VULNERABILITIES TO CLIMATE CHANGE OF MASSACHUSETTS ANIMAL SPECIES OF GREATEST CONSERVATION NEED

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1. INTRODUCTION

Over the last decade, the Commonwealth of Massachusetts has addressed the potential and actual impacts of climate change on state flora and fauna. The state's involvement began in 2007 when, led by the Division of Fisheries and Wildlife (DFW) and assisted by Manomet Center for Conservation Research, it carried out one of the first habitat vulnerability assessments in North America (Manomet, 2010). The new methods and processes that resulted were later applied to vulnerability assessments in North America and elsewhere. In 2011, the state assisted the Northeastern Association of Fish and Wildlife Agencies (NEAFWA) in organizing and leading a pioneering three-year, thirteen-state research effort to evaluate the vulnerabilities of fish and wildlife habitats to climate change in the northeast, from Maine south to West Virginia (NEAFWA, 2012).

This focus on climate change vulnerabilities led to three important early realizations: (1) simply categorizing and scoring vulnerabilities might not lead to better conservation outcomes. It was vital to also understand why some resources were more or less vulnerable to climate change in order to identify potential intervention points on which conservation actions and strategies could be based. (2) simply producing research results was not enough; these results had to be cast as specific conservation actions. Moreover (3), these actions needed to be communicated in a useful form to conservation "actors", such as state agencies, land trusts, land managers, etc. These realizations led to the next step on the Commonwealth's journey to effective conservation in an age of climate change - the Massachusetts Wildlife Climate Action Tool (CAT).

The CAT is a web-based tool that provides users with the best scientific information on the changing climate, helps identify which fish and wildlife resources and habitats might be most vulnerable to a changing climate, provides all of this information at a city and town level, and identifies adaptation strategies that could reduce the climate change impacts on natural resources. The tools and techniques (adaptation strategies) offered in the CAT have to be sufficiently specific to provide meaningful options for landowners and other decision-makers. In general, adaptation strategies include relatively familiar conservation measures, from land conservation and habitat management to changes in land-use regulations. However, they also include some new and less familiar conservation ideas such as assisting species in colonizing new regions that could become suitable under future climate change conditions, so-called assisted migration. The one common feature of these conservation strategies that make them true adaptation strategies is that their use will reduce the climate vulnerability of the fish and wildlife resource in question.

Built during 2015 and 2016, the development of the CAT was funded by the Commonwealth's DFW and the Department of Fish and Game. The actual development was carried out through the cooperation of the Massachusetts Cooperative Research Unit and the Center for Agriculture, Food and the Environment of the University of Massachusetts at Amherst, as well as the Department of Interior Northeast Climate Science Center, also located on the UMASS Amherst Campus. This extensive effort from multiple groups has resulted in a dynamic tool containing an abundance of information, which is continuously being updated as new data become available. In the spring of 2016, it was decided that the CAT would be more effective if information on state special status species was included. Although the results of other state vulnerability assessments are listed in the CAT, no Massachusetts-wide species vulnerability assessment has ever been conducted. This information needed to cover the likely vulnerabilities to climate change of these already sensitive species and address management actions which could assist in their conservation, despite a changing climate.

In the 2015 iteration of the Commonwealth's Wildlife Action Plan (http://www.mass.gov/eea/agencies/dfg/dfw/wildlife-habitat-conservation/state-wildlife-conservation-strategy.html), 570 species were identified as Species in Greatest Conservation Need (SGCN), including plants, vertebrates and invertebrates. DFW recognized that as many as possible of these species should be evaluated and included in the CAT in terms of: a) their likely vulnerabilities to climate change, and b) management actions that could lead to effective conservation outcomes. The Massachusetts Rapid Assessment Project (MRAP), initiated in June 2016, comprises a first step toward these two important goals.

In the MRAP work thus far we have addressed the question: how vulnerable are SGCN likely to be to climate change during the remainder of this century. We have also begun the process of identifying and describing potential management actions that could lessen the effects of climate change on these species. In the remainder of this report we detail several outcomes of the work so far: how we selected SGCN for analysis; how we developed analytical tools to evaluate species' vulnerabilities; how we applied the tools; and the results obtained. We have not yet evaluated all 570 species of SGCN - this would have required more time and resources than were available. We have, however, evaluated a significant number in a diversity of taxa, and we hope that the remainder can be covered in subsequent stages of this ongoing project[1]. We anticipate that future work will detail the results of vulnerability assessment and management analysis on additional SGCN.

[1] We were not able, given the time constraints, to assess the vulnerabilities of SGCN plants. It is hoped that this can be redressed in a future phase of the project.

2. PLANT AND ANIMAL RAPID ASSESSMENT PROTOCOLS

The vulnerability assessment process is not an end in itself. It is, however, an essential step toward being able to plan and implement effective adaptation strategies under a changing climate. For this to occur, it is essential that effective vulnerability assessment predictive models or frameworks are incorporated into conservation plans. If a predictive vulnerability assessment model is to meet these goals, it must include a number of components:

Estimates of vulnerabilities of species to future climate change. The model must be able to quantify and rank the vulnerabilities of the target species to future climate change projections. This component of the model must be able to incorporate the two main components of vulnerability:

- The sensitivity of the species to both the direct effect of changing climatic factors on the organisms, and indirect effects as the changing climate impacts essential components of the species' habitat.

- The adaptive capacity of the species (i.e., its ability to respond effectively to the changing climate by, for example, changing its behavior to lessen the impacts).

Exposure assessment. The degree of vulnerability of a species is a function of not only its sensitivity to changing environmental conditions, but also the assumptions that are made by the assessor about the likely future degree of climate change. Any species vulnerability assessment must be specific about the latter (Galbraith and Price, 2009; Glick *et al*. 2011). Thus, before evaluating the likely impacts of climate change on organisms, it is necessary to project the likely degree of change that the organisms will be subjected to, i.e., the exposure. It is important to note that since we do not know the precise relationship between exposure and response for most organisms (i.e., we do not know whether, for example, a 2.5^{o}F or 3.0^{o}F change would result in different population responses), we consider it sufficient to approximate, or bookend, the potential change in exposure.

Results of climate modeling analyses for the Northeast Region of the United States project climatic changes over the remainder of this century (e.g., NECIA, 2006; Walsh *et al*., 2014) that vary based on several different greenhouse gas emissions scenarios, from a "business-as-usual" scenario, where current rates of emissions continued unabated, to more moderate scenarios where reductions in emissions are enacted in the next few decades. Extrapolation from the results of these region-wide studies to projected changes in Massachusetts reveals that by the last two decades of the century the following general changes are projected to occur[2]:

Mean Annual Temperature. Under business-as-usual emissions scenarios, the mean annual temperature of the Commonwealth is projected to increase by about 3-5^{o} C (5-9^{o}F). Under more conservative emissions scenarios, the temperature increase is projected to be about 2-3^{o}C (4-5^{o}F)

[2] To learn more about how future climates are modeled, emissions scenarios, and future climates visit the "Learning About Climate Change" section of the Massachusetts Climate Action Tool website (climateactiontool.org).

Most of this increase in temperature is projected to occur during the winter months. For the purposes of this analysis we conservatively assume that the mean annual temperature in the Commonwealth will increase by between 4 and 6^{o}F by the last two decades of the century.

Extended Growing Season. Plant growing seasons in Massachusetts are projected to lengthen by 1-2 months by starting earlier in the spring and extending further into the fall, depending on the emissions scenario.

Changes in Precipitation. The projections for this variable from the climate models are less certain than those for temperature (e.g., NECIA, 2006). However, many models project a few percentage points increase in annual precipitation (by approximately 5-10%). Models indicate that more winter precipitation will fall as rain and less as snow, with a resulting decrease in area covered by snow (with the snow line retreating upward in elevation), the length of the "snow-lie" season, and snow pack depth.

Extreme Events. The frequency, duration, and severity of extreme droughts and floods are projected to increase under both moderate and business-as-usual emissions scenarios (e.g., NECIA, 2006).

Soil Moisture Changes. Given the uncertainty associated with projecting future precipitation patterns, modeling results for soil moisture are also uncertain. However, if summer droughts become more frequent, longer, and more severe, and evapotranspiration rates increase, it is likely that they may be accompanied by sporadic and significant reductions in soil moisture.

Sea Level Rise. Over the remainder of this century, sea level on the Massachusetts coastline is projected to rise between 50cm and 1m (Sallenger *et al*., 2005; and reviewed in Galbraith, 2014), inundating many coastal habitats that are currently intertidal, such as ocean beaches, mudflats and sandflats, and salt marshes. Rising sea levels, together with more severe onshore storms could result in frequent inundation of habitats currently above the high tide line and injuries to salt-intolerant plants and other organisms.

Vulnerabilities of species to non-climate stressors. If the goal of the modeling process is to inform projections of likely future changes in a species' status and distribution, it is important to consider the non-climate stressors that may impact them. In some situations, climate change may be the major future determinant of a species' status. However, in other instances the impacts of a changing climate may be minor in comparison to the likely future effects of other stressors, such as habitat loss, invasive species, societal responses, etc.

Uncertainty evaluation. Modeling the vulnerabilities and impacts of current and future climate change is beset with uncertainty. Specific uncertainties arise at all stages of the modeling process; from the climate modeling process, to assumptions about the intrinsic and extrinsic vulnerabilities of the species to climatic factors, to uncertainties about future vulnerabilities to non-climate stressors, to human responses to environmental changes, and to the adaptive capacities of the resources. While it may be possible to reduce some of these uncertainties by building better models or by gathering more data, many of them are irreducible in the foreseeable future. Thus, our challenge is to learn how to make decisions in the face of uncertainty, rather than be immobilized by it. In the context of vulnerability assessment modeling, this means including a comprehensive and detailed appraisal of how certain we can be about our pronouncements – essential information for conservation managers and planners when evaluating how to react to vulnerability information. The uncertainty/certainty evaluation component of any vulnerability assessment cannot be an afterthought, but is an essential and critical component of the process.

Process transparency. Vulnerability evaluation will always be a "work-in-progress", since we cannot be definitive about the outcomes of climate change acting on ecological resources until they are actually observable. Thus, our conclusions must be provisional and adaptable as new information becomes available and our process transparent and explicit about why we adopted certain assumptions and/or scores rather than others. A reader should be able to clearly and easily follow the process and logic-steps that were undertaken.

A number of species and habitat vulnerability models have been developed and applied over the last 10-15 years. Species models have included those by Galbraith and Price (2009), Williams *et al*. (2008), and Galbraith *et al*. (2014). Habitat models are less numerous but include those developed for Massachusetts (Manomet, 2010), and for the entire Northeast Region (NEAFWA, 2012). Many of these models (and the vulnerability assessment process, in general) are described further in Glick *et al*. (2011).

The current project presents a unique challenge in that, ultimately, the model(s) are to be applied to a large number (570) of Massachusetts SGCN, and a great diversity of taxa, from plants to vertebrates (mammals, birds, fish, and herps), to aquatic and terrestrial invertebrates (mollusks, crustaceans, odonates, lepidopterans, etc.). If all of these diverse organisms were to be processed in a reasonable time scale of months, rather than years, then the applied model(s) would have to be a type of rapid assessment, rather than highly detailed and time-consuming models. Therefore, a new rapid assessment process was developed for this project.

2.1 The Massachusetts Rapid Assessment Protocols

Based on previous species models (e.g., Galbraith and Price, 2009; Williams *et al*., 2008; and other species models in Glick et al., 2011), two spreadsheet-based models were developed for the Massachusetts SGCN project, a plant model (the Massachusetts Rapid Assessment Protocol for plants (Plant MRAP)), and a model for animals (the Massachusetts Rapid Assessment Protocol for animals (Animal MRAP)). Each model (Attachments 1 and 2) is basically a ranking questionnaire for taxon experts or specialists that incorporates what is known about the potential relationships between the organisms' ecologies, behaviors, physiologies, and life histories and climate. In this way, the three components of vulnerability – sensitivity, exposure, and adaptive capacity – are addressed in individual questions and incorporated into a final rank for each species.

Each MRAP is based on 14 factors or variables that describe the potential relationships between the species' status, distribution, ecology, and physiology, and the degree of climate change. For each SGCN, experts on that taxon were asked to rank the species' vulnerabilities to climate change (and other stressors) for each of the factors using a 4-point numerical scale of 0-3, where 3 is the most vulnerable rank. They were also asked to rank the uncertainty associated with each factor score, again on a 4-point scale. The vulnerability and uncertainty scores for each of the factors in the MRAPs are then combined into total vulnerability and uncertainty scores, which are then assigned to one of three vulnerability/uncertainty categories: Most Vulnerable, Vulnerable, and Least Vulnerable, and High Uncertainty, Medium Uncertainty, and Low Uncertainty. The vulnerability and uncertainty score thresholds for this latter action are <14, 14-25, and >25 (based on the actual distributions of species vulnerability and uncertainty scores - see Section 5.1). In theory, it would be possible to divide the uncertainty and vulnerability scores for the various species into more than 3 categories. However, we believe that this would imply a far greater degree of precision than was attainable in this project.

The MRAPs were developed through an iterative process: a first version of each was developed by Dr. Hector Galbraith of EcoSolutions, based on his work developing previous vulnerability assessment frameworks. This was then submitted to taxon experts (see Section 4) who commented and suggested revisions. These revisions were incorporated by Dr. Galbraith, resulting in final versions. Thus, the experts who populated the models with information also had a hand in their development.

2.2 Relationships between MRAPs and adaptation/management actions

The MRAPs not only evaluate how vulnerable to climate change a species may be, they also identify the variables that contribute to their vulnerabilities. For example, a species may be vulnerable because of projected changes in soil moisture content, or in changes in the pressures due to invasive species or pests, or because the habitat in which the species resides is particularly vulnerable, or because other (non-climate) stressors are likely to exert increasing effects. These results are not just vulnerability factors, they also are potential adaptation intervention points and can be used to identify and formulate protective management tactics. These will be carried forward into the next phase of the project - the identification and description of effective management options.

3. SELECTING SGCN FOR ANALYSES

The 570 SGCN named in the Massachusetts State Wildlife Action Plan comprise a large and diverse (taxonomically, ecologically, morphologically, and physiologically) group of organisms. Given this, it is to be expected that their responses and potential vulnerabilities to climate change vary widely, from likely to be adversely impacted, to little or no effect, to likely to benefit. More practically, this large and diverse array of organisms poses a major logistical challenge to vulnerability assessors who operate under time and resource limitations. One solution (see above) is to use screening level and rapid assessment protocols that will expedite the assessment process. The other solution, also applied in this project, was to phase the approach. In this first phase of the project we selected the SGCN that utilized, in at least one phase of their life histories, habitats that had been previously categorized as Highly Vulnerable to climate change in both the first Massachusetts habitat vulnerability analysis (Manomet, 2010) or for middle New England in the 13-state habitat analysis (NEAFWA, 2012). These highly vulnerable habitats were:

High elevation Spruce-Fir Forest
Coldwater Rivers and Streams
Smaller Coldwater Lakes and Ponds
Boreal Swamp
Bogs, Fens, other Peatlands
Coastal Mud and Sandflats
Coastal Brackish Marsh.

This process resulted in the identification of a total of 349 SGCN, listed in Attachment 5. They comprise 197 species of plants, 52 birds, 25 fish, 15 mammals, 9 reptiles/amphibians, and the remaining 51 species of aquatic and terrestrial invertebrates. It is interesting to note that of the 570 SGCN named in the SWAP, this analysis has shown that 63% occupy habitats that have been previously designated as Highly Vulnerable to climate change, complicating the future conservation of these species.

We concentrated first on applying the MRAPs to the animal species, leaving the plants and other remaining species for a subsequent phase of the project.

4. THE EXPERT PANEL APPROACH

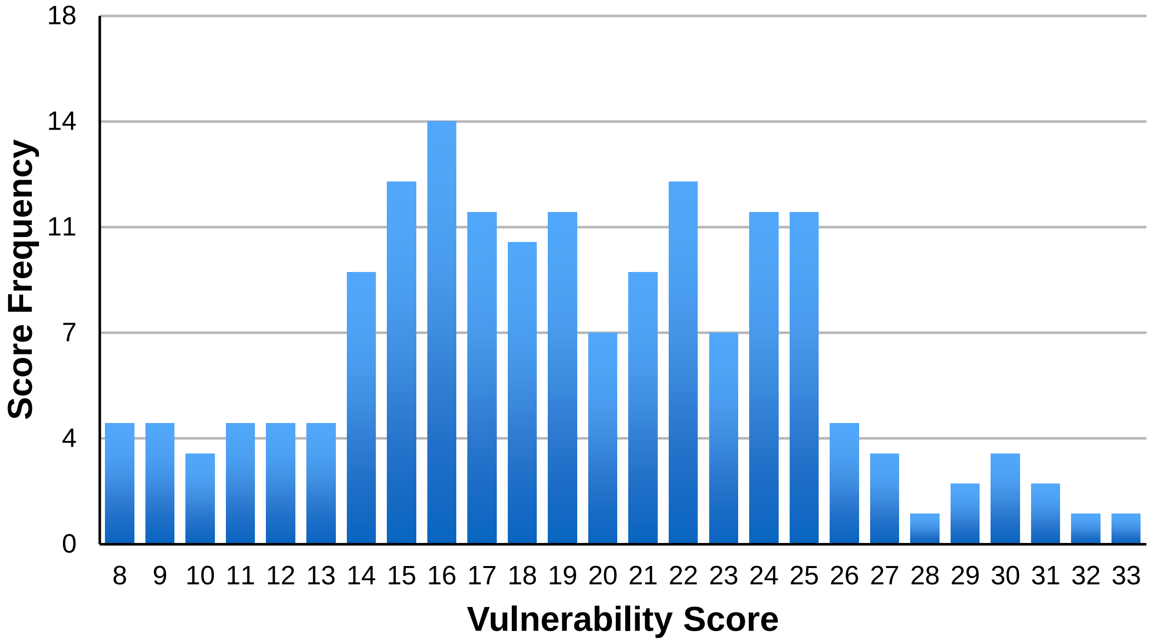
4.1 Expert Panel Members

Early in the planning of this project, it was realized that a panel of experts with expertise in the wide array of taxa to be evaluated would be necessary to complete the work. To this end, we approached 18 experts who agreed to help in the project (Attachment 3 lists these experts and their affiliations). The two main tasks of the experts were to comment on and help develop the MRAPs, and to populate the MRAPs with information based on their taxon-specific expertise. To date, the expert panel has evaluated 163 species.

4.2 SGCN Profiles

As an aid to the expert panel in their assessment of species vulnerabilities, Toni Lyn Morelli and Jennifer R. Smetzer of the Department of Interior Northeast Climate Science Center, USGS, and University of Massachusetts, respectively, prepared “species profiles” Each of these summarizes what is known about specific SGCN responses to climate change to date, and that is anticipated under future scenarios (Attachment 4). They also highlight where other factors are expected to exacerbate the effects of climate change. This information was obtained through a systematic review of the peer-reviewed literature, primarily using the ISI Web of Knowledge to search for papers on each species related to “climate”, “temperature”, “drought”, “flood”, or “precipitation”. A substantial amount of information was available from the Massachusetts Climate Action Tool, a project produced by Scott Jackson, Michelle Staudinger, Steve DeStefano, Toni Lyn Morelli, and others. In addition, Staudinger, Morelli, and Bryan’s (2015) Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans was an important resource for these reports, including work by Colton Ellison and Stephen Jane. Funding for these reports was provided by Massachusetts Department of Fish and Wildlife and the Department of Interior Northeast Climate Science Center. Also, on carrying out the evaluation of species’ vulnerabilities, many of the experts carried out their own reviews of the available literature and information.

Figure 1. Frequency Distribution of Vulnerability Scores



5. RESULTS

5.1 SGCN Vulnerabilities by Taxon

All of the 163 animal vulnerability and uncertainty scores and categories are presented in Attachment 6, while the MRAP factor scores for each species are presented in Attachment 7. The Vulnerability scores in Attachment 6 vary from 8 (Black Bear) to 33 (Sedge Wren) with the majority scoring between 14 and 25 (Figure 1).

The vulnerability scores and categories are broken down by taxon in Table 1. Across taxa, 14% of species were categorized as being Most Vulnerable (>25), 74% were Vulnerable (14-25), and 12% were Least Vulnerable (<14). The fact that a total of 88% of species were in the two more vulnerable categories is not surprising as these animal are SGCN and their admission to that list may "preconfigure" them as being more vulnerable to climate change, since they often are species with small, fragmented populations that are already being impacted by non-climate stressors. Also, as explained in Section 3 above, we selected species that were known to be dependent during at least a part of their life-cycles on habitats that had been recognized as highly vulnerable to climate change during previous habitat vulnerability assessments. What is somewhat unexpected is that these "vulnerable habitat" species comprise, as stated in Section 3, 63% of the total SGCN list, which highlights the vulnerability of SGCN, in general, to projected climate change in Massachusetts.

When comparing vulnerability categories among taxa, no consistent differences are apparent except that mammals generally seem to be less vulnerable than other taxa - 64% are Most Vulnerable or Vulnerable, compared with 92% of birds, 80% of fish, and 88% of herps. 36% of mam-

Table 1. Animal taxa vulnerability scores.

Taxon	Number of Species	Most Vulnerable	Vulnerable	Least Vulnerable
Mammals	14	0 (0%)	9 (64%)	5 (36%)
Birds	52	7 (13%)	41(79%)	4 (8%)
Fish	25	6 (24%)	14 (56%)	5 (20%)
Herps	9	3 (33%)	5 (55%)	1 (12%)
Lepidoptera	17	1 (6%)	14 (81%)	2 (12%)
Odonates	27	2 (7%)	22 (81%)	3 (12%)
Other Aquatic Inverts	19	4 (21%)	15 (79%)	0 (0%)
All Taxa	163	23 (14%)	120 (74%)	20 (12%)

mals are Least Vulnerable, compared with much lower figures for other taxa (Table 1). This may reflect the generalist habitat and dietary requirements of extant mammals in Massachusetts (Morelli *et al*. *In prep*).

All taxa except mammals had representatives that were in the highest vulnerability category (Table 2)[3]. The species in bold in Table 2 are those where the level of uncertainty regarding the vulnerability scores were either Medium or Low. These are the species in which we have the greatest degree of confidence about their Most Vulnerable rank.

We also addressed the question: what differentiates the scoring patterns of species that are Most Vulnerable to climate change from those that are less vulnerable? To investigate this, we looked first at species that scored Most Vulnerable (Table 2), specifically at the distribution of scores of 3 (most vulnerable) in the 5 factors in the animal MRAP that quantify vulnerability to climate change: F1 (vulnerability to increased ambient temperatures), F2 (vulnerability to changing precipitation patterns), F4 (vulnerability to extreme events), F7 (primarily using habitats that are vulnerable to climate change), and F8 (limited adaptation capacity). We found that for the 23 Most Vulnerable species the frequency of 3 scores in each of these factors was 17, 12, 9, 17, and 11, respectively. So, a majority or a large plurality of the 23 species scored 3 in these 5 factors. We then ran the same analysis on the 21 species that scored Least Vulnerable and found that the frequencies of scores of 3 in the 5 Factors were 0 in all cases.

This analysis shows that while many SGCN are currently threatened because of other factors not related to climate change (e.g., small, fragmented populations, actions of other stressors, inability to manage, etc.), they are not necessarily vulnerable to climate change. These less vulnerable species generally scored approximately 8-15 in the MRAP. In contrast, the SGCN that scored Most Vulnerable in our scoring exercises had high scores in many of the factors that the Least Vulnerable species also scored highly in, but they also scored very highly in the climate change-related factors. Broadly, climate change added approximately 10-15 points to the scores of these species, effectively doubling their vulnerability rankings. This result greatly complicates the future conservation of these SGCN.

5.2 Uncertainties

For 74% of the 163 species that were scored, the level of uncertainty was either Low or Medium (Table 3). The four vertebrate taxa (mammals, birds, fish, herps) generally had lower levels of uncertainty with 8 - 27% scoring with Low Uncertainty, whereas no invertebrate taxa scored such low levels of uncertainty. If we combine Low and Medium levels of uncertainty, the vertebrate taxa scored between 79% and 100%, while the invertebrates scored between 11% and 88%. These differences are, perhaps, to be expected since the biologies and ecologies of the vertebrate taxa may be better understood than the invertebrates.

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[3] It should be noted that four of the bird species listed as most vulnerable in Table 2 are already at or close to extinction in Massachusetts: Sedge Wren; Olive-sided Flycatcher; Blackpoll Warbler; and Rusty Blackbird breed only in very small numbers and, in the best case, sporadically. These have been retained in the analyses because their status might reflect the effects of the changing climate, among other potential stressors.

Among those taxa for which we have one or more independent estimates of vulnerability (mammals, herps, fish, odonates) it is apparent that while the vulnerability scores of different assessors may vary, the differences are generally small and most assessors arrived at similar results (Attachment 6).

Table 2. Most Vulnerable SGCN and their uncertainty categories.
Bold indicates lower levels of uncertainty. LU = Low Uncertainty, MU = Medium Uncertainty, HU = High Uncertainty.

Taxon	**Species**	**Uncertainty Score**
Mammals	none	
Birds	**Common Loon** **Common Gallinule** **Piping Plover** **Sedge Wren** **Olive-sided Flycatcher** **Blackpoll Warbler** **Rusty Blackbird**	MU MU MU LU LU MU MU
Fish	**Shortness Sturgeon** **Atlantic Salmon** **Longnose Sucker** **Northern Redbelly Dace** Slimy Sculpin Lake Chub	MU LU MU MU HU HU
Herps	**Timber Rattlesnake** **Wood Turtle** **Jefferson Salamander**	LU MU MU
Lepidoptera	**Bog Elfin**	MU
Odonates	**Scarlet Bluet** **Pine Barrens Bluet**	MU MU
Other Aquatic Inverts	**Eastern Pearlshell** Brook Floater Dwarf Wedge Mussel Yellow lamp Mussel	MU HU HU HU

On the other hand, for taxa in which we have independent uncertainty scores from different assessors (mammals, herps, odonates) the uncertainty scores vary more widely than the vulnerability scores (Attachment 6). For example, in some amphibian/reptile species, the uncertainty scores varied between 6 and 20. It is unclear why there should be so much more variation in uncertainty scoring than in vulnerability scoring. Perhaps it is because the experts that were providing alternative scores varied in their degree of familiarity with the taxon. For example, for the mammals the scores were generally pretty close; there was a 2-3 point difference between highest and lowest uncertainty ratings across most species, with the biggest difference among the three bat species and the bobcat. On average, the difference was 5.2 points of uncertainty score points (thus, on average, the duplicate scores different by just over 5 points). On the other hand, the mean difference in uncertainty scores for herpetological species was 10.4, with a greatest difference was 15. There was even more variation with the odonates; the 17 species had a mean difference of 9.2, with a greatest difference of 19. Details can be found in Attachment 6. So there was more agreement in mammals, which are also a better studied taxon. Alternatively, it could be related to differences in experts' attitudes toward risk, with more sanguine experts assigning lower levels of uncertainty, and more "pessimistic" experts assigning higher levels. This needs further exploration.

Table 3. Animal taxa uncertainty scores.

Taxon	Number of Species	Low Uncertainty	Medium Uncertainty	High Uncertainty
Mammals	14	3 (21%)	8 (58%)	3 (21%)
Birds	52	14 (27%)	35 (67%)	3 (6%)
Fish	25	2 (8%)	19 (76%)	4 (16%)
Herps	9	2 (22%)	7 (78%)	0 (0%)
Lepidoptera	17	0 (0%)	15 (88%)	2 (12%)
Odonates	27	0 (0%)	13 (48%)	14 (52%)
Other Aquatic Inverts	19	0 (0%)	2 (11%)	17 (89%)
All Taxa	163	21 (13%)	99 (61%)	43 (26%)

6. ADAPTATION/MANAGEMENT IMPLICATIONS

This phase of the SGCN project was intended, primarily, to describe the vulnerabilities to climate change of SGCN, rather than to answer specific questions about how these species or their habitats could be managed to attempt to ameliorate the effects of the changing climate. This is an important issue and will be addressed in subsequent phases of this project. Nevertheless, the results obtained thus far from this assessment do provide some indications of how possible such adaptive management might be for different species. Factor 12 in the animal MRAP (Attachment 1) asks the question: will it be possible to mitigate the impacts of stressors (including climate change) on the species? Scoring the possibility of amelioration allows the possibility of beginning to identify which species may be more amenable to mitigation (score 0 or 1) to those less likely to be amenable (score 2 or 3). Of course, these results do not inform us of how to mitigate (that is the focus of the second phase of this project).

Table 4 summarizes the scores for Factor 12 for the various taxa. These data show that across all taxa, 58% of SGCN fall into the two least likely categories for mitigation (scores equal 3 or 2). 41% of SGCN are in the two more likely categories (scores equal 1 or 0). Of all taxa, Lepidoptera, scoring 1 or 0 for 82% of species hold out the greatest potential for mitigation, closely followed by fish at 72% of species, while odonates and herps hold out the least.

Table 4. Animal taxa Factor 12 scores.

Taxon	Number of Species	Score 3 (lowest likelihood of mitigation)	Score 2	Score 1	Score 0 (highest likelihood of mitigation)
Mammals	14	6 (43%)	4 (28%)	2 (14%)	2 (14%)
Birds	52	16 (31%)	20 (38%)	14 (27%)	2 (4%)
Fish	25	1 (4%)	6 (24%)	14 (56%)	4 (16%)
Herps	9	3 (30%)	4 (44%)	1 (11%)	1 (11%)
Lepidoptera	17	0 (0%)	3 (18%)	8 (47%)	6 (35%)
Odonates	27	4 (15%)	22 (81%)	1(4%)	0 (0%)
Other Aquatic Inverts	18	3 (17%)	3 (17%)	11 (61%)	1 (5%)
All Taxa	162	33 (20%)	62 (38%)	51 (31%)	16 (10%)

Table 5 lists the SGCN that scored 0 or 1 in Factor 12 and thus may be (on the basis of this preliminary scoring) more amenable to adaptation actions. This conclusion, however, requires further expert discussion in a subsequent phase of this project.

Table 5. Animal SGCN scoring 1 or 0 for Factor 12 in MRAP.
Uncertainty categories of Highly Vulnerable SGCNs.

Taxon	Species	Factor 12 score
Fish	Shortnose Sturgeon	1
	Blueback Herring	1
	Alewife	1
	American Shad	1
	American Eel	1
	Sea Lamprey	1
	Longnose Sucker	1
	Northern Redbelly Dace	1
	Lake Chub	1
	American Brook Lamprey	1
	Blacknose Dace	0
	Longnose Dace	1
	Brook Trout	0
	Fallfish	0
	White Sucker	1
	Banded Sunfish	0
	Swamp Darter	1
	Common Shiner	0
Herps	Northern Red-bellied Cooter	1
	Eastern Ribbon Snake	0
Birds	Wood Thrush	1
	Louisiana Waterthrush	1
	Pied-Billed Grebe	1
	Barn Owl	1
	Common Nighthawk	1
	Purple Martin	0
	Bank Swallow	1
	American Bittern	0
	Sora	1
	Marsh Wren	1
	Least Bittern	1
	Northern Harrier	1
	King Rail	1
	Common Gallinule	1
	Northern Parula	1
	Eastern Meadowlark	1

Table 5. Animal SGCN scoring 1 or 0 for Factor 12 in MRAP. Uncertainty categories of Highly Vulnerable SGCNs.		
Mammals	Moose Eastern Red Bat Bobcat Black Bear	1 1 0 0
Lepidoptera	Hessel's Hairstreak Dion Skipper Heath Metarranthis Chain-dotted Geometer Slender Clearwing Precious Underwing Drunk Apamea Moth Northern Brocade Moth Cord-grass Borer Water-willow Borer Chain-fern Borer Pitcher-plant Borer Pale Green Pinion Dune Sympistis	1 1 1 1 1 1 0 0 0 0 0 0 1 1
Odonates	Ocellated Darner	1
Other Aquatic Inverts	Alewife Floater Eastern Lampmussel Eastern Pearlshell Triangle Floater Tidewater Mucket Eastern Pondmussel Brook Floater Dwarf Wedgemussel Creeper Yellow Lampmussel Slender Walker Coastal Swamp Amphipod Smooth Branched Sponge	1 1 1 1 1 1 1 1 1 1 0 0 1

It is hoped that a later phase of this project will examine the adaptive management potential for SGCN in greater detail. This will require working with the panel of taxon experts that we have already assembled in a guided workshop process to identify and evaluate the efficacy, feasibility, and economic likelihood of specific management options. These will then be posted on the CAT to guide conservation actors in the Commonwealth.

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