Framework for assessing the vulnerability of Alberta's biodiversity to climate change

---

Chris Shank

June, 2012

Prepared for the Biodiversity Management and Climate Change Adaptation Project

---

Disclaimer:
The material in this publication does not imply the expression of any opinion on the part of any individual or organization other than the authors. Errors, omissions or inconsistencies in this publication are the sole responsibilities of the authors.

The authors and ABMI assume no liability in connection with the information products or services made available by the institute. While every effort is made to ensure the information contained in these products and services is correct, the ABMI disclaims any liability in negligence or otherwise for any loss or damage which may occur as a result of reliance on this material.

CCEMC makes no warranty, express or implied, nor assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information contained in this publication, nor that use thereof does not infringe on privately owned rights. The views and opinions of the author expressed herein do not necessarily reflect those of CCEMC. The directors, officers, employees, agents and consultants of CCEMC are exempted, excluded and absolved from all liability for damage or injury, howsoever caused, to any person in connection with or arising out of the use by that person for any purpose of this publication or its contents.

Use of this material:

Alberta Biodiversity Monitoring Institute
CW-405 Biological Sciences
University of Alberta
Edmonton, Alberta, Canada T6G 2E9
Phone: (780) 492-6322
E-mail: abmiinfo@ualberta.ca

This report was produced as part of the Biodiversity Management and Climate Change Adaptation Project. This project is led by the Alberta Biodiversity Monitoring Institute, with collaborators from the University of Alberta and the Miistakis Institute. The project receives its core funding from the Climate Change and Emissions Management (CCEMC) Corporation.

www.biodiversityandclimate.abmi.ca


Executive Summary

The Biodiversity Management and Climate Change Adaptation project is intended to provide Alberta's Biodiversity Management System with the knowledge and tools necessary to undertake effective planning for implementing adaptive actions to cope with a changing future climate. The project was officially initiated in May 2012. It is comprised of 5 sub-projects intended to be closely integrated and complementary. This paper represents the first Quarterly Report and describes early planning by the Alberta Biodiversity and Climate Change Team with particular emphasis on the approach to vulnerability assessment to be undertaken as Phase 1. It is intended to ensure that the proposed directions taken by the Project Team are understood and supported by the Government of Alberta. Initially, the project will concentrate on assessing the vulnerability of Alberta's terrestrial species to climate change.

Climate change vulnerability is comprised of three components; the degree of direct or indirect climate change exposure experienced, the inherent sensitivity of the species to this change, and the intrinsic abilities of the species or ecosystem to adapt to future climate stressors. Objectively and systematically determining species vulnerability to climate change is a critical component of adaptation planning by identifying which species or systems are likely to most affected and by promoting understanding of why they are likely to be vulnerable.

A wide range of terrestrial species (mammals, birds, herptiles, invertebrates and vascular plants) will be assessed for vulnerability to climate change. Priority will be given to Terrestrial Fine Filter Species defined in the Biodiversity Management System, "At Risk" species identified by the General Status of Alberta Wild Species, "Major Invasive Species" identified by McClay et al. 2004, and "High Responsibility Species" identified by the Alberta Biodiversity Monitoring Institute. The intent is to ensure representation from taxonomic groups, Natural Regions, Land Use Framework Regions, and ecological guilds. Appendix 1 presents a long list of candidate species.

Recommendations are made regarding the climate data to use in the vulnerability analysis and more broadly throughout the project. The A2 emission scenario, representing high emissions, will be used throughout the project. The following General Circulation Models, representing different future conditions, will be used:

1. INM-CM3.0, Russia — wetter
2. CGCM3.1(T47), Canada — wetter and less seasonal
3. GFDL-CM2.1, USA — drier
4. UKMO-HadGEM1, UK — drier and much warmer
5. ECHAM5/MPI-OM, Germany — most representative model overall
6. Ensemble mean of 15 designated GCMs.

These recommendations will undergo expert review over the next few months. The ClimateWNA database will be used for downscaled historical and future climate data. Vulnerability assessments will be undertaken for the future periods 2040 – 2060 and 2080 – 2100.

Ten published vulnerability index tools were examined and compared. Of these, only NatureServe's Climate Change Vulnerability Index is considered to meet all the requirements of the Alberta assessment.

The project will explore a variety of approaches to species distribution modeling; that is, predicting the spatial distributions of selected Alberta plant and animal species under projected scenarios of climate change and adaptation strategies. As the first step, statistical models will be built characterizing climate conditions that Alberta species currently experience. With the experience gained from this modeling and from vulnerability analysis, more sophisticated models will be developed for some species in which climate change interacts with many the covariates that affect species distributions.

The Project Team recognizes the importance of producing on-line map products. Readily accessible GIS data will ensure spatial data generated by the project will be available for research purposes. Simplified and dynamic on-line visualizations will help the general public understand potential effects of climate change and adaptation actions on biodiversity. Products, approaches and platforms will be considered over the next several months.

Preface

This report is intended to serve two purposes. First, it is a project milestone document required under the agreement between the Climate Change and Emissions Management Corporations (CCEMC) and the Alberta Biodiversity Monitoring Institute (ABMI). Second, it is intended to inform the Steering Committee of the Project Team's recommended research directions and to ensure that early decisions are agreed upon by all parties. The Steering Committee is requested to review this document over the summer and assess how it meshes with the mandates, information needs and currently on-going work of individual organizations. It is primarily intended as a basis for further discussions.

This report was prepared by the Alberta Biodiversity and Climate Change Team comprised of the following members:

Dr. Dan Farr	Project Manager, ABMI
Shauna-Lee Chai	ABMI
Dr. Chris Shank	ABMI
Tom Habib	ABMI
Dr. Erin Bayne	University of Alberta
Dr. Scott Nielsen	University of Alberta
Diana Stralberg	University of Alberta
Jessica Stolar	University of Alberta
Guy Greenaway	Miistakis Institute
Tracy Lee	Miistakis Institute
Greg Chernoff	Miistakis Institute
Ken Sanderson	Miistakis Institute
Angele Vickers	Alberta Environment and Sustainable Resource Development

Table of Contents

1. Introduction

The Biodiversity Management and Climate Change Adaptation project is intended to provide Alberta's Biodiversity Management System (BMS) (Norris 2012) with the knowledge and tools necessary to undertake effective planning for implementing adaptive actions to cope with a changing future climate. The intent of the BMS is to support the Land Use Framework (LUF) by providing consistent and scientifically credible assessment of biodiversity risk for inclusion in each of the LUF planning processes. The BMS specifies (p. 42) that potential effects of climate change on biodiversity should be included in scenario modeling.

The project was officially initiated in May 2012. It is comprised of 5 sub-projects intended to be closely integrated and complementary. Phase 1 entails developing research strategies and undertaking a climate change vulnerability assessment for Alberta's terrestrial plants and animals.

This paper represents the first Quarterly Report and describes early planning by the Project Team with particular emphasis on the approach to vulnerability assessment to be undertaken as Phase 1. It is intended to ensure that the proposed directions to be taken by the Project Team are understood and supported by the Government of Alberta (GoA).

2. Climate Change Vulnerability Assessment

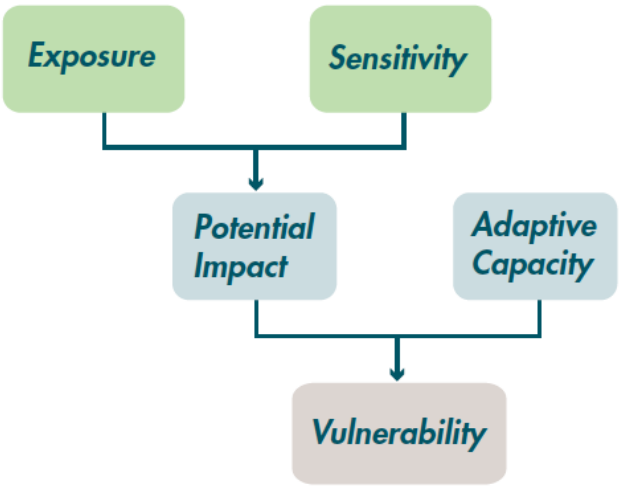


Figure 1. Components of climate change vulnerability (Glick et al. 2011)

Climate change vulnerability is comprised of three components; the degree of direct or indirect climate change exposure experienced, the inherent sensitivity of the species to this change, and the intrinsic abilities of the species or ecosystem to adapt to future climate stressors (Figure 1). Objectively and systematically determining species vulnerability to climate change is a critical component of

adaptation planning by identifying which species or systems are most likely to most be affected and by promoting understanding of why they are likely to be vulnerable (Glick et al. 2011).

This project will initially take two approaches to vulnerability assessment. The first is to develop species vulnerability indices based on a rapid assessment of species biology and expected exposure to climate change. The second is to assess possible future distributions of species based climate projections. With the experience gained the project will seek to further advance the science of vulnerability assessment by developing approaches that integrate species distribution models, vulnerability indices and human land use into practical approaches to effective adaptation planning.

2.1. Audience and Purpose of the Vulnerability Assessment

The intended audience for the vulnerability assessment is primarily GOA managers. The intent is to inform development of climate change adaptation by establishing which species or groups of species are inherently at the greatest risk from climate change and, therefore, most in need of adaptive mitigation. This process represents Step 2 in the Climate Change Adaptation Framework Manual (SRD, 2010)

2.2. Species to Assess

Initially, the vulnerability assessment will evaluate individual species. However, species are components of communities that combine to create complex ecosystems. Species composition of ecosystems and communities may reassemble under changing climatic conditions as species move to areas that are climatically suitable and interact with other components of the changing biotic community. Evaluating the likelihood that communities novel to Alberta will develop with climate change will be a component of the project in the future. As well, NatureServe is developing a habitat climate change vulnerability assessment tool which will be evaluated for its applicability to Alberta.

Alberta's biodiversity includes more than 80,000 species (www.abmi.ca) with the majority being arthropods, algae and fungi (Figure 2).

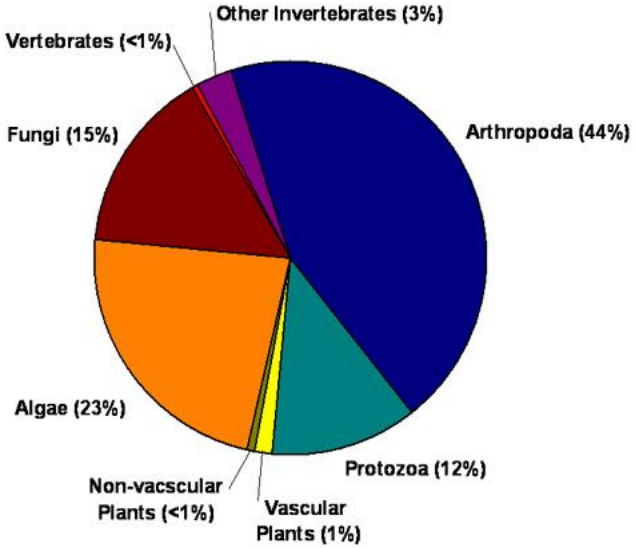


Figure 2. Proportion of Alberta's species diversity in different taxonomic groups (http://www.abmi.ca/abmi/aboutabmi/aboutabmi.jsp;jsessionid=4BC21171E391B33F49798543053F8ADF?categoryId=121&subCategoryId=403&pageCategoryId=51).

Most of these species are unknown to science. Alberta's General Status of Wildlife Species (2010) has assessed the status of 5082 terrestrial species in the following groups:

- 110 Mammals
- 433 Birds
- 8 Reptiles
- 16 Amphibians
- 72 Black Flies
- 30 Bumblebees
- 192 Butterflies
- 400 Ground Beetles
- 50 Horse Flies
- 80 Lady Beetles
- 95 Macromoths
- 44 Mosquitoes
- 75 Odonates
- 606 Spiders
- 1969 Vascular Plants
- 522 Mosses
- 380 Lichens

As well, the Alberta Conservation Information Management System (ACIMS) tracks or watches about 2060 species and ecological communities. The Alberta Native Plants Council Rogue's Gallery lists 227 species of alien/invasive plants.

This vulnerability assessment, and the project more generally, will be limited to terrestrial plants and animals. This focuses the project, reflects the expertise of the Project Team, uses existing data effectively, and ensures minimal overlap with the CCEMC watershed management project. Special emphasis will be placed on alien species, particularly those with harmful, invasive characteristics.

A tentative list of candidate species for vulnerability assessment is presented in Appendix 1. Choosing which species to assess for climate change vulnerability will

be a continuing process based on advice from a wide range of experts and managers. We recommend that choice of species should be guided by the following criteria:

- Initially, treat only species currently in Alberta. Immigrating species will be addressed through the spatial modeling component later in the project.
- The suite of species to be assessed should be allocated to taxonomic groups in roughly in the following arbitrary percentages and numbers:

Mammals	20%
Birds	20%
Reptiles	4%
Amphibians	8%
Invertebrates	16%
Vascular Plants	25%
Non-vascular Plants	7%

  The intent of addressing a wide variety of species is to assess whether there are consistent taxonomic patterns in vulnerability to climate change.
- Representative and typical species from all 6 Alberta Natural Regions (Aspen Parkland, Boreal Forest, Canadian Shield, Grassland, Foothill and Rocky Mountain) and the 7 LUF Planning Regions (Lower Athabasca, Lower Peace, North Saskatchewan, Red Deer, South Saskatchewan, Upper Athabasca, Upper Peace). Natural Regions are a better categorization for research purposes and LUF Regions are better for government planning activities. Ensuring appropriate spatial representation will be undertaken during establishment of species ranges.
- All species listed in the General Status of Alberta Wild Species (2010) as "At Risk", N = 26.
- Prioritize ABMI "High Responsibility" species. These are defined as species having >10% of their global breeding range in Alberta prior to European settlement (Alberta Biodiversity Monitoring Institute 2009).
- Prioritize alien species listed by McClay et al. (2004) as a "major invasive species" or a "potential threat".
- Include all "Terrestrial Fine Filter Species" indicators defined by SRD's Biodiversity Monitoring System (Norris 2012):

Moose
Elk
Deer
Bighorn Sheep
Lynx
Marten
Richardson's Ground Squirrel
Pronghorn Antelope
Woodland Caribou
Grizzly Bear
Sharp-tailed Grouse
Prairie Rattlesnake
Ferruginous Hawk
Sprague's Pipit
Long-billed Curlew
Burrowing Owl
Grassland Vertebrates
Old Forest Birds
Tree Cavity Nesting Birds
Human Associated Vertebrates
Alien/Invasive Vascular Plants

2.3. Climate Datasets

Increasing emissions of heat-trapping greenhouse gases will change future climates in ways that can only be projected using computer models. These models are based on emission scenarios representing assumptions about future levels of emissions based on plausible states of energy use, population growth, and technological advances. Emission scenarios drive a wide variety of General Circulation Models (GCMs) developed by different research groups using different approaches. GCMs provide very large-scale results and, to be useful at regional and local scales, must be downscaled using a variety of techniques. The resulting matrix of different emissions scenarios, GCMs and downscaling approaches leads to a bewildering variety of choices. Glick et al. (2011) provide a useful overview.

The project needs to decide on which emission scenarios, GCMs and downscaling to employ. This will be consistent across all components of the project to ensure consistency and comparability of results.

2.3.1. Emissions Scenarios

In 2000, the IPCC developed a standard set of emission scenarios known collectively as Special Report on Emissions Scenarios (SRES). There are four "families" of scenarios (A1, A2, B1, B2) each with a "story-line" and within each family there may be "scenario groups". For example, A1B is characterized by low population growth, very high GDP growth, very high energy use, low land use changes, medium resource availability, rapid technological change that favors a balance of fossil and non-fossil fuels.

The fifth IPCC report, to be completed in 2014, will develop new emission scenarios based on different metrics called Representative Concentration Pathways (RCP). There will be only four RCPs representing the range of emission scenarios with emissions measured in CO_2 equivalents.

Actual emissions from 2000 to 2010 were near the A2 scenario projections (Manning et al. 2010), one of the two highest scenarios. Consequently, the project will use only the A2 emission scenario. Effects from less aggressive emission scenarios will be similar but appear later and can therefore be approximated. Maintaining only one emission scenario dramatically reduces the number of output states.

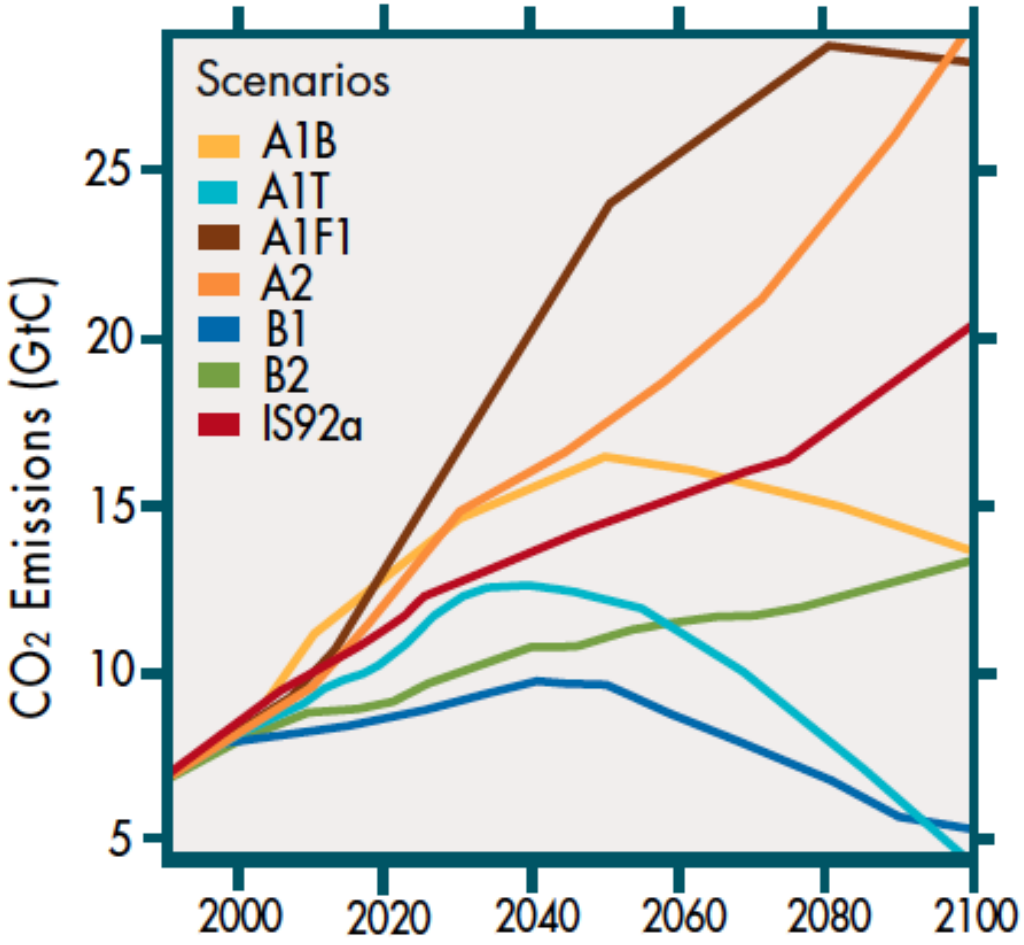


Figure 3. Projected carbon emissions under different SRES scenarios. Taken from Glick et al. (2011).

2.3.2. General Circulation Models

As of the IPCC's 4th Assessment report in 2007, 24 general circulation models (GCMs) developed by 17 climate modeling groups from 12 countries have been used to develop projections of future climate scenarios as part of the World Climate Research Project (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3) (Meehl et al. 2007) (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php). Although these models share fundamental characteristics and are not generally independent from one another (Jun et al. 2008, Masson and Knutti 2011, Pennell and Reichler 2011), the projections they produce can be quite variable and there is no consensus on how best to combine them (Knutti et al. 2009). Oftentimes, a few GCMs are somewhat arbitrarily (or rarely, systematically) selected for comparison purposes. Recently it has become popular to evaluate "multimodel" or "ensemble" predictions based on averaging across multiple GCMs. The most straightforward way to do this

is simply to average across all available models, giving each one equal weight and providing an "ensemble mean". However, this may result in inappropriate smoothing of model variability (Knutti et al. 2009). Furthermore, many have pointed out that all GCMs are clearly not created equal, and that it may be useful to weight models by their predictive accuracy, as measured by their ability to predict historic climate conditions (Gleckler et al. 2008, Knutti 2010, Terando et al. 2012). Alternatively, such an evaluation may be used to select a handful of "best" models for a given purpose. Unfortunately this is not as straightforward as it may seem, as all GCMs have their strengths and weaknesses. Different variables are better predicted by different models over different time scales and different regions, depending on how the GCMs were parameterized and which modules were best developed (Gleckler et al. 2008). Furthermore, it has been shown that historical prediction accuracy does not correlate well with future projections (Räisänen 2007, Jun et al. 2008, Knutti et al. 2009).

Although there is little agreement about which GCMs are best and how they should be combined, a few principles have emerged that can help guide their appropriate use. First, there are some models that consistently perform poorly and should probably not be used (Räisänen 2007, Scherrer 2011). Second, although multi-model ensembles have consistently outperformed individual GCMs in predicting historical climates, "a few good models are better than the multimodel average" (Knutti et al. 2009). Third, models with higher spatial resolution (generally the newer models) tend to perform better in historical climate evaluations (Chen et al. 2011), although improvements have not been as great as might have been expected (Knutti et al. 2009). Finally, it is difficult to characterize models, in terms of historical performance or future predictions, without focusing on a particular region of interest (Gleckler et al. 2008).

In light of these issues, Diana Stralberg, a University of Alberta PhD student doing species distribution modeling, has developed a process for conservatively selecting suites of models to evaluate with respect to Alberta climate change:

1. Of the 24 GCMs, eight can be excluded based on their failure to replicate key climatic processes according to one or more evaluations (Wang et al. 2007, Scherrer 2011) (marked with an 'X' in Table 1). Four of these were identified by several studies as "obviously bad" (Scherrer 2011) (last four entries in Table 1). *Ensemble projections should therefore be limited to the 16 remaining GCMs. Of these only 15 are available for emission scenario A2.*
2. These 16 GCMs have been ranked according to the combined rankings from four evaluations of historical climate predictions, two for the northern hemisphere (20°-90°) (Gleckler et al. 2008, Walsh et al. 2008), one for the arctic region (Wang et al. 2007), and one for China (Chen et al. 2011). These models have also been evaluation for their ability to accurately assess current climate at different spatial resolutions (Table 1). Although some common patterns emerged, the rankings from the four studies were quite different. *Thus, differential weighting of these 16 GCMs does not currently seem warranted. Additional Alberta-specific*

historical validation exercises would be necessary to justify explicit GCM weightings.

3. A separate consideration from historical accuracy is the nature of future projections, which may be more readily evaluated for Alberta. Groups of models can be identified as providing similar projections for Alberta. Recently, we used affinity cluster analysis (Frey and Dueck 2007) to group end-of-century (2071-2100) climate projections based on a high emissions sceanio (A2) to identify projections with similar characteristics. CMIP3 projections were downscaled to a 500-m grid cell resolution using the ClimateWNA tool (Wang et al. 2011). For a suite of 10 temperature and precipitation variables, these projections were averaged across the province and used in the cluster analysis to identify groups of models with similar future projections for these 10 climatic variables. GCMs were also plotted against the first two axes of a principal components analysis (PCA) to describe their climatic characteristics. Four groups of GCMs were identified by the cluster analysis, one of which (cluster 2) contained a single, low-ranking member (Table 1). The identified clusters were not highly distinct and varied slightly depending on climate variables used, region analyzed, and level of climate downscaling, based on exploratory analyses. *Thus, the clusters we have identified should not be over-interpreted, but may be useful as a guideline for selecting GCMs to represent broadly-defined future climate-change scenarios for Alberta. The clusters can be described as having the following future climate-change conditions: (1) smaller temperature increases than other projections; (2) wetter projections; (3) drier projections; (4) wetter and less seasonal projections (i.e. less difference between summer and winter temperatures).*
4. Multiple factors may be considered in the selection of representative GCMs from each cluster. A strictly quantitative selection of the top-ranked GCM in each cluster is not necessarily advisable given the variability in the rankings, and the fact that the first two models used in clustering are less well-established. The Russian model is generally low-ranking, and its separation in the cluster analysis suggests that it should be excluded from consideration for Alberta. Furthermore, it is desirable to include North American models, which are generally well-established and high-performing, and the Canadian model in particular. Finally, it may be desirable to evaluate the set of models that are most distinct from one another, and therefore represent the broadest set of future climate-change scenarios. This was done by directly examining the climatic distances used to identify clusters (Figure 2). *This identifies the following models as most distinct: INM-CM3.0, Russia (wetter), CGCM3.1 (T47), Canada (wetter and less seasonal), GFDL-CM2.1, USA (drier), UKMO-HadGEM1, UK (drier and much warmer). The least distinct, most central, and therefore most representative model overall is ECHAM5/MPI-OM, Germany.*

Table 1. GCM ranking and cluster membership. GCMs from CMIP3 project (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php).

GCM, Country	combo rank	Alberta cluster*
INGV-ECHAM4, Italy/Germany	1	3
CSIRO-Mk3.5, Australia	5	4
ECHAM5/MPI-OM, Germany	6	1
CCSM3, USA	6	4
GFDL-CM2.1, USA	6	3
GFDL-CM2.0, USA	7	3
UKMO-HadCM3, UK	8	3
UKMO-HadGEM1, UK	8	3
CSIRO-Mk3.0, Australia	9	1
CGCM3.1(T63), Canada	9	X
ECHO-G, Germany/Korea	11	3
CGCM3.1(T47), Canada	12	4
CNRM-CM3, France	13	3
PCM, USA	13	4
INM-CM3.0, Russia	17	2
BCCR-BCM2.0, Norway	19	1
MIROC3.2(medres), Japan	X	X
MRI-CGCM2.3.2, Japan	X	X
MIROC3.2(hires), Japan	X	X
IPSL-CM4, France	X	X
FGOALS-g1.0, China	X	X
GISS-ER, USA	X	X
GISS-EH, USA	X	X
GISS-AOM, USA	X	X

* 1= smaller temperature increase; 2 = wetter; 3 = drier; 4 = wetter and less seasonal (i.e. less difference between summer and winter temperatures).

Barrow and Yu (2005) recommend 5 emission and GCM combinations for Alberta:

1. A1B/NCARPCM cooler and wetter
2. B2(3)/CGCM2 cooler and drier
3. A2(a)/HadCM3 warmer and wetter
4. A1FI/CCSRNIES warmer and drier
5. B2(b)/HadCM3 median conditions

These models are now outdated and the recommendation therefore is that project use the following six GCMs in all aspects of the project together with the A2 emission scenario:

1. INM-CM3.0, Russia wetter
2. CGCM3.1(T47), Canada wetter and less seasonal
3. GFDL-CM2.1, USA drier
4. UKMO-HadGEM1, UK drier and much warmer
5. ECHAM5/MPI-OM, Germany most representative model overall
6. Ensemble mean of all 15 "good" GCMs available for A2 emissions.

This suite of models will be continually evaluated and updated as necessary.

2.3.3. Downscaled Climate Datasets

Historical weather and future climatic projections will be accessed from the ClimateWNA online software (Wang et al. 2011). The high accuracy downscaled dataset covers all of western North America thereby allowing species distribution modeling for species moving into or out of Alberta.

2.4. Time Frame for Projections

Vulnerability projections will be done for the periods of 2040 – 2060 and 2080 – 2100. This ensures that relatively modest, more accurately predicted, effects in the near future as well as larger and less certain ones in the further future can both be assessed. All aspects of the project will adopt these projection intervals at a minimum.

2.5. Vulnerability Assessment Tools

There are two approaches to evaluating potential climate change impacts on species; Species Distribution Models (SDMs) and Vulnerability Indices (VIs) (Rowland et al. 2011). SDMs are spatially-explicit examinations of possible shifts in species distribution as a result of climate change. SDMs can be based either on correlations of distribution with environmental conditions or mechanistic relationships between a species' physiological tolerances and future conditions. VIs are evaluative frameworks providing relative indices of vulnerability by integrating information about a species exposure and sensitivity based on published literature, observations, experiments, and climate data and projections. They can be somewhat subjective and usually have no spatial components.

Both approaches should be undertaken by this project. The first step in this project is to develop VIs. As we develop and complete SDMs, this information will be integrated into our VI approach as a critical evaluation of the validity of the VI approach. Below we describe and compare 10 approaches to creating VIs that have been published or are on-line and make recommendations on an approach that we think should be adopted.

2.5.1. Species Susceptibility To Climate Change Impacts (SSCCI)

Foden et al. (2008) undertook an ambitious ranking of climate change sensitivity (their term = "susceptibility") for species on the IUCN Red List. Actual exposure to climate change was not assessed. Instead, presumed responses to generalized climatic trends were considered. Assessments were done for 9,856 species of birds, 6,222 species of amphibians and 799 species of warm-water, reef-building corals. Expert opinion was used to score 17 biological traits categorized into 5 groups. A total of 35% of birds, 52% of amphibians and 72% for corals were considered susceptible to climate change. Only 12% of bird species are classified as Threatened by IUCN, but 80% of these are considered vulnerable to climate change. Worldwide, 32% of amphibian species are listed as Threatened and 75% of these were determined to be vulnerable to climate change.

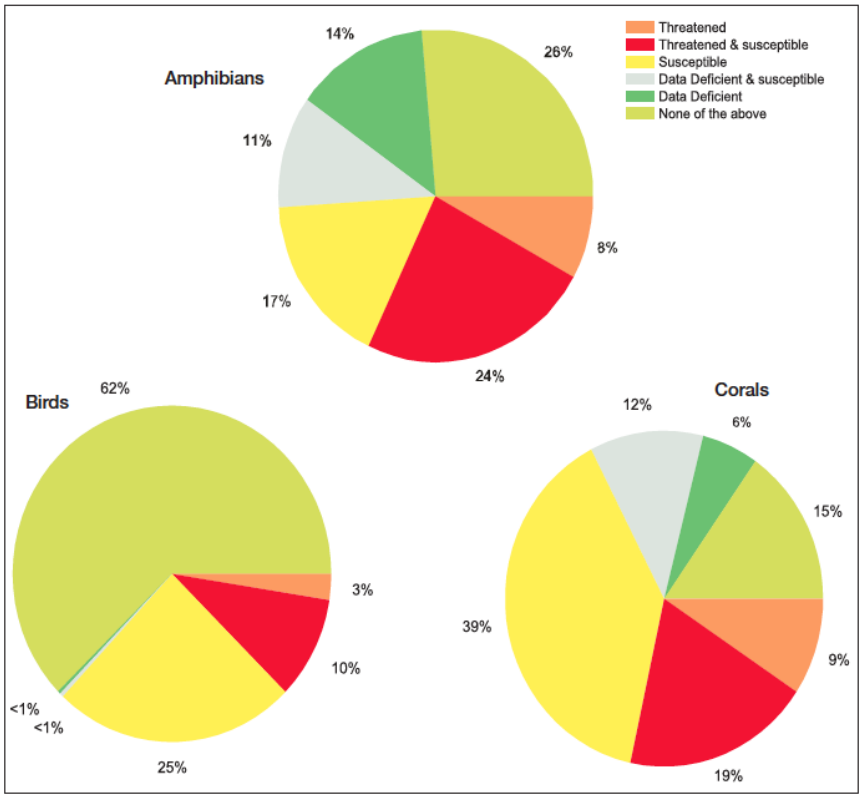


Figure 4. Results from Foden et al.'s (2008) analysis of climate vulnerable IUCN Red-listed species.

2.5.2. Climate Change Vulnerability of Migratory Species (CCVMS)

The Zoological Society of London (2010) is in the process of developing a methodology for assessing climate change vulnerability of species listed by the Convention on Migratory Species. At present, the developing method entails qualitatively evaluating species on the basis of literature reviews and expert opinion against 4 vulnerability factors:

1. vulnerability of habitats
2. ecological flexibility

3. species interactions, and
4. synergistic threats

Assessors are provided with a table of specific traits to be evaluated within each of 4 vulnerability categories and guidance on assigning severity of the impacting factors. Species are assigned to 5 levels of vulnerability according to rules. There appears to be no quantitative input of climate change exposure data. They piloted the methodology on 45 species appearing on appendices of the Convention on Migratory Species. These included 7 reptiles, 16 terrestrial mammals, 1 marine mammal, 4 fish, and 17 birds. Twenty-nine species were categorized as High Vulnerability, 16 as Medium Vulnerability and none as Low Vulnerability.

2.5.3. System for Assessing Vulnerability of Species (SAVS)

The US Forest Service has developed the System for Assessing Vulnerability of Species (SAVS) to Climate Change for terrestrial vertebrates (Bagne et al. 2011). SAVS is an easily applied tool based on an evaluation of 22 predictive criteria resulting in quantitative vulnerability and uncertainty scores. The questions are grouped into 4 factor types; habitat, physiology, phenology, and biotic interactions. The instructions say to collect climate data, but there is no specific, quantitative input of this exposure information into the evaluation. A web-based SAVS scoring sheet is available at http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/savs-climate-change-tool/.

(Coe et al. 2012) used a prototype version of the SAVS vulnerability assessment tool to assess climate change vulnerability of 30 species in the Coronado National Forest of southeastern Arizona. The area is a “sky island” complex characterized by isolated high mountain areas separated by low-lying valleys that limit dispersal for many species. Climate data were from Climate Wizard using ensemble averages from three models and two emission scenarios for temperature and three for precipitation. Thirty species were evaluated consisting of 8 birds, 13 mammals, 5 reptiles, and 4 amphibians. Twenty-nine of the species tested were considered to be vulnerable with the most susceptible being those associated with riparian habitats.

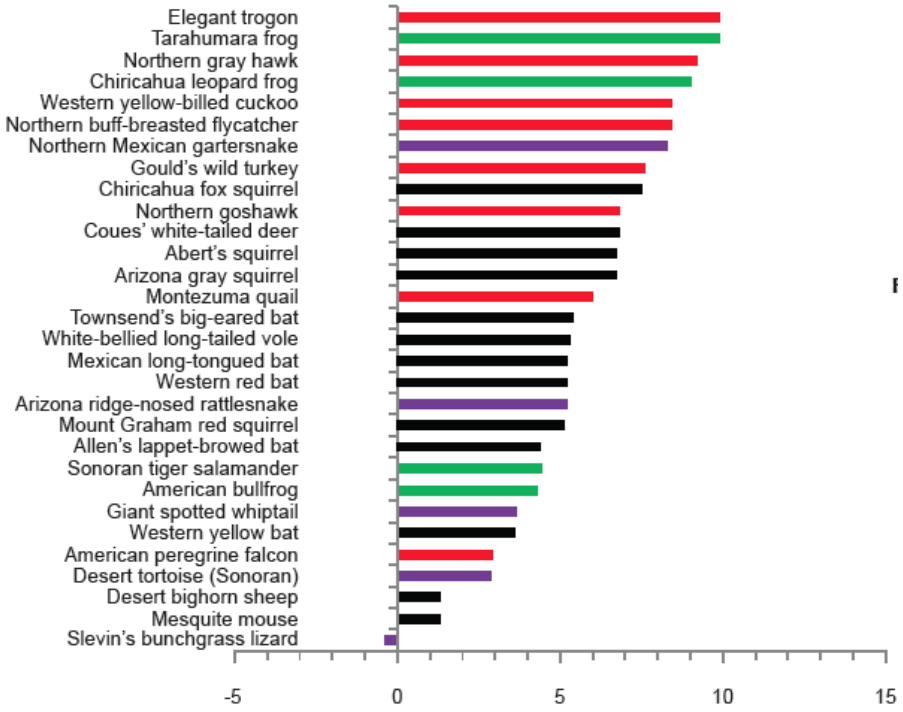
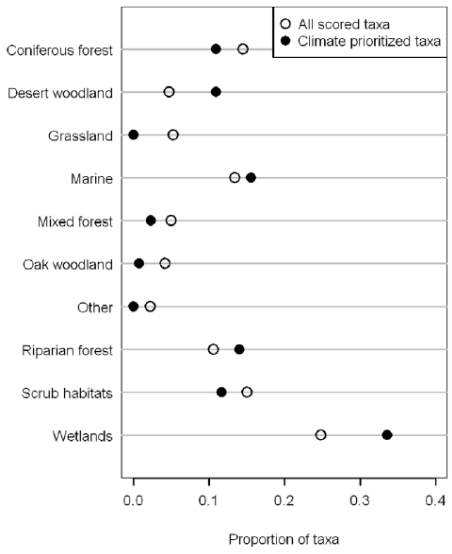


Figure 5. Results from Coe et al's (2012) analysis of climate vulnerable wildlife in Sky Islands of the southwestern US.

2.5.4. Climate Change Vulnerability Assessment of California's At-Risk Birds (CCVARB)



Gardali et al. (2012) developed a methodology to integrate climate vulnerability into an existing list of at-risk birds in California. The method entails using literature review and expert opinion to fill out a score-sheet with the following categories: habitat specialization, physiological tolerances, migratory status, dispersal ability, changes in habitat suitability, changes in food availability, and changes in extreme weather. Confidence is assessed for each answer. Summed scores were ranked into three levels of vulnerability based on natural breaks in the distributions. There are no quantitative inputs for projected climate change.

Figure 6. Example of comparative output from Gardali et al.'s (2012) analysis of climate vulnerability of California birds.

Gardali et al. (2012) determined climate change vulnerability for 358 species, subspecies and populations of California birds using 7 criteria chosen as being relevant to birds. A total of 128 (36%) were considered vulnerable. Of the 29 federally-listed taxa, 21 (72%) were considered to be climate vulnerable. Wetland species were found to be the most vulnerable.

2.5.5. Climate Change Vulnerability Assessment for Shorebird Habitat (CC-VASH)

The Climate Change Vulnerability Assessment for Shorebird Habitat (CC-VASH) is a sophisticated Excel-based assessment and decision-making tool. CC-VASH guides participants through a series of worksheets and exercises that enable them to assess the vulnerability of coastal shorebird habitats to climate change, using three categories:

- Effects of sea-level rise;
- Effects of other climate-change variables, such as predicted changes in temperature and precipitation; and,
- Effects of increased frequency and intensity of storms.

Information and guidance is available at http://www.whsrn.org/tools/climate-change-tool. The tool does not assess vulnerability of shorebird species directly, only their habitat.

2.5.6. State of the Birds: 2010 Report on Climate Change (SoB 2010)

The North American Bird Conservation Initiative U.S. Committee (2010) assessed the relative vulnerability of each United States bird species, based on five biological aspects of sensitivity to climate change (migration status, breeding habitat, dispersal ability, niche specificity, reproductive potential) as well as to a subjective assessment of the exposure of each species' habitat to climate change in the near future. They categorized species as into three levels of climate vulnerability. A majority of birds dependent on oceans, and birds on Hawaiian Islands, are highly vulnerable to climate change. Birds in coastal, arctic/alpine, and grassland habitats, as well as those on Caribbean and other Pacific islands show intermediate levels of vulnerability. Most birds in aridlands, wetlands, and forests show lower overall vulnerability. This approach appears to be a one-time assessment and was not meant to be a tool for widespread use.

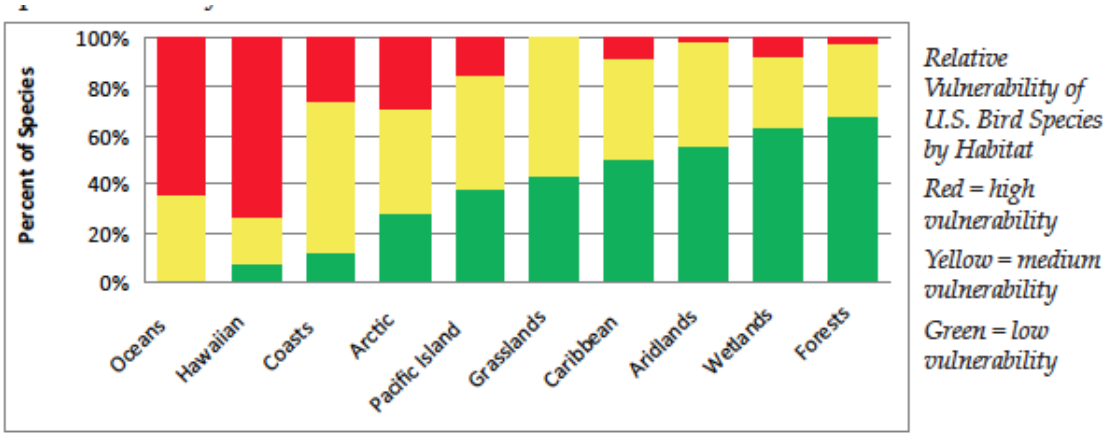


Figure 7. State of the Birds (2010) summary showing relative vulnerability to climate change of all US birds based on habitat.

2.5.7. Framework For Assessing Threats And Benefits To Species Responding To Climate Change (FATB--CC)

Thomas et al. (2011) present a framework of assessing both threats and benefits from climate change based loosely on the IUCN Red Listing process. The primary metrics are observed and modeled changes in distribution. The assessment framework consists of 6 major stages each of which has a number of steps resulting in separate scores for risks and benefits. Stage 1 entails determining decline in distribution over previous decades. Stage 2 is an assessment of projected declines in the historical or recent range. Stage 3 entails documenting observed increases outside previous range Stage 4 addresses projected increases in size of current range. Stage 5 is summarizing the scores and Stage 6 is presenting them as a table with benefits from range expansion on one axis and risk of declines on the other

(Figure 8).

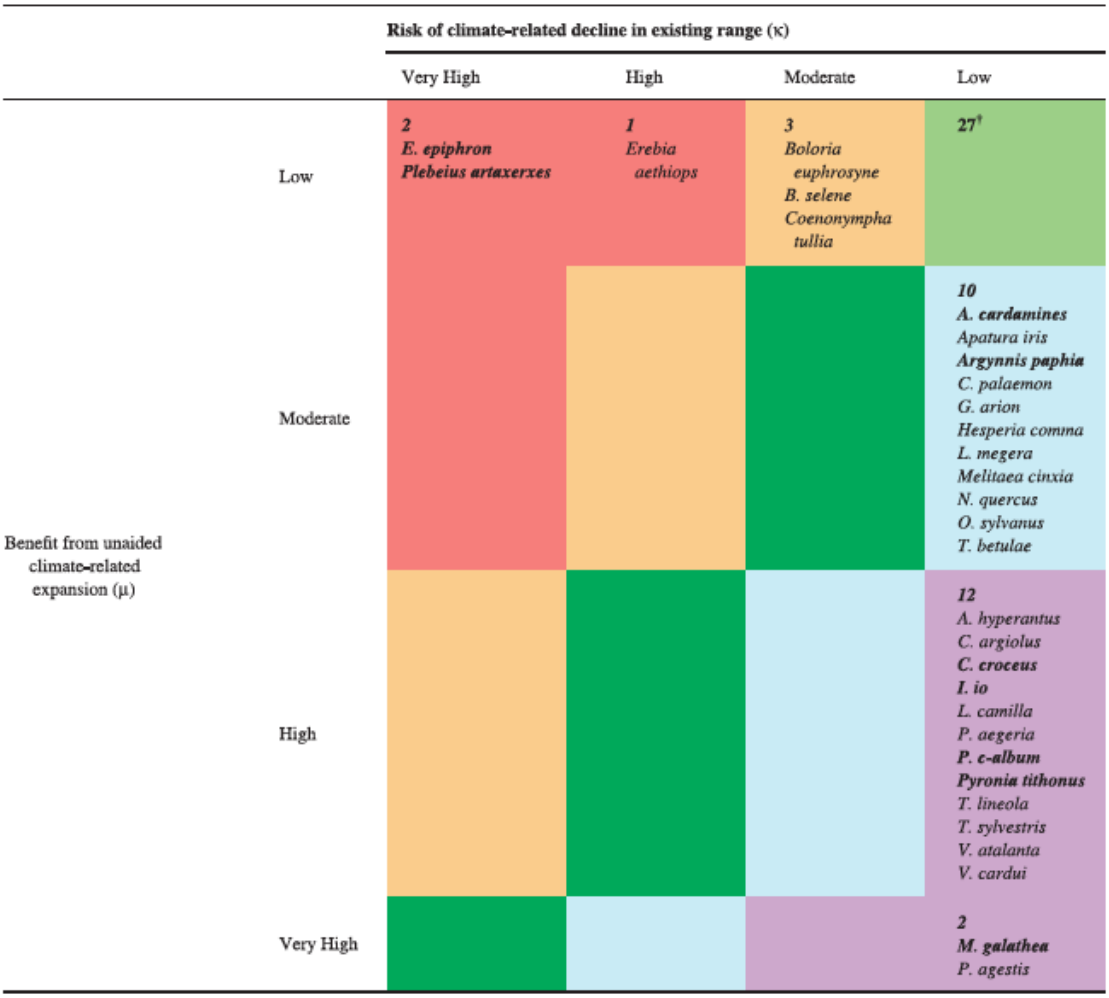


Figure 8. Summary from Thomas et al. (2011) showing species risk v benefit from climate change for 58 British butterflies.

The approach requires detailed survey data for the previous 40 years based on repeated censuses as well as completed range projections based Species Distribution models. It is in essence a hybrid SDM/VI approach.

2.5.8. Climate Change Sensitivity Database (CCSB)

The University of Washington has developed a web-based Climate Change Sensitivity Database (http://courses.washington.edu/ccdb/drupal/) providing the opportunity for on-line access and contribution to species sensitivity assessments by registered users. There is no standalone documentation for the website, but the database is quite user-friendly with help incorporated. The focus is the US Pacific Northwest, but the study area appears to cover southern BC and the Alberta Rockies (http://occri.net/wp-content/uploads/2010/09/1645-Tue-Case.pdf) and some

species assessments are range-wide. A series of questions is asked about 10 sensitivity factors. Literature sources are documented and confidence is subjectively assessed. Climate exposure data are not incorporated. The system works for a broad range of terrestrial and aquatic biodiversity.

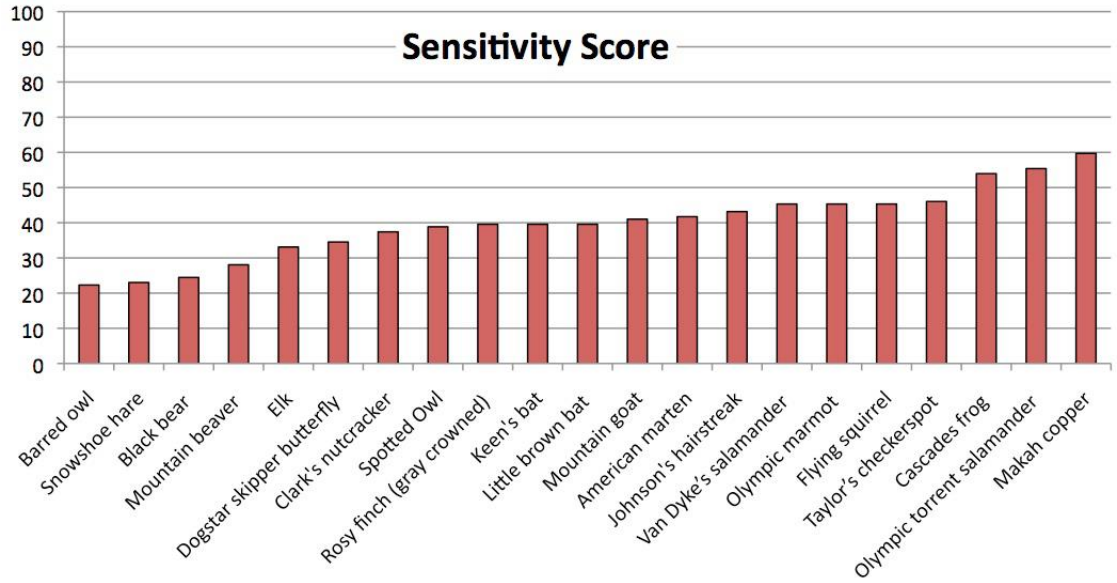


Figure 9. Sample output from a Climate Change Sensitivity Database analysis of the Olympic study area (http://occri.net/wp-content/uploads/2010/09/1645-Tue-Case.pdf)

2.5.9. A Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change (RVTES—CC)

The US Environmental Protection Agency (2009) developed a framework to categorize the relative vulnerability of at-risk species to climate change based on four modules. Module 1 assesses the baseline population vulnerability of species, excluding climate change, based on their life histories and conservation status. This is specifically targeted at the current at-risk status. Module 2 scores the vulnerability of species to potential climate change based on species characteristics. Module 3 combines Modules 1 and 2 to create an overall risk score (climate change + existing threats) in 4 categories. Module 4 is a qualitative determination of uncertainty. There is no explicit input of past or projected climate data. The framework was tested on 6 species (Figure 10) but apparently has not been more widely employed.

Species	Module 1 baseline scores	Module 2 climate change scores	Module 3 best estimate scores	Module 3 alternate scores	Module 4 certainty score
Golden-cheeked warbler	Vb2 (highly vulnerable	Vc1 (critically vulnerable)	Vo1 (critically vulnerable)	Vo2 (highly)	High
Bald eagle	Vb3 (less vulnerable)	Vc3 (less vulnerable)	Vo3 (less vulnerable)	Vo2, Vo4 (highly, least)	High
Salt marsh harvest mouse	Vb2 (highly vulnerable	Vc2 (highly vulnerable)	Vo1 (critically vulnerable)	Vo1, Vo2 (critically, highly)	Medium
Mount Graham red squirrel	Vb2 (highly vulnerable)	Vc2 (highly vulnerable)	Vo1 (critically vulnerable)	Vo1, Vo2 (critically, highly)	High
Desert tortoise	Vb3 (less vulnerable)	Vc2 (highly vulnerable	Vo2 (highly vulnerable)	Vo1, Vo3 (critically, less)	Medium
Lahontan cutthroat trout	Vb2 (highly vulnerable)	Vc2 (highly vulnerable)	Vo1 (critically vulnerable)	Vo1, Vo2 (critically, highly)	Medium

Figure 10. Summary of species evaluations using the EPA approach.

2.5.10. Climate Change Sensitivity Index (CCVI)

NatureServe has developed the Climate Change Sensitivity Index (CCVI) Young et al. (2011) based on the framework developed by (Williams et al. 2008). The CCVI uses a scoring system that integrates a species' predicted exposure to climate change within an assessment area and three sets of factors associated with climate change sensitivity, each supported by published studies: 1) exposure to climate change, 2) species specific factors (including dispersal ability, temperature and precipitation sensitivity, physical habitat specificity, interspecific interactions, and genetic factors), and 3) documented response to historical climate change. Exposure to climate change is measured by examining the magnitude of predicted temperature and moisture change within the assessment area. The software is designed for input from The Climate Wizard (http://climatewizard.org), which provides a convenient source of downscaled temperature and available moisture (Hamon AET:PET,(Hamon 1961)) predictions. Data are entered into an Excel worksheet with computations done by macros. A series of questions are asked about direct and indirect exposure to climate change and about the inherent sensitivity of species to changing climate. The tool and background information is available at http://www.natureserve.org/prodServices/climatechange/ccvi.jsp.

(Young et al. 2009) undertook a vulnerability assessment of 13 Nevada species as an early case study testing the CCVI. Table 1 shows typical output from the CCVI Excel spreadsheet.

Table 2. Factors contributing to vulnerability of selected Nevada species (Young et al. 2009). GI = Greatly Increase, SI = Somewhat Increase, N = Neutral, SD = Somewhat Decrease, Dec = Decrease, U = Unknown.

Species	Natural barriers	Anthropogenic barriers	Dispersal ability	Macro-scale temperature requirements	Micro-scale temperature requirements	Macro-scale precipitation requirements	Micro-scale precipitation requirements	Dependence on ice/snow	Physical habitat requirement	Diet specialization	Migrations - movements	Genetic variation	Index Score
Aplodontia rufa	Inc	N	Inc	SI	SI	Inc-SI	N	N	N	N	SI	U	**EV**
Rhinichthys osculus oligoporus	N	N	Inc	N	N	GI-Inc	GI	N	N	N	SI	U	**HV**
Limenitis archippus lahontani	N	N	Inc	N	SI	SI	GI	N	N	Inc	SI	U	**HV**
Ochotona princeps	GI-Inc	N	SI	SI-N	N	SI-N	N	N	Inc	N	SI	U	**HV**
Sorex palustris	Inc	N	Inc	N	SI	SI-N	GI-Inc	N	N	N	SI	U	**HV**
Oncorhynchus clarkii henshawi	N	N	N	N	Inc-SI	SI	Inc-SI	N	N	N	Inc	U	**HV**
Rana pipiens	N	N	N	N	SI	SI	GI-Inc	N	N	N	SI	U	**MV**
Draba cusickii var. pedicellata	N	N	Inc	N	SI-N	SI	N	N	SI	N/A	U	U	**MV**
Leucosticte atrata	GI	N	Dec	SI	U	SI	N	SI	Inc-SI	N	SD	U	**MV**
Populus tremuloides	N	N	GI	N-SD	Inc	SI-N	SI	N	N	N/A	U	SD	**MV**
Asclepias eastwoodiana	N	N	SI	N	N	SI	Inc	N	N	N/A	U	U	**PS**
Phrynosoma platyrhinos	N	N	N	N	SD	Inc-SI	N	N	N	SI	SI	U	**PS**
Quiscalus mexicanus	N	SD	Dec	N	N	N	N	N	N	SD	U	U	**IL**

Byers and Norris (2011) used the CCVI to undertake a climate change vulnerability assessment for 185 animal and plant species in West Virginia. The most vulnerable groups were found to be amphibians, fish, mollusks and rare plants, in that order. Birds, mammals, common plants, and cave-dwelling invertebrates were less vulnerable to climate change. At-risk species were not found to be significantly more vulnerable than more common ones. Six of the 23 CCVI risk factors assessed were strongly correlated with vulnerability to climate change across all taxonomic groups in the state. These were:

1. natural barriers to movement and dispersal
2. anthropogenic barriers to movement and dispersal
3. physiological thermal niche
4. physiological hydrological niche

5. genetic variation, and
6. modeled response.

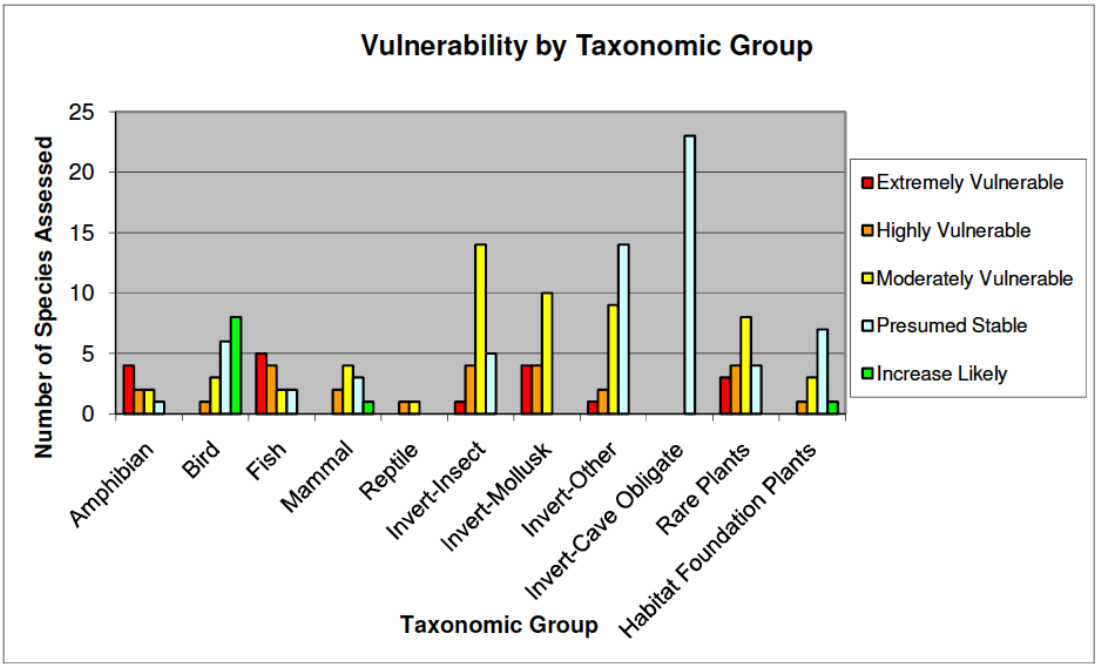


Figure 11. Results from Byers and Norris's (2011) analysis of climate vulnerable biodiversity in West Virginia using CCVI.

Dubois et al. (2011) used the CCVI tool to evaluate 21 species (5 birds, 4 reptiles, 3 amphibians, 4 mammals, 2 invertebrates and 3 alien, invasive species) in Florida. The study was followed by a spatially explicit scenario-based adaptation modeling study (Flaxman and Vargas-Moreno 2011). Climate Wizard data were used for 1 emission scenario and an ensemble average of 16 climate models. Coastal species were found to be more vulnerable than inland species and reptiles were the most vulnerable taxonomic group (Figure 12).

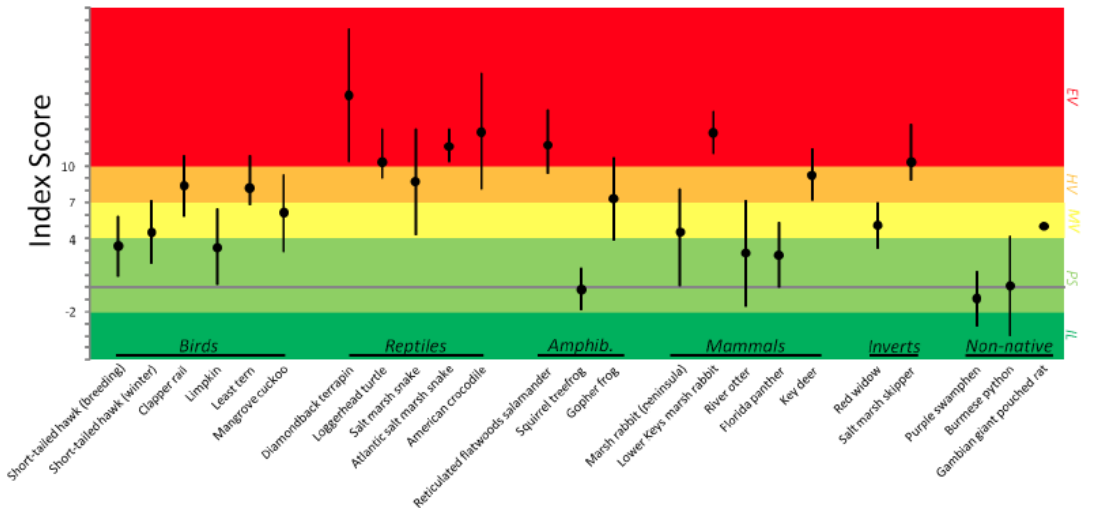


Figure 12. CCVI vulnerability rankings for 21 Florida species (Dubois et al. 2011).

http://www.natureserve.org/prodServices/climatechange/pdfs/NevadaCaseStudy_0809_web.pdf

2.5.11. Evaluation of Best Vulnerability Assessment Tools

Table 3 summarizes the attributes of the various climate change vulnerability assessment tools assessed. The intent in this project is to be able to assess all Alberta's terrestrial species in a consistent manner. Only 4 of the reviewed tools (SSSC, FATB-CC, CCSB, CCVI) are intended to address all elements of biodiversity. The SSSC and CCSB address only sensitivity, not exposure, while FATB-CC is a hybrid species distribution modeling/vulnerability assessment approach requiring large amounts of historical population trend and distribution data from both intensive surveys and projection modeling. The only suitable existing vulnerability assessment tool is CCVI.

Table 3. Summary of climate change vulnerability tool attributes.

		SSCCI	CCVMS	SAVS	CCVARB	SoB 2010	FATB-CC	CCSB	RVTES-CC	CCVI
Species		All	Migratory Vertebrates	Terrestrial Vertebrates	At-Risk Birds	Birds	All	All	At-Risk Vertebrates	All
Sensitivity										
	Physiology-based climatic thresholds	X	X	X	X			X	x	X
	Dispersal ability	X	X	X	X	X		X	X	X
	Habitat specialization	X	X		X	X		X	X	X
	Ecological specialization					X		X		X
	Biotic interaction/dependence	X	X	X					X	X
	Seasonal migrations/movements			X	X	X				
	Phenology	X	X	X						X
	Genetic Diversity			X						X
	Climate related Disease	X		X						
	Life History Traits							X		
	Sensitivity to Disturbance					X		X		X
	Sensitivity to Extreme Weather								X	
Exposure										
	Temperature/precipitation Change									X
	Historical Climate Response		X				X			X
	Projected Habitat change		X	X	X	X	X		X	X
	Change in food availability			X	X					
	Increase in extreme weather			X	X					

	Barriers to dispersal	X								x
	Non-climatic stressors		X							X
Climate and Other Information Inputs										
	Climate projections			(X)						X
	Vegetation map projections			(X)						
	Modeled species response						X			X
Software								X		X
Time per species		Low	Medium	Medium	Low	Low	Large	Low	Low	Medium
Quantitative components							X			X

(X) addressed indirectly considered or used as background information

SSCCI	Foden et al. 2008	Species Susceptibility to Climate Change Impacts
CCVMS	Zoological Society of London 2010	Climate Change Vulnerability of Migratory Species
SAVS	Bagne et al. 2011	System for Assessing Vulnerability of Species (SAVS)
CCVAB	Gardali et al. 2012	Climate Change Vulnerability Assessment of California's At-Risk Birds
SoB 2010	NA Bird Conservation Initiative 2010	State of Birds 2010
FATBSRCC	Thomas et al. 2011	Framework For Assessing Threats And Benefits To Species Responding To Climate Change
CCSB	University of Washington	Climate Change Sensitivity Database
FCRVTECC	US EPA 2009	A Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change
CCVI	Young et a. 2011	Climate Change Sensitivity Index (CCVI)

Filename = summary of tools2.xlsx

3. Species Distribution Modeling

All of the VI approaches described above rely on good-quality scientific data to evaluate risks to climate change. Over the next 3 years, the project will develop new scientific information that will be used to adapt our first version of the CCVI evaluation. Using existing biodiversity data and data currently being collected we will explore a variety of approaches to species distribution modeling. Through these models we will quantitatively evaluate changes in range and population size in Alberta. These models will be used to test our CCVI predictions and to identify potential strategies for climate change mitigation for Alberta plant and animal species under projected scenarios of climate change and adaptation strategies.

As the first step, statistical models will be built characterizing climate conditions that Alberta species currently experience (their "realized niche"). The expected distribution of a species under future climatic scenarios will be approximated by determining where the species' climatic niche will exist in the future. In essence, this approach assesses the potential change in species distribution if climate were the only factor affecting future distribution patterns. This is commonly termed "climate envelope modeling" and is currently underway at the University of Alberta with a large number of plant and animal species using data from ABMI plus numerous government and non-government databases.

It is understood that climate envelope modeling does not provide a comprehensive or accurate prediction of future species distributions as the habitat requirements of a species are more complex than climate alone. Also, the spatial resolution at which species distribution can be reliably predicted is unclear. With the experience gained from climatic envelope modeling and from vulnerability analysis, more sophisticated models will be developed for some species in which climate change interacts with many the covariates that affect species distributions. Specifically we are interested in identifying where the specific habitat of species might be able to exist in future climate change scenarios and then link changes in habitat to population size (i.e. how do distributions of trees influence abundance of birds). The factors that will alter habitat quality for wildlife with climate change are many and we will be evaluating: 1) if there are climate refugia in the province (i.e. areas of higher elevation and terrain complexity) that might allow native tree and grass species to persist thereby providing habitat for wildlife in the future. Work has begun on this element of the project and will be a focus of the later half of year 1 through year 2; and 2) how changes in wildfire frequency and size will affect forest and grassland succession. Time since past disturbance is a key driver influencing habitat quality for wildlife and is a key mechanism that will influence wildlife in Alberta with changing climate. Modelling wildlife population size as a function of wildfire dynamics will be a focus of years 2 and 3.

For species that are currently listed as being at risk the potential for a catastrophic year in the near future is a key concern (e.g., Greater Sage Grouse which were almost extirpated in 2011). Climate change seems to be altering the risk of extreme weather world-wide although evidence for Alberta per se is less clear. Extreme weather event frequency and magnitude will be evaluated as risk factors in population viability analyses for several species (i.e. Burrowing Owl, Ferruginous Hawk) for which long-term demographic data are available. Such analyses will be used to update the CCVI system for these species specifically and identify approaches to be used when evaluating immediate threats to species of concern. Genetic variability and physiological tolerance experiments will be done for several plant species. These experiments will provide a tool that can be used to evaluate the efficacy of human action as a mitigation tool as well as the importance of genetic variability in understanding risks to species. This work will be undertaken largely by faculty, post-docs, and graduate students at the University of Alberta.

4. On-line Biodiversity Mapping

The Project Team recognizes the importance of making map products widely available and is currently assessing feasible approaches. Readily accessible GIS data will ensure spatial data generated by the project will be available to government departments, academics, ENGOs and consultants for research purposes. Simplified and dynamic on-line visualizations will help the general public understand potential effects of climate change and adaptation actions on biodiversity. The level and type of website functionality will depend on an assessment of the specific questions articulated during consultation. Multi-scale spatial resolution will be necessary to simultaneously address province-wide issues as well as more local, community adaptation options. Choice of a hosting platform will be dependent on technical capabilities, cost and on-going maintenance capacities.

5. Major Recommendations and Directions

1. Limit the project focus to terrestrial animals and plants.
2. Technically integrate all 5 subprojects to ensure that all are using consistent information, endpoints, methodologies and tools.
3. Undertake envelope modeling and vulnerability assessment simultaneously over the summer and autumn of 2012.
4. Refine envelope modeling with more process-oriented modeling later in the project.
5. Further explore goals and functionality requirements for on-line mapping of climate change effects on biodiversity.
6. Use NatureServe's Climate Change Vulnerability Index as a tool for vulnerability assessment of approximately 200 Alberta terrestrial species.
7. Use the A2 emission scenario and the following 6 GCMs for all aspects of the project:
   - INM-CM3.0, Russia wetter

- CGCM3.1(T47), Canada — wetter and less seasonal
- GFDL-CM2.1, USA — drier
- UKMO-HadGEM1, UK — drier and much warmer
- ECHAM5/MPI-OM, Germany — most representative model overall
- Ensemble mean of 15 "good" GCMs

8. Use the ClimateWNA dataset for historical and future climate projections.
9. Assess climate change effects at the intervals of 2040 – 2060 and 2080 – 2100.

6. Literature Cited

Alberta Biodiversity Monitoring Institute. 2009. ABMI species pyramid: Guild definitions and species lists. ABMI, Alberta, Canada.

Bagne, K.E., M.M. Friggens, and D.M. Finch. 2011. A System for Assessing Vulnerability of Species (SAVS) to Climate Change. Vol. RMRS-GTR-257, General Technical Report. Rmrs-Gtr-257. Fort Collins, CO: U.S. Department of Agriculture, Forest Service,.

Chen, W., Z. Jiang, and L. Li. 2011. Probabilistic projections of climate change over China under the SRES A1B scenario using 28 AOGCMs. Journal of Climate **24**:4741-4756.

Barrow, E. and G. Yu. 2005. Climate Scenarios for Alberta: A Report Prepared for the Prairie Adaptation Research Collaborative (Parc) in Co-Operation With Alberta Environment. 73 pp.

Byers, E., and S. Norris. 2011. Climate Change Vulnerability Assessment of Species of Concern in West Virginia. West Virginia Division of Natural Resources, Elkins, Wv.

Coe, S.J., D.M. Finch, and M.M. Friggens. 2012. An Assessment of Climate Change and the Vulnerability of Wildlife in the Sky Islands of the Southwest. Gen. Tech. Rep. RMRS-GTR-273. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Daly, C. 2006. Guidelines for assessing the suitability of spatial climate data sets. International Journal of Climatology **26**:707-721.

Dubois, N., A. Caldas, J. Boshoven, and A. Delach. 2011. Integrating Climate Change Vulnerability Assessments Into Adaptation Planning: A Case Study Using the Natureserve Climate Change Vulnerability Index to inform conservation planning for species in Florid. [Final Report]. Washington, D.C.: Defenders of Wildlife.

Flaxman, M., and J.C. Vargas-Moreno. 2011. Considering Climate Change in Florida's Wildlife Action Planning: A Spatial Resilience Planning Approach. Research Report Fwc-2011. Cambridge, MA: Dept of Urban Studies and Planning, Massachusetts Institute of Technology.

Foden, W., G.M. Mace, J.C. Vié, A. Angulo, S.H.M. Butchart, L. DeVantier, H. Dublin, A. Gutsche, S. Stuart, and E. Turak. 2008. Species Susceptibility to Climate Change Impacts. Wildlife in a Changing World–An Analysis of the 2008 Iucn Red List of Threatened Species. Gland, Switzerland: IUCN.

Frey, B. J. and D. Dueck. 2007. Clustering by passing messages between data points. Science **315**:972-976.

Gardali, T., N.E. Seavy, R.T. DiGaudio, and L.A. Comrack. 2012. A Climate Change Vulnerability Assessment of California's At-Risk Birds. PLoS ONE 7 (3): e29507.

Gleckler, P. J., K. E. Taylor, and C. Doutriaux. 2008. Performance metrics for climate models. Journal of Geophysical Research **113**:D06104.

Glick, P., B.A. Stein, and N.A. Edleson. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. Washington, DC: National Wildlife Federation.

Hamon, W. R. 1961. Estimating Potential Evapotranspiration. Journal of the Hydraulics Division Proceedings of the American Society of Civil Engineers 87 107-20.

Jun, M., R. Knutti, and D. W. Nychka. 2008. Spatial Analysis to Quantify Numerical Model Bias and Dependence. Journal of the American Statistical Association **103**:934-947.

Knutti, R. 2010. The end of model democracy? Climatic Change **102**:395-404.

Knutti, R., R. Furrer, C. Tebaldi, J. Cermak, and G. A. Meehl. 2009. Challenges in combining projections from multiple climate models. Journal of Climate **23**:2739-2758.

Manning, MR, J. Edmonds, S. Emori, A. Grubler, K. Hibbard, F. Joos, M. Kainuma, RF Keeling, T. Kram, and AC Manning. 2010. Misrepresentation of the Ipcc Co2 Emission Scenarios. Nature Geoscience 3 (6): 376-77.

Masson, D. and R. Knutti. 2011. Climate model genealogy. Geophysical Research Letters **38**:L08703.

McClay, A.S., F.M. Fry, E.J. Korpela, R.M. Lange, L.D. Roy. 2004. Costs and threats of invasive species to Alberta's natural resources. Alberta Research Council, Edmonton.

Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor. 2007. The WCRP CMIP3 multi-model dataset: A new era in climate change research. Bulletin of the American Meteorological Society **88**:1383-1394.

Mbogga, M.S., T. Wang, C. Hansen, and A. Hamann. 2010. A Comprehensive Set of Interpolated Climate Data for Alberta. Ref. T/235.: Alberta Sustainable Resource Development.

Norris, H. 2012. Alberta's Biodiversity Management System.: Sustainable Resource Development.

North American Bird Conservation Initiative U.S. Committee. 2010. The State of the Birds 2010 Report on Climate Change, United States of America. Washington, DC: U.S. Department of the Interior.

Pennell, C. and T. Reichler. 2011. On the effective number of climate models. Journal of Climate **24**:2358-2367.Räisänen, J. 2007. How reliable are climate models? Tellus A **59**:2-29.

Rowland, E.L., J.E. Davison, and L.J. Graumlich. 2011. Approaches to Evaluating Climate Change Impacts on Species: A Guide to Initiating the Adaptation Planning Process. Environmental Management 47 (3): 322-37.

Scherrer, S. C. 2011. Present-day interannual variability of surface climate in CMIP3 models and its relation to future warming. International Journal of Climatology **31**:1518-1529.

SRD. 2010. Climate change adaptation framework manual. http://www.srd.alberta.ca/MapsPhotosPublications/Publications/documents/ClimateChangeAdaptationFrameworkManual-April%202010.pdf

Tebaldi, C., and R. Knutti. 2007. The Use of the Multi-Model Ensemble in Probabilistic Climate Projections. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 365 (1857): 2053-75.

Terando, A., K. Keller, and W. E. Easterling. 2012. Probabilistic projections of agro-climate indices in North America. Journal of Geophysical Research **117**:D08115.

Thomas, C.D., J.K. Hill, B.J. Anderson, S. Bailey, C.M. Beale, R.B. Bradbury, C.R. Bulman, H.Q.P. Crick, F. Eigenbrod, and H.M. Griffiths. 2011. A Framework for Assessing Threats and Benefits to Species Responding to Climate Change. Methods in Ecology and Evolution 2 (2): 125-42.

US Environmental Protection Agency. 2009. A Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change. Vol. EPA/600/R-09/011, Washington, D.C.: National Center for Environmental Assessment.

Walsh, J. E., W. L. Chapman, V. Romanovsky, J. H. Christensen, and M. Stendel. 2008. Global Climate Model Performance over Alaska and Greenland. Journal of Climate **21**:6156-6174.

Wang, M., J. E. Overland, V. Kattsov, J. E. Walsh, X. Zhang, and T. Pavlova. 2007. Intrinsic versus forced variation in coupled climate model simulations over the Arctic during the twentieth century. Journal of Climate **20**:1093-1107.

Wang, T., A. Hamann, D. L. Spittlehouse, and T. Q. Murdock. 2011. ClimateWNA—High-Resolution Spatial Climate Data for Western North America. Journal of Applied Meteorology and Climatology **51**:16-29.

Williams, S.E., L.P. Shoo, J.L. Isaac, A.A. Hoffmann, and G. Langham. 2008. Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. PLoS Biology 6 (12): e325.

Young, B., E. Byers, K. Gravuer, K. Hall, G. Hammerson, and A. Redder. 2011. Guidelines for Using the Natureserve Climate Change Vulnerability Index.: NatureServe.

Young, B., E. Byers, K. Gravuer, K.R. Hall, G.A. Hammerson, A. Redder, K. Szabo, and J.E. Newmark. 2009. Using the Natureserve Climate Change Vulnerability Index: A Nevada Case Study.: NatureServe.

Zoological Society of London. 2010. Climate Change Vulnerability of Migratory Species: Species Assessments. Project Report to CMS Scientific Council 16, Bonn, 28-30 June 2010.

7. Appendix 1. Interim List of Candidate Species for Assessment

This list is long and only indicative of the species that will be considered for vulnerability assessment. Species listed as "Priority" will definitely be addressed in the VI analysis. Throughout, reasonable representation will be sought for a wide range of taxonomic groups, Natural Regions, Land Use Framework Regions and ecological guilds.

Priority			General Status At Risk	Major Invasive	BMS Indicator	ABMI High Respons-ibility	Notes
	Mammals						
X	American Bison	*Bos bison*	X			X	
	American Pika	*Ochotona princeps*					
X	Arctic Shrew	*Sorex arcticus*				X	
X	Bighorn Sheep	*Ovis canadensis*			X		
X	Columbian Ground Squirrel	*Spermophilus columbianus*				X	
X	Dusky Shrew	*Sorex monticolus*				X	
X	Elk (Wapiti)	*Cervus elaphus*			X		
X	Golden-Mantled Ground Squirrel	*Spermophilus lateralis*				X	
X	Grizzly Bear	*Ursus arctos*	X		X		
X	Heather Vole	*Phenacomys intermedius*				X	
X	Least Chipmunk	*Tamias minimus*				X	
X	LynX	*Lynx canadensis*			X		
X	Marten	*Martes americana*			X		
X	Meadow Jumping Mouse	*Zapus hudsonius*				X	
X	Moose	*Alces americanus*			X		
X	Mule Deer	*Odocoileus hemionus*			X	X	
X	Northern Bog Lemming	*Synaptomys borealis*				X	
X	Ord's Kangaroo Rat	*Dipodomys ordii*	X				

X	Pronghorn Antelope	*Antilocapra americana*			X		
X	Richardson's Ground Squirrel	*Spermophilus richardsonii*		X		X	
X	Swift FoX	*Vulpes velox*	X				
X	Taiga (Yellow-Cheeked) Vole	*Microtus xanthognathus*				X	
X	Wandering Shrew	*Sorex vagrans*				X	
X	Water Vole	*Microtus richardsoni*				X	
X	White-tailed Deer	*Odocoileus virginianus*			X		
X	Caribou	*Rangifer tarandus*	X		X		
	Birds						
	Alder Flycatcher	*Empidona xalnorum*					Strahlberg analysis
	American Crow	*Corvus brachyrhynchos*					Strahlberg analysis
	American Goldfinch	*Carduelis tristis*					Strahlberg analysis
	American Kestrel	*Falco sparverius*					Strahlberg analysis
	American Pipit	*Anthus rubescens*					Strahlberg analysis
	American Redstart	*Setophaga ruticilla*					Strahlberg analysis
	American Robin	*Turdus migratorius*					Strahlberg analysis
X	American White Pelican	*Pelecanus erythrorhynchos*				X	
X	Baird's Sparrow	*Ammodramus bairdii*				X	Strahlberg analysis
	Baltimore Northern Oriole Icterus galbula	*Icterus galbula*					Strahlberg analysis
	Barn Swallow Hirundo rustica	*Hirundo rustica*					Strahlberg analysis
	Barred Owl StriX varia	*Strix varia*					Strahlberg analysis
X	Bay-breasted Warbler	*Dendroica castanea*				X	Strahlberg analysis
	Black and White Warbler	*Mniotilta varia*					Strahlberg analysis

X	Black Tern	*Chlidonias niger*				X	
	Black-Backed Woodpecker	*Picoides arcticus*					Strahlberg analysis
X	Black-Billed Magpie	*Pica hudsonia*				X	Strahlberg analysis
	Black-Capped Chickadee (Poecile atricapilla)	*Poecile atricapilla*					Strahlberg analysis
X	Black-throated Green Warbler	*Dendroica virens*				X	Strahlberg analysis
	Blackburnian Warbler	*Dendroica fusca*					Strahlberg analysis
	Blackpoll Warbler	*Dendroica striata*					Strahlberg analysis
	Blue Jay	*Cyanocitta cristata*					Strahlberg analysis
	Blue-Headed (Solitary) Vireo	*Vireo solitarius*					Strahlberg analysis
	Bobolink	*Dolichony xoryzivorus*					Strahlberg analysis
X	Bohemian WaXwing	*Bombycilla garrulus*				X	Strahlberg analysis
	Boreal Chickadee	*Poecile hudsonica*					Strahlberg analysis
	Broad-Winged Hawk	*Buteo platypterus*					Strahlberg analysis
	Brown Creeper	*Certhia americana*					Strahlberg analysis
	Brown-Headed Cowbird	*Molothrus ater*					Strahlberg analysis
X	Bufflehead	*Bucephala albeola*				X	
X	Burrowing Owl	*Athene cunicularia*	X		X		
X	California Gull	*Larus californicus*				X	Strahlberg analysis
X	Canada Warbler	*Wilsonia canadensis*				X	Strahlberg analysis
X	Cape May Warbler	*Dendroica tigrina*				X	Strahlberg analysis
	Cedar WaXwing	*Bombycilla cedrorum*					Strahlberg analysis
X	Chestnut-Collared Longspur	*Calcarius ornatus*				X	Strahlberg analysis

	Chestnut-Sided Warbler	*Dendroica pensylvanica*					Strahlberg analysis
	Chipping Sparrow	*Spizella passerina*					Strahlberg analysis
X	Clay-Colored Sparrow	*Spizella pallida*				X	Strahlberg analysis
	Common Grackle	*Quiscalus quiscula*					Strahlberg analysis
	Common Nighthawk	*Chordeiles minor*					Strahlberg analysis
	Common Raven	*Corvus corax*					Strahlberg analysis
X	Connecticut Warbler	*Oporornis agilis*				X	Strahlberg analysis
	Dark-Eyed Junco	*Junco hyemalis*					Strahlberg analysis
X	Double-Crested Cormorant	*Phalacrocora xauritus*				X	
	Downy Woodpecker	*Picoides pubescens*					Strahlberg analysis
X	Eared Grebe	*Podiceps nigricollis*				X	
	Eastern Kingbird	*Tyrannus tyrannus*					Strahlberg analysis
X	Evening Grosbeak	*Coccothraustes vespertinus*				X	Strahlberg analysis
X	Ferruginous Hawk	*Buteo regalis*	X		X		
	FoX Sparrow	*Passerella iliaca*					Strahlberg analysis
X	Franklin's Gull	*Larus pipixcan*				X	
	Golden-crowned Kinglet	*Regulus satrapa*					Strahlberg analysis
	Grasshopper Sparrow	*Ammodramus savannarum*					Strahlberg analysis
	Gray Jay	*Perisoreus canadensis*					Strahlberg analysis
	Great Gray Owl	*Strix nebulosa*					Strahlberg analysis
	Great Horned Owl	*Bubo virginianus*					Strahlberg analysis
X	Greater Sage Grouse	*Centrocercus urophasianus*	X				
X	Greater Yellowlegs	*Tringa melanoleuca*				X	

	Hairy Woodpecker	*Picoides villosus*					Strahlberg analysis
	Hammond's Flycatcher	*Empidona xhammondii*					Strahlberg analysis
	Harlequin Duck	*Histrionicus histrionicus*					
	Hermit Thrush	*Catharus guttatus*					Strahlberg analysis
	Herring Gull	*Larus argentatus*					Strahlberg analysis
	Horned Lark	*Eremophila alpestris*					Strahlberg analysis
	House Wren	*Troglodytes aedon*					Strahlberg analysis
	Killdeer	*Charadrius vociferus*					Strahlberg analysis
	Lark Sparrow	*Chondestes grammacus*					Strahlberg analysis
X	Le Conte's Sparrow	*Ammodramus leconteii*				X	Strahlberg analysis
	Least Flycatcher	*Empidona xminimus*					Strahlberg analysis
X	Lesser Yellowlegs	*Tringa flavipes*				X	
X	Long-billed Curlew	*Numenius americanus*			X		Strahlberg analysis
X	Magnolia Warbler	*Dendroica magnolia*				X	Strahlberg analysis
X	McCown's Longspur	*Calcarius mccownii*				X	Strahlberg analysis
	Merlin	*Falco columbarius*					Strahlberg analysis
X	Mountain Bluebird	*Sialia currucoides*				X	Strahlberg analysis
	Mountain Chickadee	*Poecile gambeli*					Strahlberg analysis
X	Mountain Plover	*Charadrius montanus*	X				
	Mourning Dove	*Zenaida macroura*					Strahlberg analysis
X	Mourning Warbler	*Oporornis philadelphia*				X	Strahlberg analysis
	Northern Flicker	*Colaptes auratus*					Strahlberg analysis

	Northern Harrier	*Circus cyaneus*					Strahlberg analysis
X	Northern Shoveler	*Anas clypeata*				X	Strahlberg analysis
	Northern Shrike	*Lanius excubitor*					Strahlberg analysis
	Northern Waterthrush	*Seiurus noveboracensis*					Strahlberg analysis
	Olive-Sided Flycatcher	*Contopus cooperi*					Strahlberg analysis
	Orange-Crowned Warbler	*Vermivora celata*					Strahlberg analysis
	Ovenbird	*Seiurus aurocapillus*					Strahlberg analysis
	Perefgrine Falcon	*Falco peregrinus*	X				
X	Palm Warbler	*Dendroica palmarum*				X	
X	Philadelphia Vireo	*Vireo philadelphicus*				X	Strahlberg analysis
	Pileated Woodpecker	*Dryocopus pileatus*					Strahlberg analysis
	Pine Siskin	*Carduelis pinus*					Strahlberg analysis
X	Piping Plover	*Charadrius melodus*	X				
	Purple Finch	*Carpodacus purpureus*					Strahlberg analysis
X	Red Crossbill	*Loxia curvirostra*				X	Strahlberg analysis
	Red-Breasted Nuthatch	*Sitta canadensis*					Strahlberg analysis
	Red-Eyed Vireo	*Vireo olivaceus*					Strahlberg analysis
X	Red-Necked Grebe	*Podiceps grisegena*				X	
	Red-Tailed Hawk	*Buteo jamaicensis*					Strahlberg analysis
X	Redhead	*Aythya americana*				X	
	Ring-Billed Gull	*Larus delawarensis*					Strahlberg analysis
X	Rose-Breasted Grosbeak	*Pheucticus ludovicianus*				X	Strahlberg analysis
	Ruby-Crowned Kinglet	*Regulus calendula*					Strahlberg analysis

	Ruby-Throated Hummingbird	*Archilochus colubris*					Strahlberg analysis
	Ruffed Grouse	*Bonasa umbellus*					Strahlberg analysis
X	Sandhill Crane	*Grus canadensis*				X	
	Savannah Sparrow	*Passerculus sandwichensis*					Strahlberg analysis
	Say's Phoebe	*Sayornis saya*					Strahlberg analysis
X	Sharp-tailed Grouse	*Tympanuchus phasianellus*			X		Strahlberg analysis
X	Short-eared Owl	*Asio flammeus*					
	Song Sparrow	*Melospiza melodia*					Strahlberg analysis
X	Sprague's Pipit	*Anthus spragueii*			X	X	
	Steller's Jay	*Cyanocitta stelleri*					Strahlberg analysis
	Swainson's Thrush	*Catharus ustulatus*					Strahlberg analysis
X	Tennessee Warbler	*Vermivora peregrina*				X	Strahlberg analysis
	Three-Toed Woodpecker	*Picoides tridactylus*					Strahlberg analysis
	Tree Swallow	*Tachycineta bicolor*					Strahlberg analysis
X	Trumpeter Swan	*Cygnus buccinator*	X				
	Varied Thrush	*Ixoreus naevius*					Strahlberg analysis
	Veery	*Catharus fuscescens*					Strahlberg analysis
	Vesper Sparrow	*Pooecetes gramineus*					Strahlberg analysis
	Warbling Vireo	*Vireo gilvus*					Strahlberg analysis
X	Western Grebe	*Aechmophorus occidentalis*				X	
X	Western Tanager	*Piranga ludoviciana*				X	Strahlberg analysis
	Western Wood Pewee	*Contopus sordidulus*					Strahlberg analysis
	White-Breasted Nuthatch	*Sitta carolinensis*					Strahlberg analysis

	White-Crowned Sparrow	*Zonotrichia leucophrys*					Strahlberg analysis
X	White-Throated Sparrow	*Zonotrichia albicollis*				X	Strahlberg analysis
	White-Winged Crossbill	*Loxia leucoptera*					Strahlberg analysis
X	Whooping Crane	*Grus americana*	X				
X	Wilson's Phalarope	*Phalaropus tricolor*				X	
	Wilson's Warbler	*Wilsonia pusilla*					Strahlberg analysis
X	Winter Wren	*Troglodytes troglodytes*				X	Strahlberg analysis
	Winter Wren	*Troglodytes troglodytes*					Strahlberg analysis
	Yellow Warbler	*Dendroica petechia*					Strahlberg analysis
X	Yellow-Bellied Flycatcher	*Empidonax flaviventris*				X	
X	Yellow-Bellied Sapsucker	*Sphyrapicus varius*				X	
	Yellow-Bellied Sapsucker	*Sphyrapicus varius*					Strahlberg analysis
X	Yellow-Headed Blackbird	*xanthocephalus xanthocephalus*				X	
	Yellow-Rumped Warbler	*Dendroica coronata*					Strahlberg analysis
53							
	Bullsnake	*Pituophis catenifer*					
X	Mountain Short-horned Lizard	*Phrynosoma hernandesi*	X				
	Plains Garter Snake	*Thamnophis radix*					
X	Prairie Rattlesnake	*Crotalus viridis*			X	X	
	Red-sided Garter Snake	*Thamnophis sirtalis*					
X	Wandering Garter Snake	*Thamnophis elegans*				X	
	Western Hognose Snake	*Heterodon nasicus*					
	Western Painted Turtle	*Chrysemys picta*					

	Barred Tiger Salamander	*Ambystoma mavortium*					
	Boreal Chorus Frog	*Pseudacris maculata*					
X	Canadian Toad	*Anaxyrus hemiophrys*				X	
	Columbia Spotted Frog	*Rana luteiventris*					
	Great Plains Toad	*Anaxyrus cognatus*					
	Long-toed Salamander	*Ambystoma macrodactylum*					
X	Northern Leopard Frog	*Lithobates pipiens*	X				
	Plains Spadefoot	*Spea bombifrons*					
X	Western Toad	*Anaxyrus boreas*				X	
	Wood Frog	*Lithobates sylvaticus*					
	Weidemaeyer's Admiral	*Limenitis weidemeyerii*					
	Rocky Mountain dotted blue	*Euphilotes ancilla*					Stolar analysis
	coral hairstreak	*Satyrium titus*					Stolar analysis
	Gillett's checkerspot	*Euphydryas gillettii*					Stolar analysis
	Sheridan's hairstreak	*Callophrys sheridanii*					Stolar analysis
	northern checkerspot	*Chlosyne palla*					Stolar analysis
	Lorquin's Admiral	*Limenitis lorquini*					Stolar analysis
	Hobomok skipper	*Poanes hobomok*					Stolar analysis
	Boisduval's blue	*Icaricia icarioides*					Stolar analysis
	Ruddy copper	*Lycaena rubidus*					Stolar analysis
	northern pearly-eye	*Lethe anthedon*					Stolar analysis
	Pacific fritiallary	*Boloria epithore*					Stolar analysis
	shasta blue	*Plebejus shasta*					Stolar analysis
	Acadian hairstreak	*Satyrium acadica*					Stolar analysis
	Lustrous Copper	*Lycaena cupreus snowi*					Stolar analysis
	Astarte Fritillary	*Boloria astarte*					Stolar analysis
	Little Copper	*Lycaena phlaeas*					Stolar analysis

	Pike's Old World Swallowtail	*Papilio machaon pikei*					Stolar analysis
	Woodland Skipper	*Ochlodes sylvanoides*					Stolar analysis
X	Banff Springs Snail	*Physella johnsoni*	X				
	Balsam Fir	*Abies balsamea*					Strahlberg analysis
	Subalpine Fir	*Abies bifolia*					Strahlberg analysis
	Red and White Baneberry	*Actaea rubra*					Strahlberg analysis
	Mill Creek agoseris	*Agoseris lackschewitzii*					Stolar analysis
	spike redtop	*Agrostis exarata*					Stolar analysis
	alpine bentgrass	*Agrostis humilis*					Stolar analysis
	Geyer's onion	*Allium geyeri*					Stolar analysis
	few-flowered aster	*Almutaster pauciflorus*					Stolar analysis
	Speckled Alder	*Alnus incana*					Strahlberg analysis
	Green Alder	*Alnus viridis*					Strahlberg analysis
	alpine foXtail	*Alopecurus alpinus*					Stolar analysis
	bur ragweed	*Ambrosia acanthicarpa*					Stolar analysis
	Saskatoon	*Amelanchier alnifolia*					Strahlberg analysis
	chaffweed	*Anagallis minima*					Stolar analysis
	scented pussytoes	*Antennaria aromatica*					Stolar analysis
	one-headed everlasting	*Antennaria monocephala ssp. angustata*					Stolar analysis
	Sitka columbine	*Aquilegia formosa*					Stolar analysis
	Jones' columbine	*Aquilegia jonesii*					Stolar analysis
	Lemmon's rock cress	*Arabis lemmonii*					Stolar analysis
	wideleaf polargrass	*Arctagrostis arundinacea*					Stolar analysis
	Common Bearberry	*Arctostaphylos uva-ursi*					Strahlberg analysis

	Fendler threeawn	*Aristida purpurea var. longiseta*					Stolar analysis
	clasping arnica	*Arnica amplexicaulis*					Stolar analysis
	spearleaf arnica	*Arnica longifolia*					Stolar analysis
	Parry's arnica	*Arnica parryi*					Stolar analysis
	Plains Wormwood	*Artemisia campestris*					Strahlberg analysis
	Silver Sagebrush	*Artemisia cana*					Strahlberg analysis
	Pasture Sagewort	*Artemisia frigida*					Strahlberg analysis
	Longleaf Wormwood	*Artemisia longifolia*					Strahlberg analysis
	Prairie Sagewort	*Artemisia ludoviciana*					Strahlberg analysis
	Herriot's sagewort	*Artemisia tilesii*					Stolar analysis
	big sagebrush	*Artemisia tridentata*					Stolar analysis
	green comet milkweed	*Asclepias viridiflora*					Stolar analysis
	meadow aster	*Aster campestris*					Stolar analysis
	Eaton's aster	*Aster eatonii*					Stolar analysis
	flat-topped white aster	*Aster umbellatus*					Stolar analysis
	spiny milkvetch	*Astragalus kentrophyta var. kentrophyta*					Stolar analysis
	low milk vetch	*Astragalus lotiflorus*					Stolar analysis
X	Pursh's milk vetch/woolypod milkvetch	*Astragalus purshii*				X	Stolar analysis
	fourwing saltbush	*Atriplex canescens*					Stolar analysis
	Powell's saltweed	*Atriplex powellii*					Stolar analysis
	American winter cress	*Barbarea orthoceras*					Stolar analysis
	Bog Birch	*Betula glandulosa*					Strahlberg analysis
	Alaska Birch	*Betula neoalaskana*					Strahlberg analysis
	Water Birch	*Betula occidentalis*					Strahlberg analysis
	Paper Birch	*Betula papyrifera*					Strahlberg analysis
	Dwarf Birch	*Betula pumila*					Strahlberg analysis

	beggartick	*Bidens frondosa*					Stolar analysis
	smooth boisduvalia	*Boisduvalia glabella*					Stolar analysis
	ascending grape fern	*Botrychium ascendens*					Stolar analysis
	western moonwort	*Botrychium hesperium*					Stolar analysis
	lance-leaved grape fern	*Botrychium lanceolatum*					Stolar analysis
	grapefern	*Botrychium michiganense*					Stolar analysis
	Mingan grape fern	*Botrychium minganense*					Stolar analysis
	leathery grapefern	*Botrychium multifidum var. intermedium*					Stolar analysis
	pale botrychium	*Botrychium pallidum*					Stolar analysis
	northwestern moonwort	*Botrychium pinnatum*					Stolar analysis
	little grapefern	*Botrychium simplex*					Stolar analysis
	Spathulate botrychium	*Botrychium spathulatum*					Stolar analysis
	telesoniX	*Boykinia heucheriformis*					Stolar analysis
	smooth northern-rockcress	*Braya purpurascens*					Stolar analysis
	tasselflower brickellbush	*Brickellia grandiflora*					Stolar analysis
	woodland brome	*Bromus vulgaris*					Stolar analysis
	shrubby evening-primrose	*Calylophus serrulatus*					Stolar analysis
	blue camas	*Camassia quamash var. quamash*					Stolar analysis
	alpine harebell	*Campanula uniflora*					Stolar analysis
	alpine bitter cress	*Cardamine bellidifolia*					Stolar analysis
	mountain cress	*Cardamine oligosperma var. kamtschatica*					Stolar analysis
	meadow bitter cress	*Cardamine pratensis*					Stolar analysis
	lesser brown sedge	*Carex adusta*					Stolar analysis
X	Back's sedge	*Carex backii*				X	Stolar analysis
	capitate sedge	*Carex capitata*					Stolar analysis
	Crawe's sedge	*Carex crawei*					Stolar analysis
	glacial sedge	*Carex glacialis*					Stolar analysis
	Hudson Bay sedge	*Carex heleonastes*					Stolar analysis
	Hooker's sedge	*Carex hookeriana*					Stolar analysis
	sand sedge	*Carex houghtoniana*					Stolar analysis
	coastal sand sedge	*Carex incurviformis var. incurviformis*					Stolar analysis

	two-parted sedge	*Carex lachenalii*					Stolar analysis
	lakeshore sedge	*Carex lacustris*					Stolar analysis
	Enander's sedge	*Carex lenticularis var. dolia*					Stolar analysis
	Mertens' sedge	*Carex mertensii*					Stolar analysis
	shortleaved sedge	*Carex misandra*					Stolar analysis
	Nebraska sedge	*Carex nebrascensis*					Stolar analysis
	few-fruited sedge	*Carex oligosperma*					Stolar analysis
	Parry's sedge	*Carex parryana var. parryana*					Stolar analysis
	Payson's sedge	*Carex paysonis*					Stolar analysis
	Liddon sedge	*Carex petasata*					Stolar analysis
	stone sedge	*Carex petricosa*					Stolar analysis
	alpine sedge	*Carex podocarpa*					Stolar analysis
	Presl's sedge	*Carex preslii*					Stolar analysis
	cyperus-like sedge	*Carex pseudocyperus*					Stolar analysis
	turned sedge	*Carex retrorsa*					Stolar analysis
	beaked sedge	*Carex rostrata*					Stolar analysis
	umbellate sedge	*Carex umbellata*					Stolar analysis
	foX sedge	*Carex vulpinoidea*					Stolar analysis
	yellow paintbrush	*Castilleja cusickii*					Stolar analysis
	stiff yellow paintbrush	*Castilleja lutescens*					Stolar analysis
	shortstalk chickweed	*Cerastium brachypodum*					Stolar analysis
	Leatherleaf	*Chamaedaphne calyculata*					Strahlberg analysis
	aridland goosefoot	*Chenopodium desiccatum*					Stolar analysis
	narrow-leaved goosefoot	*Chenopodium leptophyllum*					Stolar analysis
	smooth goosefoot	*Chenopodium subglabrum*					Stolar analysis
	Watson's goosefoot	*Chenopodium watsonii*					Stolar analysis
	golden saXifrage	*Chrysosplenium iowense*					Stolar analysis
	green saXifrage	*Chrysosplenium tetrandrum*					Stolar analysis
	meadow thistle	*Cirsium scariosum*					Stolar analysis
	Williams' miterwort	*Conimitella williamsii*					Stolar analysis
	common tickseed	*Coreopsis tinctoria*					Stolar analysis

	Beaked Hazelnut	*Corylus cornuta*					Strahlberg analysis
	slender hawksbeard	*Crepis atribarba*					Stolar analysis
	limestone hawksbeard	*Crepis intermedia*					Stolar analysis
	small-flowered hawk's-beard	*Crepis occidentalis*					Stolar analysis
	Kelsey's cat's eye	*Cryptantha kelseyana*					Stolar analysis
X	Tiny Cryptanthe	*Cryptantha minima*	X				Stolar analysis
	fragile rockbrake	*Cryptogramma stelleri*					Stolar analysis
	wild comfrey	*Cynoglossum virginianum var. boreale*					Stolar analysis
	sand nut-grass	*Cyperus schweinitzii*					Stolar analysis
	stemless lady's-slipper	*Cypripedium acaule*					Stolar analysis
	mountain lady's-slipper	*Cypripedium montanum*					Stolar analysis
	mountain bladderfern	*Cystopteris montana*					Stolar analysis
	poverty oat grass	*Danthonia spicata*					Stolar analysis
	slender hairgrass	*Deschampsia elongata*					Stolar analysis
	Sitka clubmoss	*Diphasiastrum sitchense*					Stolar analysis
	Great Basin calicoflower	*Downingia laeta*					Stolar analysis
	whitlow-grass	*Draba juvenilis*					Stolar analysis
	Macoun's whitlow-grass	*Draba macounii*					Stolar analysis
	Porsild's whitlow-grass	*Draba porsildii*					Stolar analysis
	Carolina draba	*Draba reptans*					Stolar analysis
	whitlow-grass	*Draba ventosa*					Stolar analysis
	slender-leaved sundew	*Drosera linearis*					Stolar analysis
	male fern	*Dryopteris filix-mas*					Stolar analysis
	Silverberry	*Elaeagnus commutata*					Strahlberg analysis
	elliptic spikerush	*Eleocharis elliptica*					Stolar analysis
	Aunt Lucy	*Ellisia nyctelea*					Stolar analysis
	twoleaf waterweed	*Elodea bifoliata*					Stolar analysis
	spreading wheatgrass	*Elymus scribneri*					Stolar analysis
	Virginia wildrye	*Elymus virginicus*					Stolar analysis
	talus willowherb	*Epilobium clavatum*					Stolar analysis
X	Glaucous willowherb	*Epilobium glaberrimum*				X	High

							Responsibility
	willowherb	*Epilobium lactiflorum*					Stolar analysis
	pale fleabane	*Erigeron pallens*					Stolar analysis
	taproot fleabane	*Erigeron radicatus*					Stolar analysis
	trifid-leaved fleabane	*Erigeron trifidus*					Stolar analysis
	nodding umbrella-plant	*Eriogonum cernuum*					Stolar analysis
	arctic cottongrass	*Eriophorum callitrix*					Stolar analysis
	spotted trumpetweed	*Eupatorium maculatum*					Stolar analysis
	northern rough fescue	*Festuca altaica*					Stolar analysis
X	Rough fescue	*Festuca campestris*				X	High Responsibility
	smallflower fescue	*Festuca minutiflora*					Stolar analysis
	western fescue	*Festuca occidentalis*					Stolar analysis
	Rainier pleated gentian	*Gentiana calycosa*					Stolar analysis
	moss gentian	*Gentiana fremontii*					Stolar analysis
	fowl mannagrass	*Glyceria elata*					Stolar analysis
	clammy hedge-hyssop	*Gratiola neglecta*					Stolar analysis
	Gumweed	*Grindelia squarrosa*					Strahlberg analysis
	Broomweed	*Gutierrezia sarothrae*					Strahlberg analysis
	Pacific oakfern	*Gymnocarpium disjunctum*					Stolar analysis
X	Slender Mouse-ear-cress	*Halimolobos virgata*	X				
	long-leaved bluets	*Hedyotis longifolia*					Stolar analysis
	salt heliotrope	*Heliotropium curassavicum*					Stolar analysis
	woolly hawkweed	*Hieracium cynoglossoides*					Stolar analysis
	alpine sweet grass	*Hierochloe alpina*					Stolar analysis
	Pacific clubmoss	*Huperzia haleakalae*					Stolar analysis
	fir clubmoss	*Huperzia selago*					Stolar analysis
	woollen-breeches	*Hydrophyllum capitatum*					Stolar analysis
	tufted hymenopappus	*Hymenopappus filifolius*					Stolar analysis
	large Canada St. John's-wort	*Hypericum majus*					Stolar analysis
	Scouler's St. Johnsonwort	*Hypericum scouleri ssp. scouleri*					Stolar analysis

	streambank wild hollyhock	*Iliamna rivularis*					Stolar analysis
	Western Blue Flag	*Iris missouriensis*					Stolar analysis
	spiny-spore quillwort	*Isoetes echinospora*					Stolar analysis
	two-glumed rush	*Juncus biglumis*					Stolar analysis
	narrowpanicle rush	*Juncus brevicaudatus*					Stolar analysis
	few-flowered rush	*Juncus confusus*					Stolar analysis
	thread rush	*Juncus filiformis*					Stolar analysis
	Parry's rush	*Juncus parryi*					Stolar analysis
	moor rush	*Juncus stygius var. americanus*					Stolar analysis
	island purslane	*Koenigia islandica*					Stolar analysis
	tall blue lettuce	*Lactuca biennis*					Stolar analysis
	Tamarack	*Larix laricina*					Strahlberg analysis
	western larch	*Larix occidentalis*					Stolar analysis
	Common Pepper-grass	*Lepidium densiflorum*					Strahlberg analysis
	arctic bladderpod	*Lesquerella arctica var. purshii*					Stolar analysis
	alpine lewisia	*Lewisia pygmaea var. pygmaea*					Stolar analysis
	American dunegrass	*Leymus mollis*					Stolar analysis
	awl-leaf lilaea	*Lilaea scilloides*					Stolar analysis
	northern lianthus	*Linanthus septentrionalis*					Stolar analysis
	northwestern twayblade	*Listera caurina*					Stolar analysis
	broadlipped twayblade	*Listera convallarioides*					Stolar analysis
	bulbous woodland star	*Lithophragma glabrum*					Stolar analysis
	smallflower woodland-star	*Lithophragma parviflorum*					Stolar analysis
	alpine azalea	*Loiseleuria procumbens*					Stolar analysis
	biscuit-root	*Lomatium cous*					Stolar analysis
	marsh felwort	*Lomatogonium rotatum*					Stolar analysis
	Fly Honeysuckle	*Lonicera caerulea*					Strahlberg analysis
	Twining Honeysuckle	*Lonicera dioica*					Strahlberg analysis
	Bracted Honeysuckle	*Lonicera involucrata*					Strahlberg analysis

	Kettle Falls lupine	*Lupinus minimus*					Stolar analysis
	hairy woodrush	*Luzula acuminata*					Stolar analysis
	inundated clubmoss	*Lycopodiella inundata*					Stolar analysis
	American water-horehound	*Lycopus americanus*					Stolar analysis
	lowland yellow loosestrife	*Lysimachia hybrida*					Stolar analysis
	white adder's-mouth	*Malaxis monophylla*					Stolar analysis
	bog adder's-mouth orchid	*Malaxis paludosa*					Stolar analysis
	hairy waterclover	*Marsilea vestita*					Stolar analysis
	Smith's melicgrass	*Melica smithii*					Stolar analysis
	purple oniongrass	*Melica spectabilis*					Stolar analysis
	prairie bluebells	*Mertensia lanceolata*					Stolar analysis
	large-flowered lungwort	*Mertensia longiflora*					Stolar analysis
	nodding microseris	*Microseris nutans*					Stolar analysis
	manyflowered monkeyflower	*Mimulus floribundus*					Stolar analysis
	yellow monkeyflower	*Mimulus guttatus*					Stolar analysis
	elegant stitchwort	*Minuartia elegans*					Stolar analysis
	pinesap	*Monotropa hypopithys*					Stolar analysis
	narrowleaf minerslettuce	*Montia linearis*					Stolar analysis
	scratch grass	*Muhlenbergia asperifolia*					Stolar analysis
	marsh muhly	*Muhlenbergia racemosa*					Stolar analysis
	false buffalograss	*Munroa squarrosa*					Stolar analysis
	nodding waternymph	*Najas flexilis*					Stolar analysis
	small baby-blue-eyes	*Nemophila breviflora*					Stolar analysis
	prairie false dandelion	*Nothocalais cuspidata*					Stolar analysis
	Leiberg's waterlily	*Nymphaea leibergii*					Stolar analysis
	pygmy waterlily	*Nymphaea tetragona*					Stolar analysis
	low yellow evening-primrose	*Oenothera flava*					Stolar analysis
	western false gromwell	*Onosmodium molle*					Stolar analysis
	Louisiana broom-rape	*Orobanche ludoviciana*					Stolar analysis
	one-flowered cancer-root	*Orobanche uniflora*					Stolar analysis
	little ricegrass	*Oryzopsis exigua*					Stolar analysis

	little-seed rice grass	*Oryzopsis micrantha*					Stolar analysis
	smooth sweet cicely	*Osmorhiza longistylis*					Stolar analysis
	purple sweet cicely	*Osmorhiza purpurea*					Stolar analysis
	Davis locoweed	*Oxytropis campestris var. davisii*					Stolar analysis
	haresfoot locoweed	*Oxytropis lagopus var. conjugans*					Stolar analysis
	northwestern groundsel	*Packera contermina*					Stolar analysis
	ragwort	*Packera subnuda*					Stolar analysis
	tapered rosette grass	*Panicum acuminatum*					Stolar analysis
	alpine poppy	*Papaver pygmaeum*					Stolar analysis
	rooted poppy	*Papaver radicatum ssp. kluanense*					Stolar analysis
	American pellitory	*Parietaria pensylvanica*					Stolar analysis
	small northern grass-of-parnassus	*Parnassia parviflora*					Stolar analysis
	large-flowered lousewort	*Pedicularis capitata*					Stolar analysis
	flame-colored lousewort	*Pedicularis flammea*					Stolar analysis
	woolly lousewort	*Pedicularis lanata*					Stolar analysis
	arctic lousewort	*Pedicularis langsdorfii ssp. arctica*					Stolar analysis
	Gaston's cliff brake	*Pellaea gastonyi*					Stolar analysis
	smooth cliff brake	*Pellaea glabella*					Stolar analysis
	western dwarf cliffbrake	*Pellaea glabella ssp. occidentalis*					Stolar analysis
	smooth cliffbrake	*Pellaea glabella ssp. simplex*					Stolar analysis
	shrubby beardtongue	*Penstemon fruticosus var. scouleri*					Stolar analysis
	linear-leaved scorpionweed	*Phacelia linearis*					Stolar analysis
	alpine phacelia	*Phacelia lyallii*					Stolar analysis
	long beechfern	*Phegopteris connectilis*					Stolar analysis
	slender phloX	*Phlox gracilis ssp. gracilis*					Stolar analysis
	false dragonhead	*Physostegia ledinghamii*					Stolar analysis
	Engelmann Spruce	*Picea engelmannii*					Strahlberg analysis
	White Spruce	*Picea glauca*					Strahlberg analysis
	Black Spruce	*Picea mariana*					Strahlberg analysis
	small butterwort	*Pinguicula villosa*					Stolar analysis

X	Whitebark Pine	*Pinus albicaulis*					Stolar analysis
	Jack Pine	*Pinus banksiana*					Strahlberg analysis
	Lodgepole Pine	*Pinus contorta*					Strahlberg analysis
X	Limber Pine	*Pinus flexilis*					Stolar analysis
	western ribgrass	*Plantago canescens*					Stolar analysis
	slender bog orchid	*Platanthera stricta*					Stolar analysis
	Sandberg bluegrass	*Poa gracillima*					Stolar analysis
	Letterman's bluegrass	*Poa lettermanii*					Stolar analysis
	Sandberg bluegrass	*Poa nevadensis*					Stolar analysis
	northern bluegrass	*Poa stenantha*					Stolar analysis
	clammyweed	*Polanisia dodecandra*					Stolar analysis
	gaywings	*Polygala paucifolia*					Stolar analysis
	broadleaf knotweed	*Polygonum minimum*					Stolar analysis
	Watson's knotweed	*Polygonum polygaloides ssp. confertiflorum*					Stolar analysis
	western polypody	*Polypodium hesperium*					Stolar analysis
	Siberian polypody, western polypody	*Polypodium sibiricum*					Stolar analysis
	Balsam Poplar	*Populus balsamifera*					Strahlberg analysis
	Trembling Aspen	*Populus tremuloides*					Strahlberg analysis
	leafy pondweed	*Potamogeton foliosus*					Stolar analysis
	floating-leaf pondweed	*Potamogeton natans*					Stolar analysis
	bluntleaf pondweed	*Potamogeton obtusifolius*					Stolar analysis
	white-stem pondweed	*Potamogeton praelongus*					Stolar analysis
	narrowleaf pondweed	*Potamogeton strictifolius*					Stolar analysis
	Drummond's cinquefoil	*Potentilla drummondii*					Stolar analysis
	sandhills cinquefoil	*Potentilla finitima*					Stolar analysis
	Hooker's cinquefoil	*Potentilla hookeriana*					Stolar analysis
	staghorn cinquefoil	*Potentilla multifida*					Stolar analysis
	featherleaf cinquefoil	*Potentilla multisecta*					Stolar analysis
	bushy cinquefoil	*Potentilla paradoxa*					Stolar analysis

	hairy cinquefoil	*Potentilla villosa*					Stolar analysis
	arrowleaf rattlesnakeroot	*Prenanthes sagittata*					Stolar analysis
	Greenland primrose	*Primula egaliksensis*					Stolar analysis
	Pin Cherry	*Prunus pensylvanica*					Strahlberg analysis
	Choke Cherry	*Prunus virginiana*					Strahlberg analysis
	dwarf woollyheads	*Psilocarphus brevissimus var. brevissimus*					Stolar analysis
	Arctic wintergreen	*Pyrola grandiflora*					Stolar analysis
	early buttercup	*Ranunculus glaberrimus*					Stolar analysis
	western buttercup	*Ranunculus occidentalis var. brevistylis*					Stolar analysis
	hairy buttercup	*Ranunculus uncinatus*					Stolar analysis
	Bog Labrador Tea	*Rhododendron groenlandicum*					Strahlberg analysis
	Lapland rosebay	*Rhododendron lapponicum*					Stolar analysis
	Wild Black Currant	*Ribes americanum*					Strahlberg analysis
	Skunk Currant	*Ribes glandulosum*					Strahlberg analysis
	Wild Gooseberry	*Ribes hirtellum*					Strahlberg analysis
	Northern Black Currant	*Ribes hudsonianum*					Strahlberg analysis
	Whitestem Gooseberry	*Ribes inerme*					Strahlberg analysis
	Bristly Black Currant	*Ribes lacustre*					Strahlberg analysis
	trailing black currant	*Ribes laxiflorum*					Stolar analysis
	Northern Gooseberry	*Ribes oxyacanthoides*					Strahlberg analysis
	Wild Red Currant	*Ribes triste*					Strahlberg analysis
	Sitka mistmaiden	*Romanzoffia sitchensis*					Stolar analysis
	bluntleaf yellowcress	*Rorippa curvipes*					Stolar analysis
	bluntleaf yellowcress	*Rorippa curvipes var. truncata*					Stolar analysis
	Modoc yellowcress	*Rorippa tenerrima*					Stolar analysis
	Prickly Rose	*Rosa acicularis*					Strahlberg analysis

	Prairie Rose	*Rosa arkansana*					Strahlberg analysis
	Common Wild Rose	*Rosa woodsii*					Strahlberg analysis
	Dwarf Raspberry	*Rubus arcticus*					Strahlberg analysis
	Cloudberry	*Rubus chamaemorus*					Strahlberg analysis
	Wild Red Raspberry	*Rubus idaeus*					Strahlberg analysis
	Dwarf Bramble	*Rubus pedatus*					Strahlberg analysis
	Dewberry	*Rubus pubescens*					Strahlberg analysis
	spiral ditchgrass	*Ruppia cirrhosa*					Stolar analysis
	knotted pearlwort	*Sagina nodosa*					Stolar analysis
	broadleaf arrowhead	*Sagittaria latifolia*					Stolar analysis
	Alaska willow	*Salix alaxensis var. alaxensis*					Stolar analysis
	Shrubby Willow	*Salix arbusculoides*					Strahlberg analysis
	Athabasca Willow	*Salix athabascensis*					Strahlberg analysis
	Beaked Willow	*Salix bebbiana*					Strahlberg analysis
	Hoary Willow	*Salix candida*					Strahlberg analysis
	undergreen willow	*Salix commutata*					Stolar analysis
	Pussy Willow	*Salix discolor*					Strahlberg analysis
	Smooth Willow	*Salix glauca*					Strahlberg analysis
	wolly willow	*Salix lanata ssp. calcicola*					Stolar analysis
	Velvet-fruited Willow	*Salix maccalliana*					Strahlberg analysis
	Myrtle-leaved Willow	*Salix myrtillifolia*					Strahlberg analysis
	Bog Willow	*Salix pedicellaris*					Strahlberg analysis
	Basket Willow	*Salix petiolaris*					Strahlberg analysis

	Flat-leaved Willow	*Salix planifolia*					Strahlberg analysis
	False Mountain Willow	*Salix pseudomonticola*					Strahlberg analysis
	Firmleaf Willow	*Salix pseudomyrsinites*					Strahlberg analysis
	Balsam Willow	*Salix pyrifolia*					Strahlberg analysis
	Scouler's Willow	*Salix scouleriana*					Strahlberg analysis
X	Purple pitcher plant	*Sarracenia purpurea*				X	Stolar analysis
	saXifrage	*Saxifraga ferruginea*					Stolar analysis
	whiplash saXifrage	*Saxifraga flagellaris ssp. setigera*					Stolar analysis
	Nelson's saXifrage	*Saxifraga nelsoniana ssp. Porsildiana*					Stolar analysis
	alpine saXifrage	*Saxifraga nivalis*					Stolar analysis
	brook saXifrage	*Saxifraga odontoloma*					Stolar analysis
	Small-fruited Bulrush	*Scirpus microcarpus*					Strahlberg analysis
	Pacific stonecrop	*Sedum divergens*					Stolar analysis
	Silver Buffaloberry	*Shepherdia argentea*					Strahlberg analysis
	Canada Buffaloberry	*Shepherdia canadensis*					Strahlberg analysis
	annual skeletonweed	*Shinnersoseris rostrata*					Stolar analysis
	arctic catchfly	*Silene involucrata*					Stolar analysis
	pale blue-eyed grass	*Sisyrinchium septentrionale*					Stolar analysis
	Western Mountain-ash	*Sorbus scopulina*					Strahlberg analysis
	northern bur-reed	*Sparganium hyperboreum*					Stolar analysis
	prairie cordgrass	*Spartina pectinata*					Stolar analysis
	salt-marsh sand spurry	*Spergularia salina*					Stolar analysis
	prairie wedge grass	*Sphenopholis obtusata*					Stolar analysis
	northern slender lady's tresses	*Spiranthes lacera*					Stolar analysis
	longstalk starwort	*Stellaria arenicola*					Stolar analysis
X	Curled Starwort	*Stellaria crispa*				X	Stolar analysis
	rush-pink	*Stephanomeria runcinata*					Stolar analysis

	Moquin's sea-blite	*Suaeda moquinii*					Stolar analysis
	poison suckleya	*Suckleya suckleyana*					Stolar analysis
	buttercup suksdorfia	*Suksdorfia ranunculifolia*					Stolar analysis
	Indian tansy	*Tanacetum bipinnatum ssp. huronense*					Stolar analysis
	western redcedar	*Thuja plicata*					Stolar analysis
	cushion Townsend daisy	*Townsendia condensata*					Stolar analysis
	stemless Townsend daisy	*Townsendia exscapa*					Stolar analysis
X	Western Spiderwort	*Tradescantia occidentalis*	X				
	Clinton's bulrush	*Trichophorum clintonii*					Stolar analysis
	dwarf bulrush	*Trichophorum pumilum*					Stolar analysis
X	Small-flowered Sand Verbena	*Tripterocalyx micranthus*	X				Stolar analysis
	tall trisetum	*Trisetum cernuum*					Stolar analysis
	Common Cattail	*Typha latifolia*					Strahlberg analysis
	Common Nettle	*Urtica dioica*					Strahlberg analysis
	Dwarf Bilberry	*Vaccinium caespitosum*					Strahlberg analysis
	Tall Bilberry	*Vaccinium membranaceum*					Strahlberg analysis
	Common Blueberry	*Vaccinium myrtilloides*					Strahlberg analysis
	oval-leaf blueberry	*Vaccinium ovalifolium*					Stolar analysis
	Small Cranberry	*Vaccinium oxycoccos*					Strahlberg analysis
X	Bog Bilberry	*Vaccinium uliginosum*				X	Stolar analysis
	Bog Cranberry	*Vaccinium vitis-idaea*					Strahlberg analysis
	water speedwell	*Veronica catenata*					Stolar analysis
	Low-bush Cranberry	*Viburnum edule*					Strahlberg analysis
	Macloskey's violet	*Viola pallens*					Stolar analysis
	prairie violet	*Viola pedatifida*					Stolar analysis
	upland yellow violet	*Viola praemorsa ssp. linguifolia*					Stolar analysis
	Columbian watermeal	*Wolffia columbiana*					Stolar analysis

	smooth woodsia	*Woodsia glabella*					Stolar analysis
	Soapweed	*Yucca glauca*	X				
X	Porsild's Bryum	*Mielichhoferia macrocarpa (Bryum porsildii)*	X				
X	Powder-rimmed camouflage lichen	*Melanelia albertana*				X	
X	None?	*Melanelixia subaurifera*				X	
X	None?	*Peltigera kristinssonii*				X	
	alsike clover	*Trifolium hybridum*					
	annual sow-thistle	*Sonchus asper*					
	baby's breath	*Gypsophyla paniculata*					
	blueweed	*Echium vulgare*					
	bull thistle	*Cirsium vulgare*					
	cicer milkvetch	*Astragalus cider*					
	Cinquefoil, Sulphur	*Potentilla recta*					
	common burdock	*Arctium minus*					
X	Common crupina	*Crupina vulgaris*			X		Potential threat
	common mullein	*Verbascum thapsus*					
X	common tansy	*Tanacetum vulgare*		X			
X	creeping thistle (Canada thistle)	*Cirsium arvense*		X			
X	crested wheatgrass	*Agropyron pectiniforme*		X			
	dalmation toadflaX	*Linaria dalmatica*					
	downy brome	*Bromus tectorum*					
	field scabious (blue buttons)	*Knautia arvensis*					
X	Garlic Mustard	*Alliaria petiolata*			X		Potential threat
	Himalayan balsam	*Impatiens glandulifera*					
	hound's tongue	*Cynoglossum officinale*					
	japanese knotweed	*Fallopia japonica*					

X	Kentucky bluegrass	*Poa pratensis*		X	X		
	Knapweed, Russian	*Acroptilon repens*					
	leafy spurge	*Euphorbia esula*					
	meadow hawkweed	*Hieracium caespitosum*					
	mouse-ear hawkweed	*Hieracium pilosella*					
	nodding thistle	*Carduus nutans*					
	orange hawkweed	*Hieracium aurantiacum*					
X	oXeye daisy	*Leucanthemum vulgare*		X			
	perennial sow thistle	*Sonchus arvensis*					
	pineapple weed	*Matricaria discoidea*					
	purple loosestrife	*Lythrum salicaria*					
	salt cedar	*Tamarix ramosissima*					Potential threat
	scentless chamomile	*Tripleurospermum inodorum*					
X	Smooth brome	*Bromus inermis*		X			
	spotted knapweed	*Centaurea maculosa*					
	St John's-wort, common	*Hypericum perforatum*					
X	Tall buttercup	*Ranunculus acris*		X			
	tall hawkweed	*Hieracium piloselloides*					
X	Timothy	*Phleum pratense*		X			
	white cockle	*Silene latifolia*					
X	white sweet-clover	*Melilotus alba*		X			
	wild caraway	*Carum carvi*					
	Yellow star-thistle	*Centaurea solstitialis*					Potential threat
	yellow sweet-clover	*Melilotus officinalis*					
	yellow toadflaX	*Linaria vulgaris*					
X	Swine	*Sus scrofa*		X	X		
X	Norway Rat	*Rattus norvegecus*		X	X		
X	Black (Roof) Rat	*Rattus rattus*		X	X		
X	European Starling	*Sturnus vlugaris*		X			
X	House Sparrow	*Passer domesticus*		X			
	Brown longhorn beetle	*Tetropium fuscum*					Potential threat

	Asian longhorn beetle	*Anoplophora glabripennis*					Potential threat
	Larger European shoot beetle	*Tomicus piniperda*					
	Asian gypsy moth	*Lymantria dispar*					Potential threat
	Mountain pine beetle	*Dendroctonus ponderosae*					
X	Seven-spotted lady beetle	*Coccinella septempunctata*		X			
	Larger European pine shoot beetle	*Tomicus piniperda*					Potential threat
	European skipper	*Thymelicus lineola*					Stolar analysis

NUMBER OF SPECIES	***647***
Priority Species	**119**
At Risk Species	***22***
Mammals	***26***
Birds	***141***
Reptiles	***8***
Amphibians	***10***
Invertebrates	***19***
Vascular Plants	***393***
Non-vascular Plants	***4***
Alien/invasives	***58***