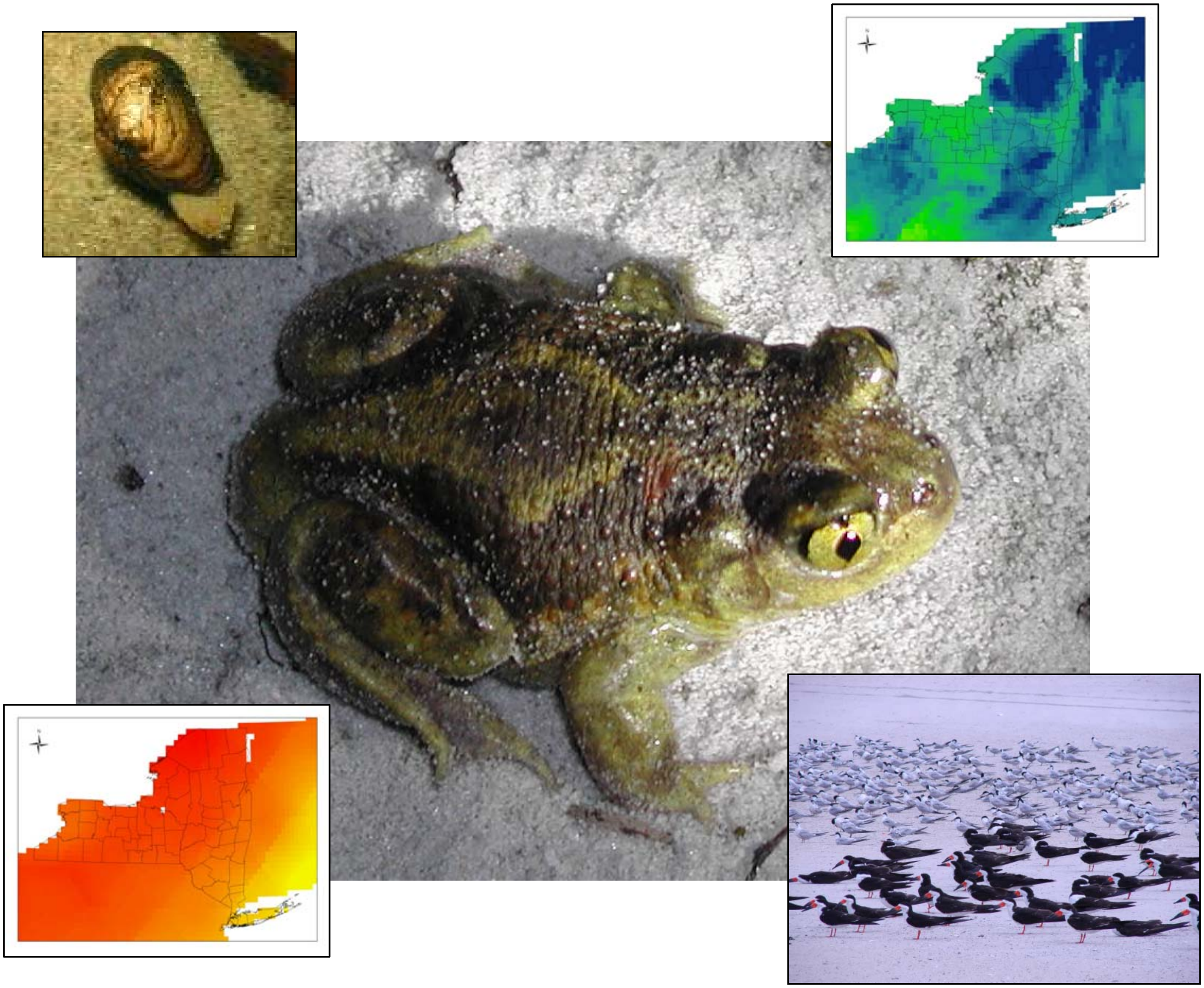

Vulnerability of At-risk Species to Climate Change in New York

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Cover photos: Brook floater (*Alismodonta varicosa*) by E. Gordon, Spadefoot toad (*Scaphiopus holbrookii*) by Jesse Jaycox, and Black Skimmers (*Rynchops niger*) by Steve Young. Climate predictions are from www.climatewizard.org.

Executive summary

Vulnerability assessments are rapidly becoming an essential tool in climate change adaptation planning. As states revise their Wildlife Action Plans, the need to integrate climate change considerations drives the adoption of vulnerability assessments as critical components. To help meet this need for New York, we calculated the relative vulnerability of 119 of New York's Species of Greatest Conservation Need (SGCN) using NatureServe's Climate Change Vulnerability Index (CCVI). Funding was provided to the New York Natural Heritage Program by New York State Wildlife Grants in cooperation with the U.S. Fish and Wildlife Service Division of Wildlife and Sport Fish Restoration.

We selected species spanning taxonomic groups that we thought 1) might be susceptible to climate change, 2) would be good indicators of vulnerability of species in similar habitats, and 3) would have sufficient data to allow conducting the assessment. The CCVI treats climate-change vulnerability as resulting from two factors: exposure and sensitivity. Direct exposure to climate change is assessed using predictions of future changes in temperature and moisture availability based on averages of global circulation models. Indirect exposure considers predicted sea-level rise, existence of barriers to movement, and effects of alternative energy development. Sensitivity is assessed using a variety of factors, including dispersal capability, known sensitivity to changes in temperature and moisture regime, reliance on interspecific interactions, genetic diversity, and expected phenological shifts with changing climate. Finally, the CCVI incorporates documented and modeled effects on the target species. The output is one of five categories of vulnerability: Extremely Vulnerable, Highly Vulnerable, Moderately Vulnerable, Not Vulnerable/Presumed Stable, or Not Vulnerable/Increase Likely. The CCVI also provides a confidence estimate for the information provided.

In New York, species ranged from Highly to Extremely Vulnerable (e.g., frosted elfin, brook floater, tiger salamander) to Presumed Stable (e.g., timber rattlesnake, russet-tipped clubtail, spotted turtle). Nearly all species rated as Highly or Extremely Vulnerable were associated with aquatic or seasonally wet habitats. Mussels emerged as especially vulnerable to climate change, given their low mobility, issues with aquatic connectivity, and reliance on other species for dispersal. The primary factors that drove our assessments included genetic variation, phenological responses, natural and anthropogenic barriers to dispersal, and restriction to specific geological features. Vulnerability was only weakly associated with conservation status. Species at the southern edge of their range in New York might become extirpated from the state. Our results agreed broadly with those from Pennsylvania and West Virginia.

Additional species in need of assessment include plants, crayfish, cave obligates, and functional or habitat groups of species. Our assessment makes several key points: 1) aquatic and terrestrial habitat connectivity must be maintained and restored, 2) for some species, stressors other than climate change are more limiting to their viability; 3) for some species, climate change will likely result in their extirpation no matter what management actions are taken; and 4) long-term monitoring is vital to detecting changes in New York's wildlife populations.

Acknowledgements

Funding was provided to the New York Natural Heritage Program by New York State Wildlife Grants in cooperation with the U.S. Fish and Wildlife Service Division of Wildlife and Sport Fish Restoration. Thanks to Patty Riexinger, Dan Rosenblatt, Tracey Tomajer, Lisa Holst, Carl Herzog, Paul Novak, Tom Bell, Gregg Kenney, Angie Ross, Brianna Gary, and others in NYSDEC who supported this effort and suggested species for the assessment. Thanks also to Tim Tear, Michelle Brown, Marci Bortmann, Marilyn Jordan, Kristin France, and other TNC staff for suggestions and feedback on the list of species. Bruce Young from NatureServe answered our questions about the CCVI. We borrowed some style and ideas for presenting information from Byers and Norris (2011). At NYNHP, Tim Howard taught R and helped with data analysis and editing. Dorothy Evans and Fiona McKinney provided support, feedback, and random assistance at all stages. Andrea Chaloux helped with species selection and Aissa Feldmann helped prepare the final document.

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Introduction

Background and justification

Polar bears may be the most charismatic and well known animal facing imminent threats from our changing climate, but the ramifications of warming, drought, flooding, and intense storms will be felt throughout the animal kingdom. The anticipated effects of climate change on some species include shifting distributions, changes in abundance, delayed or advanced migration events, altered sex ratios, changes in a variety of interspecific interactions, and many more. These kinds of changes have already been seen in a variety of taxa all over the globe (Sala et al. 2000, Schneider and Root 2002, Walther et al. 2002, Parmesan and Yohe 2003, Root et al. 2003, Parmesan and Galbraith 2004, Lawler et al. 2006, Lawler et al. 2009, DeWan et al. 2010, Glick et al. 2011).

Although a great deal of attention has been focused on the world's arctic regions and the tropics, New York and the northeastern U.S. also have been the focus of considerable research and planning in recent years. For example, recent studies have shown shifts in breeding ranges of New York's birds that are consistent with climate change (Zuckerberg et al. 2010), changes in phenology of multiple taxa in the Shawangunk Mountains (Cook et al. 2008), and shifts in the state's odonate fauna that appear to be climate related (Corser et al. in preparation, Corser 2010, White et al. 2010). Planning efforts specific to the region have emerged as well. The Northeast Climate Impacts Assessment Team (Frumhoff et al. 2007) released "Confronting Climate Change in the US Northeast," which summarized the current state of research, modeling, and planning efforts for the region. And Jenkins (2010) outlined a conservation plan for the Adirondacks in the face of climate change. Now, New York is beginning the process of revising its State Wildlife Action Plan. With the first iteration completed in 2005 (NYSDEC 2005), New York qualified for State Wildlife Grants funds and now must revise the plan by 2015. A requirement from the U.S. Fish and Wildlife Service is that states must address climate change in their Plan revision.

One planning tool that is increasingly employed for focusing conservation and management attention on appropriate targets is the vulnerability assessment. These assessments typically take the form of models in which the inputs are characteristics of species or ecosystems and the output is a rating of relative vulnerability. These kinds of risk assessments have a long history in wildlife management and conservation (Boyce 1992, Ruggiero et al. 1994, Faith and Walker 1996), but only recently have standardized assessment tools been available for addressing the threat of climate change. Vulnerability assessments may be especially useful to highlight conservation targets that would not have otherwise received attention, or to focus management on species susceptible to an emerging threat like climate change. The Association of Fish and Wildlife Agencies (2009) has promoted these kinds of assessments as a useful way for states to address climate change in their State Wildlife Action Plan revisions.

At what level to focus vulnerability assessments—species or ecosystems—has been a topic of some debate. Paleoecological studies have demonstrated that ecological communities have disassembled and reassembled in different configurations as individual species responded to changing climate in myriad ways (Hunter et al. 1988; Beier and Brost 2010). Indeed, the entire present biota of New York has only existed here for the past 10-12,000 years, so clearly there has been much recent dynamism in its makeup, with species distributions in constant flux, expanding and contracting as (a)biotic conditions have changed. Some in the conservation community have used this presumption to call for a focus on systems rather than species (Beier and Brost 2010, Anderson and Ferree 2010). NatureServe (2008) eloquently made the argument for addressing both:

> "*While conservation is often targeted towards habitats, and there is a need to understand likely changes in ecosystem conditions and processes, we feel strongly that understanding the effects of climate change on*

individual species is essential as well, not only to target species conservation efforts, but also to understand and project future changes to community and ecosystem composition and structure."

New York State is funding a similar look at the vulnerability of New York's habitat types to climate change (H. Galbraith, pers. comm.), and the results herein will be more useful when integrated with that ongoing analysis.

Available tools and existing efforts

Several tools are now available for assessing the relative vulnerability of species to climate change. The University of Washington (2011) has created a Climate Change Sensitivity Database for species in the Pacific Northwest. It is populated with sensitivity rankings on 10 variables for hundreds of species and allows user-defined weights that drive the calculation of a sensitivity index. The U.S. EPA (2009) has released "A Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change," which combines an assessment of baseline vulnerability with climate change vulnerability, with an explicit assessment of confidence.

NatureServe's Climate Change Vulnerability Index (CCVI; Young et al. 2010) has emerged as an easily applied and objective analysis that many U.S. states have recently adopted. One of its chief strengths is that it is designed to be used in conjunction with NatureServe's conservation status ranks (S-ranks; Master et al. 2009), which are an existing global standard for assessing conservation status based on rarity, trends, and threats. Another strength lies in its explicit incorporation of scientific uncertainty into the assessment: assessors are free to pick a range of values for each factor, and this uncertainty is quantified in a Confidence score. Finally, an Excel workbook is available to calculate index values and document them permanently.

We chose NatureServe's CCVI as the most appropriate tool to assist wildlife managers in New York with planning for climate change adaptation. We ran the CCVI on 121 species, mainly Species of Greatest Conservation Need (SGCN; NYSDEC 2005), that spanned taxonomic groups and habitat associations. We envision that our results will help highlight species-specific conservation needs previously unrecognized. Further, as New York State revises its list of SGCN, we imagine that vulnerability to climate change could be a criterion that allows some otherwise secure species to be recognized as needing conservation attention. In this document we describe our process and make management recommendations based on the results.

Methods

Species selection

We selected species that we thought 1) might be susceptible to climate change, either directly through climate shifts or indirectly through sea-level rise and alternative energy development (this led to the selection of some species on the edges of their ranges and species in coastal and boreal ecosystems); 2) would be good indicators of other species in their habitat; and/or 3) would have sufficient data to allow conducting an assessment. Further, we looked for a balance across taxonomic groups. While other states (Byers and Norris 2011; Pennsylvania Natural Heritage Program 2011) have run the index on plants, our project was funded by State Wildlife Grants and thus focused on Species of Greatest Conservation Need (SGCN), which in New York are all animals. A few species not currently listed as SGCN were included, with the thought that should they be highlighted as vulnerable to climate change, they could be added to the list of SGCN in the upcoming revision process.

In consultation with colleagues at the New York State Department of Environmental Conservation (NYS DEC) and The Nature Conservancy (TNC), we selected 119 species for analysis. Note that this total includes the Boreal Chorus Frog as distinct from the Western Chorus Frog, as per Lemmon et al. (2007). Species' scientific names appear in Tables 2-4 and Appendices B-D.

CCVI methodology

Here we summarize the CCVI methods and discuss specific items unique to New York. Readers are referred to Young et al. (2010) and Byers and Norris (2011) for a fuller documentation.

The CCVI bases its determination of vulnerability to climate change on two main factors: **exposure** to future projected climate change and **sensitivity** to climate change (Table 1; Figure 1). Exposure is further subdivided into direct exposure (projected changes in temperature and moisture availability within the species' range) and indirect exposure (distribution relative to sea level rise, natural and anthropogenic barriers to dispersal, and new land uses aiming to mitigate climate change). It is scored based on the percentage of the species' range within New York that falls into categories of projected changes temperature or moisture. Projections for the year 2050 were downloaded from The Nature Conservancy's Climate Wizard (www.climatewizard.org), which uses downscaled climate models from Maurer et al. (2009; Figure 2).

Sensitivity to climate change is based on a variety of factors, including dispersal capability; past climate regime (Figure 3) and reliance on specific thermal and hydrological conditions; dependence on disturbance; dependence on snow or ice cover; restriction to certain geological types; reliance on interspecific interactions (e.g., herbivory and predator/prey relationships); genetic variation; and climate-related changes in phenology (Table 1). Each species is scored for each sensitivity factor from "decrease vulnerability" to "greatly increase vulnerability" (or a subset range of these categories), with three to six of these categories available for each factor (Figure 1). Descriptions of each factor and examples of how to score them are available in the spreadsheet to help assessors make choices with scoring. Some factors are optional, but certain numbers of factors in each group must be filled out or the Index score is "Insufficient Evidence."

Documented or modeled responses to climate change from the peer-reviewed literature are incorporated as a final factor (Table 1). These were rarely available for our selected species.

The output is one of five categories of vulnerability and one indicating lack of evidence. Definitions, and the abbreviations that are used throughout this document, follow (from Young et al. 2010).

Extremely Vulnerable (EV): Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.

Highly Vulnerable (HV): Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.

Moderately Vulnerable (MV): Abundance and/or range extent within geographical area assessed likely to decrease by 2050.

Not Vulnerable/Presumed Stable (PS): Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.

Not Vulnerable/Increase Likely (IL): Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.

Insufficient Evidence (IE): Available information about a species' vulnerability is inadequate to calculate an Index score.

Table 1. Variables assessed in the CCVI. See Young et al. (2010) for details.

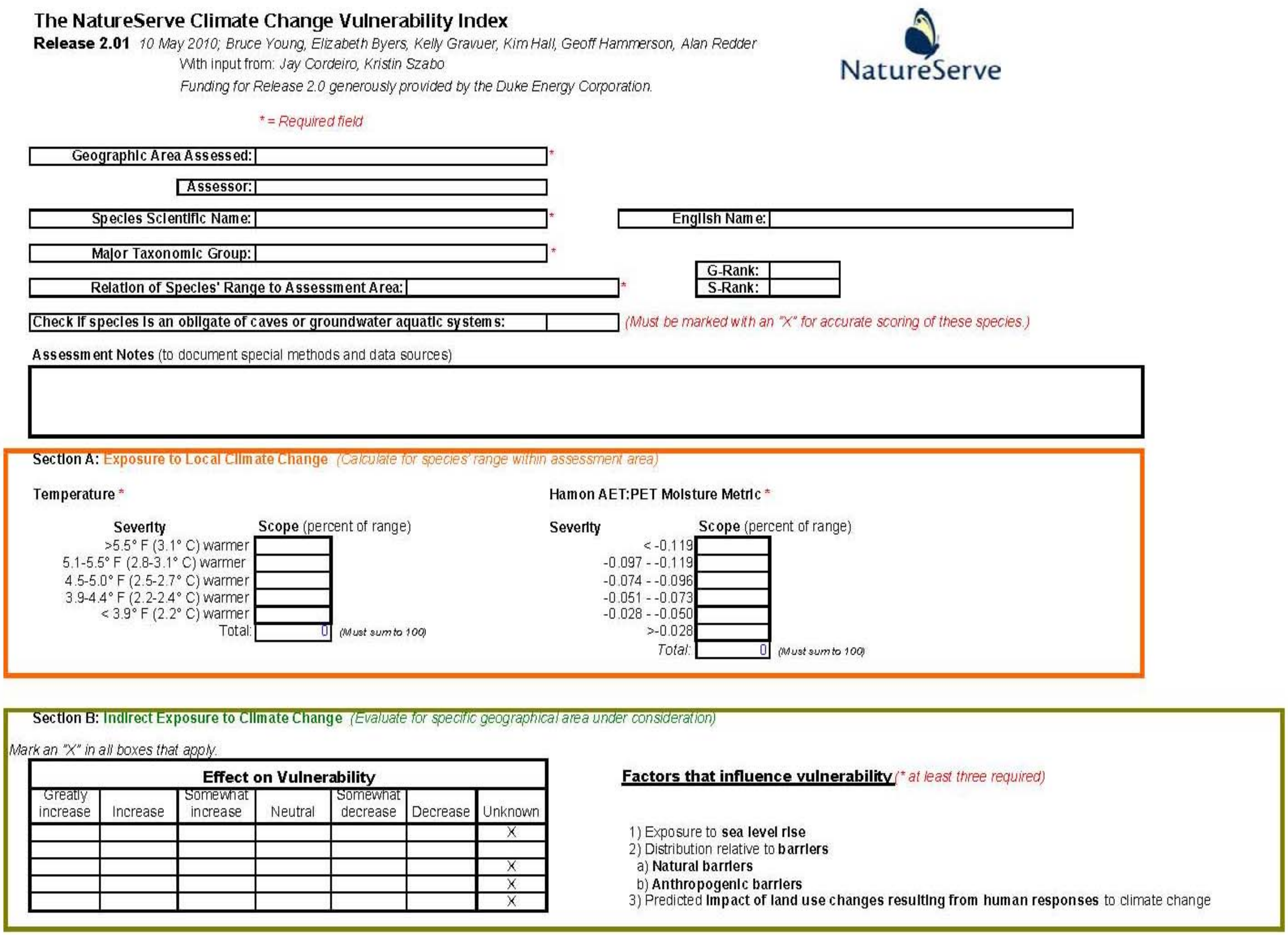
Direct exposure to local projected climate change
Percent of species' range in five categories of increasing temperature
Percent of species' range in six categories of changing moisture regime

Indirect exposure to climate change
Exposure to sea level rise
Distribution relative to natural barriers
Distribution relative to anthropogenic barriers
Predicted impact of land use changes resulting from human responses to climate change

Factors that influence sensitivity to climate change
Dispersal and movements
Predicted sensitivity to changes in temperature
Predicted sensitivity to changes in precipitation, hydrology, or moisture regime
Dependence on a specific disturbance regime likely to be impacted by climate change
Dependence on ice, ice-edge, or snow-cover habitats
Restriction to uncommon geological features or derivatives
Dependence on other species to generate habitat
Dietary versatility (animals only)
Pollinator versatility (plants only)
Dependence on other species for propagule dispersal
Other interspecific interactions
Measured genetic variation
Occurrence of bottlenecks in recent evolutionary history
Phenological response to changing seasonal temperature and precipitation dynamics

Documented or modeled response to climate change
Documented response to recent climate change
Modeled future (2050) change in population or range size
Overlap of modeled future (2050) range with current range
Occurrence of protected areas in modeled future (2050) distribution

Other intrinsic factors
Taxonomic group
Obligation to cave or groundwater aquatic habitats
Relation of species' range to assessment area
State conservation status rank (S-rank)
Global conservation status rank (G-rank)



The NatureServe Climate Change Vulnerability Index

Release 2.01 *10 May 2010; Bruce Young, Elizabeth Byers, Kelly Gravuer, Kim Hall, Geoff Hammerson, Alan Redder*
With input from: *Jay Cordeiro, Kristin Szabo*
Funding for Release 2.0 generously provided by the Duke Energy Corporation.

NatureServe

** = Required field*

Geographic Area Assessed: *
Assessor:
Species Scientific Name: * English Name:
Major Taxonomic Group: *
Relation of Species' Range to Assessment Area: *
G-Rank:
S-Rank:
Check if species is an obligate of caves or groundwater aquatic systems: *(Must be marked with an "X" for accurate scoring of these species.)*

Assessment Notes (to document special methods and data sources)

Section A: Exposure to Local Climate Change *(Calculate for species' range within assessment area)*

Temperature *

Severity	**Scope** (percent of range)
>5.5° F (3.1° C) warmer	
5.1-5.5° F (2.8-3.1° C) warmer	
4.5-5.0° F (2.5-2.7° C) warmer	
3.9-4.4° F (2.2-2.4° C) warmer	
< 3.9° F (2.2° C) warmer	
Total:	0 *(Must sum to 100)*

Hamon AET:PET Moisture Metric *

Severity	**Scope** (percent of range)
< -0.119	
-0.097 - -0.119	
-0.074 - -0.096	
-0.051 - -0.073	
-0.028 - -0.050	
>-0.028	
Total:	0 *(Must sum to 100)*

Section B: Indirect Exposure to Climate Change *(Evaluate for specific geographical area under consideration)*

Mark an "X" in all boxes that apply.

Greatly increase	Increase	Somewhat increase	Neutral	Somewhat decrease	Decrease	Unknown	**Factors that influence vulnerability** *(* at least three required)*
						X	1) Exposure to **sea level rise**
							2) Distribution relative to **barriers**
						X	a) **Natural barriers**
						X	b) **Anthropogenic barriers**
						X	3) Predicted **impact of land use changes resulting from human responses** to climate change

Figure 1. A screen shot of the CCVI form.

Section C: Sensitivity

Mark an "X" in all boxes that apply.

Effect on Vulnerability

Factors that influence vulnerability *(* at least 10 required)*

Factor	Greatly increase	Increase	Somewhat increase	Neutral	Somewhat decrease	Decrease	Unknown
1) **Dispersal and movements**							X
2) Predicted **sensitivity to temperature** and **moisture changes**							
a) Predicted **sensitivity to changes in temperature**							
i) **historical thermal niche**							X
ii) **physiological thermal niche**							X
b) Predicted **sensitivity to changes in precipitation, hydrology, or moisture regime**							
i) **historical hydrological niche**							X
ii) **physiological hydrological niche**							X
c) Dependence on a **specific disturbance regime** likely to be impacted by climate change							X
d) Dependence on **ice, ice-edge, or snow-cover habitats**							X
3) **Restriction to uncommon geological features or derivatives**							X
4) **Reliance on interspecific interactions**							
a) Dependence on **other species to generate habitat**							X
b) **Dietary versatility** (animals only)							X
c) **Pollinator versatility** (plants only)							X
d) Dependence on **other species for propagule dispersal**							X
e) Forms part of an **interspecific interaction** not covered by 4a-d							X
5) **Genetic factors**							
a) Measured **genetic variation**							X
b) Occurrence of **bottlenecks** in recent evolutionary history *(use only if 5a is "unknown")*							X
6) **Phenological response to** changing seasonal temperature and precipitation dynamics							X

Section D: Documented or Modeled Response to Climate Change *(Optional; May apply across the range of a species)*

Mark an "X" in all boxes that apply.

Effect on Vulnerability

(Optional)

Factor	Greatly increase	Increase	Somewhat increase	Neutral	Somewhat decrease	Decrease	Unknown
1) **Documented response** to recent climate change							X
2) Modeled **future (2050) change in population** or **range size**							X
3) **Overlap** of modeled future (2050) range with current range							X
4) Occurrence of **protected areas in modeled future (2050) distribution**							X

Climate Change Vulnerability Index

Insufficient Evidence

Notes:

Confidence in Species Information

—-

* Histogram below

Figure 1 (continued).

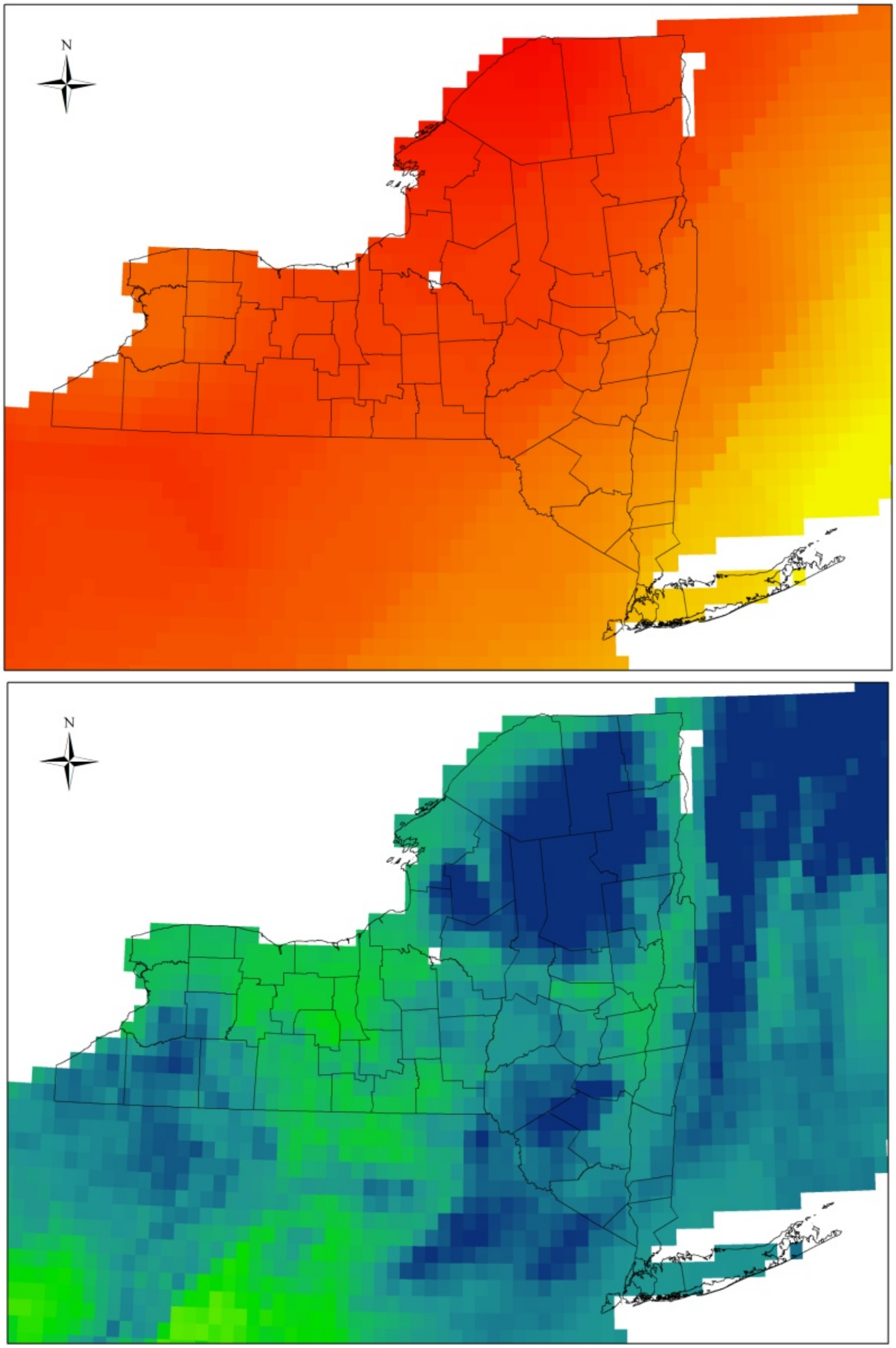


Figure 2. (Top) Projected temperature increase for New York State by 2050, increasing from yellow (~4.5°F) to red (~5.5°F). (Bottom) Projected decreases in moisture availability by 2050, from bright green (most drying) to dark blue (least drying). Data from www.climatewizard.org.

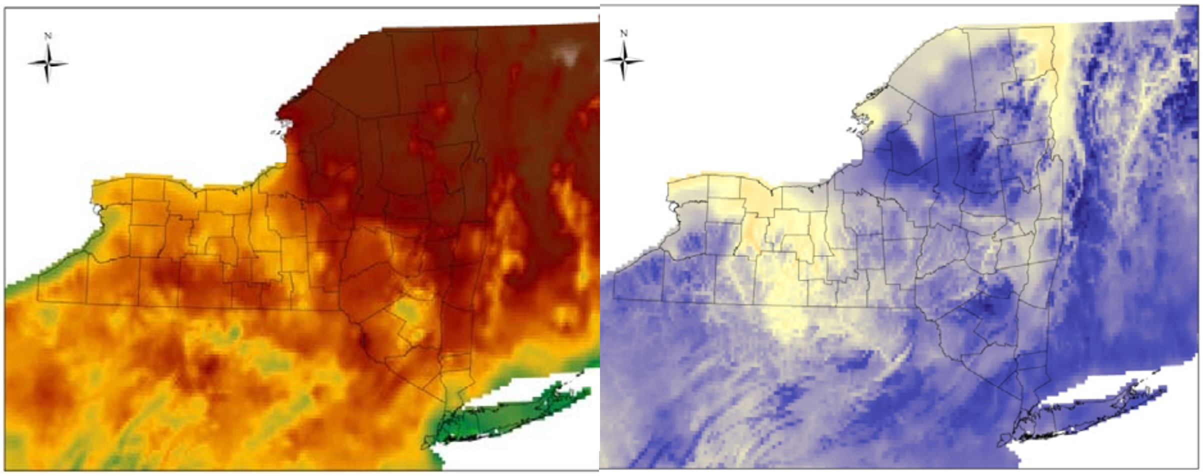


Figure 3. Climate regime in New York over the past 50 years: temperature (left; increasing temperature from green to red) and precipitation (right; increasing precipitation from white to dark blue). Data from www.climatewizard.org.

The CCVI also provides a confidence estimate for the information provided, which is based on the degree of certainty in the factor values as represented by the frequency of multiple categories of vulnerability being selected for a given factor.

Results and discussion

Seventy (59%) of the 119 species assessed were determined to be vulnerable (EV, HV, or MV) to climate change (Figure 4). Assessment scores of all species are documented in Appendices B through D. Two Noctuid moths, *Sideridis maryx* (maroonwing) and *Trichoclea artesta* (Hairy artesta) were determined to have Insufficient Evidence for assessing vulnerability because of a lack of available information, and are not treated any further here.

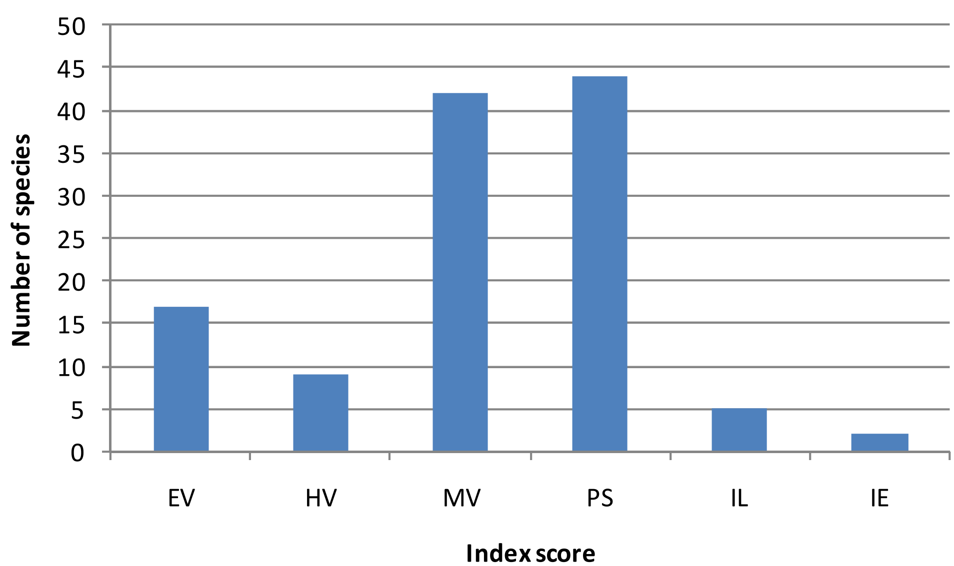


Figure 4. Number of species in each category of vulnerability. See page 3 for index abbreviations.

Species rated as "Extremely Vulnerable" or "Highly Vulnerable"

Seventeen species were rated as "Extremely Vulnerable" and nine as "Highly Vulnerable" (Table 2). Twenty-four (89%) of these species are aquatic or closely associated with aquatic and seasonally wet habitats. The remaining three are butterflies that are poor dispersers and are dependent on a single foodplant.

Table 2. Species assessed as "Extremely Vulnerable" or "Highly Vulnerable." Codes are defined in Appendix A.

Taxonomic group	Scientific name	Common name	Global status	State status	State listing
Extremely vulnerable					
Amphibian	*Ambystoma tigrinum*	Eastern tiger salamander	G5	S1S2	E
Amphibian	*Cryptobranchus alleganiensis*	Hellbender	G3G4	S2	SC
Bird	*Falcipennis canadensis*	Spruce grouse	G5	S2	E
Fish	*Acipenser brevirostrum*	Shortnose sturgeon	G3	S1	E
Fish	*Acipenser fulvescens*	Lake sturgeon	G3G4	S1S2	T
Fish	*Acipenser oxyrinchus*	Atlantic sturgeon	G3	S1	T
Fish	*Prosopium cylindraceum*	Round whitefish	G5	S1S2	E
Insect	*Callophrys irus*	Frosted elfin	G3	S1S2	T
Insect	*Hemileuca* sp. 1	Bogbean buckmoth	G1Q	S1	E
Insect	*Plebejus melissa samuelis*	Karner blue	G5T2	S1	E
Mollusk	*Alasmidonta heterodon*	Dwarf wedgemussel	G1	S1	E
Mollusk	*Alasmidonta varicosa*	Brook floater	G3	S1	T
Mollusk	*Lasmigona subviridis*	Green floater	G3	S1S2	T
Mollusk	*Ligumia recta*	Black sandshell	G5	S2	
Mollusk	*Margaritifera margaritifera*	Eastern pearlshell	G4	S2	
Mollusk	*Novisuccinea chittenangoensis*	Chittenango ovate amber snail	G1	S1	E
Reptile	*Glyptemys muhlenbergii*	Bog turtle	G3	S2	E
Highly vulnerable					
Amphibian	*Ambystoma opacum*	Marbled salamander	G5	S3	SC
Amphibian	*Rana septentrionalis*	Mink frog	G5	S5	
Amphibian	*Scaphiopus holbrooki*	Eastern spadefoot	G5	S2S3	SC
Fish	*Cottus cognatus*	Slimy sculpin	G5	S4	
Fish	*Salvelinus fontinalis*	Brook trout	G5	S5	
Insect	*Euchloe olympia*	Olympia marble	G4G5	S1	SC
Insect	*Siphlonisca aerodromia*	Tomah mayfly	G2G3	S1	E
Mollusk	*Amblema plicata*	Three-ridge	G5	S1	
Reptile	*Kinosteron subrubrum*	Mud turtle	G5	S1	E

Species rated as "Moderately Vulnerable"

Forty-three species were assessed as "Moderately Vulnerable" to climate change (Table 3).

Table 3. Species assessed as "Moderately Vulnerable." Codes are defined in Appendix A.

Taxonomic group	Scientific name	Common name	Global status	State status	State listing
Amphibian	*Acris crepitans*	Cricket frog	G5	S1	E
Amphibian	*Pseudacris maculata*	Boreal chorus frog	G5	S2	
Amphibian	*Pseudacris triseriata*	Western chorus frog	G5	S2	
Amphibian	*Rana sphenocephala*	Southern leopard frog	G5	S1S2	SC
Bird	*Ammodramus caudacutus*	Saltmarsh sharp-tailed sparrow	G4	S3	
Bird	*Ammodramus maritimus*	Seaside sparrow	G4	S2S3	SC
Bird	*Caprimulgus carolinensis*	Chuck-will's widow	G5	S1	PB
Bird	*Catharus bicknelli*	Bicknell's thrush	G4	S2	SC
Bird	*Charadrius melodus*	Piping plover	G3	S3B	E
Bird	*Contopus cooperi*	Olive-sided flycatcher	G5	S3	
Bird	*Haematopus palliatus*	American oystercatcher	G5	S3	
Bird	*Laterallus jamaicensis*	Black rail	G4	S1	E
Bird	*Rallus longirostris*	Clapper rail	G5	S3	
Bird	*Rynchops niger*	Black skimmer	G5	S2	SC
Bird	*Sterna dougallii dougallii*	Roseate tern	G4T3	S1B	E
Bird	*Tringa semipalmata*	Willet	G5	S1	
Fish	*Alosa sapidissima*	American shad	G5	S4	P
Fish	*Ammocrypta pellucida*	Eastern sand darter	G4	S2	T
Fish	*Anguilla rostrata*	American eel	G4	S3	
Fish	*Catostomus utawana*	Summer sucker	G2	S2	
Fish	*Coregonus artedi*	Cisco or lake herring	G5	S3	
Fish	*Coregonus clupeaformis*	Lake whitefish	G5	S4	
Fish	*Enneacanthus obesus*	Banded sunfish	G5	S1S2	T
Fish	*Ichthyomyzon greeleyi*	Mountain brook lamprey	G3G4	S1	SC
Fish	*Lota lota*	Burbot	G5	S3	
Fish	*Notropis anogenus*	Pugnose shiner	G3	S1	E
Insect	*Cicindela hirticollis*	Hairy-necked tiger beetle	G5	S1S2	
Insect	*Erynnis persius persius*	Persius duskywing	G5T1T3	S1	E
Insect	*Hemileuca maia* ssp. 5	Coastal barrens buckmoth	G5T3	S2	SC
Insect	*Oeneis jutta*	Jutta arctic	G5	S1	
Insect	*Pteronarcys comstocki*	Spiny salmonfly	G3	SNR	
Mollusk	*Anodonta implicata*	Alewife floater	G5	S1S2	
Mollusk	*Lampsilis fasciola*	Wavyrayed lampmussel	G5	S1	T
Mollusk	*Ligumia nasuta*	Eastern pondmussel	G4	S2S3	
Mollusk	*Villosa fabalis*	Rayed bean	G2	S1	E
Mammal	*Martes americana*	American marten	G5	S3	
Mammal	*Myotis leibii*	Small-footed bat	G3	S2	SC

Taxonomic group	Scientific name	Common name	Global status	State status	State listing
Mammal	*Myotis sodalis*	Indiana bat	G2	S1	E
Mammal	*Sylvilagus transitionalis*	New England cottontail	G3	S1S2	SC
Reptile	*Emydoidea blandingii*	Blanding's turtle	G4	S2S3	T
Reptile	*Heterodon platirhinos*	Eastern hog-nosed snake	G5	S3	SC
Reptile	*Malaclemys terrapin*	Diamondback terrapin	G4	S3	G

Species rated as "Presumed Stable" or "Increase Likely"

Forty-four species were rated as "Presumed Stable" and five as "Increase Likely" (Table 4).

Table 4. Species assessed as "Presumed Stable" or "Increase Likely." Codes are defined in Appendix A.

Taxonomic group	Scientific name	Common name	Global status	State status	State listing
Presumed stable					
Amphibian	*Eurycea longicauda*	Longtail salamander	G5	S2	SC
Amphibian	*Plethodon wehrlei*	Wehrle's salamander	G4	S3	
Bird	*Ammodramus henslowii*	Henslow's sparrow	G4	S3B	T
Bird	*Chlidonias niger*	Black tern	G4	S2	E
Bird	*Dolichonyx oryzivorus*	Bobolink	G5	S5	
Bird	*Euphagus carolinus*	Rusty blackbird	G4	S2	PB
Bird	*Picoides arcticus*	Black-backed woodpecker	G5	S3?	
Bird	*Picoides dorsalis*	American three-toed woodpecker	G5	S2	PB
Bird	*Poecile hudsonicus*	Boreal chickadee	G5	S3	
Fish	*Etheostoma olmstedi*	Tessellated darter	G5	S5	
Fish	*Lepomis megalotis*	Longear sunfish	G5	S1	T
Fish	*Menidia menidia*	Atlantic silverside	G5	S2S3	
Fish	*Moxostoma duquesnii*	Black redhorse	G5	S2	SC
Fish	*Percina macrocephala*	Longhead darter	G3	S1	T
Insect	*Chlosyne gorgone*	Gorgone checkerspot	G5	S1	
Insect	*Cicindela ancocisconensis*	Appalachian tiger beetle	G3	S2	
Insect	*Cicindela marginipennis*	Cobblestone tiger beetle	G2	S1	
Insect	*Cordulegaster erronea*	Tiger spiketail	G4	S1	
Insect	*Enallagma recurvatum*	Pine barrens bluet	G3	S1	T
Insect	*Gomphus vastus*	Cobra clubtail	G5	S1	
Insect	*Heptagenia culacantha*	A Mayfly	G2G3	SNR	
Insect	*Hygrotus sylvanus*	Sylvan Hygrotus diving beetle	GU	S1	
Insect	*Ischnura ramburii*	Rambur's forktail	G5	S2S3	
Insect	*Ophiogomphus howei*	Pygmy snaketail	G3	S1	SC
Insect	*Somatochlora cingulata*	Lake emerald	G5	S1	
Insect	*Somatochlora forcipata*	Forcipate emerald	G5	S1S3	
Insect	*Somatochlora minor*	Ocellated emerald	G5	S1S3	

Taxonomic group	Scientific name	Common name	Global status	State status	State listing
Insect	*Stylurus plagiatus*	Russet-tipped clubtail	G5	S1	
Insect	*Sympetrum danae*	Black meadowhawk	G5	S2S3	
Insect	*Tachopteryx thorei*	Gray petaltail	G4	S2	SC
Insect	*Williamsonia fletcheri*	Ebony boghaunter	G4	S1	
Mammal	*Alces americanus*	Moose	G5	S3S4	G
Mammal	*Lasiurus cinereus*	Hoary bat	G5	S4	
Mammal	*Myotis lucifugus*	Little brown bat	G5	S5	
Reptile	*Apalone spinifera*	Spiny softshell	G5	S2S3	SC
Reptile	*Clemmys guttata*	Spotted turtle	G5	S3	SC
Reptile	*Crotalus horridus*	Timber rattlesnake	G4	S3	T
Reptile	*Eumeces anthracinus*	Coal skink	G5	S2S3	G
Reptile	*Eumesces (Plestiodon) fasciatus*	Five-lined skink	G5	S3	G
Reptile	*Glyptemys insculpta*	Wood turtle	G4	S3	SC
Reptile	*Regina septemvittata*	Queen snake	G5	S1	E
Reptile	*Sceloporous undulatus*	Eastern fence lizard	G5	S1	T
Reptile	*Sistrurus catenatus catenatus*	Eastern massasauga	G3G4	S1	E
Reptile	*Terrepene carolina*	Box turtle	G5	S3	SC
Increase likely					
Insect	*Cicindela patruela*	Northern barrens tiger beetle	G3T3	S1	
Insect	*Gomphus rogersi*	Sable clubtail	G4	S1	
Insect	*Progomphus obscurus*	Common sanddragon	G5	S1	SC
Insect	*Rhionaeschna mutata*	Spatterdock darner	G4	S2S3	
Reptile	*Coluber constrictor*	Eastern racer	G5	S4	

Factors affecting vulnerability

Some taxonomic groups were determined to be more vulnerable to climate change than others. All mollusks assessed were determined to be vulnerable, with over 50% of the species assessed rated as Extremely Vulnerable (Figure 5). Similarly, 40% of amphibians were rated as Extremely or Highly Vulnerable. Birds and mammals, on the other hand, were less vulnerable on the whole, with only one bird species and no mammals rated as Extremely Vulnerable or Highly Vulnerable. Nearly 70% of reptiles assessed were rated Presumed Stable or Increase Likely, with only the Bog Turtle (EV) and Mud Turtle (HV) rating higher than Moderately Vulnerable, due to dispersal barriers and their aquatic nature.

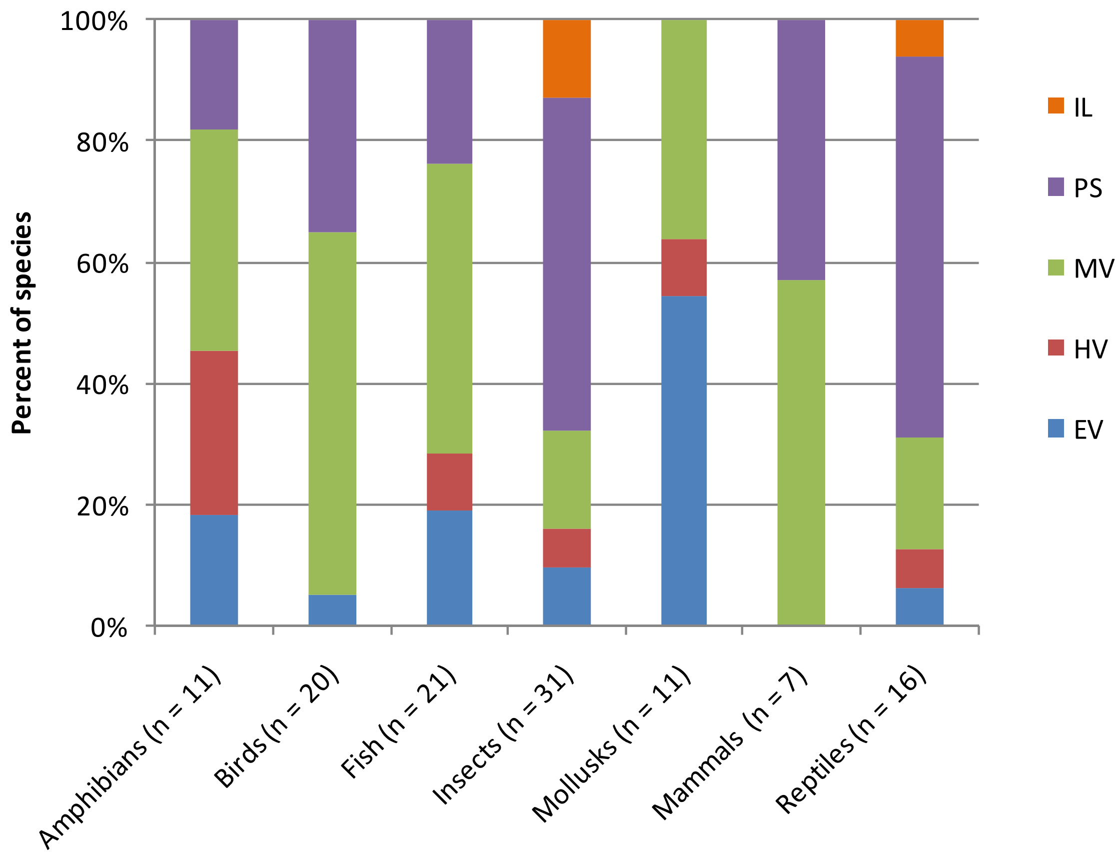


Figure 5. Percent of species within seven taxonomic groups in each vulnerability category. See page 3 for index abbreviations.

Conservation status and vulnerability to climate change were not perfectly related to one another. Although over 60% of the most imperiled species in the state (rank of S1) were assessed as vulnerable to climate change, over 70% of species ranked as apparently secure in the state (S4) were also assessed as vulnerable (Figure 6). Similarly, apart from the most globally imperiled species, global conservation status rank was unrelated to vulnerability (Figure 7). NatureServe notes that the vulnerability index is intended to be used in conjunction with the conservation status rank, and it is conceivable that certain highly imperiled species might not be threatened primarily by climate change, but by more immediate threats such as habitat destruction, overcollection, or disease unrelated to climate. Nevertheless, only S1 and S2 species were ranked as EV, indicating that the highly restricted ranges of the most imperiled species in NY likely subjects these species to enhanced threats from climate change.

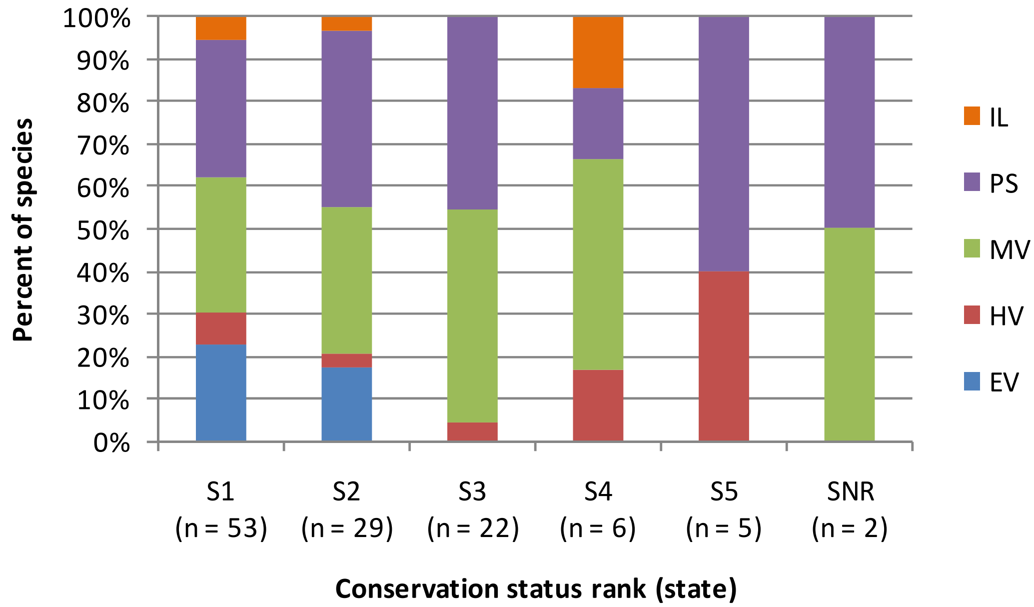


Figure 6. Percent of species within six rounded state conservation status ranks in each vulnerability category. See page 3 for index abbreviations.

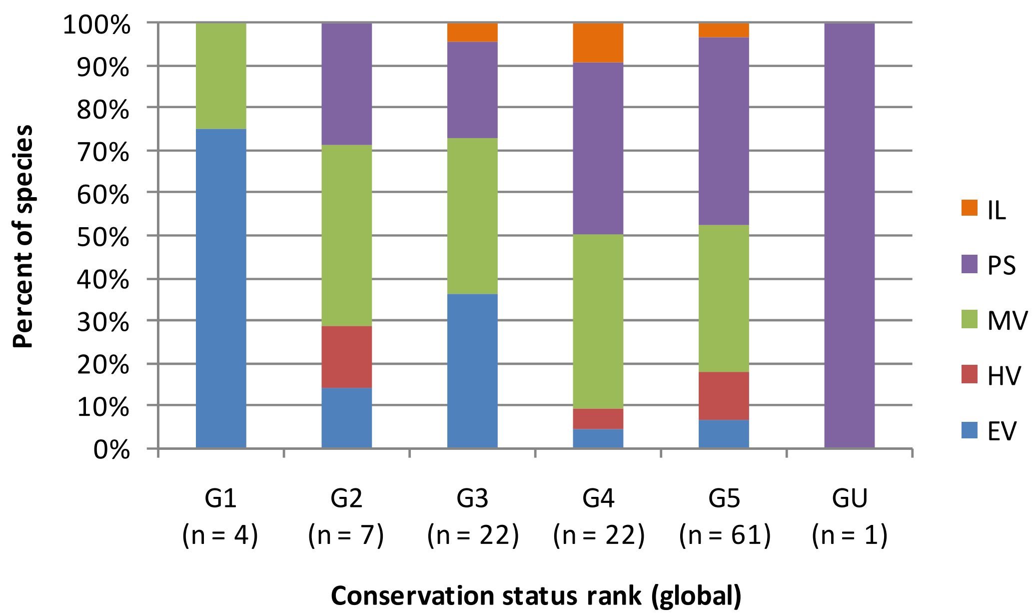


Figure 7. Percent of species within six rounded global conservation status ranks in each vulnerability category. See page 3 for index abbreviations.

To determine the factors most important in assessing vulnerability, we built classification trees using the Random Forests (Breiman 2001; Liaw and Wiener 2002) package in R (R Development Core Team 2011), a technique from the field of machine learning. The Random Forests routine is to build thousands of classification and regression trees using bootstrap samples of the data set and predictors. This method can provide multiple solutions for a given problem, making it effective at finding different combinations of factors influencing the dependent variable (in this case, the vulnerability index). We limited our predictor variables to the exposure and sensitivity variables influencing vulnerability (i.e., omitting documented and modeled responses) and imputed (estimated) values recorded as "Unknown," as the routine does not accept missing data. We ran the Random Forests routine on three variants of the vulnerability index: 1) the index as calculated; 2) the index collapsed into three categories (not vulnerable [increase likely and presumed stable], moderately vulnerable, and highly vulnerable [highly vulnerable and extremely vulnerable]; and 3) the index collapsed into two categories (not vulnerable [increase likely and presumed stable] and vulnerable [moderately vulnerable, highly vulnerable, and extremely vulnerable]). As the results of these analyses were very similar, we report only the results using the full 5-level index.

The validation component of the Random Forests routine was highly successful in predicting each species' assigned vulnerability category, with 86.32% correct classification (Table 5). When vulnerability categories were collapsed, the routine was even more successful, but those results are omitted here for brevity.

Genetic factors predisposing species to potential climate change effects were easily the most important in our assessments (Figure 8). Species with reduced genetic variation are less likely to be able to respond to environmental change (e.g., Aitken et al. 2008). When documented and modeled responses were included in earlier analyses (omitted here), they were in the top position. Likely, these factors were so important in part because information on them was limited to <30% of the species (genetic variation, n = 32; genetic bottleneck, n = 36; phenological response, n = 36, documented response, n = 12, modeled response, n = 6) and typically limited to species of already elevated concern and those suspected to be vulnerable to climate change (and therefore a focus of research).

Table 5. Confusion matrix generated by the Random Forests routine, showing assessed values (rows) and predicted values (columns) along with the associated error rate. The overall error rate of the classification was 13.68%. See page 3 for index abbreviations.

	IL	PS	MV	HV	EV	Error (%)
IL	1	3	1	0	0	80.0
PS	0	44	0	0	0	0.0
MV	0	1	40	0	1	4.8
HV	0	2	2	2	3	77.8
EV	0	1	1	1	14	17.6

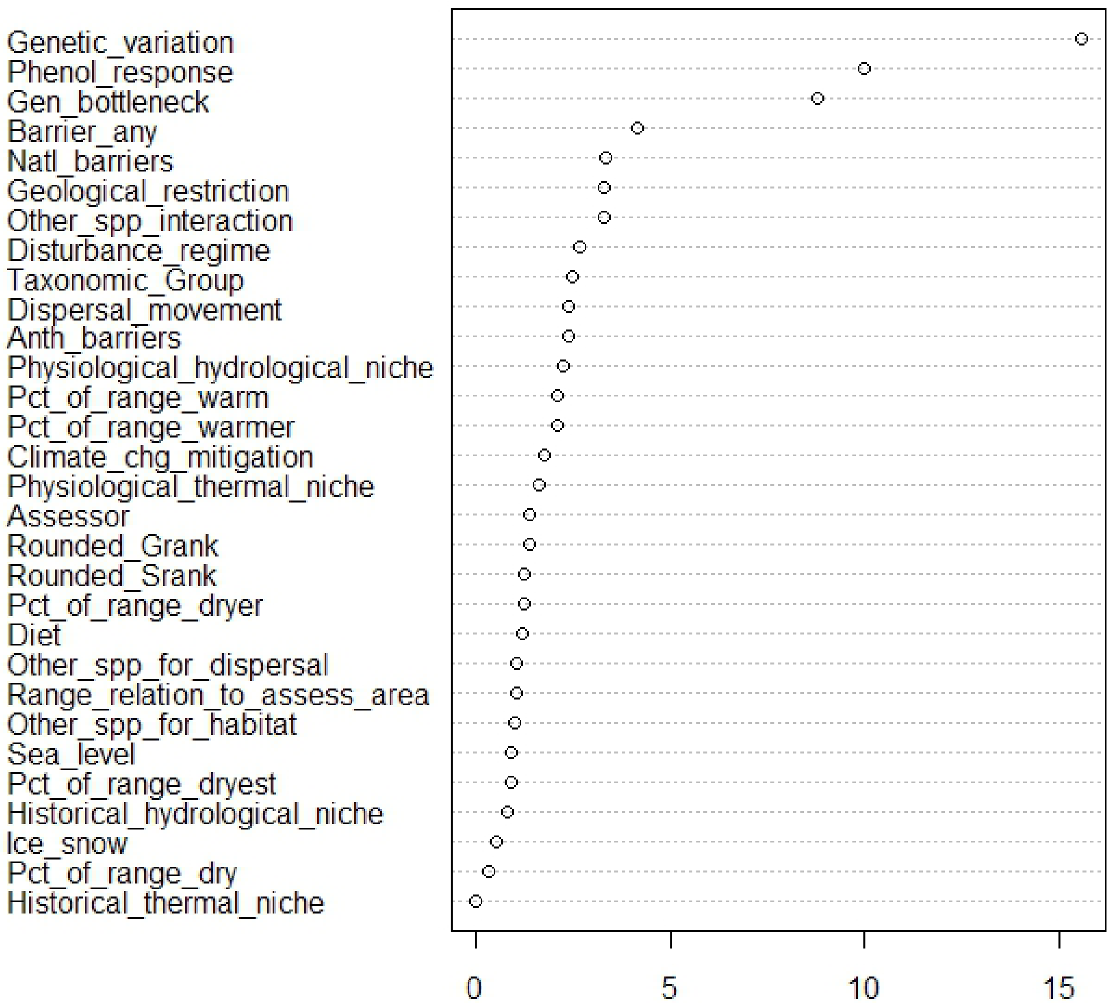


Figure 8. Relative importance (increasing to the right) of 30 variables in classifying species by vulnerability category. See Table 1 and Young et al. (2010) for variable definitions.

Barriers to dispersal emerged as one of the most important factors in our assessments, as was also found in West Virginia (Byers and Norris 2011). The composite variable highlighting any barrier to dispersal, whether natural or anthropogenic ("Barrier_any"), was the strongest of these predictors. Restriction to certain geological substrates ("Geological_restriction") was also a strong predictor, with species reliant on single geological types being assessed as more vulnerable than species occurring on multiple geological types.

Several factors expected to influence vulnerability did not emerge as important in our assessment. Climate change exposure as measured by the percent of the species' range in different categories of increased temperature ("Pct_of_range_warm"; "Pct_of_range_warmer") and decreased moisture availability ("Pct_of_range_dry"; "Pct_of_range_dryer"; "Pct_of_range_dryest") did not emerge as important predictors. This is likely because these factors varied little across the state (Figure 2), highlighting a need for finer scale predictions for a greater separation among species at the state scale, or at smaller scales. The position of the species' range relative to New York ("Range_relation_to_assess_area") also was not a major factor (Figure 9), although 67% of species on the southern edge of their range in NY were assessed as possibly moving out of the state in the supplementary Index Notes field (Figure 10). Thus, although the index value might suggest a lack of vulnerability rangewide, within New York many species ranges may shift to the point of extirpation from the state. Similarly, 36% species on the northern edge of their ranges had Index Notes suggesting they might expand their range within NY even though they might have been assessed as not highly vulnerable to climate change (Figure 10).

Another surprise was that vulnerability to sea-level rise ("Sea_level") was relatively unimportant in determining overall vulnerability. This pattern may result from an accident of geography: New York's coastal areas are also its most southern. The 15 species whose exposure to rising sea levels greatly increased their vulnerability are for the most part restricted to Long Island within NY and eight of these species are on the northern edge of their range there. Ten of the species are birds, which have good movement capabilities and few barriers to dispersal (Young et al. 2010). A total of 28 species were determined to have increased vulnerability from sea-level rise.

Comfortingly, the identity of the Assessor ("Assessor"; MDS, JDC, KAP, or ELW) was not a primary factor in the rating. Recognizing that different assessors could interpret data differently and thus score species differently, we met several times as we worked through the index calculator to calibrate our assessments. Further, we all calculated the Index for the moose, and found our results were within one half-step of one another. Future efforts also should take into account potential assessor bias in climate change vulnerability assessments.

Admittedly, we are unsure whether our results reflect purely the importance of each variable in arriving at final index values in our particular case, or whether they also reflect unequal and undisclosed weighting of factors in the calculation. This is discussed further on page 20.

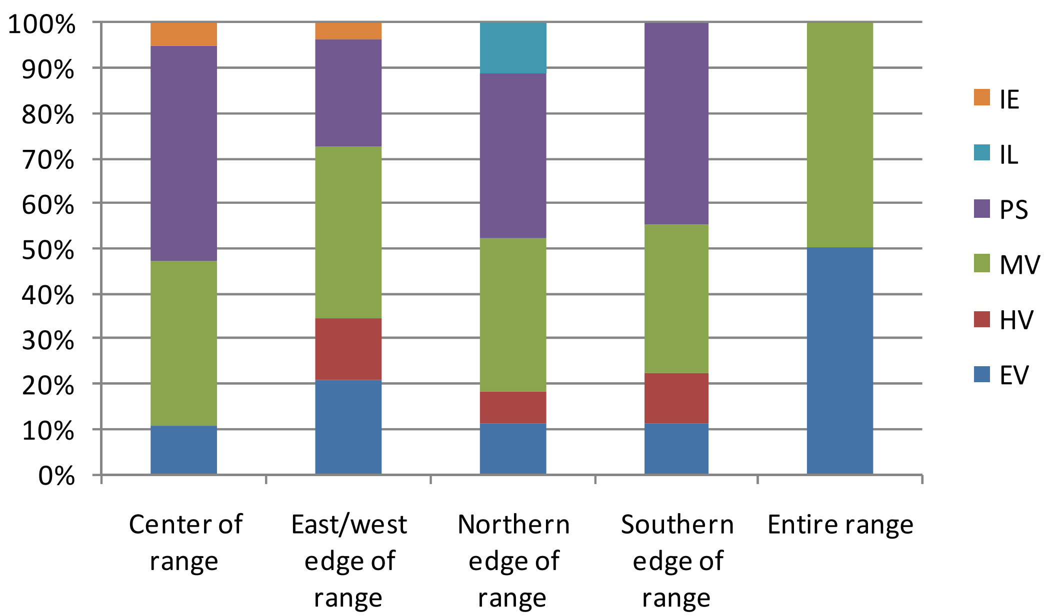
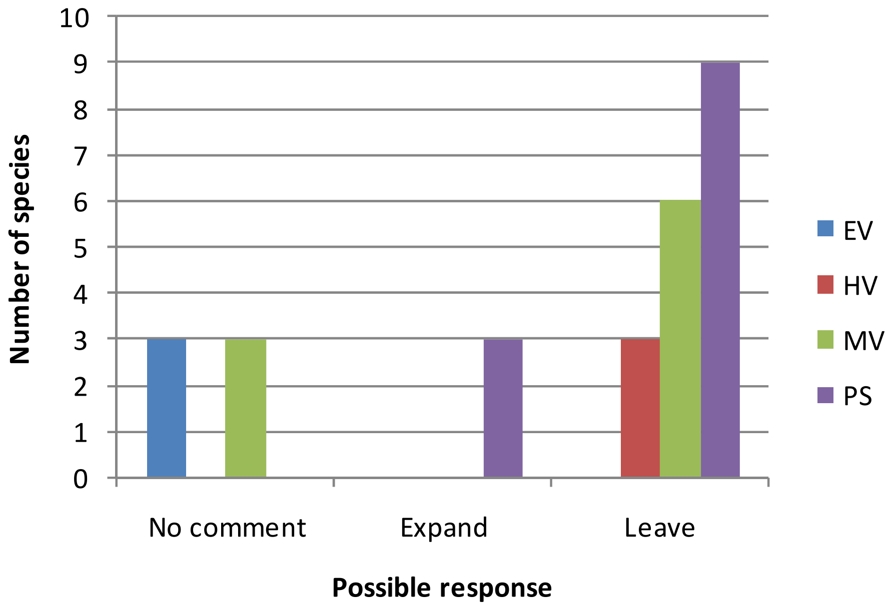


Figure 9. Percent of species in each vulnerability category categorized according to the position of their range relative to New York.



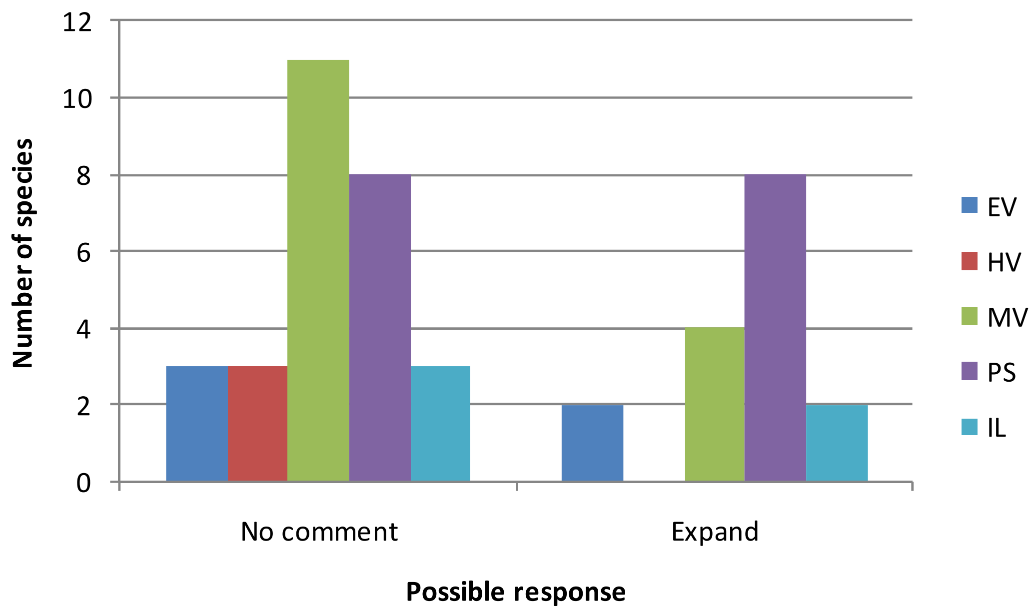


Figure 10. Index notes and vulnerability categories for species on the southern edge (top) and northern edge (bottom) of their range in New York.

Comparisons to other states

Two other states in the Northeast—Pennsylvania and West Virginia—have recently completed similar analyses to inform their State Wildlife Action Plans. As noted above, the overall results of our assessments were quite similar, with over half of species in each state assessed as vulnerable to climate change. Of course, the proportion of species assessed as vulnerable depends greatly on the species selected for analysis, as conducting the analysis on all species is not possible given constraints of funding, time, and available information. We aimed to select species we thought might prove vulnerable to climate change, as did Byers and Norris (2011), and most of the species selected were already of conservation concern, so caution should be used in extrapolating these results to all species.

Our results broadly agreed with those from Pennsylvania and West Virginia (Table 6). New York and Pennsylvania assessed 12 species in common, while New York and West Virginia had 17 species in common. In the vast majority of cases, the final index values matched exactly or were off by one step (e.g., "Presumed Stable" versus "Moderately Vulnerable"). Differences in index values might result from true differences in vulnerability among states or differences in interpretation of data; a full analysis of these differences is beyond the scope of this report. There were two cases where results differed by more than one step: the small-footed bat and the spatterdock darner (Table 6). The bat was rated most vulnerable in Pennsylvania and least in West Virginia, with our assessment happily in between; assessors differed in their ratings on multiple factors for this species. The darner was rated more vulnerable in its dispersal ability, physiological thermal and hydrological niches, and reliance on specific geological types in West Virginia than in New York; while some of these characteristics may differ across species' ranges, this seems to be a case of differences between the assessors in their interpretation of the species' biology.

Table 6. Index values for species in our assessment that were also assessed by either Pennsylvania or West Virginia. Species assessed by Pennsylvania and West Virginia but not New York are not included here.

Taxonomic Group	Common name	Scientific name	New York	Penn.[1]	West Virginia[2]
Amphibian	Eastern hellbender	*Cryptobranchus alleganiensis*	EV	EV	
Amphibian	Eastern spadefoot	*Scaphiopus holbrooki*	HV		HV
Bird	Bobolink	*Dolichonyx oryzivorus*	PS		MV
Bird	Henslow's sparrow	*Ammodramus henslowii*	PS	IL	IL
Bird	Olive-sided flycatcher	*Contopus cooperi*	MV		PS
Fish	American eel	*Anguilla rostrata*	MV		PS
Fish	Brook trout	*Salvelinus fontinalis*	HV		HV
Fish	Slimy sculpin	*Cottus cognatus*	HV		EV
Insect	Appalachian tiger beetle	*Cicindela ancocisconensis*	PS	MV	PS
Insect	Cobblestone tiger beetle	*Cicindela marginipennis*	PS		MV
Insect	Northern barrens tiger beetle	*Cicindela patruela*	IL	PS	
Insect	Spatterdock darner	*Aeshna mutata*	IL		MV
Insect	Tiger spiketail	*Cordulegaster erronea*	PS		PS
Mammal	Hoary bat	*Lasiurus cinereus*	PS		PS
Mammal	Indiana bat	*Myotis sodalis*	MV		MV
Mammal	Small-footed bat	*Myotis leibii*	MV	EV	PS
Mollusk	Brook floater	*Alasmidonta varicosa*	EV		EV
Mollusk	Dwarf wedgemussel	*Alasmidonta heterodon*	EV	EV	
Mollusk	Eastern pearlshell	*Margaritifera margaritifera*	EV	EV	
Mollusk	Green floater	*Lasmigona subviridis*	EV		HV
Mollusk	Rayed bean	*Villosa fabalis*	MV	EV	
Reptile	Bog turtle	*Glyptemys muhlenbergii*	EV	EV	
Reptile	Spotted turtle	*Clemmys guttata*	PS	MV	MV
Reptile	Timber rattlesnake	*Crotalus horridus*	PS	IL	
Reptile	Wood turtle	*Glyptemys insculpta*	PS	IL	

Suggestions for further development of the CCVI

On the whole, we found the CCVI easy and efficient to use (most species took an hour or less) and well documented, and it generally yielded results that made sense to us. However, we did find some areas for improvement and some nuances of using the tool that could use further investigation and development. For example, we noted that the CCVI does not allow for climate-induced changes in physiology, although some of these changes could be addressed in the Physiological Thermal Niche field; it was unclear to us where to score species that have evolved within a certain thermal niche but may not be showing a "preference for environments toward the warmer end of the spectrum," as the field is defined. An example is the Blanding's turtle, which has temperature-dependent sex determination of its young, and for which warming could substantially tilt sex ratios toward females (Janzen 1994). Altered sex ratios could have serious consequences for population structure, yet we felt the Blanding's turtle was assessed to be less vulnerable to climate change than it should have been.

We found that certain mobile insects, even cold-adapted ones, were assessed as essentially invulnerable to climate change and around 60% of the insects that we ran were Presumed Stable (Figure 5) despite abundant evidence that this taxon is intimately coupled to thermal regimes (Frazier et al. 2006). Among the many taxa currently documented to be shifting their ranges in response to climate change, dragonflies have demonstrated the fastest rates of movement (Hickling et al. 2006) and it is well known that cold adapted glacial relict species are most highly vulnerable to a warming climate (Calosi et al. 2008). Yet the boreal dragonflies of the genus *Somatochlora* and *Williamsonia* all scored as Presumed Stable despite the fact that these species have most likely been retreating northward from NY for hundreds, if not thousands of years. We suspect that the lack of dispersal barriers for these mobile ectotherms caused them to score as less vulnerable in the calculator. Similarly, birds, which have high mobility and are good dispersers, nearly always scored low on the vulnerability scale. However, species like the black rail, which occurs in salt marshes that are subject to inundation, may not have suitable habitat to disperse to (especially within New York).

Susceptibility to disease, brought on by a warming climate, was one factor that was not addressed in the CCVI but that could cause significant mortality events. Interaction between disease and climate change is a well-accepted hypothesis for the global decline of many amphibians (Pounds et al. 2006, Lips et al. 2008). Northern hibernating bat species are now showing similar declines (Blehert et al. 2009), although no link to climate has yet been made. Similarly, moose populations in the upper Midwest are declining and increased susceptibility to pathogens and parasites in heat stressed animals may be one factor related to this decline (Lenarz et al. 2009). Disease-caused mortality events might be one of the ways in which species ranges contract under changing environmental conditions.

As noted on page 16, it would be useful if finer scale climate projections were available, as well as a range of temperature and moisture categories more tailored to the assessment area. In the current version for a state like New York, little variation exists in the values able to be assigned for climate change exposure, thus limiting the role of this set of variables in the overall assessment. These variables did not emerge as important in our assessment, yet we know that the relative degree of exposure to changing temperature and moisture is an important determinant of a species' likely response. Future versions of the CCVI could allow for user-defined categories based on the scale of data available and the size of the assessment area. Indeed, we are developing finer scale data for New York State and the ability to utilize these data in future CCVI assessments would be very beneficial.

We would have preferred if the algorithm used to calculate scores were made more transparent and flexible, much as NatureServe has done for its Element Rank Calculator (NatureServe 2009). Such transparency will allow users to understand the results and the relative weightings of factors. Without this information, we were unable to determine the degree to which our analysis of the relative importance of factors reflected biological importance versus the weights of each factor in the algorithm. Further, user-defined weights would allow assessors to adjust the importance of factors for their specific situation; this feature is allowed in some similar calculators (e.g., University of Washington 2011).

Future assessments and research needs

Should New York wish to pursue further species-specific vulnerability assessments, we have some suggestions. We were tasked with assessing 100 species; with input from DEC and TNC we came up with a list of 195 priority species and assessed 119. The additional species for which there was interest in a vulnerability assessment are listed in Appendix E. Beyond this list, other taxonomic groups would make for interesting comparisons. Given the high level of vulnerability identified for aquatic species, running the index on crayfish could prove informative, but we had little data on Malacostracans and NY Natural Heritage tracks few organisms in this Order. At least one northeastern state, West Virginia, has found some crayfish species highly vulnerable to climate change (Byers and Norris 2011). Cave obligates were uniformly assessed as "Presumed Stable" in West Virginia (Byers and Norris 2011) due to the predicted resistance of cave ecosystems to changes in climate, but it would be useful to confirm those findings in New York. And importantly, other states (Byers and Norris 2011; Pennsylvania Natural Heritage Program 2011; Young et al. 2009) have assessed vulnerability of plants, and many species have emerged as highly and extremely vulnerable to climate change. Finally, because coastal and marine ecosystems are expected to undergo some of the most dramatic transformations with climate change (Harley et al. 2006), conducting a vulnerability analysis on marine species (and ecosystems) is vital to determine where specifically to focus management attention. Scoring catadromous species like American eel proved challenging as well. NatureServe's CCVI is not designed for marine species (Young et al. 2010) but perhaps can be adapted or broadened in future versions.

As is alluded to above, conducting vulnerability analyses on groups of species could nicely complement assessments of individual species and ecosystems or habitats. Appropriate targets would be functional groups (e.g., decomposers, pollinators), habitat guilds (e.g., cave obligates, marine invertebrates, spring and seep breeders), or biogeographical assemblages (e.g., boreal birds, cold-adapted dragonflies). Important patterns might emerge from such analyses that would be missed through a focus on only the species and ecosystem levels. For example, disparate individual species-level vulnerabilties may point towards the disassembly of a community (McMahon et al. 2009), while similar predicted vulnerabilities may help us understand the vulnerability of a habitat or ecosystem as a whole.

A regional, or ecoregional, approach to vulnerability assessment would be valuable given the small size of eastern states; shared ecosystems, species, geological history, and climate regimes; and likely similar responses of species within the region. Further, climate change mitigation and adaptation efforts are likely to be most relevant and successful at regional or ecoregional scales (Mawdsley et al. 2009; Heller and Zavaleta 2009; Frumhoff et al. 2007). NatureServe (Young et al. 2010) notes that although the CCVI is intended to work at a "scale of from the size of a national park or wildlife refuge to a state.... It could be used for a regional analysis in the case of several eastern states...." We highly recommend that this kind of project be conducted for the Northeast.

An important corollary benefit of conducting a vulnerability assessment is the identification of information gaps. While we recognize that absolute certainty is not possible in responding to the threat of climate change, we do believe that research into some facets of species' life histories, ecologies, and behaviors could greatly improve our chances of sustaining New York's biodiversity: 1) thermal tolerances of mussels in all life stages; 2) phenological responses of many species to changing seasonal temperature and precipitation dynamics (efforts such as the National Phenology

Network [http://www.usanpn.org/] should eventually provide some of these data); 3) genetic variation of many species, especially invertebrates and fish; 4) distribution, natural history, and ecology of many invertebrates (e.g., the Noctuid moths that we did not find enough information about to assess); 5) the degree to which landscape features serve as barriers to low- and moderate-mobility taxa; and 6) modeled responses to climate change (some of which are in progress for the Hudson Valley [T. Howard and M. Schlesinger, NY Natural Heritage Program]). As some of these research needs are met in coming years, the information generated can inform a refined vulnerability assessment.

Looking beyond vulnerability assessments: Management and monitoring recommendations

Our vulnerability assessment is not a final product, but a means to an end (Glick et al. 2011). A full treatise of management and monitoring needs for New York in the face of climate change is beyond the scope of this report. However, Byers and Norris (2011) and Glick et al. (2011) provide some recommendations that are applicable here and below we make a few additional recommendations based on our results. We hope our results and recommendations will be useful to NYS DEC as it revises its Wildlife Action Plan.

The fact that most of the species assessed as Highly or Extremely Vulnerable in our analyses were associated with aquatic or seasonally wet habitats, and the identification of barriers to dispersal as an important component of our vulnerability scores, together highlight the importance of aquatic connectivity in New York's landscape. Specialists in climate-change adaptation have long argued that maintaining and restoring habitat connectivity is paramount in biodiversity preservation (Mawdsley et al. 2009; Heller and Zavaleta 2009; Byers and Norris 2011). Many aquatic species are blocked from seasonal and migratory movements by dams without suitable aquatic organism passage and inadequately designed and situated culverts (Rahel 2007, Cote et al. 2009), which will further compound potential difficulties for species shifting to more favorable climates. Aquatic connectivity should be considered to accommodate the needs of a broad array of taxa, including rare and vulnerable species, in the design of fish passages and culverts. New York has undergone several planning efforts related to aquatic connectivity (e.g., The Nature Conservancy 2011) and implementation of these plans would be a wise investment in facilitating biodiversity adaptation.

Maintaining terrestrial connectivity is just as vital, because species faced with inhospitable climates must move across a landscape of varying suitability to access new suitable habitats (Krosby et al. 2010). This is especially true for rare species restricted to certain geological features (Anderson and Ferree 2010) and we found that geological restriction was an important driver of our vulnerability scores.

Another valuable outcome of this procedure is that it allows biologists to ascertain which life-history traits of a particular species are most vulnerable to climate change and further highlights that other factors might pose more immediate threats to certain imperiled species. Two iconic bird species at their extreme southern range margins clearly demonstrate this situation. First, our assessment of the black tern found this bird's range in NY to be Presumed Stable, thus giving further weight to other causes of imperilment such as the degradation and loss of freshwater marshes. Fortunately, effective management strategies for this species and other associated marshbirds have been demonstrated at WMAs and Wildlife Refuges around the state (New York Natural Heritage Program 2011a). On the other hand, the spruce grouse was found to be Extremely Vulnerable to climate change, suggesting that even despite intensive management to favor it, the population in NY will likely continue to decline under a warming climate.

Monitoring will be an essential component of any adaptive management strategy for addressing climate change and other threats to New York's wildlife (Glick et al. 2011). Broad-scale, long-term monitoring of multiple taxa in an occupancy framework (Manley et al. 2004, Mackenzie et al. 2006) will help 1) test hypotheses about vulnerability, which are essentially what the CCVI provides; 2) detect unanticipated changes in wildlife populations; 3) identify which stressors in addition to climate change need mitigation; and 4) reveal range shifts and changes in phenology. Long-term monitoring datasets and repeated atlases have already revealed shifts that have been vital in demonstrating wildlife responses to climate change (Parmesan et al. 1999; Hitch and Leberg 2007; Zuckerberg et al. 2010). There is a pressing need to establish a solid baseline of data that will allow us to detect these changes in New York's wildlife and make the most informed conservation and management decisions in the face of this unprecedented global threat.

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Appendix A: Key to codes used in tables

Vulnerability Index Scores

EV	Extremely Vulnerable: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
HV	Highly Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
MV:	Moderately Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
PS:	Not Vulnerable/Presumed Stable: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
IL:	Not Vulnerable/Increase Likely: Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.
IE:	Insufficient Evidence: Available information about a species' vulnerability is inadequate to calculate an Index score.

Individual Risk Factor Scores

GI	Greatly increase vulnerability
Inc	Increase vulnerability
SI	Somewhat increase vulnerability
N	Neutral
SD	Somewhat decrease vulnerability
Dec	Decrease vulnerability
U	Unknown

NatureServe Conservation Status Ranks

NY Natural Heritage's statewide inventory efforts revolve around lists of rare species and all types of natural communities known to occur, or to have historically occurred, in the state. These lists are based on a variety of sources including museum collections, scientific literature, information from state and local government agencies, regional and local experts, and data from neighboring states.

Each rare species is assigned a rank based on its rarity and vulnerability. Like all state Natural Heritage Programs, NY Natural Heritage's ranking system assesses rarity at two geographic scales: global and state. The global rarity rank reflects the status of a species or community throughout its range, whereas the state rarity rank indicates its status within New York. Global ranks are maintained and updated by NatureServe, which coordinates the network of Natural Heritage programs. Both global and state ranks are usually based on the range of the species or community, the number of occurrences, the viability of the occurrences, and the vulnerability of the species or community around the globe or across the state. As new data become available, the ranks may be revised to reflect the most current information. Subspecific taxa are also assigned a taxon rank which indicates the subspecies' rarity rank throughout its range.

For the most part, global and state ranks follow a straightforward scale of 1 (rarest/most imperiled) to 5 (common/secure), as follows:

G1, S1 Critically imperiled because of rarity (5 or fewer occurrences, or few remaining acres or miles of stream) or factors making it especially vulnerable to extinction rangewide (global) or in New York (state)

G2, S2 Imperiled because of rarity (6-20 occurrences, or few remaining acres or miles of stream) or factors demonstrably making it very vulnerable to extinction (global) or extirpation from New York (state)

G3, S3 Either uncommon or local, typically with 21 to 100 occurrences, limited acreage, or miles of stream rangewide (global) or in New York (state)

G4, S4 Apparently secure rangewide (global) or in New York (state)

G5, S5 Demonstrably secure, though it may be quite rare in parts of its range

Note that combination (or "range") ranks are possible (e.g., S1S2, S2S3). These ranks reflect uncertainty in the information available such that it could not be determined whether one or the other rank was appropriate. They do not indicate a value in between the two numbers.

There are some additional codes:

GH, **SH** Only known historically rangewide (global) or not reported in NY the last 20 years

GX, SX Apparently extinct (global) or extirpated from NY (state)

GU, SU Lack of information or substantial conflicting information about status or trends makes ranking infeasible at this time

SNA A visitor to the state but not a regular occupant (such as a bird or insect migrating through the state), or a species that is predicted to occur in NY but that has not been found.

SNR No effort has yet been made to rank the species.

Appendix B: Vulnerability index scores

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Amphibians							
Acris crepitans	Cricket Frog	G5	S1	MV	VH		Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010, New York Natural Heritage Program 2011b
Ambystoma opacum	Marbled Salamander	G5	S3	HV	VH		Chaloux et al. 2010
Ambystoma tigrinum	Eastern Tiger Salamander	G5	S1S2	EV	VH		Chaloux et al. 2010, New York Natural Heritage Program 2011c
Cryptobranchus alleganiensis	Hellbender	G3G4	S2	EV	VH	Species may expand range in assessment area.	Sabatino and Routman 2009, Chaloux et al. 2010, Lyons-Swift and Howard 2010
Eurycea longicauda	Longtail Salamander	G5	S2	PS	VH		Chaloux et al. 2010, Lyons-Swift and Howard 2010, New York Natural Heritage Program 2010a
Plethodon wehrlei	Wehrle's Salamander	G4	S3	PS	VH		Gibbs et al. 2007, Lyons-Swift and Howard 2010, NatureServe 2010
Pseudacris maculata	Boreal Chorus Frog	G5	SU	MV	Low		Lemmon et al. 2007 Northern New York only
Pseudacris triseriata	Western Chorus Frog	G5	S2	MV	Mod		NatureServe 2010 Western New York only
Rana septentrionalis	Mink Frog	G5	S5	HV	VH	Species range may shift and perhaps leave the assessment area.	Popescu and Gibbs 2009, NatureServe 2010
Rana sphenocephala	Southern Leopard Frog	G5	S1S2	MV	Mod		NatureServe 2010
Scaphiopus holbrooki	Eastern Spadefoot	G5	S2S3	HV	VH		Chaloux et al. 2010, Lyons-Swift and Howard 2010
Birds							
Ammodramus caudacutus	Saltmarsh Sharp-tailed Sparrow	G4	S3	MV	VH		Greenlaw and Rising 2011
Ammodramus henslowii	Henslow's Sparrow	G4	S3B	PS	VH		Herkert et al. 2002
Ammodramus maritimus	Seaside Sparrow	G4	S2S3	MV	VH		Erwin et al. 2006, Post et al. 2009
Caprimulgus carolinensis	Chuck-will's Widow	G5	S1	MV	High		McGowan and Corwin 2008, NatureServe 2010, New York Natural Heritage Program 2010b
Catharus bicknelli	Bicknell's Thrush	G4	S2	MV	Mod	Species range may shift and perhaps leave the assessment area.	New York Natural Heritage Program 2011d
Charadrius melodus	Piping Plover	G3	S3B	MV	High		Haig and Oring 1988, Elliott-Smith and Haig 2004, NatureServe 2010, New York Natural Heritage Program 2010b, United States Fish and Wildlife Service 2011

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Chlidonias niger	Black Tern	G4	S2	PS	Mod	Species range may shift and perhaps leave the assessment area.	New York Natural Heritage Program 2011a
Contopus cooperi	Olive-sided Flycatcher	G5	S3	MV	VH	Species range may shift and perhaps leave the assessment area.	Altman and Sallabanks 2000
Dolichonyx oryzivorus	Bobolink	G5	S5	PS	Low		Martin and Gavin 1995, Rodenhouse et al. 2008
Euphagus carolinus	Rusty Blackbird	G4	S2	PS	VH	Species range may shift and perhaps leave the assessment area.	Avery 1995, NatureServe 2010
Falcipennis canadensis	Spruce Grouse	G5	S2	EV	VH		McGowan and Corwin 2008, Ross and Johnson 2009
Haematopus palliatus	American Oystercatcher	G5	S3	MV	VH		Nol and Humphrey 1994
Laterallus jamaicensis	Black Rail	G4	S1	MV	VH		Eddleman et al. 1994
Picoides arcticus	Black-backed Woodpecker	G5	S3?	PS	VH	Species range may shift and perhaps leave the assessment area.	Dixon and Saab 2000, NatureServe 2010
Picoides dorsalis	American Three-toed Woodpecker	G5	S2	PS	VH	Species range may shift and perhaps leave the assessment area.	Leonard, Jr. 2001, NatureServe 2010
Poecile hudsonicus	Boreal Chickadee	G5	S3	PS	VH	Species range may shift and perhaps leave the assessment area.	Ficken et al. 1996, NatureServe 2010
Rallus longirostris	Clapper Rail	G5	S3	MV	VH		Eddleman and Conway 2011
Rynchops niger	Black Skimmer	G5	S2	MV	VH		Gochfeld and Burger 1994
Sterna dougallii dougallii	Roseate Tern	G4T3	S1B	MV	VH		Gochfeld et al. 1998
Tringa semipalmata	Willet	G5	S1	MV	VH		Lowther et al. 2001
Fish							Bain et al. 1998, National Marine Fisheries Service 1998, Walsh et al. 2001, NYSDEC 2010a, NatureServe 2010, New York Natural Heritage Program 2010b, NOAA Fisheries 2011, New York Natural Heritage Program 2011e

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Acipenser brevirostrum	Shortnose Sturgeon	G3	S1	EV	VH		Massachusetts Natural Heritage & Endangered Species Program 2003, Reist et al. 2006, Atlantic States Marine Fisheries Commission 2009, NatureServe 2010, New York Natural Heritage Program 2010b, NOAA National Marine Fisheries Service 2010, Atlantic States Marine Fisheries Commission 2011a, NYSDEC 2011a, New York Natural Heritage Program 2011f
Acipenser fulvescens	Lake Sturgeon	G3G4	S1S2	EV	VH		Massachusetts Natural Heritage & Endangered Species Program 2003, Reist et al. 2006, Atlantic States Marine Fisheries Commission 2009, NatureServe 2010, New York Natural Heritage Program 2010b, NOAA National Marine Fisheries Service 2010, Atlantic States Marine Fisheries Commission 2011a, NYSDEC 2011a, New York Natural Heritage Program 2011f
Acipenser oxyrinchus	Atlantic Sturgeon	G3	S1	EV	VH		Waldman et al. 1996, NYSDEC 2005, Kraft et al. 2006, Reist et al. 2006, Atlantic States Marine Fisheries Commission 2010, NYSDEC 2010a, NatureServe 2010, Atlantic States Marine Fisheries Commission 2011b
Alosa sapidissima	American Shad	G5	S4	MV	Mod		Bouton 1988, NYSDEC 2005, Kraft et al. 2006, NatureServe 2010, New York Natural Heritage Program 2010b, 2011g, "Fishbase" 2011
Ammocrypta pellucida	Eastern Sand Darter	G4	S2	MV	Mod		Carlson 1998, ASMFC 2000, Wirth and Bernatchez 2003, NYSDEC 2005, 2010a, NatureServe 2010, Dittman 2011
Anguilla rostrata	American Eel	G4	S3	MV	Low		Morse and Daniels 2009, Carlson 2010, "Fishbase" 2011
Catostomus utawana	Summer Sucker	G2	S2	MV	High		Kraft et al. 2006, NatureServe 2010
Coregonus artedi	Cisco or Lake Herring	G5	S3	MV	Mod		Kraft et al. 2006, Claramunt et al. 2010, Ebener et al. 2010, Stott et al. 2010
Coregonus clupeaformis	Lake Whitefish	G5	S4	MV	High	Species range may shift and perhaps leave the assessment area.	Smith 1985, Strauss 1989, Fujishin et al. 2009, NYSDEC 2010a, NatureServe 2010, "Fishbase" 2011
Cottus cognatus	Slimy Sculpin	G5	S4	HV	Low		NYSDEC 2005, NatureServe 2010, New York Natural Heritage Program 2010b, NYSDEC 2011b, Pennsylvania Natural Heritage Program 2011b, "Fishbase" 2011
Enneacanthus obesus	Banded Sunfish	G5	S1S2	MV	Mod		McKenna et al. 2010, NatureServe 2010, "Fishbase" 2011
Etheostoma olmstedi	Tessellated Darter	G5	S5	PS	Mod		Smith 1985, Kraft et al. 2006, McKenna et al. 2010, NatureServe 2010, New York State Department of Environmental Conservation 2010
Ichthyomyzon greeleyi	Mountain Brook Lamprey	G3G4	S1	MV	Low		Carlson and Daniels 2004, Wells and Haynes 2011
Lepomis megalotis	Longear Sunfish	G5	S1	PS	Mod		Kraft et al. 2006, Jackson et al. 2008, Carrie et al. 2009, McKenna et al. 2010, NatureServe 2010, Stapanian et al. 2010

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Lota lota	Burbot	G5	S3	MV	Mod	Species range may shift and perhaps leave the assessment area.	Fay et al. 1983, NatureServe 2010, Baumann and Conover 2011, New York Natural Heritage Program 2011h
Menidia menidia	Atlantic Silverside	G5	S2S3	PS	Mod		Reid 2006, NatureServe 2010, New York State Department of Environmental Conservation 2011
Moxostoma duquesnii	Black Redhorse	G5	S2	PS	VH	Species may expand range in assessment area.	Carlson and Daniels 2004, Kraft et al. 2006, McKenna et al. 2010, NatureServe 2010, "Fishbase" 2011
Notropis anogenus	Pugnose Shiner	G3	S1	MV	Mod		Carlson and Daniels 2004, NYSDEC 2010b, NatureServe 2010
Percina macrocephala	Longhead Darter	G3	S1	PS	Mod		Smith 1985, Steinhart et al. 2007, NYSDEC 2010a, NatureServe 2010, NYSDEC 2011c, "Fishbase" 2011
Prosopium cylindraceum	Round Whitefish	G5	S1S2	EV	VH		Smith 1985, Bernatchez and Danzmann 1993, Carlson 1998, Chu et al. 2005, Kraft et al. 2006, Ficke et al. 2009, NYSDEC 2010a, NatureServe 2010, "Fishbase" 2011
Salvelinus fontinalis	Brook Trout	G5	S5	HV	VH		
Insects							
Callophrys irus	Frosted Elfin	G3	S1S2	EV	High		New York Natural Heritage Program 2011i
Chlosyne gorgone	Gorgone Checkerspot	G5	S1	PS	VH	Species may expand range in assessment area.	Kerr 2001, NatureServe 2010
Cicindela ancocisconensis	Appalachian Tiger Beetle	G3	S2	PS	VH		NatureServe 2010, Schlesinger and Novak 2011
Cicindela hirticollis	Hairy-necked Tiger Beetle	G5	S1S2	MV	VH		NatureServe 2010, Schlesinger and Novak 2011
Cicindela marginipennis	Cobblestone Tiger Beetle	G2	S1	PS	VH		NatureServe 2010, Hudgins et al. 2011, Schlesinger and Novak 2011
Cicindela patruela	Northern Barrens Tiger Beetle	G3T3	S1	IL	VH		NatureServe 2010, Schlesinger and Novak 2011
Cordulegaster erronea	Tiger Spiketail	G4	S1	PS	VH	Species may expand range in assessment area.	White et al. 2010
Enallagma recurvatum	Pine Barrens Bluet	G3	S1	PS	VH		NatureServe 2010, New York Natural Heritage Program 2010c, White et al. 2010, New York Natural Heritage Program 2010b
Erynnis persius persius	Persius Duskywing	G5T1 T3	S1	MV	High		NatureServe 2010, New York Natural Heritage Program 2010b, Reese 2011, The Xerces Society 2011
Euchloe olympia	Olympia Marble	G4G5	S1	HV	Low		Parshall 2002
Gomphus rogersi	Sable Clubtail	G4	S1	IL	Low		NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c
Gomphus vastus	Cobra Clubtail	G5	S1	PS	VH		NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Hemileuca maia ssp 5	Coastal Barrens Buckmoth	G5T3	S2	MV	Mod		Tuskes et al. 1996, New York State Department of Environmental Conservation 2005, NatureServe 2010, New York Natural Heritage Program 2010b
Hemileuca sp. 1	Bogbean Buckmoth	G1Q	S1	EV	High		Legge et al. 1996, Tuskes et al. 1996, Pryor 1998, Stanton 1998, Gradish and Tonge 2010, NatureServe 2010, New York Natural Heritage Program 2010b
Heptagenia culacantha	A Mayfly	G2G3	SNR	PS	Mod	Species may expand range in assessment area.	Evans et al. 1985, Myers et al. 2010, NYSDEC 2010c, NatureServe 2010, New York Natural Heritage Program 2010b
Hygrotus sylvanus	Sylvan Hygrotus Diving Beetle	GU	S1	PS	VH	Species range may shift and perhaps leave the assessment area.	NatureServe 2010
Ischnura ramburii	Rambur's Forktail	G5	S2S3	PS	VH		NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c
Oeneis jutta	Jutta Arctic	G5	S1	MV	High	Species range may shift and perhaps leave the assessment area.	NatureServe 2010
Ophiogomphus howei	Pygmy Snaketail	G3	S1	PS	High		NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c
Plebejus melissa samuelis	Karner Blue	G5T2	S1	EV	Mod		Packer et al. 1998, United States Fish and Wildlife Service 2003, NatureServe 2010, New York Natural Heritage Program 2010b, 2011j
Progomphus obscurus	Common Sanddragon	G5	S1	IL	Low	Species may expand range in assessment area.	White et al. 2010
Pteronarcys comstocki	A Stonefly: Spiny Salmonfly	G3	SNR	MV	Mod		Myers et al. 2010, NatureServe 2010, NYSDEC 2010c
Rhionaeschna mutata	Spatterdock Darner	G4	S2S3	IL	VH	Species may expand range in assessment area.	White et al. 2010
Sideridis maryx	Maroonwing	G4	S2S3	IE	---		NatureServe 2010 Distribution within NY not documented.
Siphlonisca aerodromia	Tomah Mayfly	G2G3	S1	HV	Mod	Species range may shift and perhaps leave the assessment area.	Gibbs 1993, Gibbs and Siebenmann 1996, Myers et al. 2010, NatureServe 2010, New York Natural Heritage Program 2010b, NYSDEC 2010c
Somatochlora cingulata	Lake Emerald	G5	S1	PS	VH	Species range may shift and perhaps leave the assessment area.	White et al. 2010

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Somatochlora forcipata	Forcipate Emerald	G5	S1S3	PS	VH	Species may expand range in assessment area.	Corser 2010, White et al. 2010
Somatochlora minor	Ocellated Emerald	G5	S1S3	PS	VH	Species range may shift and perhaps leave the assessment area.	Corser 2010, White et al. 2010
Stylurus plagiatus	Russet-tipped Clubtail	G5	S1	PS	VH		Corser 2010, White et al. 2010
Sympetrum danae	Black Meadowhawk	G5	S2S3	PS	High	Species may expand range in assessment area.	NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c
Tachopteryx thorei	Gray Petaltail	G4	S2	PS	Mod	Species may expand range in assessment area.	White et al. 2010
Tricholea artesta	Hairy Artesta	G5	S1S3	IE	----		NatureServe 2010
Williamsonia fletcheri	Ebony Boghaunter	G4	S1	PS	VH	Species may expand range in assessment area.	NatureServe 2010, White et al. 2010, New York Natural Heritage Program 2010b, 2010c
Mammals							
Alces americanus	Moose	G5	S3S4	PS	High	Species range may shift and perhaps leave the assessment area.	Ferguson et al. 1993, Lenarz et al. 2009, Fuller n d Compilation of 4 assessments; took most common, average, or spanned values. Took majority value if 3/4 agreed; if 2 vs. 2, spanned value; if 3+ different answers, averaged value.
Lasiurus cinereus	Hoary Bat	G5	S4	PS	VH		Distribution within NY hasn't been assessed yet. Appears to be broadly distributed with more occurrences at higher elevations in northern part of the state. Exposure to local climate change for species range are estimates and assume a relatively even statewide distribution which may not be the case.
Martes americana	American Marten	G5	S3	MV	High	Species range may shift and perhaps leave the assessment area.	Mech and Rogers 1977, Wisely et al. 2004, Broquet et al. 2006, Carroll 2007, Romanski and Belant 2008
Myotis leibii	Small-footed Bat	G3	S2	MV	High		NatureServe 2010
Myotis lucifugus	Little Brown Bat	G5	S5	PS	Mod		Frick et al. 2010
Myotis sodalis	Indiana Bat	G2	S1	MV	Mod	Species may expand range in assessment area.	Frick et al. 2010
Sylvilagus transitionalis	New England Cottontail	G3	S1S2	MV	Mod		
Mollusks							
Alasmidonta heterodon	Dwarf Wedgemussel	G1	S1	EV	Mod		Strayer and Jirka 1997, NatureServe 2010, New York Natural Heritage Program 2011j

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Alasmidonta varicosa	Brook Floater	G3	S1	EV	Mod		Strayer and Jirka 1997, Elderkin et al. 2007, NatureServe 2010
Amblema plicata	Three-ridge	G5	S1	HV	Mod		Strayer and Jirka 1997, King et al. 1999, Kipp and Benson 2007, NatureServe 2010, North Carolina Wildlife Resources Commission 2011, Pennsylvania Natural Heritage Program 2011c
Anodonta implicata	Alewife Floater	G5	S1S2	MV	Mod		
Lampsilis fasciola	Wavyrayed Lampmussel	G5	S1	MV	Low	Species may expand range in assessment area.	NatureServe 2010
Lasmigona subviridis	Green Floater	G3	S1S2	EV	VH	Species may expand range in assessment area.	Strayer and Jirka 1997, New York Natural Heritage Program 2009, NatureServe 2010
Ligumia nasuta	Eastern Pondmussel	G4	S2S3	MV	Mod	Species may expand range in assessment area.	
Ligumia recta	Black Sandshell	G5	S2	EV	Mod		Strayer and Jirka 1997, New York Natural Heritage Program 2009, NatureServe 2010
Margaritifera margaritifera	Eastern Pearlshell	G4	S2	EV	VH		Strayer and Jirka 1997, New York Natural Heritage Program 2009, NatureServe 2010
Novisuccinea chittenangoensis	Chittenango Ovate Amber Snail	G1	S1	EV	VH		NatureServe 2010
Villosa fabalis	Rayed Bean	G2	S1	MV	Low	Species may expand range in assessment area.	U.S. Fish and Wildlife Service 2010a, 2010b
Reptiles							
Apalone spinifera	Spiny Softshell	G5	S2S3	PS	VH		Weisrock and Janzen 2000, Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Clemmys guttata	Spotted Turtle	G5	S3	PS	Low		Parker and Whiteman 1993, Brooks 2004, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Coluber constrictor	Eastern Racer	G5	S4	IL	VH		Gibbs et al. 2007, Burbrink et al. 2008, Lyons-Swift and Howard 2010, NatureServe 2010
Crotalus horridus	Timber Rattlesnake	G4	S3	PS	VH	Species may expand range in assessment area.	NatureServe 2010
Emydoidea blandingii	Blanding's Turtle	G4	S2S3	MV	Mod		Herman and Scott 1992, Mockford et al. 2005, Hannah 2008
Eumeces anthracinus	Coal Skink	G5	S2S3	PS	Low	Species may expand range in assessment area.	Gibbs et al. 2007, Lyons-Swift and Howard 2010, NatureServe 2010
Eumesces (Plestiodon) fasciatus	Five-lined Skink	G5	S3	PS	VH		Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Glyptemys insculpta	Wood Turtle	G4	S3	PS	High		Gibbs et al. 2007, Amato et al. 2008, Chaloux et al. 2010, NatureServe 2010

Scientific Name	Common Name	GRank	SRank	Index	Confi-dence	Index Notes	Assessment Sources and Notes
Glyptemys muhlenbergii	Bog Turtle	G3	S2	EV	VH		Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010, Rosenbaum and Nelson 2010, New York Natural Heritage Program 2011l
Heterodon platirhinos	Eastern Hog-nosed Snake	G5	S3	MV	VH		Michener and Lazell Jr 1989, Barnett and Abbuhl 2007, Gibbs et al. 2007, Lyons-Swift and Howard 2010, NatureServe 2010
Kinosteron subrubrum	Mud Turtle	G5	S1	HV	High		Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Malaclemys terrapin	Diamondback Terrapin	G4	S3	MV	VH		Simoes and Chambers 1999, Gibbs et al. 2007, NatureServe 2010, Feinberg and Burke 2011
Regina septemvittata	Queen Snake	G5	S1	PS	VH	Species may expand range in assessment area.	Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010
Sceloporous undulatus	Eastern Fence Lizard	G5	S1	PS	VH		Angert et al. 2002, Gibbs et al. 2007, Angilletta Jr et al. 2009, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Sistrurus catenatus catenatus	Eastern Massasauga	G3G4	S1	PS	Low		Seigal et al. 1998, Gibbs and Weatherhead 2001, Chaloux et al. 2010, Lyons-Swift and Howard 2010, NatureServe 2010
Terrepene carolina	Box Turtle	G5	S3	PS	VH		Gibbs et al. 2007, Chaloux et al. 2010, Lyons-Swift and Howard 2010

Appendix C: Intrinsic and modeled risk factor scores

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Amphibians																			
Acris crepitans	Cricket Frog	SI-N	N	SD	SD	GI	N	N	N	U	N	U	U	U	Inc	SI	Inc	U	U
Ambystoma opacum	Marbled Salamander	SI	N	SD	SD	GI-Inc	N	N	SI-N	SI	N	N	U	SI	N/A	SI	U	U	U
Ambystoma tigrinum	Eastern Tiger Salamander	SI	N	SD	SD	GI-Inc	SI	N	Inc	SI	N	N	U	Inc	N/A	SD	U	U	U
Cryptobranchus alleganiensis	Hellbender	SI-N	N	GI-Inc	SD	SI-N	N	N	U	N	Inc-SI	N	U	Inc-SI	N/A	U	U	U	U
Eurycea longicauda	Longtail Salamander	SI	N	SD	N-SD	Inc-SI	N-SD	N	SI	N	N	U	U	SI-N	N/A	N	U	U	U
Plethodon wehrlei	Wehrle's Salamander	SI	N	SD	SD	SD	N	N	SI-N	U	N	U	U	U	U	N	U	U	U
Pseudacris maculata	Boreal Chorus Frog	SI-N	N	GI-Inc	N	GI-Inc	SI	SI	N	U	N	U	U	SD	N/A	SD	SI-N	U	U
Pseudacris triseriata	Western Chorus Frog	SI-N	N	SI-N	N	GI-Inc	SI	N	N	U	N	U	U	SD	N/A	SD	N	U	U
Rana septentrionalis	Mink Frog	N	N	GI	SD	GI	N	GI	SD	U	N	N	N	U	N	U	U	U	U
Rana sphenocephala	Southern Leopard Frog	N	N	N-SD	SD	GI	N	N	N-SD	N	N	N	N	U	N	U	U	U	U
Scaphiopus holbrooki	Eastern Spadefoot	SI	N	SD	SD	N	U	N	Inc	N	N	N	N	U	N	SD	U	U	U
Birds																			
Ammodramus caudacutus	Saltmarsh Sharp-tailed Sparrow	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Ammodramus henslowii	Henslow's Sparrow	U	N	N	N-SD	N	N	N	N	N	N	N	N	U	U	U	U	U	U
Ammodramus maritimus	Seaside Sparrow	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Caprimulgus carolinensis	Chuck-will's Widow	Dec	N	SD	SD	SD	Inc	N	Inc-SI	U	N	U	U	U	Inc	N	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Catharus bicknelli	Bicknell's Thrush	SD-Dec	N	GI	SD	N	Inc-SI	N	Inc	N	N	U	SI	SD	N/A	N	SD	Inc	U
Charadrius melodus	Piping Plover	Dec	N	SI-N	SD	N	Inc-SI	N	SI	N	N	N	N	N	N/A	U	U	U	U
Chlidonias niger	Black Tern	Dec	N	Inc	N	Inc	SI-N	U	SD	SI-N	Inc-SI	U	U	U	N	SD	N-SD	U	U
Contopus cooperi	Olive-sided Flycatcher	SD	N	Inc-SI	SD	Inc-SI	N	N	N	SI	SI	N	N	U	N	U	U	U	U
Dolichonyx oryzivorus	Bobolink	Dec	N	N	N-SD	N	N	N	N	N	N	N	N	U	U	U	U	SI	U
Euphagus carolinus	Rusty Blackbird	Dec	N	GI	SD	GI	N	N	N	N	N-SD	N	N	U	U	U	U	U	U
Falcipennis canadensis	Spruce Grouse	N-SD	N	GI	SD	N	Inc-SI	SI-N	SI	U	SD	U	U	U	Inc	N	U	U	U
Haematopus palliatus	American Oystercatcher	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Laterallus jamaicensis	Black Rail	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Picoides arcticus	Black-backed Woodpecker	Dec	N	GI	N-SD	N-SD	SD	N	N	N	SI	N	N	U	N	U	U	U	U
Picoides dorsalis	American Three-toed Woodpecker	Dec	N	GI	N-SD	N-SD	SD	N	N	N	SI	N	N	U	N	U	U	U	U
Poecile hudsonicus	Boreal Chickadee	Dec	N	GI	N-SD	N	N	N	N	N	N-SD	N	N	U	N	U	U	U	U
Rallus longirostris	Clapper Rail	Dec	N	N	SD	N	Inc	N	SI	N	U	N	N	U	U	U	U	U	U
Rynchops niger	Black Skimmer	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Sterna dougallii dougallii	Roseate Tern	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Tringa semipalmata	Willet	Dec	N	N	SD	N	Inc	N	SI	N	N	N	N	U	U	U	U	U	U
Fish																			
Acipenser brevirostrum	Shortnose Sturgeon	Dec	N	N	N-SD	GI-Inc	Inc-SI	N	Inc	N	N	N	U	SD	N/A	U	U	U	U
Acipenser fulvescens	Lake Sturgeon	Dec	N	Inc-SI	N-SD	Inc-SI	Inc-SI	N	Inc	N	N	N	U	SI	N/A	U	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Acipenser oxyrinchus	Atlantic Sturgeon	Dec	N	N	SD	GI-Inc	Inc-SI	N	Inc	N	N	N	U	N	N/A	U	U	U	U
Alosa sapidissima	American Shad	Dec	N	N	N-SD	GI-Inc	Inc-SI	N	SI	N	N	N	U	SD	N/A	U	U	U	U
Ammocrypta pellucida	Eastern Sand Darter	N-SD	N	N	N-SD	SI-N	N-SD	N	Inc-SI	N	N	N	U	U	U	U	U	U	U
Anguilla rostrata	American Eel	Dec	N	N-SD	N-SD	GI-Inc	SI-N	N	SI-N	N	N	N	U	U	U	U	U	U	U
Catostomus utawana	Summer Sucker	N-SD	N	SI	SD	GI-Inc-SI	N	N	N	N	N-SD	N	N	U	SI	U	U	U	U
Coregonus artedi	Cisco or Lake Herring	SD	N	SI	N-SD	N	SI	SI	N	N	N	N	N	U	U	U	U	U	U
Coregonus clupeaformis	Lake Whitefish	SD	N	SI	N-SD	N	SI	SI	N	N	N	N	N	U	U	U	U	U	U
Cottus cognatus	Slimy Sculpin	SD-Dec	N	GI-Inc	N-SD	Inc-SI	SI-N	N	SI-N	N	SD	N	U	SI-N	N/A	U	U	U	U
Enneacanthus obesus	Banded Sunfish	SD	N	N	SD	Inc-SI	SI-N	N	SI-N	N	N	N	U	U	U	U	U	U	U
Etheostoma olmstedi	Tessellated Darter	Inc-SI-N	N	SI-N	N-SD	N	SI-N	N	N	N	N	N	N	U	U	U	U	U	U
Ichthyomyzon greeleyi	Mountain Brook Lamprey	U	N	Inc-SI-N	SD	N	SI	N	N	N	N	N	N	U	U	U	U	U	U
Lepomis megalotis	Longear Sunfish	U	N	N-SD	N	N	SI	N	N	N	N	N	N	U	Inc-SI	U	U	U	U
Lota lota	Burbot	SD	N	Inc-SI	N-SD	N	SI	N	N	N	N	N	N	U	U	U	U	U	U
Menidia menidia	Atlantic Silverside	SD	N	N-SD	N-SD	N	SI	N	SI	N	N	N	N	U	U	U	U	U	U
Moxostoma duquesnii	Black Redhorse	SD	N	U	U	N-SD	SI	N	N	N	N	N	N	U	U	U	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Notropis anogenus	Pugnose Shiner	U	N	U	N	U	SI	N	N	N	N	N	N	U	SI	U	U	U	U
Percina macrocephala	Longhead Darter	U	N	U	N-SD	N	SI	N	SI	N	N	N	N	U	U	U	U	U	U
Prosopium cylindraceum	Round Whitefish	SD-Dec	N	GI-Inc	N-SD	Inc-SI	SI-N	N	Inc-SI	N	N	N	U	U	U	U	U	U	U
Salvelinus fontinalis	Brook Trout	Dec	N	GI-Inc	N-SD	Inc-SI	Inc-SI	N	Inc	N	N	N	U	SI-N	N/A	U	U	SI	SI
Insects																			
Callophrys irus	Frosted Elfin	SI-N	N	N-SD	SI	N	SD-Dec	N	Inc	GI-Inc-SI	Inc	N	U	U	U	U	U	U	U
Chlosyne gorgone	Gorgone Checkerspot	SD-Dec	N	SI-N-SD	SD	N	U	N	N	N	SI-N	N	N	U	U	U	N-SD	U	U
Cicindela ancocisconensis	Appalachian Tiger Beetle	Dec	N	N	SI-N	N	Inc-SI-N	N	Inc	N	U	N	N	U	N	U	U	U	U
Cicindela hirticollis	Hairy-necked Tiger Beetle	Dec	N	N	SI-N	N	Inc-SI	N	Inc	N	U	N	N	U	N	U	U	U	U
Cicindela marginipennis	Cobblestone Tiger Beetle	Dec	N	N	SI-N	N	Inc-SI-N	N	Inc	N	U	N	N	U	N	U	U	U	U
Cicindela patruela	Northern Barrens Tiger Beetle	Dec	N	SD	SD	SI	Dec	N	Inc	U	U	N	N	U	U	U	U	U	U
Cordulegaster erronea	Tiger Spiketail	SD	N	Inc-SI	N-SD	GI	N	N	SI	N	N	U	U	U	N	SD	U	U	U
Enallagma recurvatum	Pine Barrens Bluet	N	N	N	SD	N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Erynnis persius persius	Persius Duskywing	N	N	SI-N	SD	N	N-SD	N	Inc	SI	Inc	N	U	U	U	U	U	U	U
Euchloe olympia	Olympia Marble	N-SD	N	N	N	SI-N	Inc-SI-N	N	Inc	N	SI-N	N	N	U	U	U	U	U	U
Gomphus rogersi	Sable Clubtail	SD	N	N	SD	N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Gomphus vastus	Cobra Clubtail	SD	N	N	N	N	SI-	N	SD	N	N	N	N	U	U	U	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
							N												
Hemileuca maia ssp 5	Coastal Barrens Buckmoth	N-SD	N	SI-N	SD	Inc-SI	N-SD	N	Inc	N	Inc	N	U	U	U	U	U	U	U
Hemileuca sp. 1	Bogbean Buckmoth	SI-N	N	Inc-SI	SD	Inc-SI	Inc-SI	N	SI	N	Inc	N	U	SI	N/A	U	U	U	U
Heptagenia culacantha	A Mayfly	N	N	SI-N	N-SD	N	SI-N	N	Inc	N	N	N	N	U	U	U	U	U	U
Hygrotus sylvanus	Sylvan Hygrotus Diving Beetle	SD	N	N	N	U	N	N	N	N	N	N	U	U	U	U	U	U	U
Ischnura ramburii	Rambur's Forktail	N	N	N	SD	N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Oeneis jutta	Jutta Arctic	SI	N	GI-Inc-SI	N-SD	GI	N	N	N	N	SI-N	N	N	SD	N/A	U	U	Inc-SI	U
Ophiogomphus howei	Pygmy Snaketail	SD	N	N	SD	N	SI-N	N	SD	N	N	N	N	U	U	U	U	U	U
Plebejus melissa samuelis	Karner Blue	N	N	GI-Inc-SI	N-SD	N	N-SD	N	Inc	SI	Inc	N	U	Inc	N/A	U	U	U	U
Progomphus obscurus	Common Sanddragon	SD-Dec	N	N-SD	N-SD	SI	N	N	SI	N	N	U	U	N	N/A	SD	U	U	U
Pteronarcys comstocki	A Stonefly: Spiny Salmonfly	N	N	SI-N	N-SD	N	SI-N	N	Inc	N	N	N	N	U	U	U	U	U	U
Rhionaeschna mutata	Spatterdock Darner	Dec	N	SD	N-SD	Inc-SI	U	U	SD	N	N	N	U	U	N	SD	SD	U	U
Sideridis maryx	Maroonwing	U	N	N	N	SI-N	Inc-SI-N	N	Inc	N	SI-N	N	N	U	U	U	U	U	U
Siphlonisca aerodromia	Tomah Mayfly	N	N	SI-N	N	GI	SI	N	Inc	N	N	N	N	U	U	N	U	U	U
Somatochlora cingulata	Lake Emerald	Dec	N	GI	SD	N	N	N	N	N	N	U	U	U	U	SD	U	U	U
Somatochlora forcipata	Forcipate Emerald	SD	N	Inc	N-SD	SI-N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Somatochlora minor	Ocellated Emerald	Dec	N	GI	SD	N	N	N	N	N	N	U	U	U	U	SD	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Stylurus plagiatus	Russet-tipped Clubtail	Dec	N	SD	N	N	N	U	SI	N	N	U	U	U	U	SD	N	U	U
Sympetrum danae	Black Meadowhawk	N	N	Inc	N-SD	SI-N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Tachopteryx thorei	Gray Petaltail	Dec	N	SD	N-SD	GI-Inc	SI-N	N	Inc-SI	N	N	N	U	U	U	SD	U	U	U
Trichoclea artesta	Hairy Artesta	N-SD-Dec	N	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Williamsonia fletcheri	Ebony Boghaunter	N	N	Inc	N-SD	SI-N	N	N	SD	N	N	N	N	U	U	U	U	U	U
Mammals																			
Alces americanus	Moose	Dec	N	GI-Inc	N-SD	N	N	N	SD	N	N	N	U	SI	N/A	SI-N-SD	SI-N	U	U
Lasiurus cinereus	Hoary Bat	Dec	N	U	N-SD	N	N	N	N	N	N	N	N	U	U	U	U	U	U
Martes americana	American Marten	Dec	N	Inc-SI	N-SD	N	N	GI	N	N	N	N	N	SI	N/A	U	U	N	N
Myotis leibii	Small-footed Bat	Dec-SD	N	N	N-SD	Inc-SI	N	N	SI	N	SI-N	N	N	U	Inc	SI-N	U	U	U
Myotis lucifugus	Little Brown Bat	Dec	N	N	N-SD	Inc-SI	N	N	Inc	N	SI-N	N	N	U	SI-N	SI-N	U	U	U
Myotis sodalis	Indiana Bat	Dec	N	N	N-SD	Inc-SI	N	N	Inc	N	SI-N	N	N	U	Inc-SI	SI-N	U	U	U
Sylvilagus transitionalis	New England Cottontail	SI-N	N	U	SD	SI-N	N	N	N	N	N	N	N	U	SI	U	U	U	U
Mollusks																			
Alasmidonta heterodon	Dwarf Wedgemussel	GI-Inc	N	N-SD	SD	GI-Inc	N	N	Inc	N	SD	Inc	U	U	N	U	U	U	U
Alasmidonta varicosa	Brook Floater	GI-Inc	N	N-SD	SD	GI-Inc	N	N	Inc	N	SD	Inc	U	U	N	U	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Amblema plicata	Three-ridge	SI-N	N	SD	N-SD	SI	SI-N	N	SI-N	N	SD	Inc	U	Inc-SI	N/A	U	U	U	U
Anodonta implicata	Alewife Floater	N-SD	N	U	N-SD	N	SI	N	SI-N	N	N	Inc-SI	N	U	SI	U	U	U	U
Lampsilis fasciola	Wavyrayed Lampmussel	N-SD	N	U	N-SD	N	SI	N	SI-N	N	N	SI	N	U	SI	U	U	U	U
Lasmigona subviridis	Green Floater	SD-Dec	N	N	N	GI-Inc	Inc-SI	N	Inc-SI	N	N	Inc-SI	U	U	U	U	U	U	U
Ligumia nasuta	Eastern Pondmussel	N-SD	N	U	N-SD	N	SI	N	N	N	N	Inc-SI	N	U	SI	U	U	U	U
Ligumia recta	Black Sandshell	GI-Inc	N	SD	N-SD	GI-Inc	N-SD	N	Inc	N	SD	Inc	U	U	N	U	U	U	U
Margaritifera margaritifera	Eastern Pearlshell	GI-Inc	N	GI	N-SD	GI-Inc	SI-N	N	Inc	N	SD	Inc	U	U	N	U	U	U	U
Novisuccinea chittenangoensis	Chittenango Ovate Amber Snail	GI	N	N	SD	GI	Inc	N	Inc	N	Inc-SI-N	N	N	U	U	U	U	U	U
Villosa fabalis	Rayed Bean	N-SD	N	U	N-SD	N	SI	N	SI-N	N	N	SI	N	U	SI	U	U	U	U
Reptiles																			
Apalone spinifera	Spiny Softshell	SD-Dec	N	SD	N-SD	SI	N	N	Inc-SI	U	SD	U	U	Inc	N/A	N	U	U	U
Clemmys guttata	Spotted Turtle	N	N	N	N-SD	Inc-SI-N	N	N	SD	N	SD	N	N	Inc-SI	N/A	U	U	U	U
Coluber constrictor	Eastern Racer	SD	N	SD	N-SD	N	N-SD	N	Dec	SI-N	SD	U	U	SD	N/A	N	U	U	U
Crotalus horridus	Timber Rattlesnake	SD	N	SD	SD	N	N	N	U	N	N	N	N	N	N/A	U	U	U	U
Emydoidea blandingii	Blanding's Turtle	N	N	Inc-SI-N	N-SD	GI-Inc	N	N	SI	N	N	N	N	U	N	U	U	U	U
Eumeces anthracinus	Coal Skink	N	N	SD	N	SD	Inc-SI	N	SI	SI-N	N	U	U	U	SI	N	U	U	U

Scientific Name	Common Name	Dispersal/ movement	Historical thermal niche	Physiological thermal niche	Historical hydrol niche	Physiological hydrol niche	Disturbance	Ice/snow	Phys habitat	Other spp for hab	Diet	Other spp disp	Other spp interaction	Genetic var	Gen bottleneck	Phenol response	Doc response	Modeled change	Modeled overlap
Eumesces (Plestiodon) fasciatus	Five-lined Skink	N	N	SD	N-SD	SD	SI-N	N	Inc-SI	SI-N	N	U	U	N	N/A	N	SI	U	U
Glyptemys insculpta	Wood Turtle	SI-N	N	Inc-SI	N-SD	N	N	N	Dec	N	SD	U	U	Inc	N/A	N	U	U	U
Glyptemys muhlenbergii	Bog Turtle	SI-N	N	Inc	SD	GI-Inc	Inc	N	Inc	Inc	SD	U	U	Inc	N/A	N	U	U	U
Heterodon platirhinos	Eastern Hog-nosed Snake	N	N	SD	U	N	SI-N	N	SI	SI	SI	U	U	U	N	U	U	U	U
Kinosteron subrubrum	Mud Turtle	N	N	SD	SD	GI-Inc	N	N	N	U	SD	U	U	U	Inc-SI	N	U	U	U
Malaclemys terrapin	Diamondback Terrapin	SD	N	SD	SD	SI	N	N	SI	N	SD	U	U	U	Inc	N	U	U	U
Regina septemvittata	Queen Snake	SD	N	N	N-SD	SI-N	N	N	SD	N	SI	N	N	U	U	U	U	U	U
Sceloporous undulatus	Eastern Fence Lizard	N	N	SD	SD	SD	SI-N	N	SI	SI	N	U	U	N-SD	N/A	N	SI	U	U
Sistrurus catenatus catenatus	Eastern Massasauga	SD	N	N	N	SI-N	Inc-SI	N	SD	N	N	N	N	SI	N/A	U	U	U	U
Terrepene carolina	Box Turtle	SI-N	N	SD	SD	N	SI-N	N	N	U	SD	U	U	SI-N	N/A	SI	U	SI	U

Appendix D: Exposure and geography risk factor scores

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Amphibians											
Acris crepitans	Cricket Frog	Northern edge of range		100		100		N	N	Inc-SI	U
Ambystoma opacum	Marbled Salamander	Northern edge of range		100		100		N	SI	Inc	U
Ambystoma tigrinum	Eastern Tiger Salamander	Northern edge of range		100		100		GI	GI	GI	SI
Cryptobranchus alleganiensis	Hellbender	Northern edge of range	100			100		N	SI-N	GI-Inc	SI
Eurycea longicauda	Longtail Salamander	Northern edge of range	85	15	35	65		N	N	N	U
Plethodon wehrlei	Wehrle's Salamander	Northern edge of range	100		25	75		N	N	N	U
Pseudacris maculata	Boreal Chorus Frog	East/west edge of range	100		50	50		N	Inc	N	U
Pseudacris triseriata	Western Chorus Frog	East/west edge of range	15	85	85	15		N	Inc-SI	N	U
Rana septentrionalis	Mink Frog	Southern edge of range	100		5	50	45	N	N	N	N
Rana sphenocephala	Southern Leopard Frog	Northern edge of range		100		100		N	Inc-SI	Inc-SI	Inc-SI-N
Scaphiopus holbrooki	Eastern Spadefoot	Northern edge of range		100	33	67		Inc	Inc	GI	U
Birds											
Ammodramus caudacutus	Saltmarsh Sharp-tailed Sparrow	Southern edge of range		100		100		GI	N	N	SI
Ammodramus henslowii	Henslow's Sparrow	East/west edge of range	80	20	55	45		N	N	N	SI
Ammodramus maritimus	Seaside Sparrow	Northern edge of range		100		100		GI	N	N	SI
Caprimulgus carolinensis	Chuck-will's Widow	Northern edge of range		100		100		GI	SI-N	SI-N	U
Catharus bicknelli	Bicknell's Thrush	Southern edge of range	70	30			100	N	N	N	SI
Charadrius melodus	Piping Plover	East/west edge of range	1	99	1	99		GI	N	N	Inc-SI-N
Chlidonias niger	Black Tern	Southern edge of range	90	10	80	20		SI-N	N	N	U
Contopus cooperi	Olive-sided Flycatcher	Southern edge of range	85	15		25	75	N	N	N	SI

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Dolichonyx oryzivorus	Bobolink	East/west edge of range	67	33	50	50		N	N	N	SI
Euphagus carolinus	Rusty Blackbird	Southern edge of range	100			10	90	N	N	N	N
Falcipennis canadensis	Spruce Grouse	Southern edge of range	100				100	N	GI	N	U
Haematopus palliatus	American Oystercatcher	Northern edge of range		100		100		GI	N	N	SI
Laterallus jamaicensis	Black Rail	Northern edge of range		100	100			GI	N	N	SI
Picoides arcticus	Black-backed Woodpecker	Southern edge of range	100			15	85	N	N	N	N
Picoides dorsalis	American Three-toed Woodpecker	Southern edge of range	100				100	N	N	N	N
Poecile hudsonicus	Boreal Chickadee	Southern edge of range	100			10	90	N	N	N	N
Rallus longirostris	Clapper Rail	Northern edge of range		100		100		GI	N	N	SI
Rynchops niger	Black Skimmer	Northern edge of range		100		100		GI	N	N	SI
Sterna dougallii dougallii	Roseate Tern	Southern edge of range		100		100		GI	N	N	SI
Tringa semipalmata	Willet	East/west edge of range		100		100		GI	N	N	SI
Fish											
Acipenser brevirostrum	Shortnose Sturgeon	Center of range		100	25	75		GI	GI	GI	Inc-SI
Acipenser fulvescens	Lake Sturgeon	East/west edge of range	95	5	85	15		N	Inc-SI	GI-Inc	SI-N
Acipenser oxyrinchus	Atlantic Sturgeon	Center of range		100		100		GI	GI	GI	Inc-SI
Alosa sapidissima	American Shad	Center of range	30	70	15	85		SI	SI-N	Inc-SI	SI-N
Ammocrypta pellucida	Eastern Sand Darter	East/west edge of range	30	70	50	50		N	Inc-SI	Inc	SI-N
Anguilla rostrata	American Eel	East/west edge of range	10	90	12	86	2	Inc	SI-N	Inc-SI	SI-N
Catostomus utawana	Summer Sucker	Entire range	100			10	90	N	Inc-SI	Inc	N
Coregonus artedi	Cisco or Lake Herring	East/west edge of range	85	15	40	50	10	N	Inc-SI	SI-N	N
Coregonus clupeaformis	Lake Whitefish	Southern edge of range	95	5	15	20	65	N	Inc-SI	SI-N	N

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Cottus cognatus	Slimy Sculpin	East/west edge of range	50	50	10	75	15	N	GI-Inc	GI-Inc	Inc-SI
Enneacanthus obesus	Banded Sunfish	Center of range		100		100		SI-N	Inc-SI	Inc	Inc-SI
Etheostoma olmstedi	Tessellated Darter	Center of range	64	36	33	59	8	N	N	N	N
Ichthyomyzon greeleyi	Mountain Brook Lamprey	Northern edge of range	85	15		100		N	SI-N	SI	N
Lepomis megalotis	Longear Sunfish	East/west edge of range	40	60	100			N	SI-N	SI-N	N
Lota lota	Burbot	Southern edge of range	97	3	10	90		N	SI	SI	SI-N
Menidia menidia	Atlantic Silverside	Center of range	45	55	45	55		Inc	SI-N	SI-N	N
Moxostoma duquesnii	Black Redhorse	Northern edge of range	50	50	40	60		N	SI	SI-N	SI-N
Notropis anogenus	Pugnose Shiner	East/west edge of range	100		50	50		N	SI-N	SI-N	N
Percina macrocephala	Longhead Darter	Northern edge of range	100			100		N	SI-N	SI-N	N
Prosopium cylindraceum	Round Whitefish	Southern edge of range	100			25	75	N	GI-Inc	GI-Inc	Inc-SI
Salvelinus fontinalis	Brook Trout	East/west edge of range	80	20	3	67	30	SI	GI-Inc	GI-Inc	Inc-SI
Insects											
Callophrys irus	Frosted Elfin	Northern edge of range	10	90	50	50		SI	SI-N	GI	U
Chlosyne gorgone	Gorgone Checkerspot	Northern edge of range	100				100	N	N	N	Inc-SI
Cicindela ancocisconensis	Appalachian Tiger Beetle	Center of range	50	50	10	45	45	N	N	N	N
Cicindela hirticollis	Hairy-necked Tiger Beetle	Center of range	50	50		100		GI	N	N	N
Cicindela marginipennis	Cobblestone Tiger Beetle	Center of range	50	50		100		N	N	N	N
Cicindela patruela	Northern Barrens Tiger Beetle	Northern edge of range		100		100		N	N	N	SI
Cordulegaster erronea	Tiger Spiketail	Northern edge of range	50	50	50	50		N	N	N	U
Enallagma recurvatum	Pine Barrens Bluet	Center of range		100		100		N	N	N	SI-N

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Erynnis persius persius	Persius Duskywing	East/west edge of range		100	100			N	N	N	SI-N
Euchloe olympia	Olympia Marble	East/west edge of range	100		100			N	N	N	Inc
Gomphus rogersi	Sable Clubtail	Northern edge of range		100		100		N	N	N	SI-N
Gomphus vastus	Cobra Clubtail	Center of range	80	20	100			Inc	N	SI-N	Inc-SI-N
Hemileuca maia ssp 5	Coastal Barrens Buckmoth	East/west edge of range		100		100		N	N	N	SI-N
Hemileuca sp. 1	Bogbean Buckmoth	East/west edge of range	100		100			N	N	N	SI-N
Heptagenia culacantha	A Mayfly	Northern edge of range	50	50	50	50		N	N	N	SI-N
Hygrotus sylvanus	Sylvan Hygrotus Diving Beetle	Southern edge of range	100			100		N	N	N	U
Ischnura ramburii	Rambur's Forktail	Northern edge of range		100		100		Inc	N	N	Inc-SI
Oeneis jutta	Jutta Arctic	Southern edge of range	100				100	N	N	SI-N	N
Ophiogomphus howei	Pygmy Snaketail	Center of range	100		5	95		N	N	SI-N	SI-N
Plebejus melissa samuelis	Karner Blue	East/west edge of range	20	80	100			N	SI-N	SI-N	SI-N
Progomphus obscurus	Common Sanddragon	Northern edge of range	50	50		100		N	N	N	U
Pteronarcys comstocki	A Stonefly: Spiny Salmonfly	Center of range	100		33	50	17	N	N	N	SI-N
Rhionaeschna mutata	Spatterdock Darner	Northern edge of range	65	35	50	50		N	N	N	U
Sideridis maryx	Maroonwing	Center of range						N	N	N	Inc
Siphlonisca aerodromia	Tomah Mayfly	Southern edge of range	100			100		N	N	N	SI-N
Somatochlora cingulata	Lake Emerald	Southern edge of range	100				100	N	N	N	U
Somatochlora forcipata	Forcipate Emerald	Southern edge of range	85	15		30	70	N	N	SI-N	SI-N
Somatochlora minor	Ocellated Emerald	Southern edge of range	100				100	N	N	N	U
Stylurus plagiatus	Russet-tipped Clubtail	Northern edge of range	100			100		SD	GI	N	SI

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Sympetrum danae	Black Meadowhawk	Southern edge of range	100		33		67	N	N	N	SI-N
Tachopteryx thorei	Gray Petaltail	Northern edge of range	65	35	65	35		N	N	N	U
Trichoclea artesta	Hairy Artesta	East/west edge of range						N	N	N	U
Williamsonia fletcheri	Ebony Boghaunter	Southern edge of range	100		25		75	N	N	N	SI-N
Mammals											
Alces americanus	Moose	Southern edge of range	90	10	10	90		N	SI-N	SI-N	N
Lasiurus cinereus	Hoary Bat	East/west edge of range	100		50	50		N	N	N	Inc
Martes americana	American Marten	Southern edge of range	68	32	45	55		N	SI-N	SI-N	N
Myotis leibii	Small-footed Bat	Center of range	50	50	50	50		N	N	N	SI
Myotis lucifugus	Little Brown Bat	East/west edge of range	75	25	50	50		N	N	N	SI
Myotis sodalis	Indiana Bat	Northern edge of range	100			100		N	N	N	SI
Sylvilagus transitionalis	New England Cottontail	Southern edge of range	100			100		N	Inc-SI	Inc-SI	U
Mollusks											
Alasmidonta heterodon	Dwarf Wedgemussel	East/west edge of range	90	10	65	30	5	N	Inc	Inc-SI	SI
Alasmidonta varicosa	Brook Floater	East/west edge of range	60	40	33	34	33	N	Inc	Inc-SI	SI
Amblema plicata	Three-ridge	East/west edge of range	100			10	90	N	Inc	Inc-SI	SI
Anodonta implicata	Alewife Floater	Center of range	50	50	20	70	10	N	SI	SI	SI-N
Lampsilis fasciola	Wavyrayed Lampmussel	Northern edge of range	60	40	20	65	15	N	SI	SI	SI-N
Lasmigona subviridis	Green Floater	Northern edge of range	45	55	30	70		N	Inc-SI	GI-Inc	Inc-SI
Ligumia nasuta	Eastern Pondmussel	Northern edge of range		100		100		N	SI	SI-N	SI-N
Ligumia recta	Black Sandshell	East/west edge of range		100		100		N	Inc	Inc-SI	SI-N

Scientific Name	Common Name	NY Range Relative to Global Range	Pct_range_warmer (5 F)	Pct_range_warm (4.5 F)	Pct_range_dryest (-0.073)	Pct_range_dryer (-0.05)	Pct_range_dry (>-0.028)	Sea level	Natl barriers	Anth barriers	CC mitigation
Margaritifera margaritifera	Eastern Pearlshell	Southern edge of range	50	50	10	90		N	Inc	Inc-SI	SI
Novisuccinea chittenangoensis	Chittenango Ovate Amber Snail	Entire range	50	50	50	50		N	GI-Inc-SI-N	N	N
Villosa fabalis	Rayed Bean	Northern edge of range	5	95	40	60		N	SI	SI	SI-N
Reptiles											
Apalone spinifera	Spiny Softshell	East/west edge of range	100		75	25		N	N	SI-N	U
Clemmys guttata	Spotted Turtle	Center of range	33	67	33	67		SI-N	SI	Inc-SI	SI-N
Coluber constrictor	Eastern Racer	Northern edge of range	15	85	25	75		SI-N	SI-N	SI-N	U
Crotalus horridus	Timber Rattlesnake	Northern edge of range	50	50	20	80		N	N	Inc	SI
Emydoidea blandingii	Blanding's Turtle	Center of range	50	50	30	70		N	SI-N	Inc-SI	N
Eumeces anthracinus	Coal Skink	Northern edge of range	100		90	10		N	N	SI-N	U
Eumesces (Plestiodon) fasciatus	Five-lined Skink	Northern edge of range	40	60		100		N	SI-N	N	U
Glyptemys insculpta	Wood Turtle	Center of range	60	40	60	25	15	N	N	SI	U
Glyptemys muhlenbergii	Bog Turtle	Northern edge of range	25	75	5	95		N	Inc	Inc	U
Heterodon platirhinos	Eastern Hog-nosed Snake	Northern edge of range		100	20	80		SI	SI	SI	U
Kinosteron subrubrum	Mud Turtle	Northern edge of range		100		100		GI	GI-Inc	GI-Inc	U
Malaclemys terrapin	Diamondback Terrapin	Northern edge of range		100		100		SD	GI	GI	U
Regina septemvittata	Queen Snake	Northern edge of range	100		50	50		N	N	SI	SI-N
Sceloporous undulatus	Eastern Fence Lizard	Northern edge of range		100		100		N	N	N	U
Sistrurus catenatus catenatus	Eastern Massasauga	East/west edge of range	100		100			N	N	Inc-SI	SI-N
Terrepene carolina	Box Turtle	Northern edge of range	20	80		100		N	N	SI	U

Appendix E: Some suggested animal species for future assessments

Note: This is the list of second-priority species jointly developed by NYNHP, TNC, and NYSDEC. It does not include crayfish, cave obligates, plants, marine species and others mentioned in the discussion beginning on page 21.

Taxonomic group	Common name	Scientific name	State listing	S-rank
Amphibian	Four-toed salamander	*Hemidactylium scutatum*	SGCN	S5
Amphibian	Jefferson salamander	*Ambystoma jeffersonianum*	SC; SGCN	S4
Birds	American Black Duck	*Anas rubripes*	SGCN	S4
Birds	American Pipit	*Anthus rubescens*		SNRN
Birds	Bay-breasted Warbler	*Dendroica castanea*	SGCN	S2
Birds	Black-backed Woodpecker	*Picoides arcticus*		S3
Birds	Black-throated Blue Warbler	*Dendroica caerulescens*	SGCN	S5
Birds	Canada Warbler	*Wilsonia canadensis*	SGCN	S5
Birds	Cape May Warbler	*Dendroica tigrina*	SGCN	S2
Birds	Caspian Tern	*Hydroprogne caspia*	SGCN	S1
Birds	Chimney Swift	*Chaetura pelagica*		S5
Birds	Common Nighthawk	*Chordeiles minor*	SC; SGCN	S4
Birds	Common Tern	*Sterna hirundo*	T; SGCN	S3B
Birds	Eastern Wood-Pewee	*Contopus virens*		S5
Birds	Forster's Tern	*Sterna forsteri*		S1
Birds	Grasshopper Sparrow	*Ammodramus savannarum*	SC; SGCN	S4
Birds	Gull-billed Tern	*Gelochelidon nilotica*	SGCN	S1
Birds	Least Bittern	*Ixobrychus exilis*	T; SGCN	S3B,S1N
Birds	Least Tern	*Sternula antillarum*	T; SGCN	S3B
Birds	Lincoln's Sparrow	*Melospiza lincolnii*		S4
Birds	Little Blue Heron	*Egretta caerulea*	SGCN	S2
Birds	Louisiana Waterthrush	*Seiurus motacilla*	SGCN	S5
Birds	Purple Martin	*Progne subis*		S5
Birds	Red Crossbill	*Loxia curvirostra*		S3
Birds	Red-headed Woodpecker	*Melanerpes erythrocephalus*	SC; SGCN	S2
Birds	Ruby-throated Hummingbird	*Archilochus colubris*		S5
Birds	Scarlet Tanager	*Piranga olivacea*	SGCN	S5
Birds	Sedge Wren	*Cistothorus platensis*	T; SGCN	S3B
Birds	Sharp-shinned Hawk	*Accipiter striatus*	SC; SGCN	S4
Birds	Spotted Sandpiper	*Actitis macularia*		S5
Birds	Tennessee Warbler	*Vermivora peregrina*	SGCN	S2
Birds	Tricolored Heron	*Egretta tricolor*	SGCN	S2
Birds	Upland Sandpiper	*Bartramia longicauda*	T; SGCN	S3B
Birds	Whip-poor-will	*Caprimulgus vociferus*	SC; SGCN	S4
Birds	Wood Thrush	*Hylocichla mustelina*	SGCN	S5
Birds	Yellow-bellied Flycatcher	*Empidonax flaviventris*		S3

Taxonomic group	Common name	Scientific name	State listing	S-rank
Birds	Yellow-palm Warbler	*Dendroica palmarum*		S1
Fish	Alewife	*Alosa pseudoharengus*	SGCN	S5
Fish	Blueback Herring	*Alosa aestivalis*		S3
Fish	Deepwater Sculpin	*Myoxocephalus thompsonii*	E; SGCN	S1
Fish	Gravel Chub	*Erimystax x-punctatus*	T; SGCN	S1
Fish	Lake Trout	*Salvelinus namaycush*		S5
Fish	Mooneye	*Hiodon tergisus*	T; SGCN	S1
Fish	Ninespine Stickleback	*Pungitius pungi*	SGCN	
Fish	Rainbow Smelt	*Osmerus mordax*	SGCN	S5
Fish	Western Pirate Perch	*Aphredoderus sayanus gibbosus*	SGCN	S1
Leps	A noctuid moth	*Agrotis obliqua*	SGCN	S1
Leps	A noctuid moth	*Anomogyna rhaetica*	SGCN	S1S2
Leps	A noctuid moth	*Orthodes obscura*	SGCN	S1?
Leps	A noctuid moth	*Zale largera*	SGCN	S1
Leps	A noctuid moth	*Lithophane lepida lepida*	E; SGCN	S1
Leps	Checkered white	*Pontia protodice*	SC; SGCN	SA
Leps	Hessel's hairstreak	*Callophrys hesseli*	E; SGCN	S1
Leps	Inland barrens buckmoth	*Hemileuca maia maia*	SC; SGCN	S1
Leps	Northern metalmark	*Calephelis borealis*	SGCN	S1
Mammals	Allegheny woodrat	*Neotoma magister*	E; SGCN	S1
Mammals	Bobcat	*Felis rufus*	SGCN	S5
Mammals	Fisher	*Martes pennanti*		S5
Mammals	Silver-haired bat	*Lasionycteris noctivagans*		S4B, SZN
Marine invert	Blue Crab	*Callinectes sapidus*	SGCN	SNR
Marine invert	Hard Clam	*Mercenaria mercenaria*	SGCN	SNR
Marine invert	Ribbed Mussel	*Geukensia demissa*	SGCN	SNR
Mussels	Yellow lampmussel	*Lampsilis cariosa*	SGCN	S3
Odonates	Needham's Skimmer	*Libellula needhami*	SGCN	S3
Odonates	Rapids Clubtail	*Gomphus quadricolor*	SGCN	S3
Odonates	Septima's Clubtail	*Gomphus septima*	SC; SGCN	S1
Reptiles	Eastern Ratsnake	*Elaphe alleganiensis*	SGCN	S4
Reptiles	Eastern Ribbonsnake	*Thamnophis sauritus*		S5
Reptiles	Eastern Worm Snake	*Carphophis amoenus*	SC; SGCN	S2
Reptiles	Ringneck Snake	*Diadophis punctatus*	SGCN	S5
Reptiles	Short-headed Garternsnake	*Thamnophis brachystoma*		S3
Reptiles	Smooth Greensnake	*Liochlorophis vernalis*	SGCN	S4
Turtles	Map Turtle	*Graptemys geographica*	SGCN	S3
Turtles	Stinkpot	*Sternotherus odoratum*	SGCN	S5