watersheds (Teitsworth 2024, pers. comm.; NC NHP 2025). An analysis of the species' status conducted in 2017 delineated three extant populations – the Tar River population, Neuse River population, and the Trent River population, which is part of the greater Neuse drainage and separated from the freshwater Neuse River mainstem by brackish estuarine waters. The SSA estimated that the Tar-Pamlico River population had moderate resiliency as evidenced by site-specific and subpopulation occupancy trends over time and by habitat conditions (Service 2021). Moderate resiliency corresponded to a 30 – 50% presumed likelihood of persistence over three generations for the species (i.e., 30 – 45 years). Occupancy trends and habitat conditions

for the Neuse and Trent River populations indicated they had low resiliency (i.e., a 10 – 30% presumed probability of persistence over three generations; Service 2021). Overall, the results of the 2021 SSA indicated that the Neuse River waterdog has declined in abundance and distribution and many of the remaining populations are fragmented, leaving the species with low to moderate resiliency, limited redundancy in an already restricted endemic range, and with low to moderate adaptive potential.

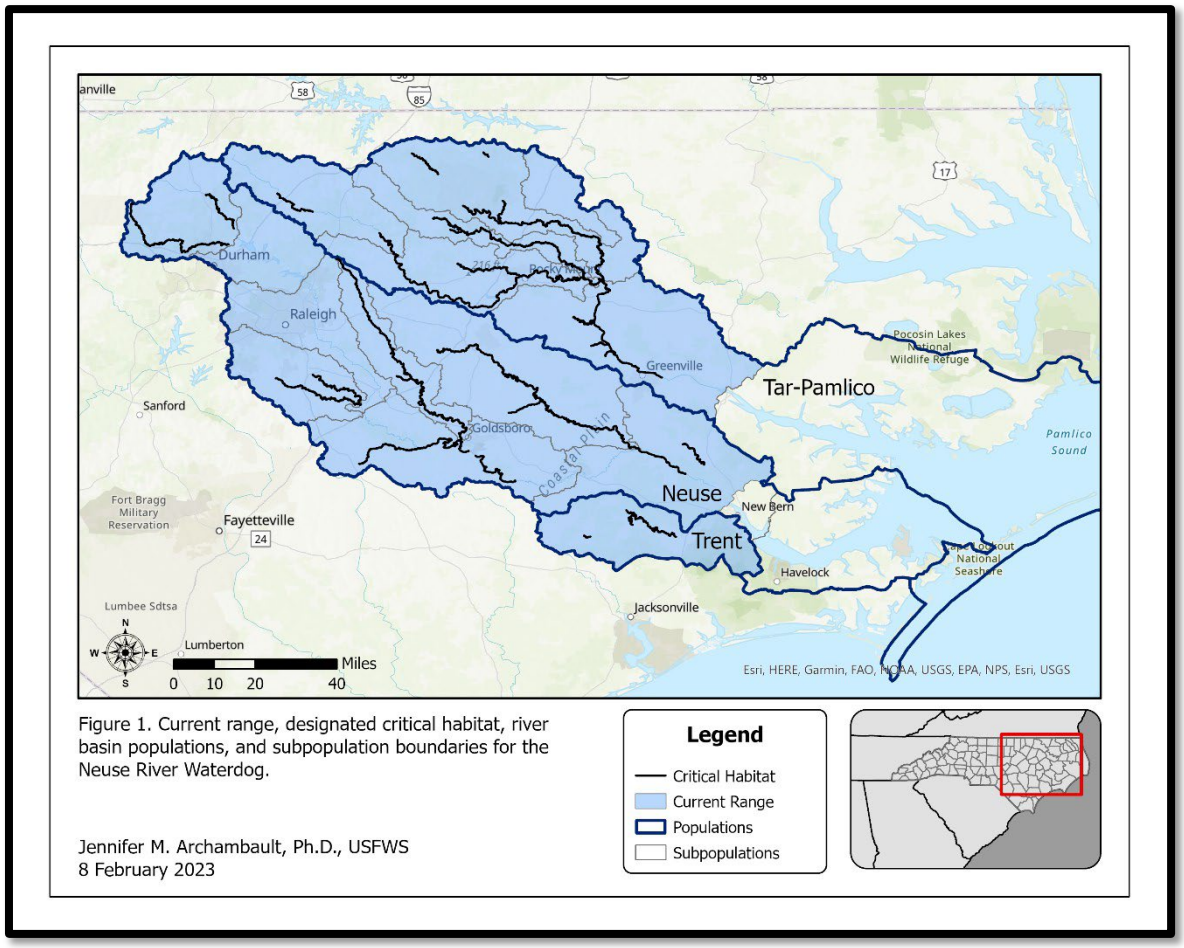

Figure 1. Current range, designated critical habitat, river basin populations, and subpopulations boundaries for the Neuse River waterdog

Recent extensive survey and research efforts since the SSA analysis and final listing have led to the documentation of Neuse River waterdogs in some locations where they were thought to be extirpated. These data show that the species is present in 42 HUC-10s, as evidenced by recent documented occurrences from 2004 to 2025 (Figure 2). Of these recent records, 360 of 517 have been added since 2018, after the SSA analysis was completed (NC NHP 2025). Subpopulation boundaries in the Neuse River population have been updated here to accurately reflect monitoring and management of the species and watershed connections (e.g., separated those above and below a major reservoir). Subpopulations are delineated as groups of HUC-10

watersheds, and the Neuse River waterdog has 13 extant subpopulations, as delineated in Figure 2. One updated HUC-10 and subpopulation occurrence is represented by two individuals found since 2021 within a two-mile portion of Crabtree Creek, a highly urbanized stream in Raleigh, NC. It is unclear whether these individuals indicate a larger presence of the species or if they are a remnant of historical populations. Adequate threat abatement is unlikely within the metropolitan landscape of that watershed.

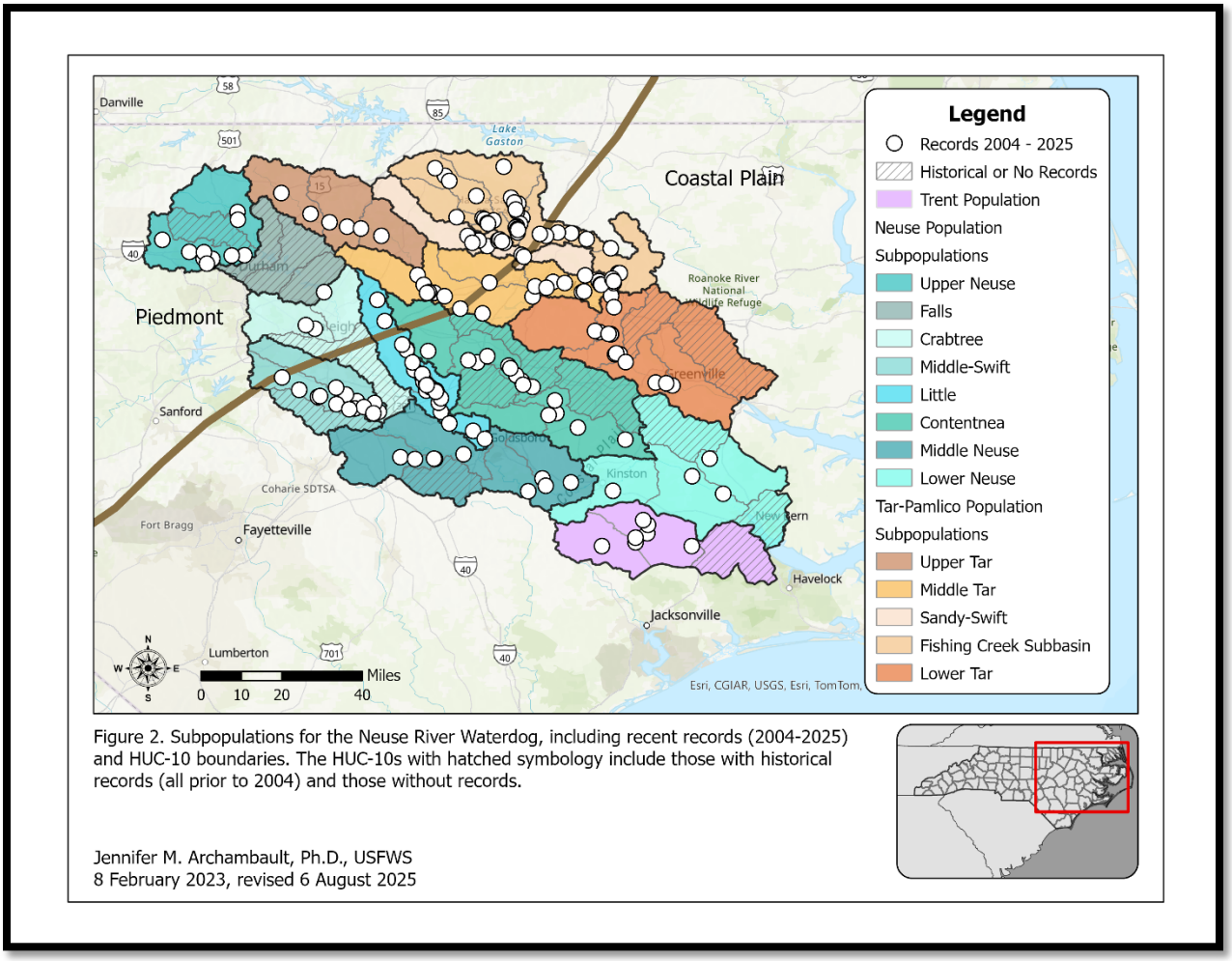

Figure 2. Subpopulations for the Neuse River Waterdog, including recent records (2004-2025) and HUC-10 boundaries. The HUC-10s with hatched symbology include those with historical records (all prior to 2004) and those without records.

Habitat Requirements and Limiting Factors

The Neuse River waterdog occurs in streams ranging from larger headwaters in the Piedmont downstream to coastal rivers, to the point of saltwater influence. This species needs clean, flowing water characterized by high dissolved oxygen concentrations. Their preferred habitats

vary with season, temperature, dissolved oxygen content, flow rate, and precipitation; however, Neuse River waterdogs maintain home retreat areas under rocks, in burrows, or under substantial cover (e.g., leaf litter) in backwater or eddy areas over hard clay, gravel, cobble, or coarse sand (Braswell and Ashton 1985). They breed once per year in late autumn and winter. Females then deposit approximately 25 – 50 fertilized eggs in spring, typically under large rocks over gravel or hard clay, where either parent can guard the rudimentary nest (NCWRC 2020). In coastal rivers where rocky habitat is limited, they nest under available cover, such as logs or holes in banks. Neuse River waterdogs eat aquatic and terrestrial invertebrates (e.g., insect larvae, small crustaceans, spiders, snails, and worms) and some vertebrates (e.g., small fishes). Juveniles and adults also rely on clean leaf litter (i.e., largely free of fine sediments) as foraging habitat.

Several specific habitat requirements of Neuse River waterdogs limit their persistence in degraded habitats. They need free flowing, highly oxygenated waters; they are not known to occur in lakes, ponds, or impounded waters, and they are unable to persist in intermittently flowing streams that regularly run dry or in perennial stream reaches dried by extended droughts (86 FR 30688). Like most amphibians, Neuse River waterdogs have permeable skin, likely making them vulnerable to pollution and other factors that degrade water quality. They also are sensitive to turbidity and sedimentation, needing uncompacted stream bed and foraging habitats (i.e., minimal fine sediments) that can support prey species. This species also needs appropriate protective cover (boulders, woody debris) that is unembedded, leaving open space underneath as a retreat area, and that is predominantly silt-free to facilitate attachment of eggs to the cover. The egg and larval life stages are particularly vulnerable to these and other stressors (e.g., predation). Finally, the slow growth, delayed reproductive maturity of Neuse River waterdogs further limits their ability to adapt to rapidly changing habitat conditions or respond to punctuated or long-term impacts to populations.

In addition to the habitat requirements described above, the final rule designating critical habitat for the Neuse River waterdog described the following physical or biological features as essential to the species' conservation (86 FR 30688):

1. Suitable substrates and connected instream habitats, characterized by geomorphically stable stream channels and banks (i.e., channels that maintain lateral dimensions, longitudinal profiles, and sinuosity patterns over time without an aggrading or degrading bed elevation) with habitats that support a diversity of native aquatic fauna (such as stable riffle-run-pool habitats that provide flow refuges consisting of silt-free gravel, small cobble, coarse sand, and leaf litter substrates) as well as abundant cover and burrows used for nesting.
2. Adequate flows, or a hydrologic flow regime (which includes the severity, frequency, duration, and seasonality of discharge over time), necessary to maintain instream habitats where the species is found and to maintain connectivity of streams with the floodplain, allowing the exchange of nutrients and sediment for maintenance of the waterdog's habitat, food availability, and ample oxygenated flow for spawning and nesting habitat.
3. Water quality (including, but not limited to, conductivity, hardness, turbidity,

temperature, pH, ammonia, heavy metals, and chemical constituents) necessary to sustain natural physiological processes for normal behavior, growth, and viability of all life stages.

4. Invertebrate and fish prey items, which are typically hellgrammites, crayfish, mayflies, earthworms, snails, beetles, centipedes, slugs, and small fish.

At the time of listing, the primary threats to the future viability of the Neuse River waterdog (i.e., the ability to sustain populations in the wild over time) were associated with the destruction, modification, or curtailment of its habitat or range, and these were expected to be exacerbated by continued urbanization and environmental change (86 FR 30688). Habitat degradation has resulted from the cumulative impacts of land uses, land use changes and associated watershed-level effects on water quality, stream flow, habitat connectivity, and instream habitat quality. Urbanization in North Carolina's Piedmont region contributes to watershed-level effects on water quality that are likely important stressors to aquatic species, including the Neuse River waterdog; these include municipal effluent outfalls and nonpoint source runoff from impervious surfaces that carry excess nutrients and chemical pollutants. Neuse River waterdog populations have experienced decline over time or localized extirpation and fragmentation in river reaches influenced by treated wastewater effluent discharges (Service 2021). Other intensive land uses and the environmental change also contribute to degraded habitat and water quality. A variety of land uses contribute to sedimentation, resulting in impacts to in embeddedness of stream substrates and loss of habitat in interstitial spaces (i.e., within the stream bed). Sedimentation also may have direct effects on Neuse River waterdogs, such as smothering eggs, clogging their external gills, hindering reproduction, and reducing insect prey. Further, sedimentation can reduce abundance of aquatic salamanders and have synergistic effects on populations when combined with other stressors (e.g., predators; Lowe et al. 2004; Moseley et al. 2008). Dams create impounded waters, which are unsuitable for this species. Biologists have noted that Neuse River waterdogs are no longer found in previously occupied streams after being impounded, whether by human construction or beavers (Service 2021). Dams and other functional barriers (e.g., perched culverts) also impede movement and dispersal, resulting in reduced opportunities for genetic exchange and loss of access to habitats.

Invasive species were cited as another threat to the Neuse River waterdog, including the red swamp crayfish (*Procambarus clarkii*), flathead catfish (*Pylodictis olivaris*), and hydrilla (*Hydrilla verticillata*). The red swamp crayfish is a commercially important species native to the southern Mississippi River drainage that has become established in many US drainages through escape or release from bait buckets, aquarium trade, or aquaculture facilities. Several studies have documented that red swamp crayfish compete with other species and feed on amphibian and fish eggs (Nagy et al. 2022). Flathead catfish (also native to the Mississippi River basin) and some other ictalurid species (e.g., blue catfish (*Ictalurus furcatus*)) are invasive in several Atlantic Slope rivers, including documented occurrences in many of the drainages where the Neuse River waterdog occurs (Fuller et al. 2022; Fuller and Neilson 2022). They are voracious predators that affect benthic fish communities and potentially affect the Neuse River waterdog. Biologists have noted reductions in abundance or the disappearance of Neuse River waterdogs from sites where red swamp crayfish and flathead catfish have invaded (86 FR 30688). Hydrilla

is an aquatic invasive plant native to Asia. It has become established across much of the eastern and southern US, including documented occurrences in some of the drainages where the Neuse River waterdog occurs (e.g., Eno River, Contentnea Creek, and lakes and ponds in the Upper Tar watershed that drain to designated critical habitats; Jacono et al. 2022). Hydrilla can affect stream habitat by altering water quality parameters (e.g., dissolved oxygen) and slowing water flow, which promotes increased sediment deposition. Although effects of these species on the Neuse River waterdog have not been quantified, evidence suggests they are problematic for native aquatic species.

The Neuse River waterdog's remaining small and fragmented populations further increase its vulnerability to ongoing stressors and stochastic or catastrophic events (Service 2021). Data on estimates of population size, recruitment, and other factors are currently lacking, and will be essential for more precisely assessing the species' status and recovery progress over time.

Recovery Strategy

The recovery vision for the Neuse River waterdog is for the species to persist in North Carolina, in multiple subpopulations with adequate abundance and recruitment supported by good water quality, clean stable instream habitats, and biodiverse riverine communities. This vision will be attainable with improved abundance within subpopulations, and with threats reduced sufficiently to allow for the species to achieve and maintain resilient, self-sustaining populations. The Neuse River waterdog also will need appropriate redundancy within and among populations to ensure that the species can withstand the effects of stochastic and catastrophic events. Successful threat abatement includes measures that improve instream physical habitat and water quality, and that reduce the impacts of stressors related to habitat degradation, habitat fragmentation, invasive species, and environmental change to the extent that biological recovery and persistence is realized.

The overall recovery strategy is to increase the resilience of Neuse River waterdog populations throughout its historical range, and to alleviate threats and protect or restore habitat such that these efforts will be successful. Riverine species are largely reliant on common public waters subjected to many inputs mediated by human activity and natural events. Thus, we expect the recovery of the Neuse River waterdog to require long-term human intervention to alleviate threats, strengthen the resiliency of existing populations, and potentially re-establish some historical populations. Planning and implementation of conservation activities to recover the Neuse River waterdog would benefit from a broader effort to conserve the native aquatic fauna in Atlantic Slope drainages. These efforts will require close coordination with partners and stakeholders, and the engagement and dedication of those parties to efficiently and effectively recover the Neuse River waterdog. Adjusting recovery activities through adaptive management will be a necessary response to new information about the species' needs, identification of new threats, or in response to changing habitat conditions.

Improving knowledge of the species' response to threats will be critical for assessing recovery. Monitoring site-specific population metrics (e.g., abundance, evidence of recruitment, age class

structure) and their trends over time is essential for accurately estimating resilience. Current estimates of resilience are based primarily on occupancy alone because such metrics were not available (Service 2021). Researching the Neuse River waterdog's genetics within and among populations will provide clarity on species representation and gene flow, which will guide management efforts (e.g., prioritization of barriers for removal or remediation; suitability for translocation or captive propagation). Exploring the feasibility of captive propagation to support recovery may be most timely soon after gaining insights on the species' current population genetics when managers can leverage existing genetic diversity.

Improving knowledge of the ecological needs of aquatic salamanders, including Neuse River waterdog, with a focus on their responses to threats, will be essential for guiding implementation of specific recovery activities. This will be achieved through routine monitoring of existing populations, researching habitat and water quality needs in relation to threats, and monitoring the outcomes of efforts to improve resiliency and redundancy. Data on the needs of associate species and other aquatic salamanders also may be informative for management and recovery of the Neuse River waterdog.

Much of the land within watersheds currently or historically occupied by the Neuse River waterdog is in private ownership. Reducing threats to populations is essential to increasing resiliency, and land acquisition, in some cases, will be an effective tool for removing threats caused by land uses that contribute to sedimentation, nutrient enrichment, stream bank instability, and other instream habitat degradation. The Service will support land acquisition and other land protection measures (e.g., conservation easements), along with community-based watershed stewardship planning and actions that benefit the species.

Reducing threats posed by habitat degradation, habitat fragmentation, and poor water quality will require a watershed-level approach involving cooperative management and engagement with local, state, and federal agencies, landowners, municipalities, and other stakeholder groups. The Service will work cooperatively with others to protect, enhance, and restore habitat integrity and water quality of stream reaches that currently support or could support the species. The Service will work with the US Environmental Protection Agency and state agencies to develop, update, or implement water quality standards and classifications that are protective of waterdogs and their habitats. The Service will actively participate in existing federal regulatory processes to avoid, minimize, and mitigate the loss and degradation of Neuse River waterdog habitat. Improving water quality and instream habitat may improve connectivity among populations isolated by these factors. The Service will further encourage the removal or remediation of physical barriers where such actions would benefit this and other species. We also will continue to engage local government decision-makers on voluntary conservation efforts for the species.

Addressing other natural and human-mediated threats will be important for improving the overall recovery potential of the Neuse River waterdog. The Service will support actions that improve knowledge about the effects of invasive species and measures that address such effects. We will also work with partners to assess the species' vulnerability to environmental change and incorporate new information into management activities to improve recovery potential. Finally,

we will work with all partners to continually assess habitat and threats to determine the recovery potential and progress.

RECOVERY CRITERIA

The goal of this Recovery Plan is to ensure the long-term viability of the Neuse River waterdog in the wild to the point that it can be removed from the Federal List of Endangered and Threatened Wildlife (50 CFR 17.11). Therefore, this Recovery Plan establishes delisting criteria for the species based on the best available information from the SSA analysis (Service 2021) and final listing rule (86 FR 30688). Criteria will be reevaluated as new information becomes available. Recovery criteria are objective, measurable conditions that, when met, indicate that a species may warrant delisting. The Neuse River waterdog will be considered for delisting when the following conditions are met:

1. Populations remain extant and persistent in the three (3) historically occupied major drainage basins (i.e., Tar-Pamlico, Neuse, and Trent; Figures 1 – 3), as evidenced by stable or increasing abundance, with sufficient numbers to support ongoing natural recruitment and multiple age classes (e.g., juveniles, eggs, or recently hatched nests in addition to adults), observed and recorded over a 20-year period.
2. At least 12 extant subpopulations are maintained, and resilience is improved as needed to support persistence across the species' range, while maintaining redundancy in at least two (2) of the three (3) occupied basins, and representation in the two (2) historically occupied physiographic provinces of the Coastal Plain and Piedmont (Figures 2 and 3).
3. Threats identified in the 2021 listing rule (86 FR 30688) and since then have been addressed and managed to the extent that habitat factors (i.e., instream habitat, water quality, water quantity, and connectivity) between and among populations are maintained at levels meeting life history requirements of the species (i.e., conditions support achievement and maintenance of Criteria 1 and 2 above). Additionally, invasive species and other identified or emergent threats occur at sufficiently low levels such that achievement Criteria 1 and 2 are supported. Finally, there is reasonable assurance of mechanisms to prevent a resurgence of existing threats or emergence of foreseeable threats to the species and its habitat.
   Examples of addressing and measuring current and foreseeable threats to the Neuse River waterdog include:
   a. Habitat degradation: regulatory mechanisms that protect water quality and govern sediment and erosion control are enforced; regulatory thresholds for water quality that are protective of aquatic life are enacted and enforced; water quality classifications are changed to prevent future impacts to designated critical habitat; instream flows (e.g., water extraction; dam releases) in designated critical habitats are managed according to conditions that are well suited for Neuse River waterdog survival and recruitment; relevant best management practices, such as for those sediment and erosion control, stormwater control, and riparian habitat protection are widely adopted.

b. Habitat fragmentation: barriers to population connectivity are removed or ameliorated such that movement and gene flow are restored or maintained (e.g., dam or culvert removal, beaver control, aquatic life passage measures, and proper culvert installation, replacement, or maintenance).
c. Invasive species: plans are developed and implemented to monitor and control invasive species in locations where they impede Neuse River waterdog recovery (e.g., predation or competition by invasive fish and crayfish species; habitat alteration by hydrilla).
d. Environmental and land use changes: sufficient data, data collection tools, and predictive models are in place to allow for accurate forecasting of future conditions related to Neuse River waterdog persistence; robust predictive models and appropriate actions are incorporated into regulatory mechanisms and Neuse River waterdog management; occupied habitats that are most vulnerable to future urbanization or land use impacts are identified and protected; habitats with the greatest resilience are identified and incorporated into management.

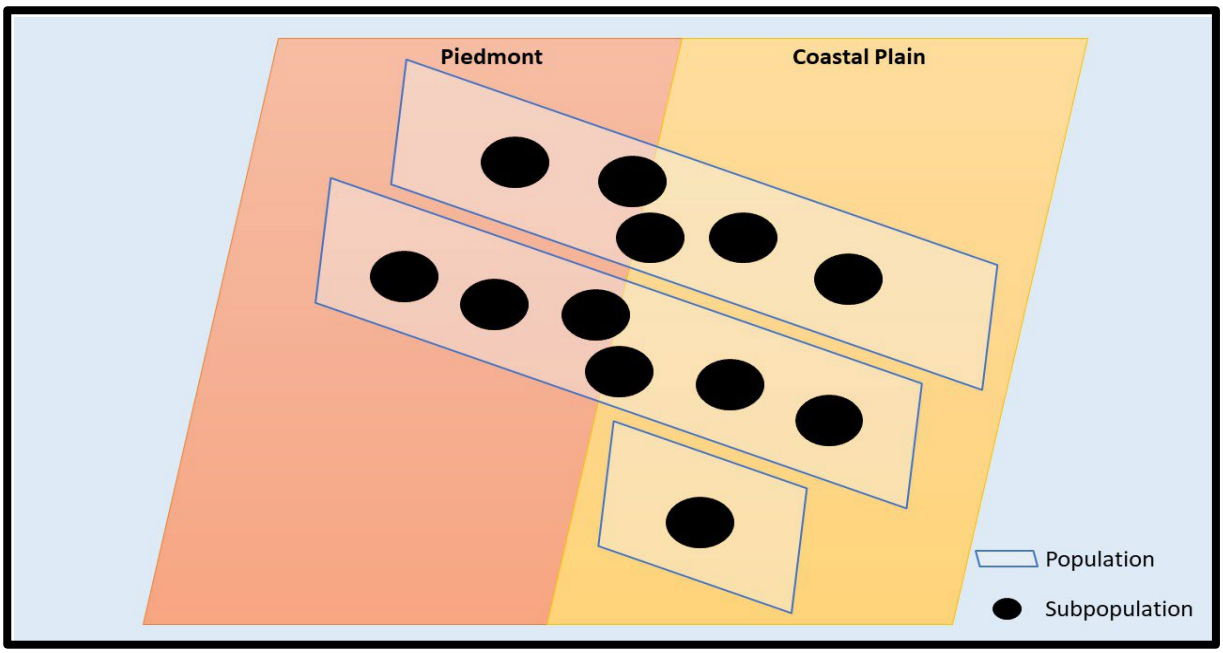

Figure 3. Conceptual diagram depicting biological recovery of the Neuse River waterdog, including persistent populations in the 3 historically occupied river basins (Criterion 1), while maintaining at least 12 extant subpopulations, including redundancy in at least 2 of the 3 occupied basins, and representation of subpopulations in the Piedmont and Coastal Plain physiographic regions across the species' range (Criterion 2). The diagram accurately depicts that some subpopulations are in watersheds that span both physiographic regions in the Tar-Pamlico and Neuse basins, and that the Trent River population is geographically restricted to the

Coastal Plain and is defined as a single subpopulation of the species.

Justification for Recovery Criteria

As described in section 4(a)(1) of the Endangered Species Act (Act), the Service may list a species based on any of the following five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; (E) other natural or human-made factors affecting its continued existence. The recovery criteria reflect the best available information on the Neuse River waterdog. They address the five factors in the Act, including those identified in the final listing rule for the Neuse River waterdog (86 FR 30688), and they incorporate the conservation principles of representation, resiliency, and redundancy (Shaffer and Stein 2000; Wolf et al. 2015) (Figure 3).

The 2021 SSA and listing rule (86 FR 30688) emphasized that the Neuse River waterdog is threatened because of reduced occupancy in several watersheds throughout its range, low resiliency in some remaining subpopulations, and reduced representation in both physiographic regions, with a pronounced loss of representation in the Piedmont (about 43%). At the time of listing, the Neuse River waterdog was extant in the three river drainages it historically occupied. However, only two subpopulations were estimated to have high resiliency, and they were restricted to the Tar-Pamlico River basin (Service 2021). These factors render the species vulnerable to further reduced representation and extirpation from portions of its current range.

Attainment and maintenance of resiliency through increased abundance and reproduction is essential for self-sustaining populations to persist over time. Criteria 1 and 2 address Factors A and E; they ensure prolonged resiliency with stable or increasing abundance, age class, and recruitment metrics measured over time. Information about the life span, age at maturity, and other basic life history factors (e.g., home range) of the Neuse River waterdog are poorly understood. The species takes about six years to reach reproductive maturity; thus, 20 years should account for about three age classes. Observing and recording evidence of natural reproduction, multiple age classes, and sufficient abundance, with stable or increasing trends to support those functions over a 20-year period, should provide reasonable assurance that multiple cohorts have contributed to the genetic diversity and adaptive capacity of the species. That time frame also should provide information about the species' resilience to stochastic or catastrophic events (e.g., drought, flooding) that may occur within its range during the monitoring period.

Criteria 1 and 2 also maintain the three current populations (i.e., occupied major river drainages). Ensuring that at least two basins (i.e., the Tar-Pamlico and Neuse) maintain subpopulation redundancy reduces the Neuse River waterdog's vulnerability to extirpation within basins and rangewide and increases the probability that the species could persist without the protection of the Act. The Trent River drainage is comparatively small and geographically restricted to the Coastal Plain; it is defined as a single subpopulation of the species and therefore does not have within-basin redundancy. However, it provides representation and redundancy to the species

overall. Designated critical habitat units span 12 subpopulation boundaries (Figure 1), further justifying this number of subpopulations, as defined in Criterion 2. The spatial location of multiple resilient subpopulations across physiographic regions maintains or enhances the Neuse River waterdog's representation by recovering and preserving behavioral, genetic, or physiological variability (i.e., adaptive capacity).

Criterion 3 addresses Factors A, C, D, and E. Threats to the Neuse River waterdog are complex, widespread, and pervasive, and they differ in their combination and severity throughout the species' range. Therefore, this criterion is less prescriptive, and it suggests a variety of options for objectively measuring aspects of the broad categories listed (i.e., habitat degradation and fragmentation, invasive species, and environmental changes). These categories are not mutually exclusive (e.g., land use changes or invasive species may contribute to habitat degradation); however, each is essential to address for successful recovery. Although Factor B (overutilization) was not implicated in the SSA or listing rule as a current threat, it should be evaluated using any new information during 5-year status reviews, in accordance with the Act, because amphibian and reptile species are vulnerable to harassment by enthusiasts and the changing interests of aquarium and other animal trades.

Habitat degradation was identified as the most important stressor (86 FR 30688), and management or abatement of threats associated with habitat degradation must be achieved for recovery. Sedimentation, impaired water quality, and barriers to movement are factors that have contributed to the decline of the Neuse River waterdog and threaten the future viability of the species (Service 2021). Criteria 3a and 3b identify several strategies for reducing these threats, improving the effectiveness of regulatory mechanisms, and measuring progress in their contributions toward recovery of the Neuse River waterdog.

Criterion 3c addresses invasive species that currently threaten the Neuse River waterdog or have the potential to affect its future viability via potential mechanisms of habitat degradation, competition, or predation (Service 2021). Invasive species contributions to the decline of the Neuse River waterdog are poorly understood and merit further investigation; control and monitoring of invasive species in Neuse River waterdog habitats will improve knowledge about their effects and ensure that they are properly accounted for in recovery efforts.

Criterion 3d addresses environmental and land use changes that affect habitat factors like water quantity, water quality, and instream habitat at watershed or landscape scales. Appropriate data collection, modeling, and monitoring of these large-scale factors will ensure that recovery actions are strategically implemented over time and space within in the species' range.

ACTIONS NEEDED

The following recovery actions are those we believe are necessary to recover the Neuse River waterdog, based on the best available data.

Recovery Action	Estimated Cost[1]	Priority[2]
1. Develop and implement a long-term population and habitat monitoring program and consistently monitor the status of populations.	$7,500,000	1
2. Maintain, enhance, and restore habitat by using voluntary conservation practices, removal of barriers, and land acquisition/conservation easements in watersheds that support Neuse River waterdog to protect extant populations and reduce threats throughout the species' range.	$70,000,000	1
3. Identify and evaluate the magnitude of existing stressors and sources of threats throughout the species range (e.g., sedimentation, industrial effluents, nonpoint source pollution, invasive species, barriers, and environmental/land use factors), and manage for their abatement.	$7,000,000	1
4. Investigate rangewide genetics, prioritizing topics that inform monitoring, management, and population restoration efforts.	$240,000	1
5. Increase knowledge of species' response to threats (e.g., habitat degradation factors, invasive species, climate, and land uses), and apply relevant knowledge from other taxa, as appropriate (e.g., congeners, Proteidae, associate species, or other larval/aquatic salamanders).	$850,000	1
6. Evaluate the relative merit and feasibility of captive propagation and translocation for population augmentation or reintroduction to improve resiliency, redundancy, and representation.	$1,000,000	2
7. Develop and adopt a rangewide species distribution model, updating it periodically as needed to inform species restoration efforts, recovery actions, and conservation planning assistance work.	$30,000	2

Recovery Action	Estimated Cost[1]	Priority[2]
8. Coordinate with local, state, and federal entities to promote Neuse River waterdog recovery, including: using existing agency programs to minimize, mitigate, or remove threats; developing methods to incentivize conservation; and increasing public awareness of the need to protect the species and its habitats.	$150,000	2
9. Implement protective water quality standards, classifications, and protections in waters within the species' range to address ongoing threats from a variety of land use practices.	$85,000	2
10. Search for undocumented occurrences within the species' current and historical range.	$200,000	3
Total Estimated Cost:	**$87,055,000**	

[1] Costs covered under existing programs are not included in this table.

[2] Recovery actions are assigned numerical priorities to highlight the relative contribution they may make toward species recovery (48 FR 43098):

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2 – An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3 – All other actions necessary to provide for full recovery of the species.

ESTIMATED COST OF DELISTING

The estimated cost of implementing recovery actions will total approximately $87,055,000 over 40 years (Table 1). Some costs are not determinable at this time, and therefore the total cost may be higher than this estimate. Some costs relate to habitat conservation that benefits multiple species and enhances ecosystem services to people (e.g., drinking water protection, open space for recreation); as such, some of these actions and their associated costs may be implemented aside from this plan.

DATE OF RECOVERY

If all actions are fully funded and implemented as outlined, including full cooperation of all partners needed to achieve recovery, we anticipate that recovery criteria for delisting could be met by 2065. However, because some factors about the Neuse River waterdog's life history remain unknown (e.g., life span, home range) and how they are influenced by environmental variables, (e.g., pervasive stressors), the actual time to achieve recovery may differ. A projected recovery period of 40 years accounts for the long-term efforts necessary to ameliorate large-scale

threats, and it accounts for at least 20 years of observing biological factors as evidence of recovery. A 20-year period of stable or increasing populations that demonstrate biological resilience, including natural recruitment and multiple age classes, should allow time for multiple cohorts to contribute to population growth. The Service will carefully monitor and assess progress toward recovery as we learn more about this species' biology and threats, and as recovery actions are funded and implemented.

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