Northeast Regional Species of Greatest Conservation Need (RSGCN) Key Limiting Factor Themes

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This summary report provides the results of the most recent review of limiting factors responsible for RSGCN population declines. A comprehensive review of species included on the RSGCN list is planned for 2021-2022.

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Background

The RSGCN list is maintained by the Northeast Association of Fish and Wildlife Agencies' (NEAFWA) Northeast Fish & Wildlife Diversity Technical Committee (NEFWDTC). The purpose of this non-regulatory regional list is to provide focus, resources, and collaboration to secure species (and their habitats) of mutual conservation concern for current and future generations in the northeast. The list includes vertebrate and invertebrate Species of Greatest Conservation Need (SGCN) from State Wildlife Action Plans (SWAPs) in the NEAFWA planning geography (Maine to Virginia, including D.C.). Northeast RSGCN are species for which the region has stewardship responsibility due to high conservation concern and/or populations that are centered in the Northeast Region. The list is updated every five years to support focused action on high priority northeast species by the NEFWDTC, development of SWAPS, and conservation planning and implementation by state fish and wildlife agencies and their partners. The current effort to review the most limiting factors for RSGCN is part of the 5-year RSGCN technical services contract workplan which will culminate in a comprehensive review of vertebrates and invertebrates in time to inform SGCN selection for 2025 SWAP revisions.

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The Northeast Fish & Wildlife Diversity Technical Committee (hereafter "Committee" or NEFWDTC) was established by the Northeast Directors (Directors) in the late 1970s and has met annually since 1986. The group serves the Directors for the purpose of "coordinating management and protection, exchanging ideas, and providing assistance with particular problems, needs, or situations relative to endangered species and wildlife diversity issues" (Committee bylaws).

Since NEFWDTC's inception forty years ago, its scope of responsibility has expanded to include thousands of species. It has followed the arc of conservation science embracing biological diversity to include invertebrates, as well as embracing the State Wildlife Grants Program call to proactively conserve and preclude listing as endangered species. Terwilliger Consulting Incorporated (TCI) is contracted by the Northeast Association of Fish & Wildlife Agencies, Inc. to provide technical support for wildlife diversity conservation, including RSGCN as these species represent the priority imperiled species in the region.

The RSGCN list provides focus for consistent regional conservation of high priority fish and wildlife species, their habitats, and identifying and addressing their key threats and vulnerabilities. Specifically:

1. SGCN from all northeastern SWAPs are considered for the RSGCN list.
2. The non-regulatory list represents species that are globally and/or regionally imperiled species for whom the Northeast Region has conservation responsibility.
3. The process for selecting RSGCN is transparent and repeatable, relying on a broad set of well-accepted conservation assessments that cross habitat types and taxonomic groups.
4. RSGCN are classified to focus attention on species with the greatest conservation need aligned with criteria of conservation concern and regional responsibility.

5. The RSGCN list is used by states and partners to facilitate coordinated conservation action considering a complex array of factors.

The threats to (and limiting factors for) RSGCN are complex and interrelated. A previous review and synthesis of Northeast SWAPs was successful at highlighting priority actions and top threats (Terwilliger Consulting Inc. and Northeast Fish and Wildlife Diversity Technical Committee 2013). However, linkages explaining why threats were responsible for the decline of species or degradation of habitats were difficult to ascertain. As outlined in the Northeast Lexicon, SWAPs use the Conservation Measures Partnership threat classification system (Crisfield and Northeast Fish and Wildlife Diversity Technical Committee 2013, Conservation Measures Partnership 2016). This system is intended to identify *direct* threats to species and habitats, but this approach can downplay or fail to capture *indirect* or *amplifying* threats (e.g. climate change, shifts in food availability or predator-prey relationships). The new data fields developed for this project address this gap and explain how (and in what ways) threats are causing declining populations (Appendix A). They are organized in four groups: habitat use and condition factors, migration and wintering strategies, food needs, and several factors of vulnerabilities due to reproduction or survivorship. Climate change was considered as a factor within all of these categories, and Research and Monitoring needs were also solicited.

Regarding habitat use and condition, habitat classification systems based on vegetative communities did not provide enough detail to describe habitat requirements for species that:

- are habitat specialists
- are affected by air, water, and soil pollution
- are associated with specific soil and water substrate conditions
- require specific vegetation structure (including percent cover and age class)
- have unique precipitation and moisture requirements
- are found near certain features like cliffs, slopes, and ravines

Objective & Outcomes

The objective of this year's effort was to identify key limiting factors impacting Northeast RSGCN. Conservation is more efficient and effective when actions are designed to mitigate threats or stressors that are known to affect species or their habitats and when there is certainty that addressing the threat is expected to result in a positive response of the target species or habitat (Foundations of Success 2007).

The objective of this year's effort was to identify key limiting factors impacting northeast RSGCN.

Documenting the most critical habitat requirements and vulnerabilities for these species will help improve outcomes of projects that involve habitat management to address habitat threats. The additional life history limiting factors will also explain why species in well-conserved habitats are in decline. Together, these factors will help conservation planners in many ways. For example, by:

- specifying the most impactful habitat condition requirements that limit a species' population

- linking species with similar habitat requirements across taxonomic groups and within broader habitat macrogroups
- identifying species with direct mortality from disease, predation, or toxicity
- revealing data gaps that may be responsible for species' declines

Methods

To accomplish this objective, a system for documenting key limiting factors was developed, populated, and reviewed. Throughout the process, NEFWDTC members and Northeast SWAP Coordinators were consulted and updated as taxonomic experts from 14 states were engaged in the RSGCN review.

Phase 1: Design and development of the process, data fields and database module. The Northeast Wildlife Action Plan Database (Database) was enhanced to capture priority aspects of food, reproduction, mortality, migration and wintering, habitat characteristics and other life history vulnerabilities. Monitoring protocols and data gaps were also documented to identify conservation action goals that address concerns across many taxonomic groups. Detailed information about the new data fields is available in separate method documentation. The development of the habitat factors was strongly influenced by previous US Forest Service work (DeGraaf and Rudis 1986, DeGraaf et al. 1992). These additional habitat fields build on the Northeast Terrestrial Habitat Classification system (Ferree and Anderson 2013). Aquatic habitat factors were based on the most recent update of the original Northeast aquatic habitat classification system with very similar factors to DeGraaf, but updated classifications (Olivero and Anderson 2008, McManamay et al. 2018).

Phase 2: Literature search and data entry. Key scientific taxonomic references (including NatureServe, SWAPs, State and Federal Listing documents, taxonomic literature, etc.) were used as a foundation and TCI prepopulated the database to prepare and format the data for taxa team review. These references were used to identify specific habitat features required by RSGCN, population level threats to RSGCN, and applied research and monitoring needs for RSGCN.

Phase 3: Taxa team review. Taxa expert lists were updated with new agency staff from 13 states and the District of Columbia. Teams were assembled, comprised of a representative from each state, for Mammals, Birds, Herpetofauna, Freshwater and Anadromous Fish, Crayfish, and Freshwater Mussels. Preliminary information was distributed to taxa teams for their review and teams met for online discussion of limiting factors during the winter of 2020. TCI facilitated calls by highlighting information needs or factors with conflicting information. Summaries of the calls were distributed to verify information and individuals were contacted to address follow-up questions through the analysis phase of the project. For other taxonomic groups known regional experts provided information for Odonates (Pam Hunt, New Hampshire Audubon), Bumble Bees (Leif Richardson, Stone Environmental), Stoneflies (Ed DeWalt, University of Illinois) and marine fish. Some information for Butterflies and Skippers and Tiger Beetles is included in the database but has not yet been reviewed. Additional information has not been entered for moths, native solitary bees, and land snails.

Phase 4: Analysis and reporting. Taxa team information across habitats and taxonomic groups was analyzed to prepare this report summarizing the limiting factors for RSGCN in the Northeast.

Results

This report communicates information and issues raised by state fish and wildlife agency and other experts who monitor these species and their threats. The results are organized by limiting factors. Unique conditions for each taxonomic group are presented within these themes. Information summarized here is documented in detail in a database with references to over 350 publications.

The Northeast has designated 358 RSGCN species (Table 1; Figure 1; Appendix B; available online at bit.ly/NE_RSGCN). Larger states and states that bridge from coastline to mountains have higher habitat diversity and higher numbers of RSGCN. The mid-Atlantic region has a higher number of narrow-range endemics due to the southern range contraction of most species during the glacial maximum (Hewitt 2000, Jackson et al. 2000) and the subsequent northward dispersal of some species.

Table 1. Number of RSGCN by taxonomic group.

Taxonomic group	Number of RSGCN
Birds	17
Mammals	21
Reptiles	17
Amphibians	13
Fish	63
Freshwater Mussels	28
Stoneflies	33
Crayfish	18
Dragonflies and Damselflies	23
Tiger Beetles	8
Terrestrial Snails	26
Moths	44
Butterflies	29
Bumble Bees	6
Native Solitary Bees	12

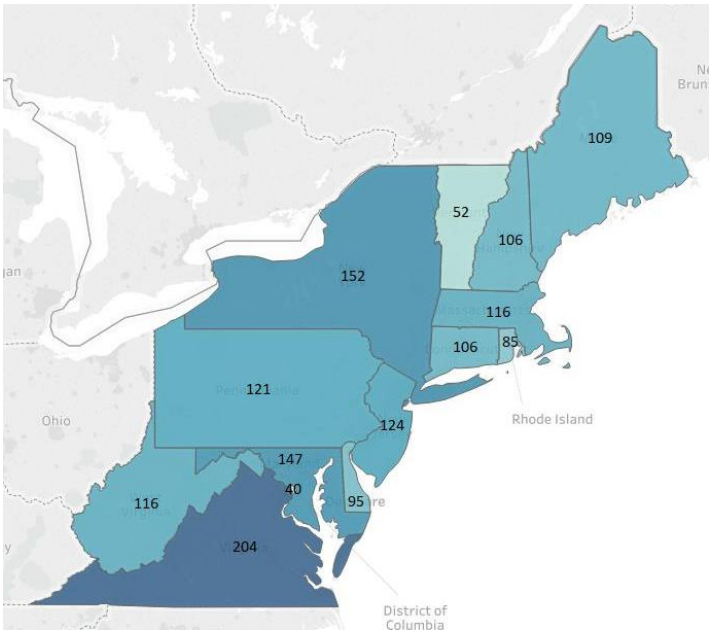


Figure 1. Map of the number of RSGCN occurring in each state. (These numbers exclude species that are understood to be state-extirpated and species for which ranges have not been entered into the database [some invertebrate taxa groups]).

This summary of additional information for RSGCN includes all vertebrate RSGCN taxa and most invertebrate taxa (terrestrial snails and native solitary bees have not been included in the most recent review due to data deficiency, and information for lepidoptera is incomplete at this time.) The content of this report represents the scope of available information, but readers are encouraged to explore the database where narrative comments for each species explain in greater detail the specific concerns for each species with references. (The updated database will be made available at https://www.neafwa.org/swap-database.html.)

The key limiting factors for RSGCN are:

- habitat requirements (pages 8-12)
- wintering or migration factors (pages 12-13)
- factors directly affecting population size or stability (disease, toxicity, genetic diversity, take, predation, Inter-species dependencies) (pages 13-19)
- climate change (pages 18-21)
- food availability (pages 21-22)

There are many ways to measure the importance of the limiting factors explored in this project. Population size can be limited by food availability, but this is factor is largely unknown for most species. Other factors directly impacting mortality or reproduction, and thus population trends, are shown in Table 2. Climate change has a strong potential to effect population trends through many mechanisms. This is also true of pollution, which has been shown to be a strong threat to aquatic RSGCN (Terwilliger Consulting Inc. and Northeast Fish and Wildlife Diversity Technical Committee 2013). While other factors have lower numbers of associated species, these factors can have very strong impacts on individual species' population trends. In some cases, these factors do not impact populations until the species has become rare due to other threats (e.g. loss of genetic diversity and predation).

Table 2. Numbers of Very High Concern, 75% or greater regional responsibility species associated with Population Factors. "Yes" indicates a known factor, "Maybe" indicates uncertainty in the degree of impact, "No" indicates the factor does not affect the species' population, "Unknown" indicates the factor was reviewed but no information is available. (Totals do not match due to differences in numbers of null values.

Population Factor	Yes	Maybe	No	Unknown
Climate Change (direct effect on population size)	19	15	0	20
Pollutants	14	10	4	25
Predation	6	12	8	27
Loss of Genetic Diversity	4	14	2	12
Take (intentional or incidental)	4	10	31	9
Disease	2	7	12	33
Reproductive Dependencies (e.g. host plants for butterflies, host fish for mussels)	6	4	29	15

We also discovered that wintering strategies can make some species more vulnerable to human activities at that time of year, or more vulnerable because of anticipated changes in winter climates. Migration is also recognized as exposing some species to specific threats. An emerging threat affecting migratory species is the expansion of wind energy production in the Appalachian Mountains. For all of these reasons, wintering and migration is considered to be growing in importance as a factor explaining declining population trends.

These factors are described in greater detail following the habitat factors described below.

Habitat Factors limiting RSGCN Populations

Determining habitat associations is a long-standing priority and challenge. Even with the coarse habitat categories used here, results indicate that many RSGCN are associated with multiple habitats. (Coarse habitat classes roughly align with formation classes of the Northeast Terrestrial Habitat Classification System. See Appendix C for crosswalk.) Some species that bridge habitats are habitat generalists with the ability to meet needs across a wide range of plant communities and physical conditions. Others are habitat specialists requiring vegetative and physical conditions characteristic of just a few habitat types. For example, 17 RSGCN require both Rivers and Forests. Some RSGCN require the forested riparian edge of the river with access to food sources in the river while others require the cool clean water in the river that can only be found if the river is buffered by forest. For each habitat type, limitations associated with habitat availability (total acreage or accessibility limited by habitat fragmentation) and habitat condition or quality are identified.

For terrestrial and freshwater habitats (Figure 2) 90 RSGCN are associated with Rivers and Streams alone, 28 RSGCN are associated with Forests, and 12 are associated with Grasslands. In addition to the 90 species found in Rivers and Streams alone, 33 RSGCN are found in various combinations of aquatic habitats including Lakes and Marshes. As noted above, 17 RSGCN are associated with both Forest and River and Stream. Importantly, 15 RSGCN that are associated with Forests or Grasslands are *also* associated with water features. Freshwater habitats, freshwater features within terrestrial habitats, and even hydrologic conditions in otherwise dry habitats (like Cliff and Talus) are important for most RSGCN. Consequently, there are many concerns related to shifting hydrologic regimes, and these are discussed in the Climate Change section on page 18.

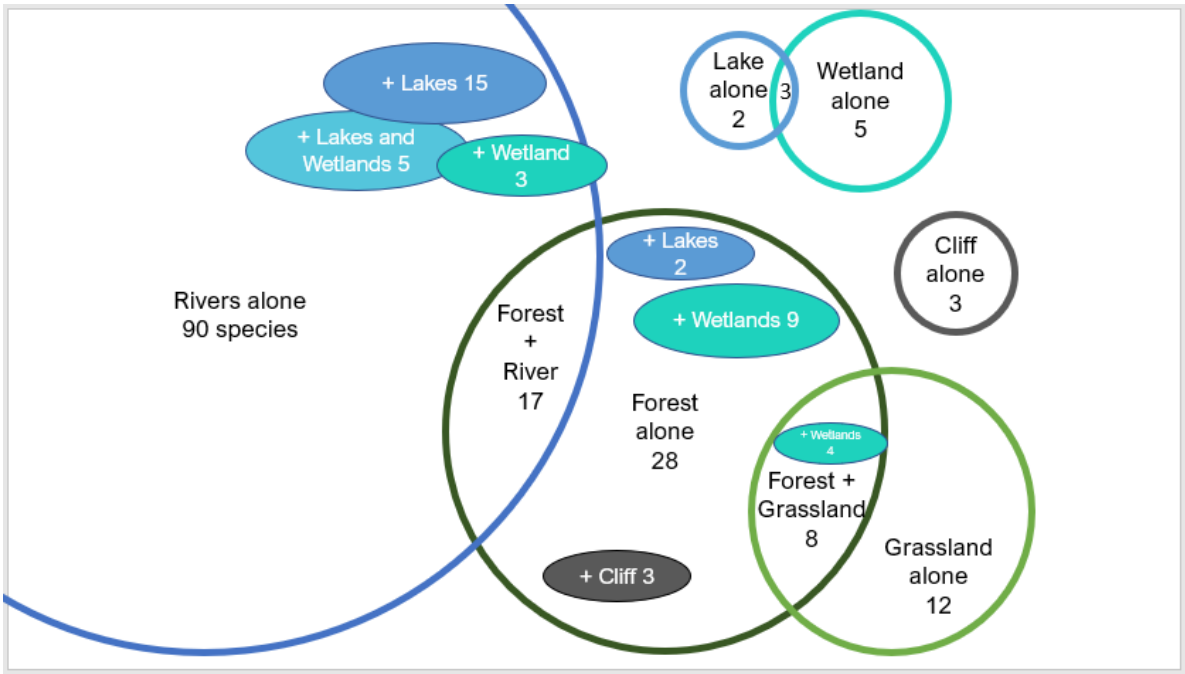


Figure 2. Numbers of species associated with some of the dominant freshwater and terrestrial habitat types and combinations. (Habitat types and combinations with 3 or fewer RSGCN are not represented.)

Habitat modifiers are also important in understanding habitat condition requirements. For example, while 10 RSGCN are associated with both Forest and Cliff habitat types, another 10 RSGCN have talus or outcrop ledges specified as habitat requirements within their forested habitat association. While habitat fragmentation was not explicitly called out in the database, challenges associated with fragmentation of high quality habitat affect many RSGCN.

Very High Concern, High Responsibility (75% or more of the range in the Northeast) RSGCN species primarily occur in River and Stream habitats (24 out of 31 species) and all but one of the others are found in or require hydrologic features like lakes, ponds, marshes, springs, seeps, or vernal pools. These species include 11 freshwater fish, 7 stoneflies, 5 freshwater mussels, 3 crayfish, 2 dragonflies and damselflies, 2 salamanders, and 1 squirrel.

Forest

Eighty-seven RSGCN are associated with forests (Figure 3). Habitat availability (a loss of suitable habitat) is considered a limiting factor for 32 species, and 35 species are limited by a wide range of activities that degrade forest conditions. More than half of the forest-associated RSGCN are invertebrate arthropods, primarily dragonflies and damselflies (18 species) or butterflies and skippers (15 species). The 17 very high concern RSGCN associated with Forests include species from a wide range of taxa groups.

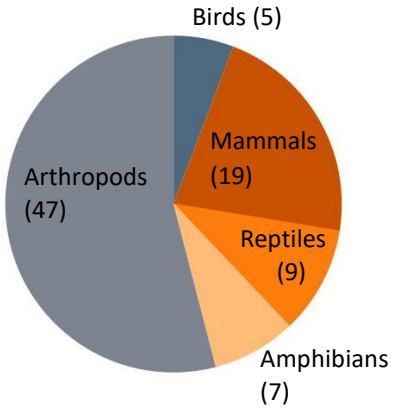


Figure 3. RSGCN (87 species) associated with forest habitats by taxonomic group.

This is the dominant habitat type for RSGCN mammals, with 19 out of 22 species associated with Forest. Six mammals are associated with Forest alone (3 bats, 2 squirrels, and the Appalachian Cottontail [*Sylvilagus transitionalis*]). Half of reptiles are associated with Forests (9 out of 17), although most of these also have additional habitat associations.

Most forest-associated RSGCN cannot be linked to a specific forest macrogroup, however 20 species across 5 taxonomic groups were linked to Northern Hardwood & Conifer, suggesting this habitat type offers specific habitat requirements that cannot be met by other forest types.

As mentioned above, water features and soil moisture requirements are important for about half of forest-associated RSGCN. Stream riparian areas are important for 32 Forest RSGCN, and another 16 species are associated with springs and seeps. Floodplains, vernal pools, and lake riparian areas are also tracked in the database. Of the 21 species with known soil moisture requirements, most require hydric or mesic conditions. Stumps, logs, debris, and snags are important habitat features for 27 mammals, reptiles, and amphibians. For species with age class requirements specified (30 species), most are associated with late successional forest (20 species), with only 3 associated with old growth, and 6 associated with early successional. (A mix of age classes is required for Wood Thrush [*Hylocichla mustelina*].) Canopy, mid story, and understory density requirements are mixed, with some species preferring moderate to high density vegetation, and others preferring sparse vegetation. High elevation forests are important for 18 species across multiple taxa groups.

Grasslands

A total of 31 RSGCN are associated with Grasslands (Figure 4), and these are primarily butterflies (11 species), bees (6), birds (4), and snakes and turtles (5). About a third of Grassland species are thought to be limited by habitat availability or condition, while the remaining species are considered data deficient.

The very high concern RSGCN associated with Grasslands include 5 butterflies and bees (Karner Blue (*Plegejus Melissa samuelis*), Frosted Elfin (*Callophrys irus*), Persius Duskywing (*Erynnis persius persius*), and Rusty-patched (*Bombus* affinis) and Variable Cuckoo Bumble Bees (*Bombus variabilis*))

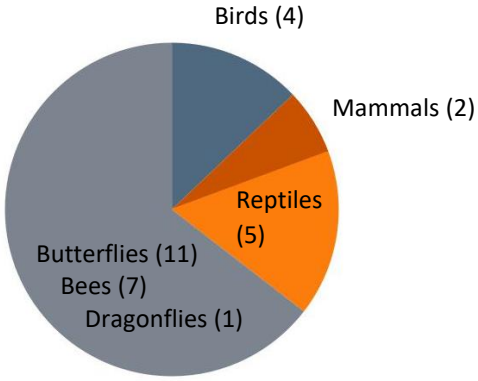


Figure 4. RSGCN (31 species) associated with grassland habitats by taxonomic group.

Wetlands

Freshwater Marshes are a primary habitat for 35 RSGCN (Figure 5). Additional species associated with Forests or other habitats also rely heavily on wetlands as a habitat modifier. About half of these species were identified as being limited by habitat availability or condition, with 5 species indicating water management structures may be a factor. Pollution (particularly excess nutrients) and invasives are degrading wetland quality with impacts to fish and dragonflies, in particular. Saltwater intrusion is an increasing threat to coastal wetlands. In developed areas, habitat fragmentation isolates wetlands with impacts to reptiles, amphibians, and mammals.

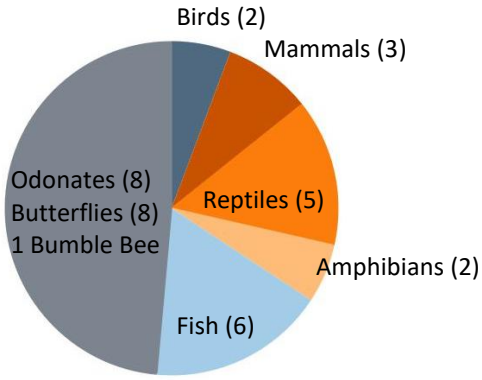


Figure 5. RSGCN (35 species) associated with freshwater marsh or wetland habitats, by taxonomic group.

Rivers and Streams

Of the 140 species associated with Rivers and Streams, 70 species have identified habitat availability as a limitation, and 82 have identified habitat condition as a limiting factor. For most of these species (65), water management structures are either fragmenting habitat and making it inaccessible, or changing water quality, substrate, or other stream water conditions to make them unsuitable.

Most species associated with Rivers and Streams are invertebrates (Figure 6), particularly freshwater mussels (28 species), stoneflies (28), crayfish (14), and dragonflies and damselflies (13). Obviously, freshwater fish (35) and anadromous fish (4) are also

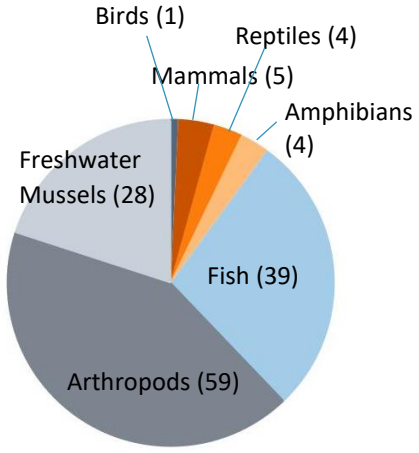


Figure 6. RSGCN (140 species) associated with river and stream habitats by taxonomic group.

reliant on Rivers and Streams. This habitat type has a large number of Very High concern (49) and High concern (42) species.

Of the 140 RSGCN associated with Rivers, more are associated with smaller- sized Rivers and Streams (Table 3). For some species, factors other than stream size are important. Substrate is important for 96 RSGCN, with most species (49) requiring sand or gravel. This requirement demonstrates the importance of protecting streams from sedimentation as taxa experts identified it as a key driver in aquatic habitats across taxa. Gradient is an important factor for 74 RSGCN, with most species requiring moderate gradients as opposed to high or low gradients. Of the 46 species with temperature requirements, none require very cold streams (<12.8 C), and most (25) require cold or cool streams (12.9-17.9 C or 18.0-21.0 C), while 8 prefer warm streams (>21.0 C). Other factors that are important for some species (dissolved oxygen, pH, or aquatic vegetation) are largely unknown.

Table 3. Number of RSGCN associated with rivers and streams by size class.

Size category	Number of associated RSGCN	Size class totals
Medium to Great Rivers	19	36
Mainstem	3	
Large Rivers	2	
Medium Rivers	12	
Headwater to Medium Rivers	35	93
Small Rivers	11	
Creek	22	
Headwater	25	

Tidal, Nearshore Coastal, and Offshore

RSGCN occurring in Nearshore or Offshore waters are largely shared among the coastal states (35 species are found in all Northeast coastal states) (Table 4). Northern Diamond-back Terrapins, Atlantic Hawksbill Sea Turtles, Scalloped Hammerhead Sharks, and Night Sharks are range-limited to the southern part of the region. All species associated with tidal marsh can be found in the Mid-Atlantic states, but only half can be found in tidal marsh areas in New England. Many of the RSGCN birds are associated with coastal habitats (12 out of 17). These species are found in tidal marshes, along tidal rivers, on the shoreline, nearshore, and even offshore.

Table 4. Number of RSGCN associated with saltwater habitats, including taxonomic distribution.

Coastal habitat type	Number of RSGCN	Taxonomic group breakdowns
Tidal Marsh	13	7 birds, 3 turtles, 1 frog, 2 butterflies
Tidal River	19	10 fish, 3 mussels, 3 birds, 2 turtles, 1 butterfly
Shoreline	13	8 birds, 3 tiger beetles, 2 turtles
Nearshore	40	28 fish, 6 turtles, 5 birds, 1 mammal
Offshore	36	28 fish, 5 turtles, 2 birds, 1 mammal (All species also listed as Nearshore)

These are also the key habitats of the marine turtles and the Northern Diamondback Terrapin (*Malaclemys t. terrapin*). The marine turtles are all long-distance migrants, with vulnerability to predation and intentional or unintentional collection (bycatch) during their migration or movements.

Marine fish are found primarily in the Nearshore and Offshore waters (22 species), and six of these are also found in the Tidal Rivers. Tidal Rivers are the specific habitat for four species including the very high concern Chesapeake Logperch (*Percina bimaculate*) and Maryland Darter (*Etheostoma sellare*).

Three mussels are found in Tidal Rivers, Yellow Lampmussel (*Lampsilis cariosa*), Tidewater Mucket (*Leptodea ochracea*), and Eastern Pondmussel (*Ligumia nasuta*).

Only one highly endangered marine mammal is listed as RSGCN – the North Atlantic Right Whale (*Eubalaena glacialis*). It migrates from its winter waters off the southeastern coast to its summer waters in the Gulf of St. Lawrence and other waters Nearshore in the North Atlantic. Ship strikes and gear entanglement are primary threats, and low reproduction combined with high mortality have led to predictions of extinction in the next 20 years.

Migration and Wintering Factors limiting RSGCN Populations

A life history characteristic or vulnerability considered a concern by taxonomic experts across all taxa was migration and wintering activity. Only about 15 RSGCN are known to migrate out of the region during the winter, while the rest do not migrate at all or migrate within the region. Of the 250 species known to winter in the Northeast, 86 of them are (or can be) active during the winter, while 57 of them are known to hibernate. About 5 species are thought to have temperature dependent hibernation (4 snakes and the Delmarva Fox Squirrel [*Sciurius niger cinereus*]).

It has become apparent that winter vulnerabilities are an important research area for multiple taxa, especially considering anticipated changes in winter temperatures. (Additional impacts of climate change on the wintering concerns described here can be found on page 17.) Discussions with taxa experts indicate that some species' activity level or wintering strategies may differ across the geographic range, with some species being more active in the southern portion of their range compared to the northernmost states. For many RSGCN herps, there is a need to determine spatial and temporal sheltering and habitat needs. For RSGCN butterflies and bees, many are known to overwinter in leaf litter or duff, dead wood, or shallow soil burrows and can be vulnerable to habitat management practices – but many species have unknown overwintering strategies.

Migratory species expend a lot of energy in migration, are vulnerable to many threats while migrating and require seasonal habitats. This is especially true for long distance migrants including birds, marine mammals and sea turtles, and anadromous fishes. For birds and bats, given the increasing number of wind energy installations, it is important to determine migration timing and triggers, routes, and any differences in timing and routes between sexes so that impacts of wind turbines can be determined and 'best management practices' can be developed. In general, migratory species may have an advantage in that they are more mobile and may be able to relocate to better quality habitats in response to climate change or habitat degradation.

In contrast to the migratory species, more sedentary or narrow range species that winter in place have little ability to seek habitats with better conditions (freshwater mussels and crayfish, isolated cave or

high elevation species, in particular). Other species have more mobility, but do not typically move far (dragonflies and damselflies, stoneflies, small mammals, and many flying terrestrial invertebrates). Note that while some odonates migrate, NE RSGCN odonates do not. Stoneflies differentiate into two life cycle strategies – "slow cycle" species grow slowly over a year or several years to become large adults without entering diapause while "fast cycle" species diapause as eggs or first instars and grow quickly to emerge as adults. The wintering strategies for the two groups are different and the "slow cycle" species can be more imperiled than the "fast cycle" species.

Aside from concerns related to migration itself, migratory tree bats have additional vulnerabilities. Active bats have been observed at times and places where they were not known to be active before, raising questions about wintering strategies and emerging vulnerabilities. Some overwinter in structures, woodpiles, and other anthropogenic habitats where they can easily be disturbed. Others are overwintering in leaf litter where they may be subjected to prescribed fire habitat management or in trees where thinning or other harvest management practices can disturb them. 'Best management practices' can be developed and promoted to minimize these impacts.

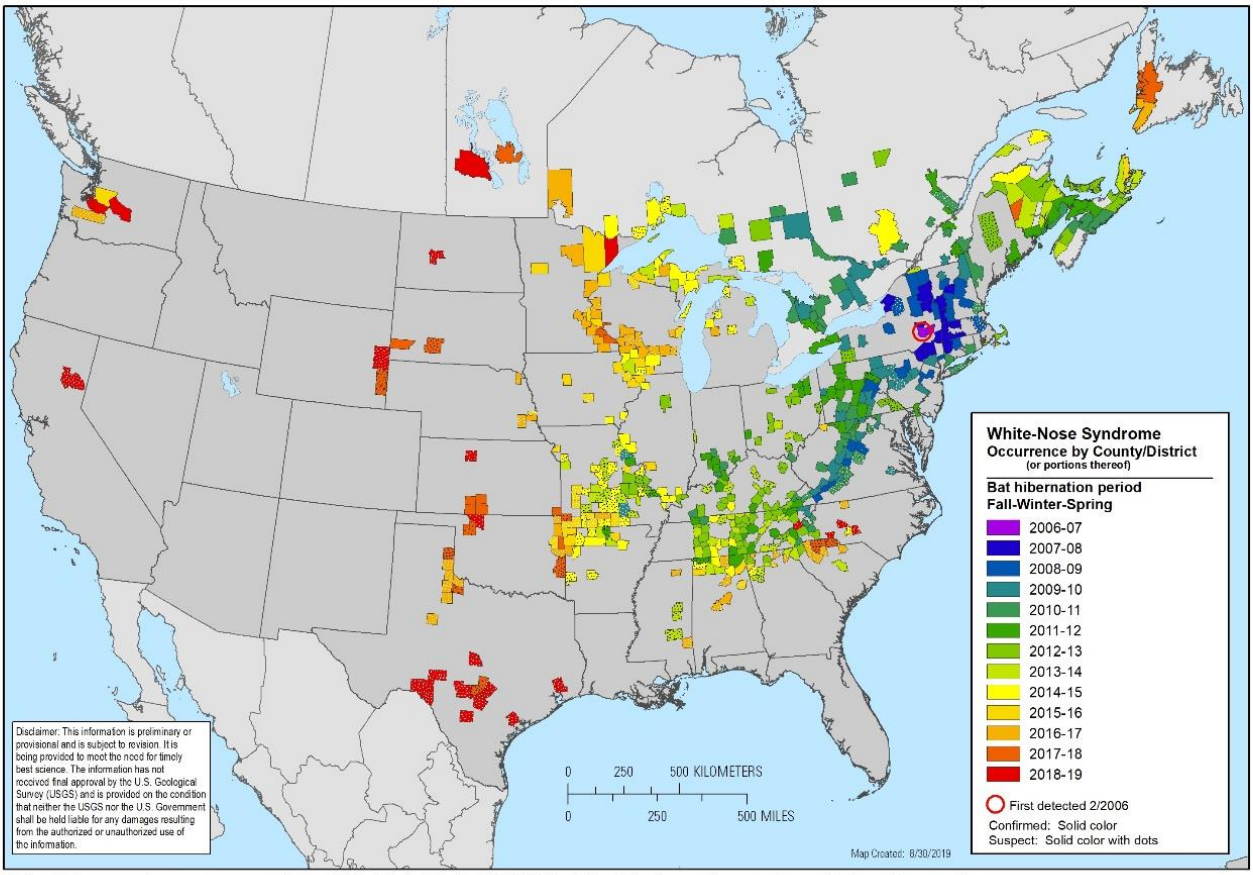
Disease Factors limiting RSGCN Populations

Most species have known diseases, but few species are known to be in decline due to mortality from disease. More often, diseases reduce fitness and potentially reproductive success or rate – and that is difficult to conclusively link to population declines. It is also important to recognize that many unknown diseases likely impact RSGCN, particularly aquatic species.

White nose syndrome is a notable exception – it is the dominant cause of decline for cave-hibernating bats including, Indiana Bat (*Myotis sodalis*), Northern long-eared Bat (*M. septentrionalis*), Little Brown Bat (*M. lucifugus*), and Tri-colored Bat (*Perimyotis subflavus*). The first known occurrences were in New York in 2007 – the Northeast region has been the epicenter for this devastating disease (Figure 8). States are tracking population decline with annual surveys. Region-wide or range-wide estimates of population decline are being investigated for Little Brown and Tri-colored Bats (USFWS, expected ~2023). For Northern Long-eared Bat, in 2015, 69% of surveyed sites in Vermont, New York, Pennsylvania, Maryland, West Virginia, and Virginia, where white nose syndrome had been present for at least 4 years were reported extinct (Frick et al. 2015). A 2019 assessment of Indiana Bat status estimated high population declines in Northeastern states: New York (-75%), West Virginia (-96%), and Pennsylvania (-99%), with the strongest populations remaining in Missouri, Indiana and Illinois (King 2019).

Ranavirus, chytrid, and mycoplasma are diseases of reptiles and amphibians and many species have tested positive for some or all of these diseases. Bumble bees are believed to be affected by diseases of honeybees (*Crithidia bombi* and *Nosema bombi*) contracted through shared floral resources. West Nile virus has significantly affected some bird species but impacts to RSGCN remain unknown. Disease impacts to most aquatic crayfish, mussel, and fish taxa are unknown and baseline information is lacking in most RSGCN taxa. Some taxonomic teams raised concern that climate change (warmer and/or wetter conditions) could worsen impacts. Fungal disease and invertebrate vectors for bacterial diseases may have more favorable conditions in some years, and if environmental conditions stress species they may become more susceptible to disease. Concerns about shifts in disease impacts related to climate change are discussed on page 17.

A highly contagious disease affecting rabbits and hares, Rabbit hemorrhagic disease (RHDV2), emerged in wild populations in British Columbia in 2019. A separate strain emerged in the southwestern U.S. in 2020. In the Northeast, RHDV2 killed 11 rabbits at a vet hospital in New York City and 4 rabbits at a single site in Ohio in 2019. It is not known to have spread to wild populations at the time of this report. This disease is an emerging threat to New England Cottontail (*Sylvilagus transitionalis*) and Appalachian Cottontail (*S. obscurus*), along with 3 other SGCN if an outbreak in the Northeast were to occur. The New England Cottontail working group and mammal biologists across the region are preparing by updating protocols to include decontamination and other methods to protect native rabbits and hares.



Citation: White-nose syndrome occurrence map - by year (2019). Data Last Updated: 8/30/2019. Available at: https://www.whitenosesyndrome.org/static-page/wns-spread-maps.

Figure 7. Map of white nose syndrome occurrence as of August 2019. credit: whitenosesyndrome.org

Toxicity Factors limiting RSGCN Populations

Pollution (including sedimentation, chemical and nutrient runoff) of our diverse Northeast aquatic systems affects up to 75% of mussels, crayfish, fish, and amphibians. Fish (25 RSGCN), mussels (23 RSGCN), and birds (8 RSGCN), have suffered population declines from toxicity as a known cause.

An analysis of toxic impacts to RSGCN fish covers the full range of water quality concerns. Anadromous fish are affected by sedimentation, nutrient runoff, and non-point source pollution. Atlantic and Shortnose Sturgeon (*Acipenser oxyrinchus* and *A. brevirostrum*, respectively) are vulnerable to spills and point-source pollution, have the potential to bioaccumulate toxins due to their long lifespan, and have

some evidence that chemical pollutants are linked to reproductive or developmental disorders. For freshwater fish, numerous point and non-point source pollutants from mining, residential land use, agricultural land use, logging, industrial effluents, and pulp mills are all affecting fish directly. Road runoff is a major concern for crayfish and other aquatic RSGCN, especially in the context of extreme weather and storm events.

For freshwater mussels there are numerous historical incidences of mortality leading to extirpation linked to specific industrial disasters (e.g. 1998 extirpation of Golden Riffleshell [*Epioblasma florentina aureola*] from the Clinch River, and reduction in Indian Creek [USFWS 2017]). The current list of contaminants of concern include industrial waste, but also insecticides, herbicides, nutrients, sedimentation, ammonia, chloride, potassium, metals, petroleum, discharges of stormwater, and many more. Previous Regional Conservation Needs (RCN) grant-funded research helped determine the conservation status of Brook Floater mussels (*Alasmidonta varicosa*) and threats to the species. The Brook Floater Working Group and current Competitive State Wildlife Grant (SWG) funded research is are building on past RCN funded research for Brook Floater and other freshwater mussels.

Despite widespread data deficiency specific toxicity concerns are identified for all taxa (Table 5). Some RSGCN are indicators of water quality. Eastern Hellbenders (*Cryptobranchus a. alleganiensis*), stoneflies, and mussels thrive in pristine water quality. For many RSGCN, the contaminants of concern and impacts of toxicity are unknown and remain a research need. For example, Diamondback Terrapins (*Malaclemys t. terrapin*) near JFK airport are currently being studied to learn about toxicity impacts. Also, in 2019 several states reported algal blooms with associated wildlife mortality – but there is considerable uncertainty in both the causes and the impacts of this emerging issue.

Table 5. Contaminants of concern for RSGCN by taxa group.

Taxa group	Contaminants of concern
Birds	mercury, lead (and other metals), oil spills, PCBs, and pesticides Exposure is direct contact and through bioaccumulation through food
Mammals	insecticides, PCBs, brominated flame retardants, organochlorines, pharmaceuticals (Secord et al. 2015) Exposure is primarily through bioaccumulation through food, but may also be direct
Marine turtles	plastics, petroleum, and metals
Amphibians	acid deposition and insecticides
Aquatic invertebrates	insecticides, organic waste, inorganic fertilizers, road salt, industrial spills Exposure is direct contact

Loss of Genetic Diversity Factors limiting RSGCN Populations

Loss of genetic diversity becomes an independent threat for isolated populations or species with precipitous declines (Frankham 2003). In general, RSGCN with greater dispersal capacity, like birds and other migratory species, seem less likely to become limited by genetic diversity, while mussels, crayfish and other more sedentary species may be more at risk. Dams and other barriers to flow limiting aquatic connectivity can generate isolated populations and loss of genetic diversity, and similar challenges with habitat connectivity in riparian, forested, or grassland habitats can also be a challenge. For example, species like Allegheny Woodrat have isolated populations because individuals cannot bridge the

distance between them. For both Allegheny Woodrat and New England Cottontail, conservation activities include captive breeding and both species require or at least respond to this intervention.

The following RSGCN (23 species) have been identified as having population declines that are probably linked to loss of genetic diversity. Taxa experts identified 50 additional species for which genetic diversity is a possible contributor to population declines (32 of these are mussels and crayfish).

- Bats: Cave-dwelling bats, decimated by white nose syndrome, are now at risk due to loss of genetic diversity. These include Indiana Bat (*Myotis sodalis*), Northern long-eared bat (*M. septentrionalis*), Little Brown Bat (*M. lucifugus*), and Tri-colored Bat (*Perimyotis subflavus*).
- Small Mammals: Some populations of the New England Cottontail (*Sylvilagus transitionalis*), Eastern Spotted Skunk (*Spilogale putorius*), and Allegheny Woodrat (*Neotoma magister*)
- Crayfish: Digger (*Creaserinus fodiens*) and Devil (*Lacunicambarus diogenes*) Sixteen additional crayfish species may be affected by loss of genetic diversity.
- Freshwater mussels: Golden Riffleshell (*Epioblasma Florentina aureola*), Atlantic Pigtoe (*Fusconaia masoni*), Yellow Lampmussel (*Lampsilis cariosa*), Cumberland and Appalachian Monkeyface (*Theliderma intermedia and sparsa*), and Tennessee Bean (*Venustaconcha trabalis*) Sixteen additional mussel species may be affected by loss of genetic diversity.
- Freshwater fish: Diamond Darter (*Crystallaria cincotta*), Blackbanded Sunfish (*Enneacanthus chaetodon*), Bridle Shiner (*Notropis bifrenatus*). At least six additional freshwater fish species may be affected by loss of genetic diversity.
- Anadromous fish: Shortnose and Atlantic Sturgeon (*Acipenser brevirostrum and oxyrinchus*)
- Birds: Roseate Tern (*Sterna dougallii*) and Golden-winged Warbler (*Vermivora chrysoptera*)
- Butterflies: Regal Fritillary (*Speyeria idalia*)

Take or Collection Factors limiting RSGCN Populations

Reptiles continue to suffer impacts from collection and persecution regionally. Collection of turtles continues to have an impact on populations – but target species and numbers collected can change in response to global market demand. Snakes are persecuted species in general. In particular, Timber Rattlesnake (*Crotalus horridus*) populations have declined due to people killing them. Some fish, herp, and mussel RSGCN are collected because of their attractiveness or rarity.

Many species are killed on roads, some in large enough numbers to contribute to declining populations, especially reptiles, amphibians, and some mammals and invertebrates. Bats using human structures as shelter are stressed by pest removal, roof replacement, and other structural renovations or human disturbance.

Some species of anadromous fish may be being harvested at an unsustainable rate, and non-harvest population monitoring techniques have been recommended to fill data deficiency gaps. Regulations exist, but research and monitoring are needed to inform their effectiveness and impact on RSGCN populations.

Predation

For most species, predation occurs at a natural rate that is not a cause of population decline. However, predators that are subsidized by humans (like feral cats and raccoons) are impacting some turtles and birds. Like loss of genetic diversity, predation can be an independent threat to the survival of a species

when population declines due to other threats that then make a species more vulnerable. Predation of nests for birds, turtles, and some small mammals is common and limits successful reproduction, but the adult life stage also has significant predation impact for many species (Table 6). The population level impacts of predation are uncertain for some groups of species, particularly crayfish, mussels, and freshwater fish.

Table 6. Number of species with population level impacts from predators by taxa group.

Taxon	Number of RSGCN known to be affected by predation	Number of RSGCN that may be affected by predation	Predators*
Birds	9	2	Mammals (cats, raccoons, and others), also other birds (hawks and owls)
Freshwater turtles	7		Raccoons
Sea turtles	4		Nest predators: Raccoons, Ghost Crabs, fox Adult predators: whales, sharks
Snakes	1	2	Cats
Freshwater Fish	6	11	Non-native stocked game fish, Brown Trout, catfish
Mussels	3	12	Raccoons, muskrats, catfish
Small Mammals	2	3	Owls and hawks
Bats		9	Owls and raptors, snakes, cats
Crayfish		16	Brown Trout, Rainbow Trout, Smallmouth Bass
Marine and Anadromous		4	Non-native, fish, and recreational and commercial fishery species (Cod, Haddock, Striped Bass)
Eastern Hellbender		1	Water Snake, Brown Trout

*List of example predators is not exhaustive

Inter-Species Relationships Factors limiting RSGCN Populations

For some RSGCN, population stability is dependent on other species. Butterflies lay eggs on host plants which are required for the offspring as a food source. Information on host plant associations is incomplete at this time, but several plant species found in xeric habitats can be seen in the list in Appendix D.

Freshwater mussels reproduce by infecting host fish with microscopic larvae (glochidia). Some mussels require specific fish species as hosts, others are generalists, and for many these relationships are unknown. Based on information in the Freshwater Mussel Host Database, fish species known to host RSGCN mussels are listed in Appendix E (Freshwater Mussel Host Database 2017). Mussel host fish include several groups of species well represented in the RSGCN list including darters, shiners, and sculpins.

A group of bumble bees are cleptoparasitic, requiring the nest of another bumble bee species to rear its young (Table 7) (Williams et al. 2014). In the case of *Bombus variabilis* and its host *B. pensylvanicus*, both species are listed RSGCN.

Table 7. Host relationships for cleptoparasitic bees including species' range and RSGCN Concern Level.

RSGCN Cleptoparasitic Bumble Bees (Bombus sp.)	States	RSGCN Concern Level	Host Bee(s)
Gypsy Cuckoo Bumble Bee (*B. bohemicus*)	MA, NH, ME	Moderate	*B. terricola* (RSGCN Moderate Concern), *B. affinis* (RSGCN Very High Concern), and probably *B. occidentalis* and *B. cryptarum*
Lemon Cuckoo Bumble Bee (*B. citrinus*)	NY, VT	Data Deficient	*B. impatiens*, *B. bimaculatus*, *B. vagans*
Variable Cuckoo Bumble Bee (*B. variabilis*)	MD	Very High	*B. pensylvanicus* (RSGCN Moderate Concern)

Many invasive plant species are changing the forest species composition, structure and health. For the most part, specific invasive plants were not linked to individual RSGCN. Emerald ash borer (*Agrilus planipennis*), gypsy moth and others are impacting forests throughout the region, presenting additional concern to RSGCN as pest control measures include insecticides, which could impact the majority of forest and aquatic RSGCN through spraying and runoff. Some RSGCN crayfish are being displaced or extirpated from specific watersheds by non-native or introduced crayfish. Climate change creates conditions for range shifts and expansions of both native and non-native species, but specific links to RSGCN have not yet been made.

Climate Change Factors limiting RSGCN Populations

Compared to other threats, specific impacts of climate change are more uncertain. However, for some groups of species there are known vulnerabilities. Over 100 RSGCN are likely to be impacted by climate change. Across all habitat types, initiatives to reconnect quality habitat are important to facilitate natural dispersal and climate driven range shifts. In the Northeast, across all habitat types, life history requirements, and taxonomic groups, the following themes emerged.

Coastal habitat resilience. In general, coastal species are threatened by sea level rise with impacts to habitat that affect shelter, nesting, and foraging – all habitat uses across life phases. Beaches and other coastal habitats remain a high priority for research and conservation action as loss or degradation of habitat have caused population declines for coastal birds, marine mammals and fishes, and sea turtles. Climate change exacerbates other threats in these coastal habitats with impacts on RSGCN.

Over-wintering. Warming winters present unique challenges for different taxa groups. Snakes are interrupting brumation on warm winter days, with potential health impacts and vulnerabilities to collection, disturbance, or killing at den sites. Bats and other species may also have temperature-dependent wintering strategies, and males and females may have different wintering behaviors or timing. Cave bats (Tri-colored [*Perimyotis subflavus*], Indiana [*Myotis sodalis*], Northern Long-eared [*Myotis septentrionalis*], Little brown [*Myotis lucifugus*], and Virginia Big-Eared [*Corynorhinus townsendii*

virginianus]) are vulnerable to White Nose Syndrome, and there is growing evidence that cave temperature and humidity may influence fungal growth. Burrowing species that rely on constant, undisturbed winter substrates and conditions such as small mammals, crayfish, mussels, and many reptile and amphibians are also becoming more vulnerable with increasing severe weather extremes. In general, less is known about vulnerabilities and requirements during winter when species are less active and often harder to observe. Yet, in the Northeast, winter temperatures may change more significantly than summer temperatures, so it is critical to understand winter vulnerabilities and any impacts climate change may have.

Hydrologic conditions. More intense precipitation events and higher flood stages are predicted in the Northeast. Concerns for freshwater mussels, stoneflies, and crayfish are primarily associated with the potential for scouring floods which have historically wiped out populations in northeast rivers, but also drought conditions which could expose mussels or prevent crayfish from burrowing. These extreme river and stream conditions would also affect freshwater fish and hellbenders, and tiger beetles which do not survive multiple day periods of inundation. Other amphibians will be affected by changes in hydrologic conditions, particularly if higher temperatures increase evapotranspiration, because of their reliance on vernal pools, wetlands, and high elevation habitats. Talus and other rocky habitats are important for snakes and amphibians, and soil moisture and humidity within the rocky spaces is important for these species and their invertebrate food sources. High elevation wetlands and subterranean hydrologic conditions are threatened by warming temperatures and drying. Burrowing crayfish, herps and small mammals require specific moisture and substrate conditions that will be impacted by storm events or intensified drought.

Food resources. Impacts of climate change on food resources are a large area of uncertainty for most taxa groups. Climate change may impact food abundance through temperature (e.g., insects or floral resources) and hydrology (e.g., aquatic insects and fish). Phenology mismatch is a concern both in terrestrial species as well as aquatic species when prey populations and food supplies may not be available during critical times of high energy demands. Red Knots (*Calidris canutus rufa*), Roseate Terns (*Sterna dougallii*), and N. Atlantic Right Whales (*Eubalaena glacialis*) are coastal examples, while bats and neotropical songbirds (including RSGCN warblers and Bicknell's Thrush [*Catharus bicknelli*]) highlight the importance of forest insect hatch timing. Offshore, initial research shows marked warming and acidification underway in Gulf of Maine waters. In combination with historic impacts of intense harvesting and weakening influence of the Labrador Current, system-level changes are likely to induce changes in species distribution and prey availability for SGCN seabirds and shorebirds, as well as increase disease risks. A reduction in zooplankton, which could be caused by warming ocean waters, would have widespread impacts on marine fish and mammals.

Other Research Needs. Some RSGCN need climate vulnerability assessments that could be accomplished efficiently for taxonomic groups such as amphibians relying on vernal pools, freshwater mussels, and hibernating bats. Specific research topics were suggested:

- **Birds.** Many birds may be limited by food availability due to phenology changes if birds' lifecycles are regulated by hours of daylight (unchanged), while prey lifecycles, particularly invertebrates, are regulated by water or air temperature (warming earlier each year). As an example, Red Knot (*Calidris canutus* rufa) migration is triggered by daylight hours, but Horseshoe Crab (*Limulus Polyphemus*) nesting and egg availability is triggered by ocean

temperature. For coastal birds, sea level rise and storm surge threaten nesting success and forage habitat suitability. Inland birds can respond to warming temperatures by shifting ranges northward and to higher elevations, but boreal species in the Northeast have little opportunity to seek refugia and birds with higher site fidelity may also adapt more slowly. While birds are less affected by disease than other taxa, there is some evidence that warmer, wetter conditions are increasing the threat of West Nile Virus for some species.

- **Mammals.** Many of the mammals share the wintering and hydrologic concerns and food resource uncertainties described above. Some of these species may also be adapting to climate change through range shifts, but survey efforts at the northern and southern edges of ranges may need to be intensified to detect range shifts. Like other taxa found only at high elevations, there are concerns about loss of suitable habitat with climate change. The North Atlantic Right Whale, one of the most endangered marine mammals, urgently requires research to understand impacts of ocean warming and acidification.
- **Reptiles**. Warming winter temperatures are affecting brumation with unknown impacts for individuals or populations. Warming temperatures during nesting will cause shifting sex ratios for almost all RSGCN turtles (e.g. Northern Diamondback Terrapins (*Malaclemys t. terrapin*) in Maryland now have a sex ratio of 9:1 females:males due, in part, to more females than males in clutches hatching in warmer nests – higher proportions of males as bycatch in crab traps also explain the shifting sex ratio.) Sea turtles and Northern Diamondback Terrapins have vulnerabilities during nesting to sea level rise or storm surge. Reptiles may also be affected by changes in hydrologic regimes, particularly moisture regimes in high elevation rocky habitats.
- **Amphibians.** Most RSGCN salamanders have specific hydrologic requirements for vernal pools, soil moisture conditions, and late summer refuges that provide humid conditions. The high elevation Plethodon species have little opportunity to seek alternative high-quality habitats and their habitats are at risk of warming or drying in late summer. Coastal RSGCN (Eastern Mud Salamander [*Pseudotriton m. montanus*] and Atlantic Coast Leopard Frog [*Lithobates kauffeldi*]), like other coastal species, have anticipated habitat degradation due to sea level rise and saltwater intrusion.
- **Fish** are affected by water temperature, ocean acidification, extreme precipitation or drought – with potential direct mortality, impaired health and fitness, and impacts to food resources and reproductive success. Climate vulnerability assessments are needed for most fish.
- **Aquatic invertebrates**. Aquatic invertebrates are particularly vulnerable to flood scour and droughts. Temperature shifts may also affect aquatic invertebrates directly. If warming water temperatures affect host fish, mussel reproduction may be limited and species ranges may retract from the southern edge. Dispersal upstream to cooler waters may be more difficult for mussels and less mobile aquatic invertebrates. For headwaters species this dispersal is limited by habitat and dams can limit dispersal for downstream species. Predicted warming water temperatures can cause algal blooms and associated degradation of water quality which may impact aquatic invertebrates. Near coasts, saltwater intrusion may make habitats unsuitable. If warming temperatures increase pressure from forest insect pests and insecticide spraying increases, runoff may impact aquatic invertebrates.

- **Butterflies**. While climate change impacts to many butterflies is unknown, the high elevation butterflies of New Hampshire and Vermont, like other high elevation species, are vulnerable due to the fact that there are no suitable habitats to disperse into. Fortunately, current habitats are well protected.

Food Factors limiting RSGCN Populations

Foraging is an important life history factor to consider when exploring vulnerabilities of RSGCN. The majority of vertebrate RSGCN are invertivores (66% in the adult life stage and 69% in the juvenile life stage) (Figure 7). Recent reports estimating severe invertebrate biomass declines globally and nationally were referenced by taxonomic experts (e.g. Hallmann et al. 2017, Wagner 2020), but in general the thresholds of insect abundance that trigger further population declines are unknown.

Taxonomic experts were able to rule out food limitations as a cause of population decline for 60 species, but more than half of RSGCN (264 species) have unknown impacts related to the availability of food as a limitation on population. Only four RSGCN have documented food resource limitations: Red Knot (*Calidris canutus*), Roseate Tern (*Sterna dougallii*), Allegheny Woodrat (*Neotoma magister*), and Acuminate Crayfish (*Cambarus cf. accuminatus*).

Most RSGCN do not rely on a single species of plant or animal as their food source. Some seem to be restricted to a small group of species, and others are food specialists and may be more vulnerable to food-related population declines (including 3 of the food limited species listed above):

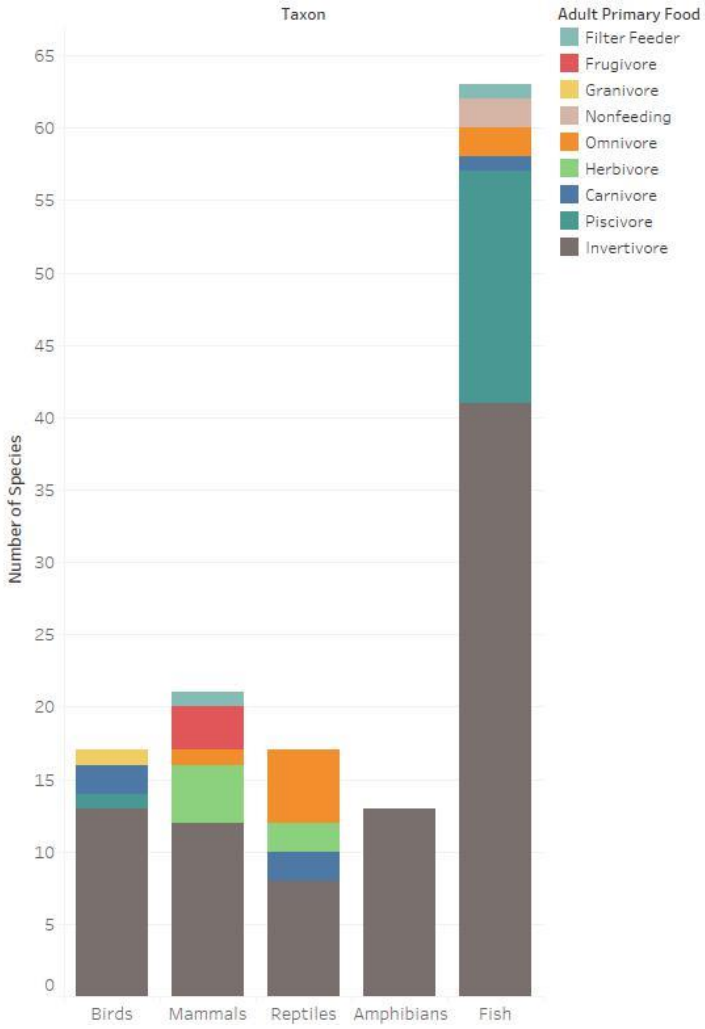


Figure 8. Primary food types for adult, vertebrate RSGCN.

- Eastern Hellbender (*Cryptobranchus a. alleganiensis*) – adults rely on crayfish, juveniles rely on mayflies
- Red Knot (*Calidris canutus*) – relies on Horseshoe Crab (*Limulus polyphemus*) eggs during migration (USFWS 2019)
- Roseate Tern (*Sterna dougallii*) – relies on sandlance (Goyert 2014)
- Allegheny Woodrat (*Neotoma magister*) – relied heavily on American chestnut, now on other mast producing tree species (LoGiudice 2008)

- Atlantic Leatherback Sea Turtle (*Dermochelys coriacea*) – relies on jellyfish
- Mountain Earthsnake (*Virginia valeriae pulchra*) – relies on earthworms (Ware 2008)
- Freshwater fish (in general) –rely on aquatic insect larvae and nymphs (midge, stonefly, caddisfly, mayfly, beetles) – requirements may be species specific or a group of species.
- Bats (in general) – relies on nocturnal lepidoptera
- Butterflies (in general) – have host plants that may be specific to a species or a group of species.

Other food-related factors involve exposure to toxicity through food sources. Related to the strong representation of invertivores, toxicity from insecticide application has potential impacts for most species. Specifically, spraying for forest pests like gypsy moth (*Lymantria dispar dispar*) and wooly adelgid (*Adelges tsugae*) was a concern for RSGCN inhabiting Forests or Rivers and Streams through consumption of invertebrates or contaminated water. It is important to note that invasive species are increasingly threatening forest health and that controlling forest pests (even biocontrols) have intrinsic risks to RSGCN and the environment. Possible changes in food limitations with climate change are described below on page 18.

Research and Monitoring

A common thread across taxa was the need for adequate research, survey and monitoring to determine baseline status and detect changes in populations before they reach critical levels beyond which they cannot be recovered. Multiple taxa recommendations included the need for rangewide consistent monitoring protocols. This proactive approach would provide for improved status assessments as well as additional opportunities for conservation avoiding the need to list at the federal level.

Across many taxa, there are ongoing efforts to clarify species, subspecies, and subpopulations particularly for freshwater mussels, crayfish, and some herpetofauna.

Invertebrate biomass. Because of the high number of vertebrate RSGCN relying on invertebrate food sources, there is a need to understand invertebrate biomass declines and thresholds of food availability that cause populations declines (Wagner 2020). This research could be focused on nocturnal insects, particularly moths, which are an important food source for bats. It could be focused on primary insect food sources for birds and include phenological studies which have begun to show that thresholds of availability can affect health and survival of offspring (e.g. Bewick et al. 2016, Damien and Tougeron 2019). Alternatively, a project could be designed to link known declines in freshwater mussels, crayfish, or other aquatic invertebrates to declines in their predators to understand how the loss of aquatic invertebrates has caused declines in fish and other water-associated vertebrate RSGCN.

Insecticide toxicity. Also related to the high number of invertivores, many taxa experts cited a concern that forest pest insecticide spraying could have toxic impacts on vertebrate RSGCN through food or water. These concerns are related to bats, birds, reptiles, amphibians, fish, and aquatic invertebrates. Pest spraying campaigns that were mentioned are for gypsy moth and hemlock wooly adelgid. However, a concern for biocontrols was also expressed and would require additional research.

Disease. There is an ongoing need to track impacts of disease in reptiles and amphibians. There is also a need to learn if diseases of freshwater mussels or crayfish are responsible for population declines. Finally, West Nile Virus is known to impact some birds but impacts to RSGCN birds are unknown.

Loss of Genetic Diversity. Some RSGCN, like the New England Cottontail and Allegheny Woodrat, are known to be limited by loss of genetic diversity and are responding to captive breeding and translocation programs. Several other RSGCN with severe declines would benefit from studies to understand remaining genetic diversity and impacts of population isolation followed by captive breeding programs to reintroduce genetic diversity in isolated populations.

Wintering. Across many taxonomic groups, wintering vulnerabilities are an area of uncertainty. Species may adapt to predicted warming winters by changing the timing of wintering or the wintering strategies, but so little is known about triggers for hibernation or migration, temperature-dependent activity states, or changes in energy demands associated with these changes in activity levels. The increase in installation of wind energy along common migration routes adds urgency to understanding timing and other aspects of migration for birds and tree bats.

Take and Collection. Much is known about impacts of collection on turtles – but collection pressure is dynamic and responsive to changes in world markets. Other snakes, colorful fish, and mussels may also be targeted for collection. Of course, many species are affected by incidental take, overfishing, or bycatch with unknown population level impacts.

Changes in hydrologic regimes. Because of the large number of RSGCN associated with hydrologically defined habitats, anticipated changes in precipitation regimes and evapotranspiration will affect many RSGCN. Sedimentation, which has already changed substrate conditions in many streams, will need to be mitigated during extreme events in the future. Some RSGCN are impacted by water management structures, the function of which may also need to be redesigned given future extreme precipitation scenarios. In Maine, a management recommendation is to conserve vernal pools with a variety of hydroperiods, and connections among them, and Maine has several research projects underway to investigate aspects of these questions ((Marvinney et al. 2020) , Amanda Cross, pers. comm).

Coastal habitats. These habitats have been degraded or reduced in size by intensive development along the coast and are now further threatened by sea level rise and storm surge. All RSGCN along the coast are affected by loss of habitat and intensified beach management. Some are affected by changing phenology of predator-prey relationships, ocean acidification, and warming temperatures. Continued efforts to improve habitat management, improve resiliency, promote living shorelines as an adaptation strategy, and monitor RSGCN are needed.

Conclusion and Opportunities

This effort was timed to inform the upcoming 2021-22 RSGCN list update, meet the CSWG proposal development period, and assist the RCN prioritization and funding processes. In support of NEFWDTC's ongoing charge to maintain the RSGCN list, and in preparation for SWAP revisions in 2025, this new information on habitat requirements and limiting factors will be combined with existing data on threats to RSGCN from the 2015 SWAPs. These additional habitat and life history data will be available within the NE SWAP database, which is used by states and their partners throughout the region to inform their wildlife diversity conservation and research priorities.

Drawing on many literature sources and personal field observations, the data now available for Northeast RSGCN has been reviewed by state taxonomic experts throughout the region to identify the key limiting life history and habitat factors specific to species' populations in the Northeast. Taxa teams

fully engaged and discussed ongoing threats but also current, emerging issues. These discussions help taxa experts working independently in each state to learn what is being found in adjacent states and improves efficiency and effectiveness for staff with limited time to track all SGCN. These results will be referenced by state wildlife diversity programs and wildlife action plan coordinators.

These results were provided to the NEFWDTC which immediately incorporated them into their established communication process for internal prioritization and then externally to partners to expand the conservation effort and develop the most effective means to address them regionally in a consistent manner. This reinforces the value of the NEFWDTC's RCN process to identify and regularly update the fish and wildlife diversity conservation priorities and issues raised by states. This information is being used to inform the current RCN 3.0 project funding that is in turn identifying the best match of partner roles and capacity to maximize effectiveness and cast a wider conservation footprint across the region. Example partner programs that can use this information include:

- Forestry programs – specifically to be incorporated into their Forest Action Plans through SWAP coordination and implementation
- Natural Resources Conservation Service and US Fish and Wildlife Service private lands programs for habitat management, agriculture, riparian buffers, wetlands, etc.
- National Oceanic and Atmospheric Administration's National Marine Fisheries Service for coordination and consultation in support of anadromous and marine species
- US Fish and Wildlife Service's Science Applications, At Risk Species, Endangered Species, and Species Status Assessment efforts to maximize efficiency in these processes which overlap with NEFWDTC and state efforts

Lessons learned through this process include the need to improve information sharing and collaboration with marine and invertebrate counterparts at the state level (e.g., marine resource agencies and departments of agriculture) as well as regional National Marine Fisheries Service offices, if anadromous and marine species are to be included as RSGCN.

Invertebrates remain underrepresented due to the lack of data and expertise. Each iteration of the RSGCN list expands to additional taxa when adequate data and expertise emerge. Nocturnal lepidopterans emerged as an important taxonomic group and should be prioritized for inclusion when possible.

Opportunities exist and may be more appropriately implemented at the regional scale to address pervasive threats. Specifically, to address the RSGCN aquatic habitat need for water quality, improved coordination with the Environmental Protection Agency, State water quality management agencies, and the US Army Corps of Engineers could include monitoring and identification of more specific taxonomic levels. Since sedimentation and pollution were identified as key drivers for RSGCN fish, mussels, crayfish, and stoneflies, research and coordination could establish new chemical thresholds for these vulnerable aquatic RSGCN.

Consistent outreach information and messaging could be developed to encourage the inclusion of RSGCN in agency and partner programs. The Northeast Conservation Information & Education Association could be engaged to accomplish this. Many opportunities for communications products have existed over the years, but these products are outside the scope of TCI's current contract. Targeted

action items and messages could be developed for each internal and external partner on why and how to conserve RSGCN. As 'best management practices' and protocols for the priority taxa identified in this report are developed, they could be promoted and distributed regionally. Improved social media and web presence is needed for more effective and extensive outreach.

On the technical side, the database remains accessible to agencies and their partners. This could be upgraded to an improved web portal/platform to increase use and accessibility. The NEAFWA website as a host has received relatively low visitation, and the database and RSGCN information could be more widely accessible to broader audiences to maximize conservation partner access and use.

In summary, state Wildlife Diversity Program Managers and Wildlife Action Plan coordinators remain committed to working together on ongoing and emerging RSGCN issues and have incorporated and applied this additional information as they review it for regional prioritization as well as in their state programs. This regional collaboration saves time and resources and produces more effective outcomes on the ground for the highest priority conservation needs for RSGCN and their habitat in the Northeast.

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Appendix A

Crosswalk of new limiting factors with Conservation Measures Partnership threat categories v 2.0. (Conservation Measures Partnership 2016)

Level 1 Threats	Level 2 Threats	Relevant New Database Fields
1. Residential & Commercial Development		All of the habitat factors can be constrained or degraded by any type of development*
2. Agriculture & Aquaculture		All of the habitat factors can be constrained or degraded by any type of development*; Breeding & Mortality #3 (toxicity)
3. Energy Production & Mining		All of the habitat factors can be constrained or degraded by any type of development*; Breeding & Mortality #3 (toxicity)
4. Transportation & Service Corridors		All of the habitat factors can be constrained or degraded by any type of development*; Breeding & Mortality #6 (take)
5. Biological Resource Use	5.1 Hunting & Collecting Terrestrial Animals	Breeding & Mortality #6 (take, incidental)
	5.3 Logging & Wood Harvesting	All of the habitat factors can be constrained or degraded by any type of development*; but see Habitat/Forest Age Class, Vegetation Density, and Indicate Other Important Habitat Attributes
	5.4 Fishing & Harvesting Aquatic Resources	Breeding & Mortality #6 (take)
6. Human Intrusions & Disturbance		See * below
7. Natural System Modifications	7.1 Fire & Fire Suppression	Habitat/Forest (Other Important Attributes) ; See * below
	7.2 Dams & Water Management Use	Habitat (specific question); See * below
8. Invasive & Problematic Species, Pathogens & Genes	8.1 Invasive Plants and Animals	Food Comments; See * below
	8.4 Pathogens & Microbes	Breeding & Mortality #2 (disease)
9. Pollution		Breeding & Mortality #3 (toxicity); See * below
10. Geological Events		See * below
11. Climate Change	11.1 Ecosystem Encroachment	See * below

	11.2 Changes in Geochemical Regimes	See * below
	11.3 Changes in Temperature Regimes	Habitat, Breeding and Mortality #8, and Migration and Wintering
	11.4 Changes in Precip & Hydrologic Regimes	Habitat, Migration and Wintering; See * below
	11.5 Severe / Extreme Weather Events	See * below
Threats with no clear category	Predation	Breeding & Mortality #5 (predation)
	Species dependencies	Food – host plants; Breeding & Mortality #7 (species reliance on others)
	Genetic Diversity	Breeding & Mortality #4 (population isolation and loss genetic diversity)
	Food limitations	Food
	Habitat Condition*	Most of the data fields in Habitat Details

*The root threats to habitat (such as Natural System modification, Invasive species, Pollution, Climate Change, and others) can cause loss of habitat availability or degradation of habitat condition, but simply specifying the threat does not adequately indicate the impact or the condition requirements. The habitat condition information is needed to explain why the threat is causing species decline.

Appendix B

RSGCN list by taxa, alphabetized by scientific name (red indicates Very High Concern). Online and downloadable at bit.ly/NE_RSGCN.

Birds

Ammodramus caudacutus (Saltmarsh Sparrow)
Aquila chrysaetos (Golden Eagle)
Calidris canutus (Red Knot)
Calidris maritima (Purple Sandpiper)
Catharus bicknelli (Bicknell's Thrush)
Charadrius melodus (Piping Plover)
Histrionicus histrionicus (Harlequin Duck)
Hylocichla mustelina (Wood Thrush)
Lanius ludovicianus migrans (Migrant Loggerhead Shrike)
Laterallus jamaicensis (Black Rail)
Melospiza georgiana nigrescens (Coastal Plain Swamp Sparrow)
Numenius phaeopus (Whimbrel)
Passerculus sandwichensis princeps (Ipswich Sparrow)
Setophaga cerulea (Cerulean Warbler)
Somateria mollissima dresseri (American Common Eider)
Sterna dougallii (Roseate Tern)
Vermivora chrysoptera (Golden-winged Warbler)

Mammals

Corynorhinus townsendii virginianus (Virginia Big-eared Bat)
Cryptotis parva (North American Least Shrew)
Eubalaena glacialis (North Atlantic Right Whale)
Glaucomys sabrinus fuscus (West Virginia Northern Flying Squirrel)
Lasionycteris noctivagans (Silver-haired Bat)
Lasiurus borealis (Eastern Red Bat)
Lasiurus cinereus (Hoary Bat)
Microtus chrotorrhinus (Rock Vole)
Myotis leibii (Eastern Small-footed Bat)
Myotis lucifugus (Little Brown Bat)
Myotis septentrionalis (Northern Long-eared Bat)
Myotis sodalis (Indiana Bat)
Neotoma magister (Allegheny Woodrat)
Perimyotis subflavus (Tri-colored Bat)
Sciurus niger cinereus (Delmarva Fox Squirrel)
Sorex dispar (Long-tailed or Rock Shrew)
Sorex palustris punctulatus (Southern/West Virginia Water Shrew)
Spilogale putorius (Eastern Spotted Skunk)
Sylvilagus obscurus (Appalachian Cottontail)
Sylvilagus transitionalis (New England Cottontail)
Synaptomys borealis (Northern Bog Lemming)

Reptiles

Caretta caretta (Atlantic Loggerhead Sea Turtle)
Chelonia mydas (Atlantic Green Sea Turtle)
Clemmys guttata (Spotted Turtle)
Coluber c. constrictor (Northern Black Racer)
Crotalus horridus (Timber Rattlesnake)
Dermochelys coriacea (Atlantic Leatherback Sea Turtle)
Emydoidea blandingii (Blanding's Turtle)
Eretmochelys i. imbricata (Atlantic Hawksbill Sea Turtle)
Glyptemys insculpta (Wood Turtle)
Glyptemys muhlenbergii (Bog Turtle)
Lepidochelys kempii (Kemp's Atlantic Ridley Sea Turtle)
Malaclemys t. terrapin (Northern Diamond-backed Terrapin)
Opheodrys vernalis (Smooth Greensnake)
Plestiodon a. anthracinus (Northern Coal Skink)
Pseudemys rubriventris pop. 1 (Northern Red-bellied Cooter)
Terrapene carolina (Eastern Box Turtle)
Virginia valeriae pulchra (Mountain Earthsnake)

Amphibians

Aneides aeneus (Green Salamander)
Cryptobranchus a. alleganiensis (Eastern Hellbender)
Desmognathus organi (Northern Pygmy Salamander)
Gyrinophilus porphyriticus duryi (Kentucky Spring Salamander)
Gyrinophilus subterraneus (West Virginia Spring Salamander)
Lithobates kauffeldi (Atlantic Coast Leopard Frog)
Plethodon hubrichti (Peaks of Otter Salamander)
Plethodon nettingi (Cheat Mountain Salamander)
Plethodon punctatus (Cow Knob Salamander)
Plethodon shenandoah (Shenandoah Salamander)
Plethodon virginia (Shenandoah Mountain Salamander)
Plethodon welleri (Weller's Salamander)
Pseudotriton m. montanus (Eastern Mud Salamander)

Anadromous Fish

Alosa pseudoharengus (Alewife)
Acipenser brevirostrum (Shortnose Sturgeon)
Alosa aestivalis (Blueback Herring)
Acipenser oxyrinchus (Atlantic Sturgeon)

Freshwater Fish

Aphredoderus sayanus gibbosus (Western Pirate Perch)
Catostomus utawana (Summer Sucker)
Clinostomus elongatus (Redside Dace)
Cottus baileyi (Black Sculpin)
Cottus carolinae kanawhae (Kanawha Sculpin)
Cottus sp. 1 (Bluestone Sculpin)
Cottus sp. 4 (Clinch Sculpin)
Cottus sp. 5 (Holston Sculpin)
Cottus sp. 7 (Checkered Sculpin)
Crystallaria cincotta (Diamond Darter)
Enneacanthus chaetodon (Blackbanded Sunfish)
Enneacanthus obesus (Banded Sunfish)
Erimonax monachus (Spotfin Chub)
Erimystax cahni (Slender Chub)
Etheostoma fusiforme (Swamp Darter)
Etheostoma longimanum (Longfin Darter)
Etheostoma maculatum (Spotted Darter)
Etheostoma osburni (Candy Darter)
Etheostoma percnurum (Duskytail Darter)
Etheostoma sellare (Maryland Darter)
Etheostoma variatum (Variegate Darter)
Etheostoma vitreum (Glassy Darter)
Exoglossum laurae (Tonguetied Minnow)
Ichthyomyzon greeleyi (Mountain Brook Lamprey)
Ictiobus cyprinellus (Bigmouth Buffalo)
Lethenteron appendix (American Brook Lamprey)
Margariscus margarita (Pearl Dace)
Notropis alborus (Whitemouth Shiner)
Notropis bifrenatus (Bridle Shiner)
Notropis scabriceps (New River Shiner)
Notropis semperasper (Roughhead Shiner)
Percina bimaculata (Chesapeake Logperch)
Percina gymnocephala (Appalachia Darter)
Percina macrocephala (Longhead Darter)
Percina notogramma (Stripeback Darter)

Marine Fish

Alopias superciliosus (Bigeye Thresher Shark)
Alopias vulpinus (Thresher Shark)
Amblyraja radiata (Thorny Skate)
Carcharhinus obscurus (Dusky Shark)
Carcharhinus signatus (Night Shark)
Carcharodon carcharias (White Shark)
Centropristis striata (Black Sea Bass)
Cynoscion regalis (Weakfish)
Dipturus laevis (Barndoor Skate)
Hippocampus erectus (Lined Seahorse)
Isurus oxyrinchus (Shortfin Mako Shark)
Isurus paucus (Longfin Mako Shark)
Lamna nasus (Porbeagle Shark)
Leucoraja ocellata (Winter Skate)
Malacoraja senta (Smooth Skate)
Paralichthys dentatus (Summer Flounder)
Pomatomus saltatrix (Bluefish)
Pseudopleuronectes americanus (Winter Flounder)
Rhincodon typus (Whale Shark)
Sphyrna lewini (Scalloped Hammerhead Shark)
Sphyrna zygaena (Smooth Hammerhead Shark)
Squalus acanthias (Spiny Dogfish)
Tautoga onitis (Tautog)
Thunnus thynnus (Atlantic Bluefin Tuna)

Invertebrates

Solitary Bees

Colletes aestivalis (A Cellophane Bee)
Epeoloides pilosula (Macropis Cuckoo)
Lasioglossum arantium (A Hairy-tongue Bee)
Lasioglossum georgeickworti (A Hairy-tongue Bee)
Lasioglossum pectinatum (A Sweat Bee)
Macropis ciliata (Fringed Loosestrife Oil-bee)
Macropis nuda (Naked Oil-collecting Bee)
Macropis patellata (Patellar Oil-collecting Bee)
Megachile ingenua (A Solitary Bee)
Nomada festiva
Nomada rodecki
Perdita novaeangliae

Bumble Bees

Bombus affinis (Rusty-patched Bumble Bee)
Bombus bohemicus/ashtoni (Gypsy/Ashton's Cuckoo Bumble Bee)
Bombus citrinus (Lemon Cuckoo Bumble Bee)
Bombus pensylvanicus (American Bumble Bee)
Bombus terricola (Yellow-banded Bumble Bee)
Bombus variabilis (Variable Cuckoo Bumble Bee)

Butterflies and Skippers

Atrytone arogos arogos (Arogos Skipper)
Boloria chariclea montinus (White Mountain Fritillary)
Calephelis borealis (Northern Metalmark)
Callophrys hesseli (Hessel's Hairstreak)
Callophrys irus (Frosted Elfin)
Callophrys lanoraieensis (Bog Elfin)
Callophrys polios (Hoary Elfin)
Cupido amyntula maritima (Western Tailed Blue)
Danaus plexippus (Monarch Butterfly)
Erora laeta (Early Hairstreak)
Erynnis lucilius (Columbine Duskywing)
Erynnis martialis (Mottled Duskywing)
Erynnis persius persius (Persius Duskywing)
Euphyes dukesi (Dukes' Skipper)
Euphyes pilatka (Palatka Skipper)
Lycaena dorcas claytoni (Clayton's Copper)
Neonympha mitchellii (Mitchell's Satyr)
Oeneis melissa semidea (White Mountain Arctic)
Oeneis polixenes katahdin (Katahdin Arctic)

Pieris virginiensis (West Virginia White)
Plebejus idas empetri (Crowberry Blue)
Plebejus melissa samuelis (Karner Blue Butterfly)
Poanes massasoit chermocki (Chermock's Mulberry Wing)
Problema bulenta (Rare Skipper)
Pyrgus wyandot (Appalachian Grizzled Skipper)
Satyrium edwardsii (Edwards' Hairstreak)
Satyrium kingi (King's Hairstreak)
Speyeria diana (Diana Fritillary)
Speyeria idalia (Regal Fritillary)

Moths

Abagrotis nefascia benjamini (Coastal Heathland Cutworm / Benjamin's Abagrostis)
Acronicta albarufa (Barrens/Albarufan Dagger Moth)
Acronicta dolli (Doll's Merolonche)
Agrotis buchholzi (Buchholz's Dart Moth)
Apamea inebriata (Drunk Apamea Moth)
Apodrepanulatrix liberaria (A Geometrid Moth)
Brachionycha borealis (Boreal Fan Moth)
Catocala herodias gerhardi (Pine Barrens Underwing)
Catocala marmorata (Marbled Underwing)
Catocala pretiosa pretiosa (Precious Underwing)
Chaetaglaea cerata (A Noctuid Moth)
Crambus daeckellus (Daecke's Pyralid Moth)
Cyclophora culicaria (Sand Myrtle Looper/Pink)
Drasteria occulta (Drasteria Moth)
Erastria coloraria (Broad-lined Erastria Moth)
Euchlaena milnei (Milne's Euchlaena Moth)
Hadena ectypa (A Noctuid Moth)
Hemipachnobia subporphyrea (Venus Flytrap Cutworm)
Heterocampa varia (A Notodontid Moth)
Hypomecis buchholzaria (Buchholz's Gray)
Lithophane lepida lepida (A Noctuid Moth)
Lycia rachelae (Twilight Moth)
Lytrosis permagnaria (A Geometrid Moth)
Melanapamea mixta (A Noctuid Moth)
Metarranthis apiciaria (Barrens Metarranthis Moth)
Metarranthis pilosaria (Coastal Swamp Metarranthis)
Metarranthis sp. Near duaria (Early Metarranthis Moth)
Neoligia semicana (Northern Brocade Moth)
Papaipema araliae (Aralia Shoot Borer Moth)
Papaipema astuta (Yellow Stoneroot Borer)
Papaipema cerina (Golden Borer Moth)
Papaipema duplicatus (Dark Stoneroot Borer Moth)
Papaipema sp. 1 (Flypoison Borer Moth)
Papaipema sp. 2 nr. pterisii (Ostrich Fern Borer Moth)
Papaipema sulphurata (Water-willow Stem Borer)
Phoberia ingenua (An Oak Moth)
Photedes carterae (Carter's Noctuid Moth)
Psectraglaea carnosa (Pink Sallow Moth)
Psectrotarsia hebardi (Stoneroot Flower Moth)
Pyrrhia aurantiago (Aureolaria Seed Borer)
Schinia septentrionalis (Northern Flower Moth)
Speranza exonerata (Barrens Itame)
Sthenopis auratus (Gold-spotted Ghost Moth)
Zale lunifera (Bold-based Zale Moth)

Tiger Beetles

Cicindela ancocisconensis (Appalachian Tiger Beetle)
Cicindela dorsalis dorsalis (Northeastern Beach Tiger Beetle)
Cicindela marginipennis (Cobblestone Tiger Beetle)
Cicindela patruela consentanea (Northern Barrens Tiger Beetle - NJ Barrens Tiger Beetle)
Cicindela patruela patruela (Northern Barrens Tiger Beetle)
Cicindela puritana (Puritan Tiger Beetle)
Cicindela rufiventris hentzii (Hentz's Red-bellied Tiger Beetle)

Dragonflies and Damselflies

Calopteryx angustipennis (Appalachian Jewelwing)
Celithemis martha (Martha's Pennant)
Cordulegaster erronea (Tiger Spiketail)
Enallagma laterale (New England Bluet)
Enallagma minusculum (Little Bluet)
Enallagma pictum (Scarlet Bluet)
Enallagma recurvatum (Pine Barrens Bluet)
Gomphus abbreviatus (Spine-crowned Clubtail)
Gomphus descriptus (Harpoon Clubtail)
Gomphus quadricolor (Rapids Clubtail)
Gomphus rogersi (Sable Clubtail)
Gomphus septima delawarensis (Septima's Clubtail (delawarensis))
Nannothemis bella (Elfin Skimmer)
Neurocordulia michaeli (Broad-tailed Shadowdragon)
Ophiogomphus anomalus (Extra-striped Snaketail)
Ophiogomphus howei (Pygmy Snaketail)
Ophiogomphus mainensis (Maine Snaketail)
Rhionaeschna mutata (Spatterdock Darner)
Somatochlora brevicincta (Quebec Emerald)
Somatochlora elongata (Ski-tipped Emerald)
Somatochlora incurvata (Incurvate Emerald)
Williamsonia fletcheri (Ebony Boghaunter)
Williamsonia lintneri (Ringed Boghaunter)

Crayfish

Cambarus callainus (Big Sandy Crayfish)
Cambarus elkensis (Elk River Crayfish)
Cambarus hatfieldi (Tug Valley Crayfish)
Cambarus magerae (Big Stone Crayfish)
Cambarus monongalensis (Blue Crayfish)
Cambarus nerterius (Greenbriar Cave Crayfish)
Cambarus pauleyi (Meadow River Mudbug)
Cambarus smilax (Greenbrier Crayfish)

Cambarus veteranus (Guyandotte River Crayfish)
Orconectes virginiensis (Chowanoke Crayfish)

Freshwater Mussels

Alasmidonta heterodon (Dwarf Wedgemussel)
Alasmidonta varicosa (Brook Floater)
Elliptio angustata (Carolina Lance Mussel)
Elliptio fisheriana (Northern Lance Mussel)
Elliptio lanceolata (Yellow Lance)
Elliptio producta (Atlantic Spike)
Epioblasma florentina aureola (Golden Riffleshell)
Epioblasma torulosa rangiana (Northern Riffleshell)
Epioblasma triquetra (Snuffbox)
Fusconaia masoni (Atlantic Pigtoe)
Fusconaia subrotunda (Longsolid)
Lampsilis abrupta (Pink Mucket)
Lampsilis cariosa (Yellow Lampmussel)
Lasmigona holstonia (Tennessee Heelsplitter)
Lasmigona subviridis (Green Floater)
Leptodea ochracea (Tidewater Mucket)
Ligumia nasuta (Eastern Pondmussel)
Pleurobema clava (Clubshell)
Pleurobema collina (James Spinymussel)
Pleuronaia dolabelloides (Slabside Pearlymussel)
Pleuronaia barnesiana (Tennessee Pigtoe)
Ptychobranchus subtentum (Fluted Kidneyshell)
Quadrula cylindrica strigillata (Rough Rabbitsfoot)
Quadrula intermedia (Cumberland Monkeyface)
Quadrula sparsa (Appalachian Monkeyface)
Venustaconcha trabalis (Tennessee Bean)
Villosa constricta (Notched Rainbow)
Villosa fabalis (Rayed Bean)

Stoneflies

Acroneuria arida (Elegant Stone)
Acroneuria flinti (Manassas Stonefly)
Allocapnia frumi (Monongahela Stonefly)
Allocapnia harperi (Stonyfork Snowfly)
Allocapnia illinoensis (Illinois Snowfly)
Allocapnia simmonsi (Spatulate Snowfly)
Alloperla aracoma (Aracoma Sallfly)
Alloperla biserrata (Dusky Sallfly)
Alloperla stipitata (Blue Ridge Sallfly)
Alloperla voinae (Lawrence Stonefly)
Alloperla vostoki (Scotia Sallfly)
Diploperla kanawholensis (Kanawhole Springfly)
Diura washingtoniana (Presidential Springfly)
Hansonoperla appalachia (Appalachian Stonefly)
Hansonoperla hokolesqua (Splendid Stonefly)
Isoperla gibbsae (Quebec stripetail)
Isoperla major (Big stripetail stonefly)
Isoperla myersi (Paddle Stripetail)
Isoperla stewarti (Stewart Stripetail)
Leuctra laura (Hampshire Needlefly)
Leuctra monticola (Montane Needlefly)
Megaleuctra flinti (Shenandoah Needlefly)
Neoperla mainensis (Maine Stone)
Ostrocerca prolongata (Bent Forestfly)
Prostoia hallasi (Swamp Forestfly)
Remenus kirchneri (Blue Ridge Springfly)
Soyedina merritti (Powdermill Forestfly)
Sweltsa holstonensis (Holston Sallfly)
Sweltsa palearata (Shenandoah Sallfly)
Sweltsa pocahontas (A Stonefly)
Taeniopteryx nelsoni (Cryptic Willowfly)
Tallaperla lobata (Lobed Roachfly)
Utaperla gaspesiana (Gaspe Sallfly)

Terrestrial Snails

Anguispira clarki (A Tigersnail)
Anguispira stihleri (Greenbrier Tigersnail)
Glyphyalinia raderi (Rader's/Maryland Glyph Snail)
Glyphyalinia sp. 1 ()
Helicodiscus diadema (Shaggy Coil)
Helicodiscus lirellus (Rubble Coil)
Helicodiscus triodus (Talus Coil)
Helicodiscus villosus (Greenbrier Coil)
Mesomphix luisant (Glossy Button)
Mesomphix sp. 1 (A Button)
Novisuccinea chittenangoensis (Chittenango Ovate Amber Snail)
Paravitrea ceres (Sidelong Supercoil)
Paravitrea hera (Spirit Supercoil)
Paravitrea mira (Funnel Supercoil)
Paravitrea pontis (Natural Bridge Supercoil)
Paravitrea reesei (Round Supercoil)
Paravitrea septadens (Brown Supercoil)
Patera panselenus (Virginia Bladetooth)
Polygyriscus virginianus (Virginia Fringed Mountain Snail)
Stenotrema simile (Bear Creek Siltmouth)
Triodopsis anteridon (Carter Threetoothed Snail)
Triodopsis picea (Spruce Knob Threetooth)
Triodopsis platysayoides (Flat-spired Threetoothed Landsnail)
Triodopsis sp. 1
Vertigo clappi (Cupped Vertigo)
Vertigo parvula (Smallmouth Vertigo)

Appendix C

Crosswalk of coarse habitat classes used in this report with Northeast Habitat Classification Systems (Ferree and Anderson 2013) and IUCN Habitat Classification Scheme.

This report	Northeast Terrestrial Habitat Classification System	IUCN Habitat Classification Scheme (Version 3.1)
Forest	Formation Class 1. Forest and Woodland	1. Forest
Grassland and Shrubland	Formation Class 2. Shrubland and Grassland	Includes 2. Savanna, 3. Shrubland, and 4. Grassland
Freshwater Marshes and Swamps	Formation Class 2. Shrubland and Grassland (as Formation within)	5. Wetlands (inland)
FC4 Captured as a modifier on forest.	Formation Class 4. Polar and High Montane	*FC4 Captured as a modifier on other habitat classes.*
Cliff and Talus	Formation Class 6. Sparsely Vegetated Rock	6. Rocky Areas
FC7/IUCN14 Not captured	Formation Class 7. Agricultural	14. Artificial - Terrestrial
FC8/IUCN14 Not captured	Formation Class 8. Developed	14. Artificial - Terrestrial
Subterranean	Formation Class 9. Subterranean	7. Caves & Subterranean Habitats
Rivers and Streams	Formation Class 10. Freshwater Surface Water (as Formation within)	5. Wetlands (inland)
Lakes and Ponds	Formation Class 10. Freshwater Surface Water (as Formation within)	5. Wetlands (inland)
IUCN8 NA	*IUCN8 NA*	8. Desert
IUCN16 Not captured	*IUCN16 Not captured*	16. Introduced Vegetation

This report	Northeast Aquatic Habitat Classification System	IUCN Habitat Classification Scheme
Tidal Rivers & Streams	Formation Class 11. Brackish Surface Water	9. Marine Neritic
Marine Nearshore	Formation Class 12. Marine	9. Marine Neritic
Marine Offshore	Formation Class 12. Marine	10. Marine Oceanic
IUCN11 Not captured	*IUCN11 Not captured*	11. Marine Deep Ocean Floor
Shoreline, Beaches & Dunes	Formation Class 5. Aquatic	12. Marine Intertidal, 13. Marine Coastal/Supratidal
Tidal Marshes & Swamps	Formation Class 5. Aquatic	12. Marine Intertidal
IUCN15 Not captured	*IUCN15 Not captured*	15. Artificial - Aquatic

Appendix D

Butterfly and Moth host plants documented in database to date.

Scientific Name	Common Name	Host Plant
Atrytone arogos arogos	Arogos Skipper	in NJ little bluestem (Schizachyrium scoparius) and pine barrens reedgrass (Calamovilfa brevipilis)
Boloria chariclea montinus	White Mountain Fritillary	
Calephelis borealis	Northern Metalmark	Senecio obovatus, now called Packera obovata (Family Asteraceae)
Callophrys hesseli	Hessel's Hairstreak	Chamaecyparis thyoides
Callophrys irus	Frosted Elfin	Lupine (Lupinus perennis, L. difformis) and Wild Indigo (Baptisia tinctoria)
Callophrys lanoraieensis	Bog Elfin	new growth of black spruce (NS)
Callophrys polios	Hoary Elfin	Bearberry (Arctostaphylos uva-ursi) and trailing arbutus (Epigaea repens)
Cupido amyntula maritima	Western Tailed Blue	
Danaus plexippus	Monarch Butterfly	milkweeds
Erora laeta	Early Hairstreak	Caterpillars each young fruit of American Beech (Fagus grandifolia) and in portions of the Great Lakes region where beech is unavailable, and in WV, nuts of Beaked Hazelnus (Corylus cornuta)
Erynnis lucilius	Columbine Duskywing	Wild columbine (Aquilegia canadensis) and sometimes garden columbine (A. vulgaris) in the buttercup family (Ranunculaceae). (NS)
Erynnis martialis	Mottled Duskywing	Ceanothus sp.
Erynnis persius persius	Persius Duskywing	Lupine or Baptisia
Euphyes dukesi	Dukes' Skipper	Larger sedges such as Carex lacustris, c. striata, or C. hyalinolepis and others.
Euphyes pilatka	Palatka Skipper	Cladium jamaicense (saw grass)
Lycaena dorcas claytoni	Clayton's Copper	Eggs laid on Potentilla fruticosa (NS)
Neonympha mitchellii	Mitchell's Satyr	sedges (ex. Carex stricta)
Oeneis melissa semidea	White Mountain Arctic	Carex bigelowii
Oeneis polixenes katahdin	Katahdin Arctic	sedge
Pieris virginiensis	West Virginia White	toothworts (Cardamine prev. Dentaria) [garlic mustard toxic]
Plebejus idas empetri	Crowberry Blue	Empetrum nigrum
Plebejus melissa samuelis	Karner Blue Butterfly	Wild lupine
Poanes massasoit chermocki	Chermock's Mulberry Wing	not 100% sure for the subspecies but the species level feeds on Carex stricta which is present at the site in Delaware where the subspecies is found.

Problema bulenta	Rare Skipper	Spartina cynosuroides. Possibly all Spartina. Possibly adapting to Phragmites
Pyrgus wyandot	Appalachian Grizzled Skipper	wild strawberry in Michigan, Potentilla candadensis elsewhere. (NS)
Satyrium edwardsii	Edwards' Hairstreak	Scrub oak (Quercus ilicifolia) and occ. Black oak (Q. velutina) (new growth in spring)
Satyrium kingi	King's Hairstreak	common sweetleaf Symplocos tinctoria
Speyeria diana	Diana Fritillary	Viola
Speyeria idalia	Regal Fritillary	Viola sp.

Appendix E

Fish known to serve as hosts to freshwater mussels (Freshwater Mussel Host Database 2017). Bolded species are RSGCN. Hosts for specific mussel species are only known for a few mussels.

- Darters: Johnny (*Etheostoma nigrum*), Fantail, Striped, Greenside, Redline, Blackside, Rainbow, Iowa, Snubnose, Barcheek, Tessellated (*E. olmstedti*), Bluebreast, Dusky, Tippecanoe (*Etheostoma tippecanoe*), **Spotted (*E. maculatum*)**
- Shiners: Common, Luxilis albeolus, Lythurus matuntinus, Popeye, Rosyface, Saffron, Silver, Telescope, Tennessee, Whitetail (*Notropis galacturus*), Striped, Warpaint, White, Rosefin, Satinfin, Spotfin (*Notropis spilopterus*)
- Chub: Bigeye (*Hybopsis amblops*), Bluehead (*Nocomis leptocephalus*), River (*Nocomis micropogon*), Creek (*Semotilus atromaculatus*), Streamline (*Erimystax dissimilis*), Blotched (*Erimystax insignis*),
- Sculpin: Banded (*Cottus carolinae*), Ozark (*C. hypselurus*), Mottled (*C. bairdii*), Slimy (*C. cognatus*), **Black (*C. baileyi*)**
- Logperch (*Percina sp.*)
- Perch: Yellow (*Perca flavescens*), White (*Morone americana*)
- Dace: Blacknose (*Rhinichthys atratulus*), Rosyside (*Clinostomus funduloides*), Mountain redbelly (*Chrosomus oreas*)
- Central stoneroller (*Campostoma anomalum pullum*)
- Bass: Largemouth (*Micropterus salmoides*) Smallmouth (*M. dolomieu*), Spotted (*M. punctulatus*)
- Rockbass (*Ambloplites rupestris*)
- Sauger (*Sander canadensis*)
- Freshwater Drum (*Aplodinotus grunniens*)
- Banded Killifish (*Fundulus diaphanous*)
- Chain Pickerel (*Esox niger*)
- White Sucker (*Catostomus commersonii*)
- Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*) Redbreast Sunfish (*Lepomis auritus*), Longear (*L. megalotis*), redear (*L. microlophus*)
- Minnow: Bluntnose (*Pimephales notatus*), Fathead (*P. promelas*)
- Brook Stickleback (*Culaea inconstans*)