Assessing climate change vulnerability and adaptation in the Great Basin: a policy perspective on resource managers and the use of science in decision-making. Final Report.

1. ADMINISTRATIVE

Dr. Eric Lindquist, Director, Public Policy Research Center,
Boise State University, 1910 University Dr, Boise, ID 83725-1036
ericlindquist@boisestate.edu 208-426-370

Title: Assessing climate change vulnerability and adaptation in the Great Basin: a policy perspective on resource managers and the use of science in decision making.

USGS Agreement number: G14AP00097 (OSU Subgrant No. GS291A-A)
Report date: November, 2016
Time period covered by report: 07/01/2014 – 06/30/2016

2. PUBLIC SUMMARY

The availability and use of climate science for decision-making involves a complex dynamic between science provider and potential user. Significant research has been conducted on the use of science in decision making, in general, and more recently on the use of such tools as vulnerability assessments (VAs), integrated assessments, and ecological and ecosystems assessments, in decision making. Findings have shown that significant barriers and constraints are in place for the integration of climate science into traditional institutional methods of decision making or planning (Leonard, et al 2008; Lindquist 2010, 2011). This research focused on the Great Basin region of the western United States (represented institutionally by the Great Basin Landscape Conservation Cooperative - GBLCC) to develop a comprehensive understanding of the use of climate science in the region, the availability and utility of vulnerability assessment for decision makers, and the science and information gaps that continue to exist for intended users. Through the development of a comprehensive literature review and an on-line survey of Great Basin related stakeholders and decision makers, research suggests that vulnerability assessments (VAs) as a general decision tool are not well understood, accepted or applied in the decision context in the Great Basin study area. The significant number of VAs available and the lack of awareness of these tools, as well as competition among decision tools in general contribute to this situation. Considering this situation, however, the utility of VAs in general, for natural resource decision making has yet to be fully explored. The rapidly moving pace of VA development, changing demands on natural resources decision makers, and a general lack of funding for decision tools creates an opportunity for further assessment of VAs in support of climate change adaptation and vulnerability in the Great Basin and beyond.

3. TECHNICAL SUMMARY

The goals of the original research project were to conduct a comprehensive assessment of the use of VAs in the Great Basin, the utility of the VAs to decision makers and stakeholders, and a greater understanding of the knowledge gaps in regard to the use of climate science in decision making in the region. Various products were proposed including annual and final reports, a literature review, and data sets from interviews and surveys, and scientific (disciplinary and interdisciplinary) publications. This report (draft) serves as the final report for the project. Survey data will be made available pending appropriate respondent identifier scrubbing and aggregation. There were not enough successful in depth interviews to warrant assessment and analysis, unfortunately. Scientific publications from the literature review and survey are in process.

A workshop was also proposed on the human dimension of vulnerability assessments and the role of social and policy sciences in the Great Basin. During the course of the project it was determined to conduct an extended session (invited) at the 2016 Great Basin Consortium S*agebrush Ecosystem Conservation: All Lands, All Hands* conference in Salt Lake City. The workshop was sparsely attended and attendees, in general, were either unfamiliar with the concept of VAs, or were hesitant to engage.

In spite of the problems with the workshop and the interviews, the project did accomplish much of the proposed research made possible by the NWCSC funding. We have a better understanding of the difficulties associated with the concept of the VA in the context of western US resource management and decision-making and have a firm foundation for future research which can address the pitfalls and problems experienced in this project. As such, the project does contribute to the advancement of scientific knowledge regionally and/or nationally.

4. PURPOSE AND OBJECTIVES

The availability and use of climate science for decision-making involves a complex dynamic between science provider and potential user. Significant research has been conducted on the use of science in decision making, in general, and more recently on the use of such tools as vulnerability assessments (VAs), integrated assessments, and ecological and ecosystems assessments, in decision making. Findings have shown that significant barriers and constraints are in place for the integration of climate science into traditional institutional methods of decision making or planning (Leonard, et al 2008; Lindquist 2010, 2011). The research proposed here will focus on the Great Basin region of the Western United States (represented institutionally by the Great Basin Landscape Conservation Cooperative - GBLCC) to develop a comprehensive understanding of the use of climate science in the region, the availability and utility of vulnerability assessment for decision makers, and the science and information gaps that continue to exist for intended users. The contentious issue of the use of public lands and grazing in the Great Basin is currently attracting attention from the general public and media and is on the policy agenda for decision makers and resource managers in the region. This context provides a unique opportunity to apply a social and policy science perspective on the use and understanding of science in this region in regard to climate change and non-climate change stressors. This proposal directly addressed the Northwest Climate Science Center Agenda Theme 4: Vulnerability and Adaptation, as well as the broader Climate Science Center objectives of "Collaboration, Communication and Translation of Science Results to Managers, Stakeholders and the Public interested in Climate Change Activity."

While integrated assessments of ecological vulnerabilities have been is use for decades, vulnerability assessments have evolved in recent years (Fussel and Klein 2006, Rothman and Robinson 1997). In addition, it has been only recently that VA development has integrated political and human dimensions (Fussel 2004, 2007). Contributing factors include an increased awareness of resilience, vulnerability and climate change impacts, and from a greater emphasis on effective and efficient decision making in government in an era of reduced and limited resources for decision making. As described by Patt et al. (2005): “Policy makers appear to be eager consumers of vulnerability assessments” (412). The methods vary, but they all emphasize providing more information for regional stakeholders and decision making. While VAs may be numerous, it has been recognized how difficult it can be to translate them into the realm of climate change decision making as the complexity of the impacted systems is compounded by an ever increasing sum of factors, system components and connections (Patt et al 2005). Added to this complexity is a limited capacity for climate change impact assessment (Wall et al 2011) and unfamiliarity with the application of VAs and their subsequent integration into climate change adaptation planning efforts. As Rowland et al (2011) and others (Buisson et al 2010) suggest, the results from VAs are often overstated, the inherent uncertainties and limitations are not fully articulated and addressed, and findings or recommendations are often integrated into management decisions without question or scrutiny. This situation can be seen in the Great Basin, too, as articulated by Chambers, et al (2008): “Managers across the Great Basin are increasingly challenged to maintain or improve the ecological conditions of these systems and the services that they provide while meeting the needs of a growing number of user groups with diverse and often opposing interests” (1). This research was directed into this science-policy nexus in order to better understand these issues and problems and to identify barriers and constraints to the effective use of VAs.

Many of the above objectives were met through the literature review and subsequent on-line survey (see detailed appendices). The proposed in-depth interviews, however, were not as successful as it proved more difficult than anticipated to engage with Great Basin resource managers through the method. This situation has been identified in other studies as has the often contentious and politicized context in which these managers operate, which makes them hesitant to engage through in depth social science means. This is significant in that it can impact future research into Great Basin (or other environmental decision-making) in general.

5. ORGANIZATION AND APPROACH

The research activities conducted in this project focused on two general methods: an extensive background literature review was conducted in order to, first, develop an understanding of VAs and the context in which they are applied, and second, an on-line survey of Great Basin-oriented decision makers and resource managers. These methods were chosen as appropriate for the scope of the project and the questions being proposed.

6. PROJECT RESULTS

This project conducted a literature review of currently available VAs and an on-line survey of Great basin decision makers and resources managers in regard to the use and utility of VAs in their decision context. These results are articulated in several appendices to this report.

The main results and findings from this project present a picture of opportunity and availability of VAs as decision tools, yet limited acceptance and use. As background, the literature review sections in this report provide an overview of vulnerability and vulnerability assessments (Appendix 2), a review of the constraints associated with VAs (Appendix 3), and a review of several case studies of current VA use in resource management (Appendix 4). These sections are intended to provide more in depth information on the current state of VAs and examples of their use.

The primary goal and purpose of the survey component (Appendix 1) of this project was to articulate a clear picture of how Vulnerability Assessments are being used, and have been used in the recent past, by stakeholders within the Great Basin Region to assess climate change impacts. The intent was to accurately capture the practices, attitudes, and thoughts regarding VAs by those “on the ground” handling climate science on a regular basis. Considering that a large component of this project is connecting concepts to practices, it was paramount that we gained an understanding of how stakeholders were managing science on a daily basis in their management or advocacy endeavors.

In order to identify and select viable stakeholders to contact, we completed a review of prominent agencies, organizations, and stakeholders with a web-based presence. We adopted a very broad definition of “stakeholder” for this project because the literature review had revealed pervasive confusion and ambiguity surrounding vulnerability assessments as a general concept and tool. Through the literature review, we were unable to fully anticipate the types of people and organizations that were most likely, or least likely, to use a VA. We were therefore cautious to make assumptions and chose instead to reach out to *all* stakeholders (i.e., anyone with an apparent interest in the GB region). This produced an extensive list of stakeholders that included land managers, federal agencies, state agencies, cattle associations, and advocacy groups for wildlife, energy, and resources. To identify as many potential stakeholders as possible, we used a snowball technique to find respondents for the survey: we would identify new stakeholders through stakeholders’ reports of their co-collaborators on climate change endeavors or related activities. Human subject and Institutional Review Board requirements for anonymity do not allow for documentation of this list in the report. We chose this approach because it allowed us to easily identify a wide variety of stakeholders and it helped to combat any unconscious bias we may have had regarding who *should* be using science in their decision-making process. Adopting a snowball technique to identify stakeholders also allowed us to identify stakeholders based on their publicly announced interest in the GB region, and not by their financial investments in projects. Regardless of resources, scope, jurisdiction and power, stakeholders were approached in the same manner when asked to participate in the survey via email.

Our survey was initially distributed to a total of 195 stakeholders that we had identified through the comprehensive inventory of Great Basin decision and resource managers. Our initial response rate was low, so a subsequent reminder was sent out. To allow our survey to be forwarded to other appropriate respondents in the offices of our stakeholders, we embedded an anonymous link to the survey within the email. We asked our stakeholders to identify others who would be able to provide us with valuable responses. We received a total of 41 responses to our survey. The general findings are discussed in the next section, with complete data and analysis in Appendix 1.

7. ANALYSIS AND FINDINGS

This section summarizes the results of the on-line survey. More details and graphical representations of the question by question responses are included in Appendix 1.

Questions 1-3: Broadly Understanding Use and Non-Use of Vulnerability Assessments

The first question on the survey revealed that 35.48% of our respondents used a VA of some kind. However, 68.75% of respondents do address climate change, through a variety of tools that do not include VAs. When those who responded that they do not use VAs were asked why, the leading response was because they had not heard of VAs (46.7%). The second most popular response was "other" (40.0%), and the third was that they do not understand how a VA works (13.3%). The relative popularity of the “other” response indicates a diversity of institutional reasons for non-use of VAs, unrelated to respondents’ level of familiarity with the decision tool. Respondents’ descriptions of their “other” reasons indicated that they had not been asked to use them by the BLM and Forest Service, that they simply fund VAs for others to use, that VAs were considered outside the scope of programs managed, or that VAs were not considered a standard tool. These initial responses mirrored the information gleaned in our literature review: VAs are relatively unknown, and managers who address climate change impacts often choose other evaluative tools.

Questions 4-10: Understanding Development and Use of Vulnerability Assessments

In response to the question, "Who developed the VA?” the leading answer was that stakeholders collaborate with other organizations when developing the VAs that they use (55.6%). Some of the names provided for collaboration included several USDA agencies and certain research universities: Natural Resources Conservation Science (NRCS); Agricultural Research Service (ARS); Animal and Plant Health Inspection Service (APHIS); Risk Management Agency (RMA); Farm Service Agency (FSA); Rural Development (RD); Forest Service (FS); University of California, Davis; University of Michigan; and University of Oregon.

Among our respondent stakeholders, the percentage order of resources considered as the focus of VAs was: Water (89%), Ecosystems (78%), Soil (66%), Wildlife (66%), Air (33%), Energy (11%), and Other (11%). These responses speak to the variation among the stakeholders we identified and contacted, as well as to the versatility of a VA. Of those who reported using VAs, over 50% of respondents indicated that they "self-initiated" the use of VAs, while 22% responded VA use was "encouraged by their organization" and 11% responded it was "required" by their organization.

When asked “In your experience, what makes a Vulnerability Assessment usable?,” respondents strongly agreed with the following reasons (in order of response rate): (1) The VA is well organized (55.56%), (2) The VA uses language I can understand (44.44%), (3) The VA discusses resources that my organization is concerned with (44.44%), (4) the VA fits the timeline my organization is interested in (22.22%), and (5) The VA uses language that my organization uses (11.11%). Thus, a VA’s organization, comprehensibility, and relevance to the organization were identified as the most influential factors determining VA usability. Respondents chose agree when identifying the following reasons that make VAs usable (in order of response rate): (1) The VA fits the timeline my organization is interested in (77.78%), (2) The VA uses language that my organization uses (66.67%), (3) The VA is well-organized (44.44%), (4) The VA uses language I can understand (44.44%), and (4) The VA discusses resources that my organization is concerned with (44.44%).

The question "Which of the following statements best describes your timeline problem?" provided the following potential answers: The VA failed to address my short-term needs; The VA failed to address my long-term needs; Both; and Other. No answers were recorded for this question.

Questions 11-20: Understanding Stakeholder Demographics

When asked for a description of their organization, nearly half identified themselves as part of a federal government agency (47.83%), 22% identified their organization as a state government agency, 13% identified their organization as a non-profit, 9% identified their organization as agricultural interest, and 9% identified as "Other."

Respondents' individual positions within their organizations were varied: 35% identified as executive management, 26% identified as middle-line management, 13% identified as administrative staff, 13% identified as research staff, 9% identified as "other," and 4% identified their role as coordination. When asked how long they had held their position, 43% responded 6 to 10 years, 22% responded 0 to 5 years, 13% responded 11 to 12 years, 9% responded 26 to 30 years, 4% responded 11 to 15 years, 4% responded 16 to 20 years, 4% responded 36 to 40 years, and 4% responded more than 40 years.

Respondents identified as 57% male and 43% female, and indicated birth years ranging between 1942 and 1979. Over half of respondents were born between 1951 and 1960 (54.5%). In addition, over half of respondents indicated they had lived in the GB region for over twenty years (52.4%). About 10% of respondents indicated having lived in the region for five years or less (9.5%). Respondents generally possessed high levels of educational attainment: 43% held a Master's degree, 35% held a PhD, MD or JD, 13% held a Bachelor's degree, and 9% held a high school diploma or GED.

Respondents were split on their interest in reviewing survey results, with 57% uninterested in receiving the results and 43% interested in receiving the results. The final survey question asked stakeholders whether we could contact them later to arrange an interview, and 90% who responded indicated yes.

8. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, results from the survey show that, despite high levels of educational attainment and a common organizational focus on climate, almost half of stakeholder respondents indicated that they had never heard of a VA. This response may reflect in part institutional preferences for other tools in climate decision-making, as 69% of respondents indicated they do engage with climate change issues, but not through VAs. Similarly, those respondents who did use VAs were often individually responsible for their adoption as a decision-making tool (56%). Only 33% of VA utilizing respondents reported use of VAs as encouraged or required by their organization, again suggesting institutional preference for other types of decision-making tools. Although not explored directly in this survey, part of that preference may be due to the outside collaboration often necessary to develop VAs, as 56% of those utilizing VAs indicated they collaborated with other institutions in VA design. Taken together, these results suggest that VAs' reputation for unpopularity may stem largely from institutional practices that encourage alternative decision-making tools, rather than direct personal experience with VAs. The reported level of self-adoption is encouraging for continued VA use over the long term; those who reported using them mostly do so because they want to. Ultimately, the low number of total respondents and lower percentage of respondents reporting on use of VAs prevent confident generalizability of the results of the survey, as suggestive as they may be. For future research, these results illuminate potential lines of inquiry directed toward certain GB stakeholder subgroups, including 1) executive management's views on VAs, 2) VA self-adopters' experience moving from non-use to use of VAs, 3) VA users' views on necessary conditions for adoption of VAs as a decision-making tool across an organization, 4) VA co-collaborator institutions' perceptions of VA collaborations.

Throughout the project, the research team also experienced a lack of understanding of and resistance to VAs that was unexpected. This was articulated in one workshop as a participant stated that VAs were just another "next big thing" in reporting and data collection, or even a power grab by federal agencies through new data requirements. This situation, and a hesitancy to engage with researchers through in depth interviews as proposed, limited the data collection aspect of the project. The ongoing politicized nature of Great Basin resource management also contributed to this hesitancy and will make any subsequent focus on this region difficult in regard to subsequent decision-making research. A broader geographic scope of VAs in context could overcome this difficulty as it could dilute the political nature of resource management and decision-making, in general. In summary, the general utility of the concept of a VA as a decision tool is still a viable research question, and one that should be considered in spite of the difficulties experienced in this project. Subsequent research design, however should consider potential negative perspectives on VA or any "new" decision tool or data collection and assessment approach.

9. MANAGEMENT APPLICATIONS AND PRODUCTS

It is anticipated that the results of this project will be of interest to and used by a broad range of resource managers not only in the Great Basin but in other geographic areas as they consider decision tools and other means to assess vulnerabilities in their respective jurisdictions. As VAs compete with other decision tools, or institutional norms and cultures and existing more familiar assessment tools, the utility of the VA concept is still in question, however. This situation can be addressed through 1) development of better case studies and best practices and success stories and examples, and 2) increased opportunities for education and learning within in and across agencies. The recent U.S. Forest Service Intermountain Adaptation Partners (IAP) Climate Change Vulnerability Assessments Workshops are one example of such an agency sponsored VA education and outreach effort (http://adaptationpartners.org/iap/index.php).

Several Great Basin related managers and decision makers were instrumental in supporting this research, including Todd Hopkins, Great Basin LCC, and Gustavo Bisbal, Northwest Climate Science Center. Numerous other Great Basin associated scientists and managers were instrumental in providing information and support through surveys and personal communication.

10. OUTREACH

The research team attended conferences and workshops related to Great Basin resource management and networked with local and regional stakeholders and representatives of federal agencies (such as BLM, USFS, USGS) and academic and agency scientists throughout the course of the project. These relationships are ongoing and will result in future research development and partnerships. The graduate student primarily funded thorough this project, Katie Gibble, presented her research several times at professional meetings. The project PI also presented project research multiple times:

Lindquist, E. (2014, May). Climate change adaptation and the changing context for resource management in the Great Basin. Presentation at the Global Land Project Open Science Meeting, Berlin, Germany.

Lindquist, E. (2016, February). Vulnerability Assessments for Managers." Presentation and workshop for the Sagebrush Ecosystem Conservation: All Lands, All Hands joint conference of the Great Basin Consortium and Western Association of Fish and Wildlife Agencies, Salt Lake City, UT.

In addition, the PI (Lindquist) participated in two regional U.S. Forest Service Intermountain Adaptation Partners (IAP) Climate Change Vulnerability Assessments Workshops (Boise, ID and Reno NV) as an invited participant. The workshops provided the opportunity to observe first hand discussion and assessments of Forest Service vulnerability assessments and the target audience reactions. Although it was not possible to conduct objective research in the context of the workshops, the overall observation of the VA material was received positively by the audience, in spite of continued uncertainty of the overall concept and utility of VAs, in general. Subsequent outreach will be conducted through planned scholarly publications and through leveraging the project for additional research, as appropriate and available.

APPENDIX 1. Online Survey Description and Findings

The primary goal and purpose of the survey component of the project was to articulate a clear picture of how Vulnerability Assessments are being used today, and have been used in the recent past, by stakeholders within the Great Basin Region to assess climate change. The intent was to accurately capture the practices, attitudes, and thoughts regarding VAs by those "on the ground" handling climate science on a regular basis. Considering that a large component of this project is connecting concepts to practices, it was paramount that we gained an understanding of how stakeholders were managing science on a daily basis in their management or advocacy endeavors.

Methodology

In the summer of 2015, the Great Basin Project transitioned from reviewing literature into developing a survey to distribute to key stakeholders with vested interests in science and decision-making within the Great Basin Region. It was important that the project linked current literature on the use of Vulnerability Assessments to the practices of stakeholders in the Great Basin Region. In order to identify and select viable stakeholders to contact, we completed a review of prominent agencies, organizations, and stakeholders with a web-based presence. We adopted a very broad definition of "stakeholder" for this project because the literature review had revealed pervasive confusion and ambiguity surrounding vulnerability assessments as a general concept and tool. At the end of the literature review, we were unable to fully anticipate the types of people and organizations that were most likely, or least likely, to use a VA. We were therefore cautious to make assumptions and chose instead to reach out to *all* stakeholders (i.e., anyone with an apparent interest in the GB region). This produced an extensive list of stakeholders that included land managers, federal agencies, state agencies, cattle associations, and advocacy groups for wildlife, energy, and resources. To identify as many potential stakeholders as possible, we used a snowball technique to find respondents for the survey: we would identify new stakeholders through stakeholders' reports of their co-collaborators on climate change endeavors or related activities. We chose this approach because it allowed us to easily identify a wide variety of stakeholders and it helped to combat any unconscious bias we may have had regarding who *should* be using science in their decision-making process. Adopting a snowball technique to identify stakeholders also allowed us to identify stakeholders based on their publicly announced interest in the GB region, and not by their financial investments in projects. Regardless of resources, scope, jurisdiction and power, stakeholders were approached in the same manner when asked to participate in the survey via email.

Survey Design

The research team used the online survey software program *Qualtrics* as the platform for distributing the survey. Because the vast majority of our stakeholders had email addresses that were publicly available, it made sense to distribute our survey via email. We began our survey design process by re-visiting our research questions and writing an exhaustive list of possible questions we wanted to ask our stakeholders. We refined our questions after consulting survey experts and members of the academic community who have engaged with VAs for years. We further revised the survey instrument to design a survey that took no longer than 12 minutes to complete. Our final survey comprised 21 questions, ranging in design from multiple choice, to simple "yes/no" questions, and questions that demanded a more descriptive answer.

Our survey was initially distributed to a total of 195 stakeholders that we had identified through the comprehensive inventory of Great Basin decision and resource managers. Our initial response rate was low, so a reminder was sent out. To allow our survey to be forwarded to other appropriate respondents in the offices of our stakeholders, we embedded an anonymous link to the survey within the email. We asked our stakeholders to identify others who would be able to provide us with valuable responses. We received a total of 41 responses to our survey. Because users in the literature were often confused about the content and concept of a VA, we provided a definition of a VA at the beginning of our survey to guide our stakeholders' responses. By providing a definition that was inclusive of all assessments that considered the vulnerability and adaptive capacity of resources and/or species to climate change, we hoped to eliminate some of the confusion around the term, and to allow as many stakeholders as possible to contribute who would benefit our study.

Survey Results

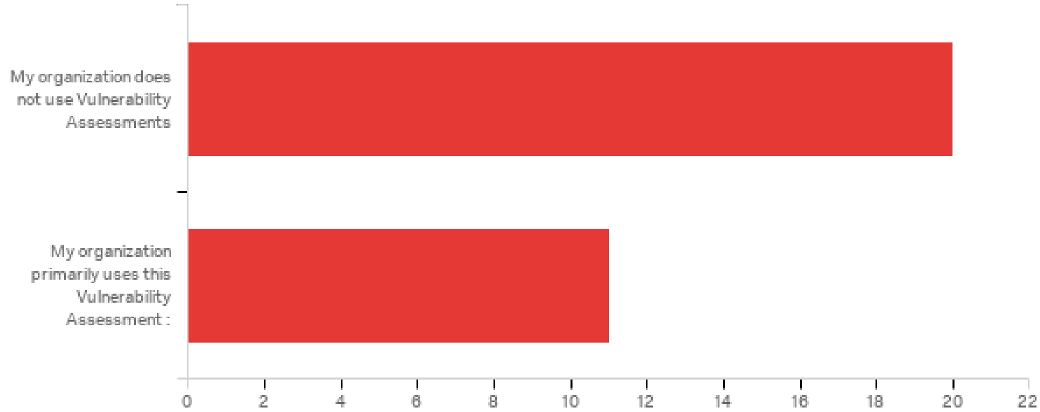
The following is a summary of the survey results. More detailed results will be made available pending the final respondent identifier scrubbing and analysis. The survey instrument will also be made available upon request.

Questions 1-3: Broadly Understanding Use and Non-Use of Vulnerability Assessments

The first question on the survey revealed that 35.48% of our respondents used a VA of some kind. However, 68.75% of respondents do address climate change, through a variety of tools that do not include VAs.

When those who responded that they do not use VAs were asked why, the leading response was because they had not heard of VAs (46.7%). The second most popular response was "other" (40.0%), and the third was that they do not understand how a VA works (13.3%). The relative popularity of the "other" response indicates a diversity of institutional reasons for non-use of VAs, unrelated to respondents' level of familiarity with the decision tool. Respondents' descriptions of their "other" reasons indicated that they had not been asked to use them by the BLM and Forest Service, that they simply fund VAs for others to use, that VAs were considered outside the scope of programs managed, or that VAs were not considered a standard tool. These initial responses mirrored the information gleaned in our literature review: VAs are relatively unknown, and managers who address climate change impacts often choose other evaluative tools.

What Vulnerability Assessment(s) does you organization use?

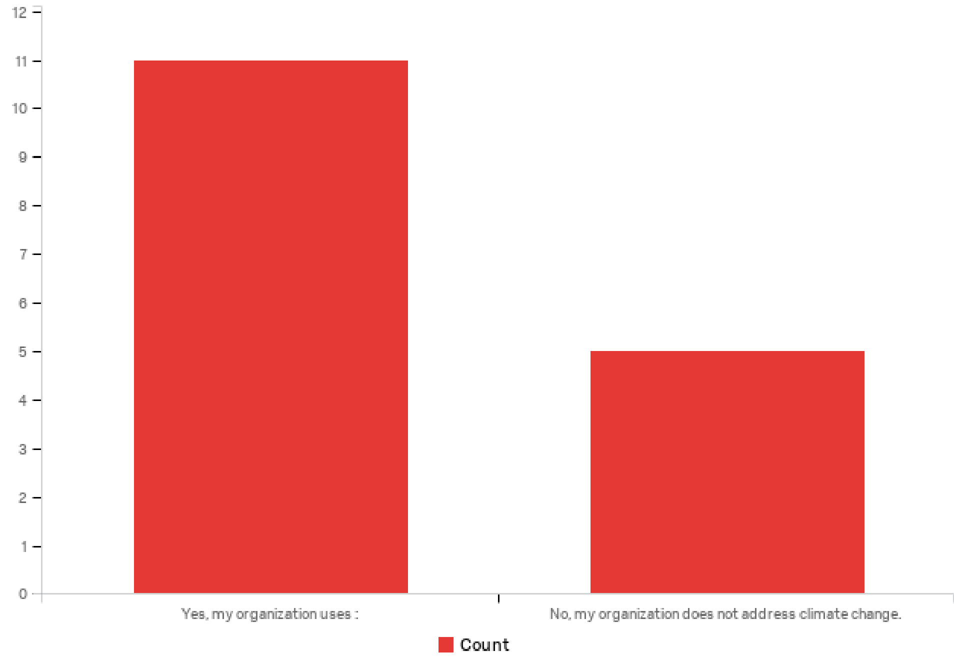


Answer	%	Count
My organization does not use Vulnerability Assessments	64.52%	20
My organization primarily uses this Vulnerability Assessment:	35.48%	11
Total	100%	31

Text - My organization primarily uses this Vulnerability Assessment:

My organization primarily uses this Vulnerability Assessment:
I am not sure of the names
Numerous NRCS tools
USDA Climate Hubs
several published assessments as well as in-house assessments
NatureServe's Climate Change Vulnerability Index
US Fish and Wildlife Service uses their own
http://ecoadapt.org/data/documents/EcoAdapt_NPCWNF_VulnerabilityAssessment_v3_4Dec2014_smallres.pdf
We do not use one specific method or tool due to the variety of analyses we undertake
National Climate Assessment

Does your organization use other tools to address climate change?

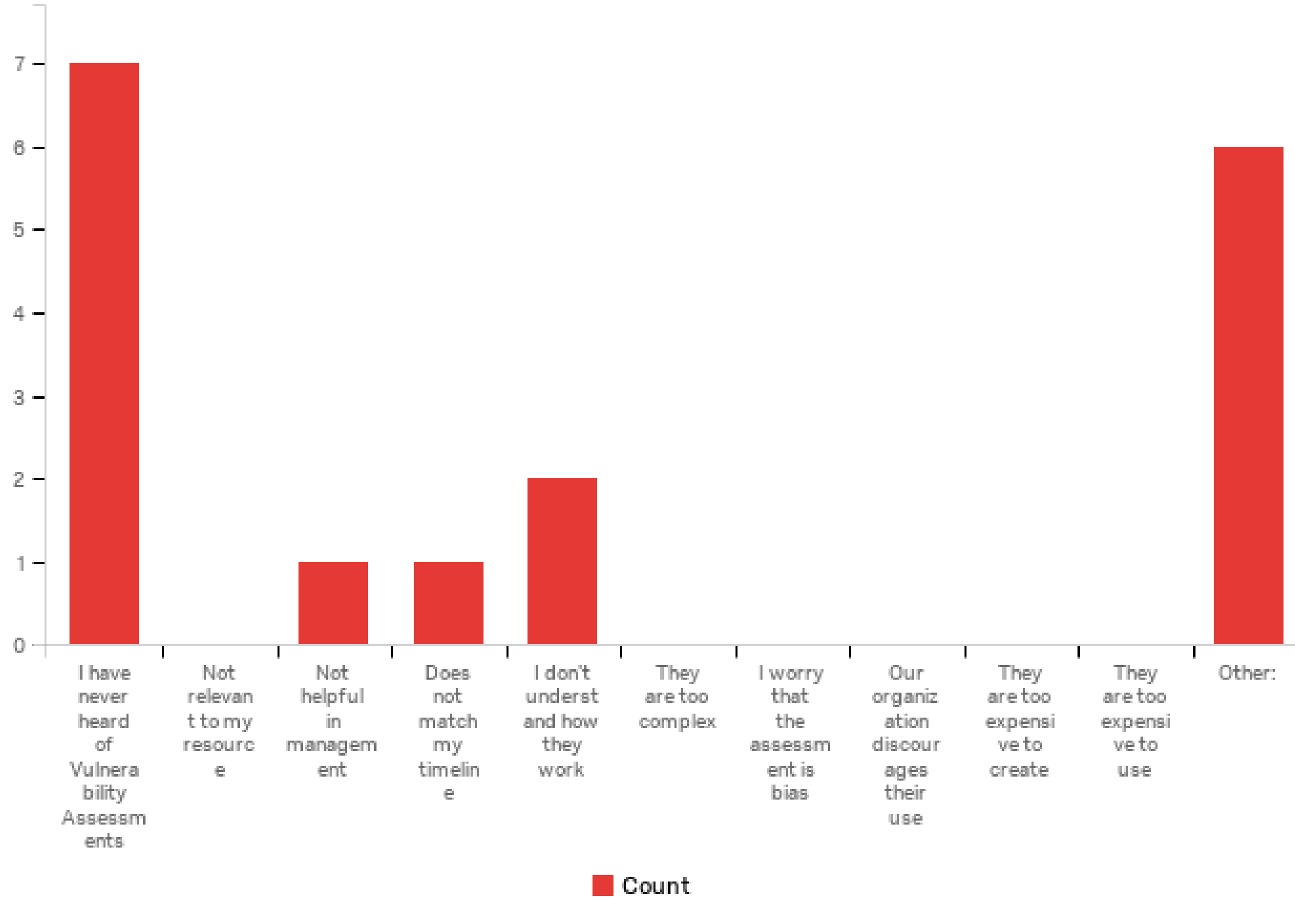


Answer	%	Count
Yes, my organization uses:	68.75%	11
No, my organization does not address climate change.	31.25%	5
Total	100%	16

Text - Yes, my organization uses:

Yes, my organization uses:
Communication, information from studies
BuRec/BLM/USGS and Utah GS
Weather condition play a roll
We perform habitat, wildlife and plant monitoring
We fund projects like yours
Various out-of-house and in-house forecasting tools and techniques
Feasibility and Basin Studies, NEPA/ESA
emissions reduction and alternative energy sources

Why don't you use Vulnerability Assessments? (Please check all that apply).



Answer	%	Count
I have never heard of Vulnerability Assessments	46.67%	7
Not relevant to my resource	0.00%	0
Not helpful in management	6.67%	1
Does not match my timeline	6.67%	1
I don't understand how they work	13.33%	2
They are too complex	0.00%	0
I worry that the assessment is bias	0.00%	0
Our organization discourages their use	0.00%	0
They are too expensive to create	0.00%	0
They are too expensive to use	0.00%	0
Other:	40.00%	6
Total	100%	15

Other:
We work primarily with the BLM and Forest Service and they have not asked us to use these assessments at this time.
Outside of the scope of the programs that the ISDA implements.
Vulnerability assessment, thus far, has not been considered a standard tool or approach
We help fund vulnerability assessments for others to use

<u>Questions 4-10: Understanding Development and Use of Vulnerability Assessments</u>

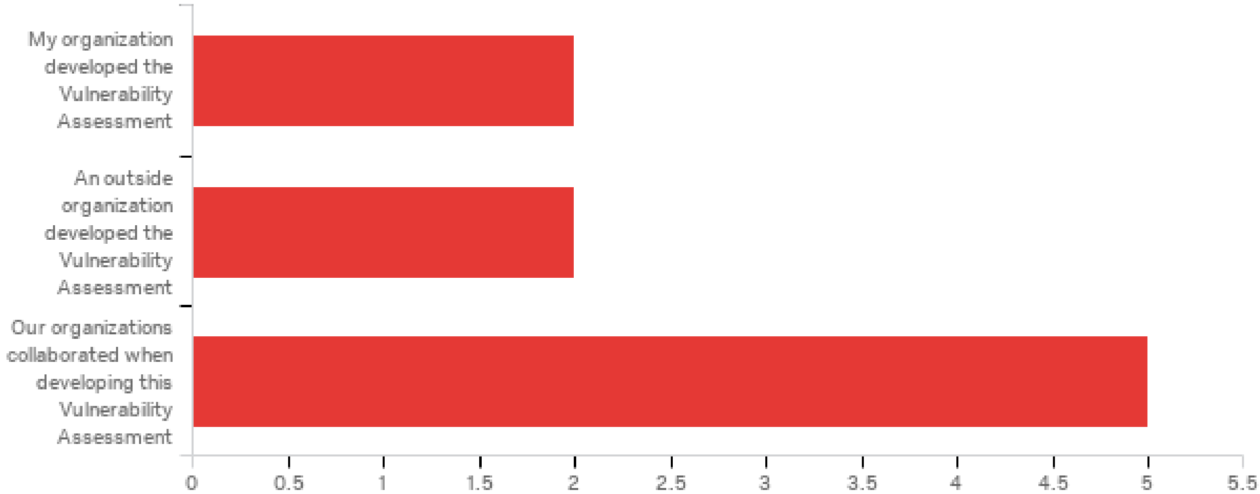
In response to the question, "Who developed the VA?" the leading answer was that stakeholders collaborate with other organizations when developing the VAs that they use (55.6%). Some of the names provided for collaboration included several USDA agencies and certain research universities: Natural Resources Conservation Science (NRCS); Agricultural Research Service (ARS); Animal and Plant Health Inspection Service (APHIS); Risk Management Agency (RMA); Farm Service Agency (FSA); Rural Development (RD); Forest Service (FS); University of California, Davis; University of Michigan; and University of Oregon.

Among our respondent stakeholders, the percentage order of resources considered as the focus of VAs was: Water (89%), Ecosystems (78%), Soil (66%), Wildlife (66%), Air (33%), Energy (11%), and Other (11%). These responses speak to the variation among the stakeholders we identified and contacted, as well as to the versatility of a VA. Of those who reported using VAs, over 50% of respondents indicated that they "self-initiated" the use of VAs, while 22% responded VA use was "encouraged by their organization" and 11% responded it was "required" by their organization.

When asked “In your experience, what makes a Vulnerability Assessment usable?,” respondents strongly agreed with the following reasons (in order of response rate): (1) The VA is well organized (55.56%), (2) The VA uses language I can understand (44.44%), (3) The VA discusses resources that my organization is concerned with (44.44%), (4) the VA fits the timeline my organization is interested in (22.22%), and (5) The VA uses language that my organization uses (11.11%). Thus, a VA’s organization, comprehensibility, and relevance to the organization were identified as the most influential factors determining VA usability. Respondents chose agree when identifying the following reasons that make VAs usable (in order of response rate): (1) The VA fits the timeline my organization is interested in (77.78%), (2) The VA uses language that my organization uses (66.67%), (3) The VA is well-organized (44.44%), (4) The VA uses language I can understand (44.44%), and (4) The VA discusses resources that my organization is concerned with (44.44%).

The question “Which of the following statements best describes your timeline problem?” provided the following potential answers: The VA failed to address my short-term needs; The VA failed to address my long-term needs; Both; and Other. No answers were recorded for this question.

Who developed the Vulnerability Assessment?

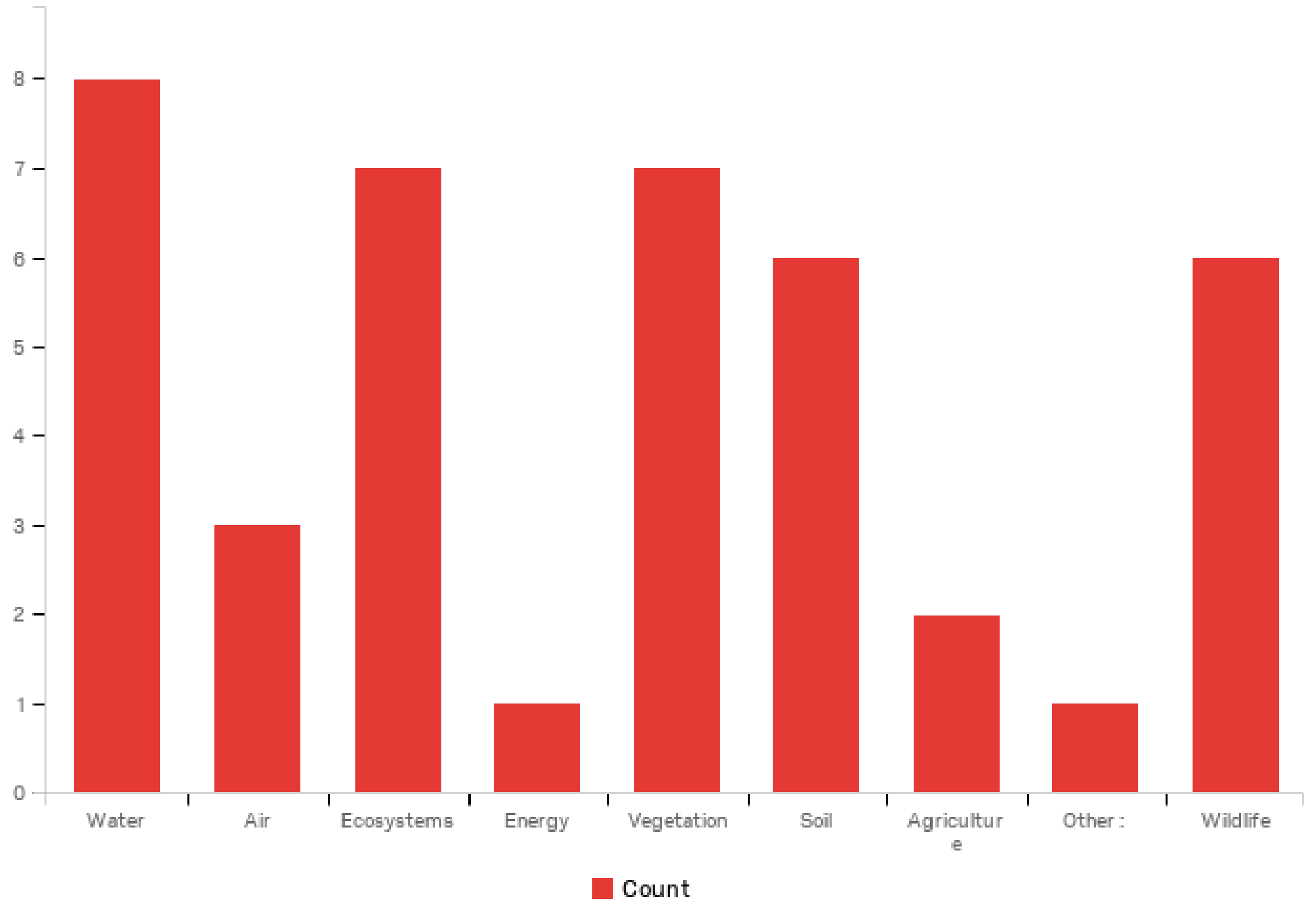


Answer	%	Count
My organization developed the Vulnerability Assessment	22.22%	2
An outside organization developed the Vulnerability Assessment	22.22%	2
Our organizations collaborated when developing this Vulnerability Assessment	55.56%	5
Total	100%	9

Please provide the name(s) of the organization(s) that you collaborated with in developing the Vulnerability Assessment.

Please provide the name(s) of the organization(s) that you collaborated with.
NRCS-ARS-APHIS-RMA-FSA-FS-RD
Several
USFS
UC Davis, U Michigan, U Oregon

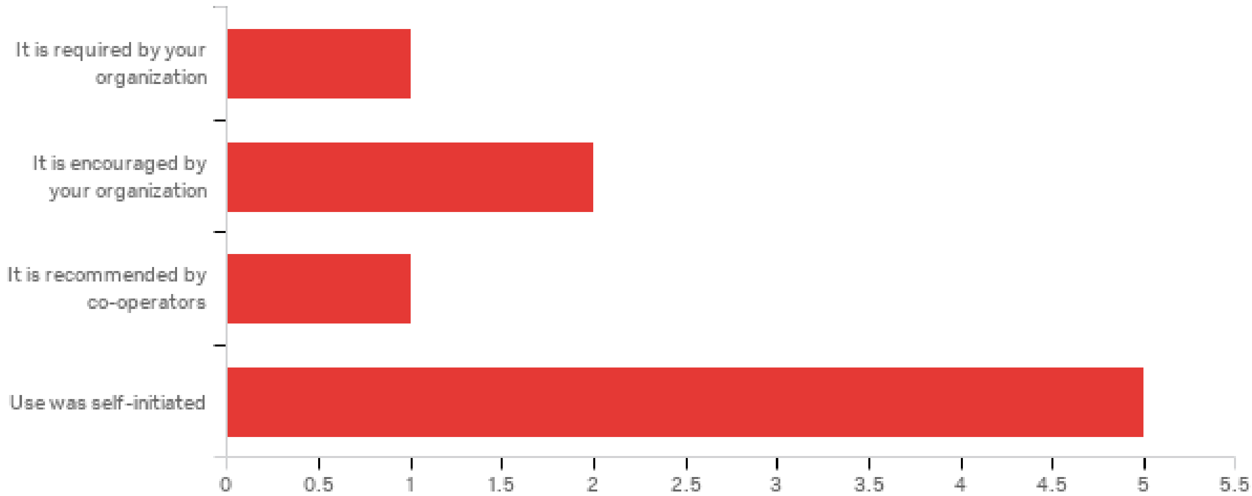
What resources are you looking at in this Vulnerability Assessment? Please check all that apply.



Answer	%	Count
Water	88.89%	8
Air	33.33%	3
Ecosystems	77.78%	7
Energy	11.11%	1
Vegetation	77.78%	7
Soil	66.67%	6
Agriculture	22.22%	2
Other :	11.11%	1
Wildlife	66.67%	6
Total	100%	9

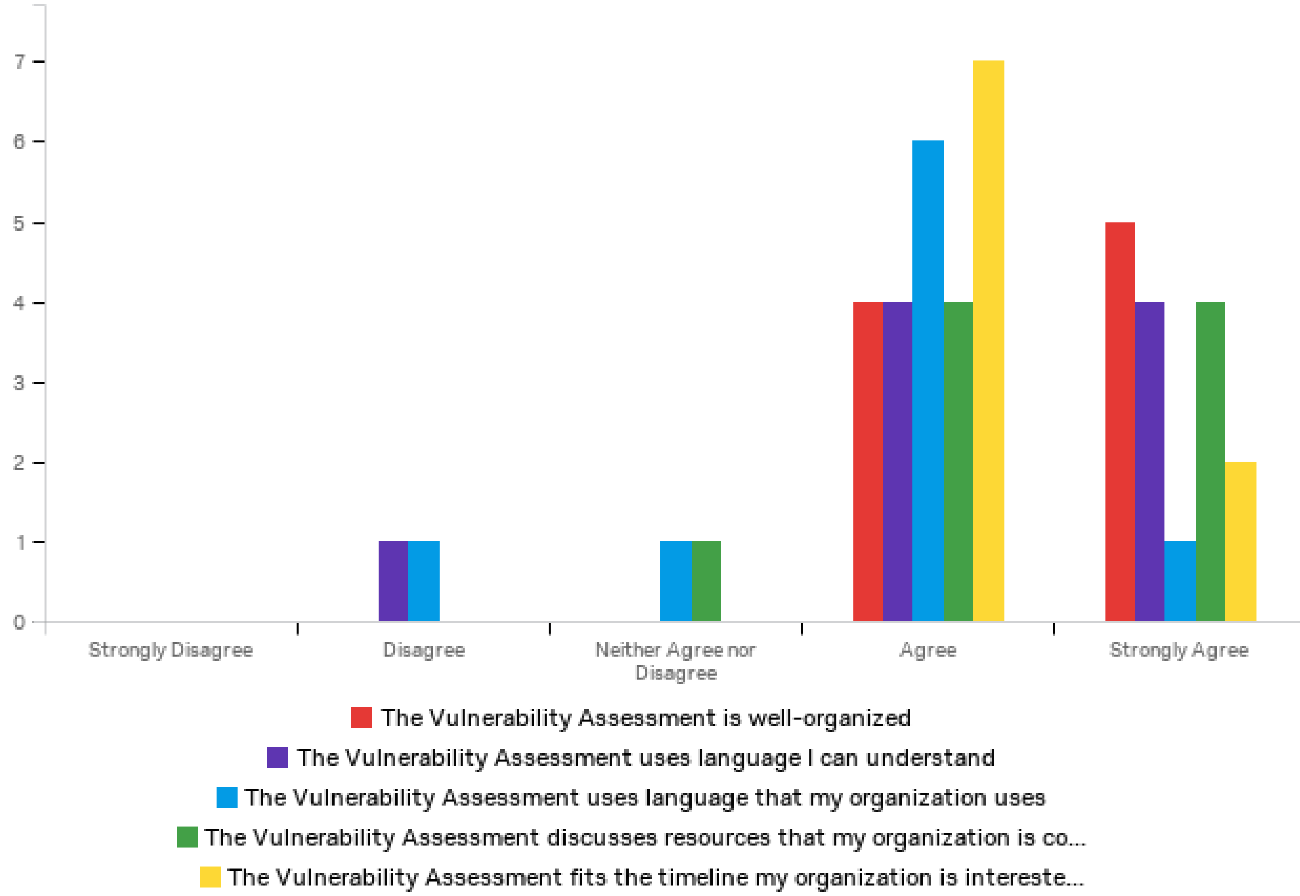
Other :
Rare plants

Your office uses Vulnerability Assessments because:



Answer	%	Count
It is required by your organization	11.11%	1
It is encouraged by your organization	22.22%	2
It is recommended by co-operators	11.11%	1
Use was self-initiated	55.56%	5
Total	100%	9

In your experience, what makes a Vulnerability Assessment usable?



Question	Strongly Disagree		Disagree		Neither Agree nor Disagree		Agree		Strongly Agree		Total
The Vulnerability Assessment is well-organized	0.00%	0	0.00%	0	0.00%	0	44.44%	4	55.56%	5	9
The Vulnerability Assessment uses language I can understand	0.00%	0	11.11%	1	0.00%	0	44.44%	4	44.44%	4	9
The Vulnerability Assessment uses language that my organization uses	0.00%	0	11.11%	1	11.11%	1	66.67%	6	11.11%	1	9
The Vulnerability Assessment discusses resources that my organization is co...	0.00%	0	0.00%	0	11.11%	1	44.44%	4	44.44%	4	9
The Vulnerability Assessment fits the timeline my organization is interested in	0.00%	0	0.00%	0	0.00%	0	77.78%	7	22.22%	2	9

Questions 11-20: Understanding Stakeholder Demographics

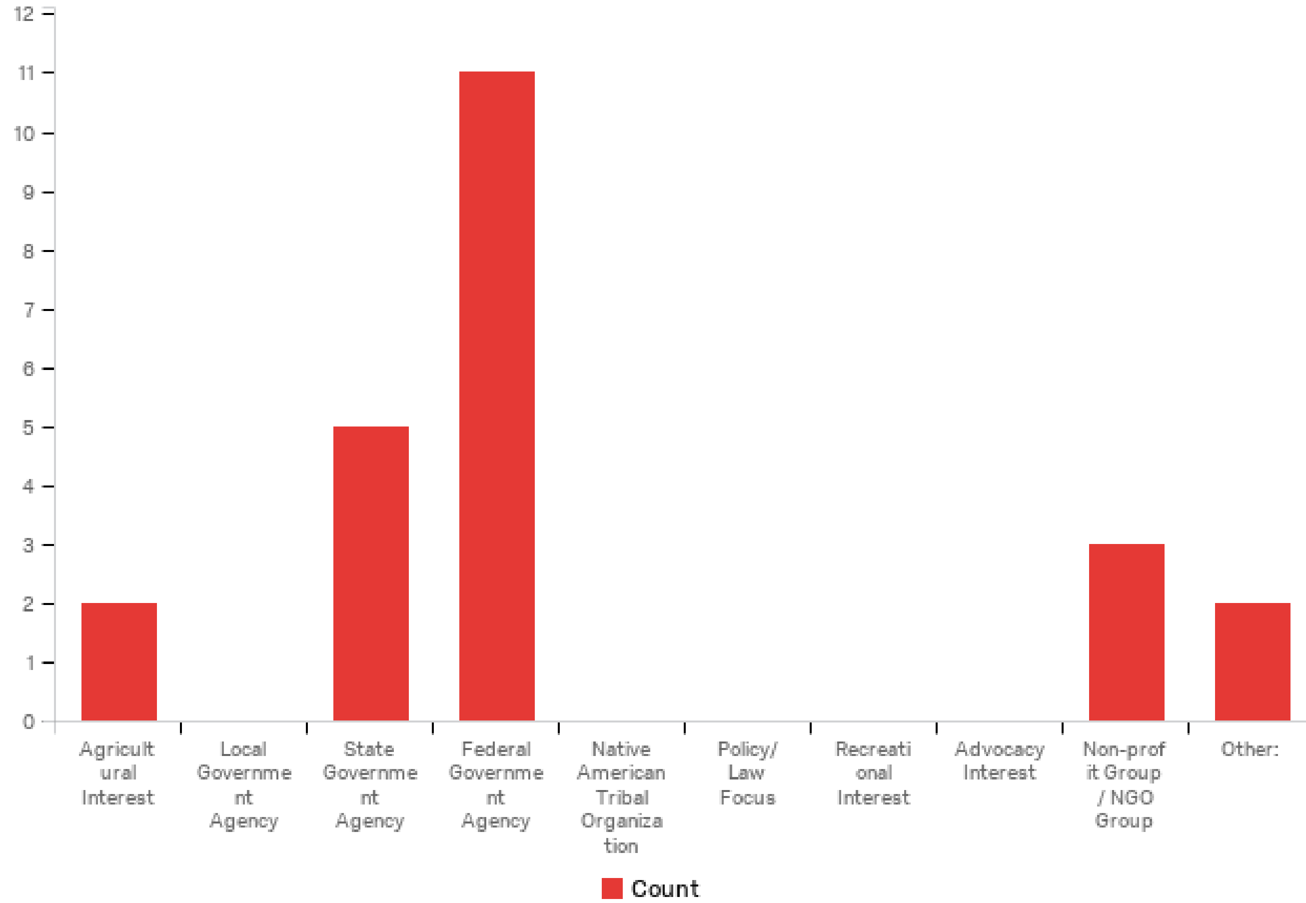
When asked for a description of their organization, nearly half identified themselves as part of a federal government agency (47.83%), 22% identified their organization as a state government agency, 13% identified their organization as a non-profit, 9% identified their organization as agricultural interest, and 9% identified as "Other."

Respondents' individual positions within their organizations were varied: 35% identified as executive management, 26% identified as middle-line management, 13% identified as administrative staff, 13% identified as research staff, 9% identified as "other," and 4% identified their role as coordination. When asked how long they had held their position, 43% responded 6 to 10 years, 22% responded 0 to 5 years, 13% responded 11 to 12 years, 9% responded 26 to 30 years, 4% responded 11 to 15 years, 4% responded 16 to 20 years, 4% responded 36 to 40 years, and 4% responded more than 40 years.

Respondents identified as 57% male and 43% female, and indicated birth years ranging between 1942 and 1979. Over half of respondents were born between 1951 and 1960 (54.5%). In addition, over half of respondents indicated they had lived in the GB region for over twenty years (52.4%). About 10% of respondents indicated having lived in the region for five years or less (9.5%). Respondents generally possessed high levels of educational attainment: 43% held a Master's degree, 35% held a PhD, MD or JD, 13% held a Bachelor's degree, and 9% held a high school diploma or GED.

Respondents were split on their interest in reviewing survey results, with 57% uninterested in receiving the results and 43% interested in receiving the results. The final survey question asked stakeholders whether we could contact them later to arrange an interview, and 90% who responded indicated yes.

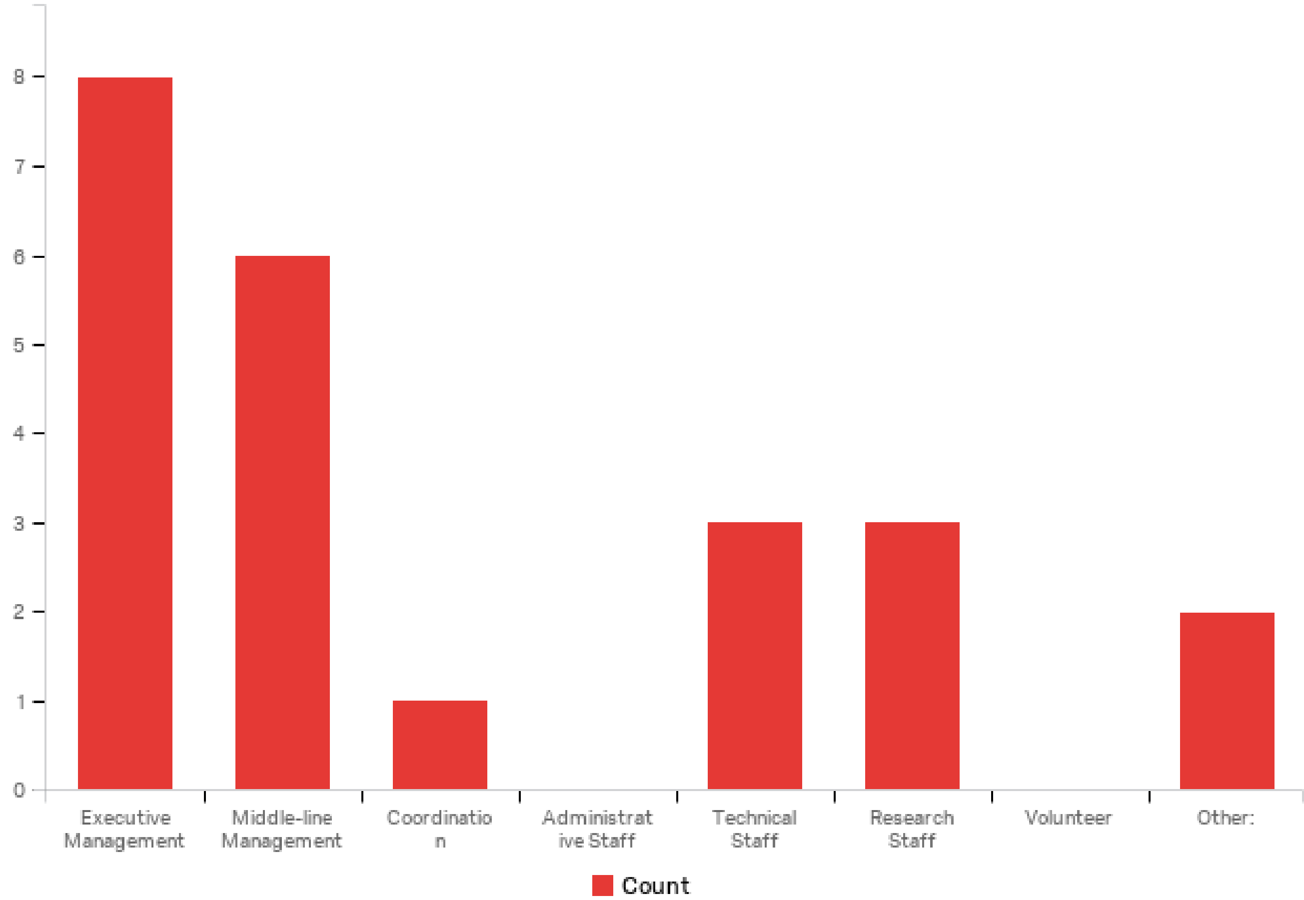
Which of the following options best describes your organization?



Answer	%	Count
Agricultural Interest	8.70%	2
Local Government Agency	0.00%	0
State Government Agency	21.74%	5
Federal Government Agency	47.83%	11
Native American Tribal Organization	0.00%	0
Policy/ Law Focus	0.00%	0
Recreational Interest	0.00%	0
Advocacy Interest	0.00%	0
Non-profit Group / NGO Group	13.04%	3
Other:	8.70%	2
Total	100%	23

Other:
non-profit conservation organization
Mining and Agriculture

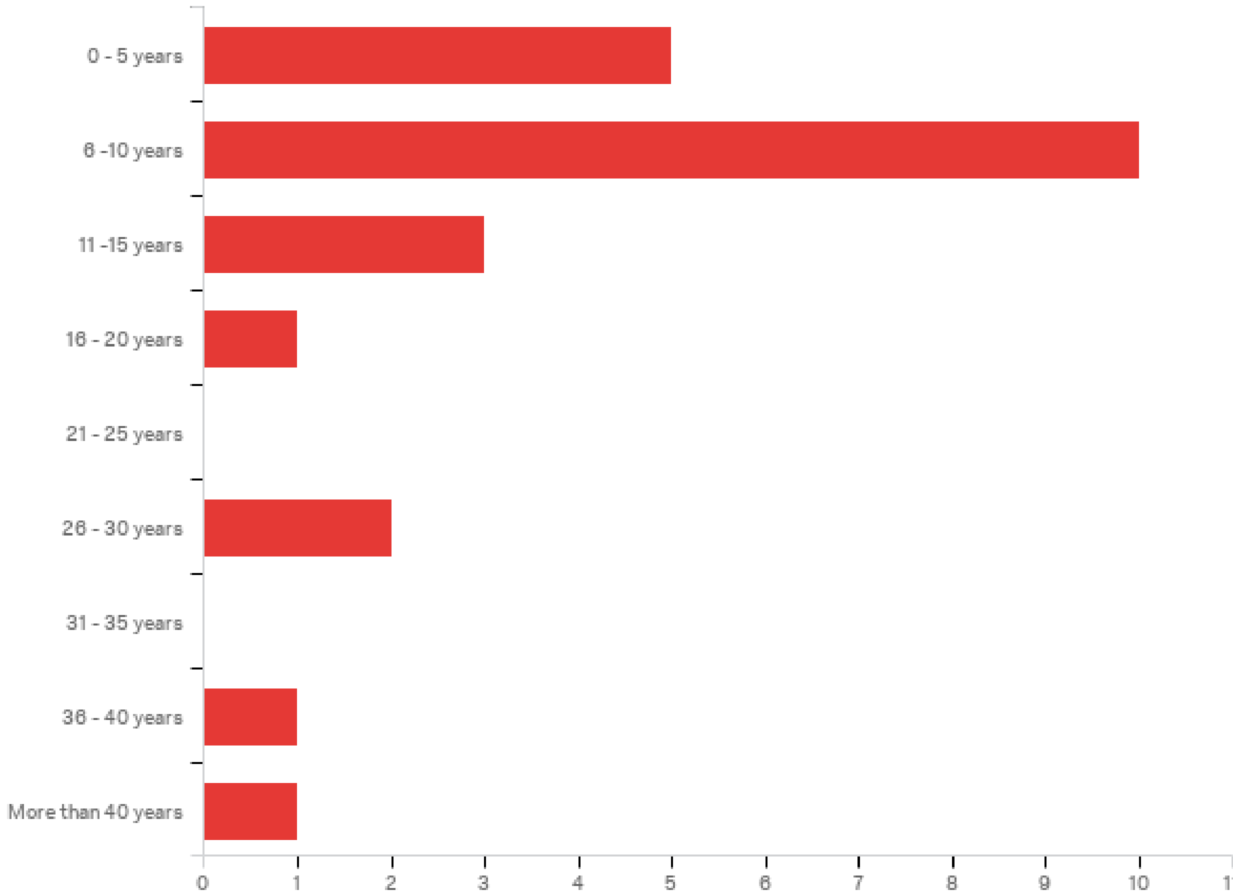
How would you best describe your position within your organization?



Answer	%	Count
Executive Management	34.78%	8
Middle-line Management	26.09%	6
Coordination	4.35%	1
Administrative Staff	0.00%	0
Technical Staff	13.04%	3
Research Staff	13.04%	3
Volunteer	0.00%	0
Other:	8.70%	2
Total	100%	23

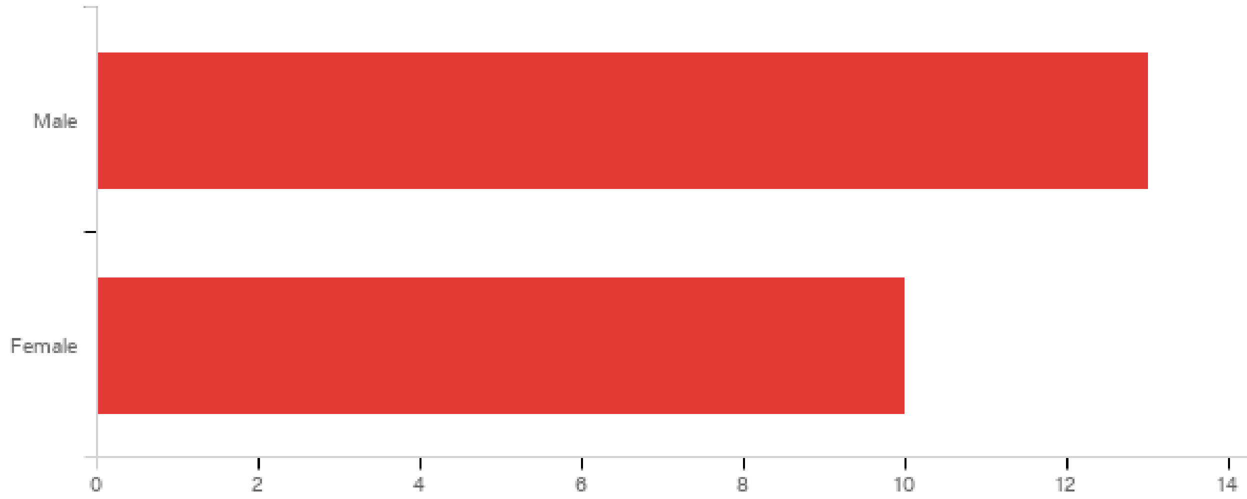
Other:
State level manager
Program Director

For how many years have you held your position?



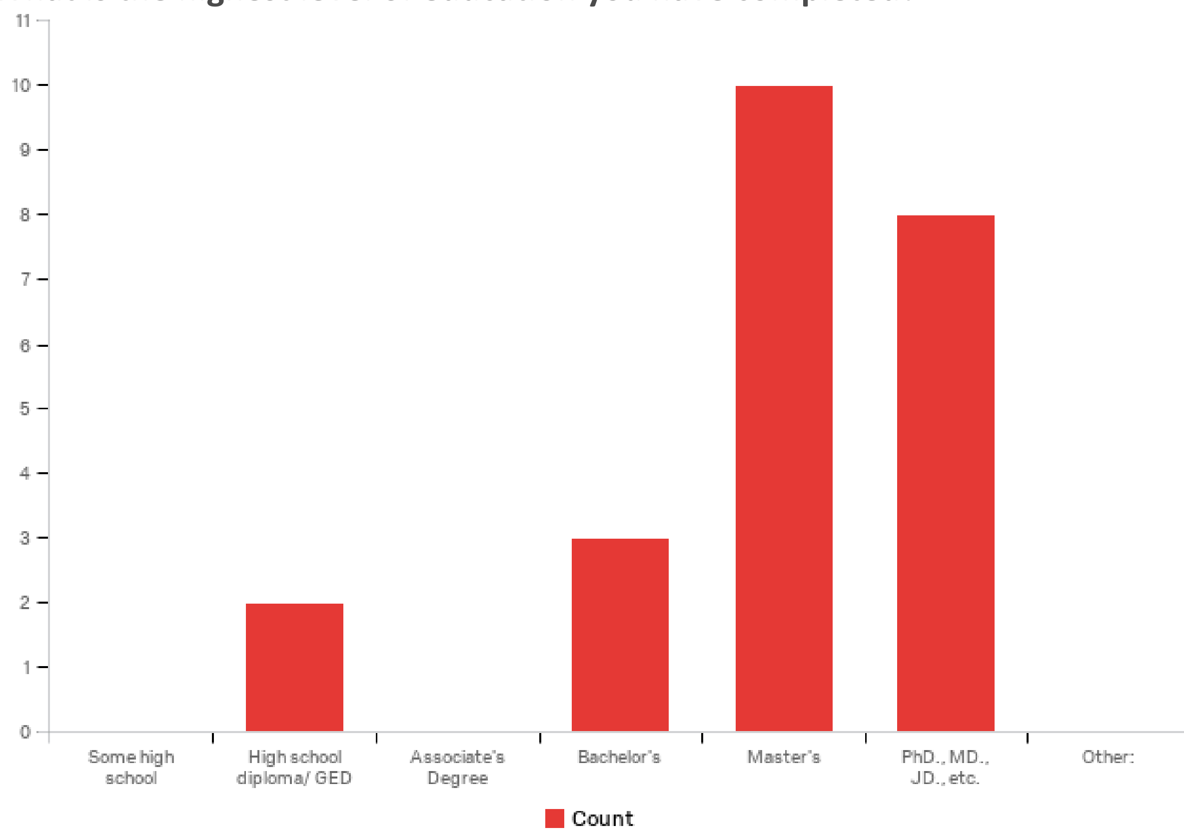
Answer	%	Count
0 - 5 years	21.74%	5
6 -10 years	43.48%	10
11 -15 years	13.04%	3
16 - 20 years	4.35%	1
21 - 25 years	0.00%	0
26 - 30 years	8.70%	2
31 - 35 years	0.00%	0
36 - 40 years	4.35%	1
More than 40 years	4.35%	1
Total	100%	23

Please indicate your sex



Answer	%	Count
Male	56.52%	13
Female	43.48%	10
Total	100%	23

What is the highest level of education you have completed?



Answer	%	Count
Some high school	0.00%	0
High school diploma/ GED	8.70%	2
Associate's Degree	0.00%	0
Bachelor's	13.04%	3
Master's	43.48%	10
PhD., MD., JD., etc.	34.78%	8
Other:	0.00%	0
Total	100%	23

Conclusion

Despite high levels of educational attainment and a common organizational focus on climate, almost half of stakeholder respondents indicated that they had never heard of a VA. This response may reflect in part institutional preferences for other tools in climate decision-making, as 69% of respondents indicated they do engage with climate change issues, but not through VAs. Similarly, those respondents who did use VAs were often individually responsible for their adoption as a decision-making tool (56%). Only 33% of VA utilizing respondents reported use of VAs as encouraged or required by their organization, again suggesting institutional preference for other types of decision-making tools. Although not explored directly in this survey, part of that preference may be due to the outside collaboration often necessary to develop VAs, as 56% of those utilizing VAs indicated they collaborated with other institutions in VA design. Taken together, these results suggest that VAs' reputation for unpopularity may stem largely from institutional practices that encourage alternative decision-making tools, rather than direct personal experience with VAs. The reported level of self-adoption is encouraging for continued VA use over the long term; those who reported using them mostly do so because they want to. Ultimately, the low number of total respondents and lower percentage of respondents reporting on use of VAs prevent confident generalizability of the results of the survey, as suggestive as they may be. For future research, these results illuminate potential lines of inquiry directed toward certain GB stakeholder subgroups, including 1) executive management's views on VAs, 2) VA self-adopters' experience moving from non-use to use of VAs, 3) VA users' views on necessary conditions for adoption of VAs as a decision-making tool across an organization, 4) VA co-collaborator institutions' perceptions of VA collaborations.

APPENDIX 2. Defining Vulnerability and Vulnerability Assessments

Executive Summary

The purpose of this paper is to describe the concepts of vulnerability to climate change and climate change vulnerability assessments (CCVAs). In the first section, "What is Vulnerability?" one of the most commonly cited definitions of climate change vulnerability is provided, though it is acknowledged that other conceptualizations exist. Thus, in the next section, "A Framework for Vulnerability", a generally applicable framework for discussing and categorizing diverse conceptualizations of vulnerability is reviewed. The intention here is to provide a way to think about vulnerability that can incorporate the majority, if not all, existing conceptualizations in such a way that they can be compared to one another. The third section, "A Brief History of Climate Change Vulnerability Assessments", describes how vulnerability assessments (VAs) have changed over time, particularly in regards to their policy focus. The final section deals with natural resource vulnerability assessments in particular, as these are the types of vulnerability assessments most relevant to resource management in the Great Basin, emphasizing the challenges associated with them. These challenges include different VAs reaching very different conclusions about the vulnerability of the same species, barriers in communication between scientists and stakeholders, and the fact that the incentives of scientists are not always necessarily conducive to providing "actionable science."

What is Vulnerability?

'Vulnerability' is defined by the Intergovernmental Panel on Climate Change (IPCC) as

> The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (2001, p. 388)

To further expand upon this definition, the IPCC (2001) defines 'exposure' as "the nature and degree to which a system is exposed to significant climatic variations" (p. 373), 'sensitivity' as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (p. 384), and 'adaptive capacity' as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (p. 365). Many climate change vulnerability assessments use this conceptualization of vulnerability being a function of exposure, sensitivity, and adaptive capacity (e.g., Bagne et al., 2011; Young et al., 2010; Williams et al., 2008; Glick et al., 2011). However, this is only a starting point, not an endpoint, for conceptualizing and operationalizing vulnerability.

'Vulnerability,' as measured in various vulnerability assessments, has escaped precise definition due to disagreement among scholars regarding not just how to measure 'sensitivity,' 'exposure' or 'adaptive capacity,' but also in terms of what variables are relevant in determining what makes a system sensitive and to what magnitude. Indeed, Timmerman (1981, p. 17) observed that "vulnerability is a term of such broad use as to be almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern." In the realm of climate change vulnerability assessments, vulnerability has been operationalized in a myriad of ways, with similar aspects in each operationalization but not similar enough overall to be easily comparable.

A Framework for Vulnerability

To alleviate the issue of disparate approaches to vulnerability assessment, Füssel (2005, 2007) offers a conceptual framework that is intended to enable different disciplines to categorize common notions of vulnerability along six dimensions. Though not all vulnerability assessments will incorporate all of them, these dimensions (should) capture all differing conceptions of vulnerability. These six dimensions are:

- Vulnerable system
- Attribute of concern
- Hazard
- Temporal reference: current vs. future vs. dynamic
- Sphere: internal vs. external vs. cross-scale
- Knowledge domain: socioeconomic vs. biophysical vs. integrated

All of these dimensions will be explained in more detail presently.

Vulnerable system: The unit of analysis. This can be a human population, a particular sector of the economy, a species, an ecosystem, a region, etc.

Attribute of concern: The valued resource or characteristic of the vulnerable system that is at risk of being impacted by a hazard. For a human population, an attribute of concern may be human lives and health; for an ecosystem, an attribute of concern may be biodiversity.

Hazard: An event, influence, or activity that can potentially cause harm to the vulnerable system. A hazard can be either a discrete event, such as an earthquake, or a continuous stressor, such as climate change (Turner II et al., 2003).

Temporal reference: The dimension of time, which can reference the present, some period in the future, or a range of time. Referencing this aspect is particularly important for assessing the effects of climate change, which, by definition, are expected to vary over time.

Sphere (or scale) and knowledge domain are categories of risk factors of the vulnerable system; risk factors can be categorized along both dimensions. Sphere can be divided into internal aspects of the vulnerable system (such as the topography of a region) or external aspects (severe storms). "Cross-scale" is a qualifier denoting a vulnerability assessment that accounts for both internal and external factors. The knowledge domain of a system refers to the disciplinary realm of the aspect being considered, that is, whether it is socioeconomic or biophysical in nature. An "integrated" assessment, under this framework, considers both socioeconomic and biophysical factors. Füssel (2007) notes that this classification schema is only a minimal structure and can be broken down into more specific categories based on the context of a specific vulnerability assessment. The following table lists some examples of vulnerability factors, categorized according to these dimensions.

Table 1
Examples for each of the four categories of vulnerability factors classified according to the dimensions sphere and knowledge domain

	Domain	
Sphere	Socioeconomic	Biophysical
Internal	Household income, social networks, access to information	Topography, environmental conditions, land cover
External	National policies, international aid, economic globalization	Severe storms, earthquakes, sea-level change

Source: Füssel (2007, p. 158)

Füssel provides examples of how this framework can be applied to vulnerability assessments that use varying terminology to describe similar concepts:

> The classification of vulnerability factors presented in Table 1 is largely compatible with the components of the integrated vulnerability framework proposed in Turner II et al. (2003), whereby 'internal socioeconomic vulnerability' corresponds to 'sensitivity', 'external socio-economic vulnerability' corresponds to 'human conditions/influences', and 'external biophysical vulnerability' corresponds to 'environmental conditions/influences'. The four elements of risk identified by Hewitt (1997, Chapter 1) are related to the four groups of vulnerability factors as follows: 'internal socioeconomic vulnerability' corresponds to 'vulnerability and adaptation' as well as 'human coping and adjustments', 'internal biophysical vulnerability' corresponds to 'intervening conditions of danger', and 'external biophysical vulnerability' corresponds to 'hazard'. The well-established terms applied in the various schools of vulnerability research are very useful in a context where their meaning is clear. The systematic terms suggested in this paper are not intended to replace them but to allow the consistent description of any vulnerability concept without having to recur to the terminology of a particular school of vulnerability research. (2007, p. 158-159)

Of course, this framework does not reconcile all of the differences that climate change vulnerability researchers have in measuring vulnerability, but provides a method of categorizing concepts that vulnerability assessments have in common but describe using different terminology. It should also be noted that not every dimension of this framework is relevant to every vulnerability assessment; for example, species vulnerability assessments, which will be discussed more below, obviously need not incorporate socioeconomic factors.

A Brief History of Climate Change Vulnerability Assessments

Füssel and Klein (2006, p. 308) list three major decision contexts in which CCVAs have been conducted:

1. Specification of long-term targets for the *mitigation* of global climate change
2. Identification of particularly vulnerable regions and/or groups in society to prioritize *resource allocation* for research and for adaptation
3. Recommendation of *adaptation measures* for specific regions and sectors

It is based on these three policy foci (mitigation, resource allocation, and adaptation) that the evolution of CCVAs can be categorized. (Note that although the term "evolution" is used, this is not meant to imply that the earlier forms of vulnerability assessment are somehow obsolete or no longer in use. Rather, what these categories represent are prototypical stages of vulnerability assessment distinguished by the policy needs they are trying to meet.

TABLE II
Characteristic properties of four different stages of climate change vulnerability assessment

	Impact assessment	Vulnerability assessment		Adaptation policy assessment
		First generation	Second generation	
Main policy focus	Mitigation policy	Mitigation policy	Resource allocation	Adaptation policy
Analytical approach	Positive	Mainly positive	Mainly positive	Normative
Main result	Potential impacts	Pre-adaptation vulnerability	Post-adaptation vulnerability	Recommended adaptation strategy
Time horizon	Long-term	Long-term	Mid- to long-term	Short- to long-term
Spatial scale	National to global	National to global	Local to global	Local to national
Consideration of climate variability, non-climatic factors, and adaptation	Little	Partial	Full	Full
Consideration of uncertainty	Little	Partial	Partial	Extensive
Integration of natural and social sciences	Low	Low to medium	Medium to high	High
Degree of stakeholder involvement	Low	Low	Medium	High
Illustrative research question	What are potential biophysical impacts of climate change?	Which socio-economic impacts are likely to result from climate change?	What is the vulnerability to climate change, considering feasible adaptations?	Which adaptations are recommended for reducing vulnerability to climate change and variability?

Source: Füssel and Klein (2006, p. 310)

Füssel and Klein (2006) conceptualize the evolution of CCVAs in four separate stages:

Impact Assessment: The distinguishing features of the impact assessment are that it exclusively focuses on mitigation as a policy option, considers only the long-term and only at large spatial scales. These types of assessments were conducted until the early half of the 1990s.[1]

First-Generation Vulnerability Assessment: The primary step forward, relative to the impact assessment, for the first-generation vulnerability assessment is that it evaluates climate

[1] Füssel and Klein's (2006) selected examples of impact assessments are Monserud et al. (1993), Leemans and van den Born (1994), Kwadijk and Middelkoop (1994), Nicholls and Leatherman (1995), Rosenzweig and Parry (1994), Martens et al. (1995), and Martens et al. (1997).

impacts in terms of their relevance for society and considers potential adaptation. Although first-generation vulnerability assessments helped to raise awareness regarding the vulnerability of important systems and possible methods of adaptation, they did not typically evaluate the feasibility of implementing those methods.[2]

Second-Generation Vulnerability Assessment: Second-generation vulnerability assessments put more emphasis on the adaptive capacity of people or systems, and thus transfer the focus from potential adaptation to feasible adaptation. In so doing, they aid in allocating scarce management resources to their most highly valued uses. To increase the efficacy of adaptation efforts, second-generation vulnerability assessments make more use of qualitative data and require greater involvement by stakeholders.[3]

Adaptation Policy Assessment: The primary purpose of what Füssel and Klein (2006, p. 321) refer to as 'adaptation policy assessments' is to present specific recommendations to policy makers and stakeholders on enhancing adaptive capacity and implementing adaptation policies. Compared to the other stages, it puts relatively less focus on assessing impacts, which are more relevant considerations for implementing mitigation policy rather than adaptation strategies.[4] Burton et al. (2002) notes that earlier forms of vulnerability assessment did not provide adequate information to stakeholders for developing adaptation policy due to the fact that they typically did not consider short-term issues, were at too large of a scale to be useful for developing specific on-the-ground adaptation procedures, and involved little consideration of the actual policy-making process. Indeed, Wellstead et al. (2013) argue that most vulnerability assessments treat policy-making as a "black box" that implements "management and policy innovations as quasi-automatic responses to climate change related changes" (p. 23).

The clearest trend that characterizes the evolution of vulnerability assessment is the increased emphasis on adaptation as a policy focus. This is most likely due to the fact that mitigation is a strategy that is far more relevant at a macro-scale while adaptation is something that can be implemented locally. As noted by Glick et al. (2011, p. 8), "Adaptation is rapidly becoming the primary lens for conservation and natural resource planning and management."

Challenges Facing Natural Resource Vulnerability Assessments

'Natural resources', as used here, refers to animal species, habitats, and ecosystems. The conceptualization of vulnerability provided above describes the necessary parts of a natural resource CCVA; that is, vulnerability is determined by sensitivity, exposure, and adaptive capacity. For example, in the US Forest Service's *System for Assessing Vulnerability of Species (SAVS) to Climate Change*, elements of evaluating sensitivity includes whether the species' sex ratio is determined by temperature, its metabolic rate, and whether temperature affects mating

[2] Examples of first-generation vulnerability assessments are presented in Smithers and Smit (1997), Smit and Pilifosova (2001), and Lim (2001).
[3] Second-generation vulnerability assessments include NAS (2001), Scheraga and Furlow (2001), Adger (1999), and Cohen et al. (2000).
[4] The one example of an adaptation policy assessment provided by Füssel and Klein (2006) is the *Climate Change and Adaptation Strategies for Human Health in Europe* in Menne and Ebi (2005).

patterns; measuring degree of exposure includes determining whether the species' breeding area is expected to change; and examples of adaptive capacity include the species' ability to colonize new areas and whether it has flexible strategies to cope with variation in resources across multiple years (Bagne et al., 2011).

In many ways, CCVAs of natural resources are less complex than those involving strictly human systems since many considerations, such as social and political aspects, are not as readily apparent.[5] Compared to the varying approaches to vulnerability in human systems, such as the "starting point" and "endpoint" distinctions presented in O'Brien et al. (2004) that are largely due to differing political values, natural resource vulnerability is comparatively straightforward, at least conceptually. With this consideration in mind, it may be surprising that there are still major differences in the outcomes of vulnerability assessments measuring the same systems. Lankford et al. (2014, p. 386) compared 3 widely used assessments of species vulnerability (the NatureServe Climate Change Vulnerability Index, the System for Assessing the Vulnerability of Species, and the Climate Change Sensitivity Database) and "found little agreement in species rankings between pairs of assessments" and "no apparent pattern within, or between, taxa or habitat associations that could explain this poor correlation." Their analysis of different assessments of the same species is one of the first of its kind, and since species assessments are relatively new, "almost no species have been evaluated by multiple assessments within the same region" (p. 393). Thus, to ensure the validity and reliability of species vulnerability assessments, further research is necessary.

Another major challenge facing natural resource CCVAs (as well as all VAs) involves producing science that is useful and communicating that research to stakeholders. There are several weak points in the communication process, in addition to institutional incentives facing scientists, which can lead to suboptimal adaptation planning. These issues (though by no means an exhaustive list) include:

- Scientists and practitioners have precious few opportunities for regular face to face interaction that can facilitate trust-building (Dabelko, 2005)
- Applied science has less prestige and rewards than basic science (Moll and Zander, 2006).
- Scientists and decision-makers have different notions of legitimate knowledge; that is, scientific knowledge vs. consideration of stakeholder values and non-scientific types of knowledge (Vogel et al., 2007).
- The scientific enterprise often sees its job as producing knowledge only, rather than producing information that is useful in decision-making (Dilling & Lemos, 2011).
- To advance their academic careers, scientists are incentivized to publish in academic journals, which tend to favor unique scientific contributions rather than science that is most useful to resource managers. In addition, journal publication time frames can be too

[5] This, however, does not mean political or economic considerations are not present at all. If nothing else, these considerations should be incorporated into any adaptation assessment or planning, as that aspect involves human decision-making.

long of a process to provide timely information for managing urgent conservation problems (Meffe, 2001).

As can be seen here, the use of CCVAs face challenges in both the natural science and social science realms. Some of the most serious issues facing the former realm are uncertainty regarding climate change predictions and improvement of the reliability and validity of vulnerability assessments. Regarding the latter realm, the most pressing issue may be creating an incentive structure that rewards scientists for creating "actionable science" that is delivered in a timely fashion to decision-makers.

Conclusion

This paper defines vulnerability, provides a framework to categorize aspects of vulnerability assessments and compare them, discusses types of vulnerability assessments, and addresses the challenges that producers and consumers of CCVAs encounter. Vulnerability can most generally be defined as a function of sensitivity a system has to a hazard, the level of exposure that system bears, and the ability of that system to adapt to that hazard. In general, a vulnerability assessment should define the system in question, the valued attribute of that system, the hazard to which that system attribute(s) is vulnerable, and the time horizon, scale and knowledge domain under consideration. Vulnerability assessments to date can be categorized according to the policy objectives they are attempting to inform, whether that be mitigation, adaptation, or both, Climate change vulnerability assessments, particularly regarding natural resources, are a relatively new tool and thus require further experimentation and evaluation in order to maximize their accuracy and usefulness to resource managers and other stakeholders.

References

Adger, N. W. (1999). Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. *World Development*, *27*(2), 249–269. http://doi.org/10.1016/S0305-750X(98)00136-3

Bagne, K. E., Friggens, M. M., Finch, D. M., & others. (2011). A system for assessing vulnerability of species (SAVS) to climate change. Retrieved from http://docs.lib.noaa.gov/noaa_documents/NOAA_related_docs/USDA/RMRS-GTR_257.pdf

Cohen, S. J., Miller, K. A., Hamlet, A. F., & Avis, W. (2000). Climate Change and Resource Management in the Columbia River Basin. *Water International*, *25*(2), 253–272. http://doi.org/10.1080/02508060008686827

Dabelko, G. D. (2005). Speaking Their Language: How to Communicate Better with Policymakers and Opinion Shapers – and Why Academics Should Bother in the First Place. *International Environmental Agreements: Politics, Law and Economics*, *5*(4), 381–386. http://doi.org/10.1007/s10784-005-8329-8

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689. http://doi.org/10.1016/j.gloenvcha.2010.11.006

Füssel, H.-M. (2004). Coevolution of the political and conceptual frameworks for climate change vulnerability assessments. In *Proceedings of the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change "Knowledge for the Sustainability Transition. The Challenge for Social Science". Global Governance Project, Amsterdam, The Netherlands* (pp. 302–320). Retrieved from http://www.researchgate.net/publication/228746318_Coevolution_of_the_political_and_conceptual_frameworks_for_climate_change_vulnerability_assessments/file/79e41509902590fa5f.pdf

Füssel, H.-M. (2005). Vulnerability in climate change research: A comprehensive conceptual framework. Retrieved from http://escholarship.org/uc/item/8993z6nm.pdf

Füssel, H.-M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, *17*(2), 155–167. http://doi.org/10.1016/j.gloenvcha.2006.05.002

Füssel, H.-M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*, *75*(3), 301–329.

Glick, P., Stein, B. . A., & Edelson, N. A. (2011). Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation. Retrieved from www.nwf.org/vulnerabilityguide

Hewitt, K. (1997). *Regions of risk: a geographical introduction to disasters*. Essex, UK: Addison Wesley Longman.

IPCC. (2001). *Climate change 2001: Synthesis report. Contribution of working groups I, II, and III to the third assessment report of the intergovernmental panel on climate change [Watson, R.T. and the Core Writing Team (eds.)]*. Cambridge University Press.

Kwadijk, J., & Middelkoop, H. (1994). Estimation of impact of climate change on the peak discharge probability of the river Rhine. *Climatic Change*, *27*(2), 199–224. http://doi.org/10.1007/BF01093591

Lankford, A. J., Svancara, L. K., Lawler, J. J., & Vierling, K. (2014). Comparison of climate change vulnerability assessments for wildlife. *Wildlife Society Bulletin*, *38*(2), 386–394. http://doi.org/10.1002/wsb.399

Leemans, R., & Born, G. J. van den. (1994). Determining the potential distribution of vegetation, crops and agricultural productivity. *Water, Air, and Soil Pollution*, *76*(1-2), 133–161. http://doi.org/10.1007/BF00478338

Lim, B. (2001). UNDP–GEF Workshop for Developing an Adaptation Policy Framework for Climate Change. Preliminary Report. *St. Adele, Canada*.

Martens, W. J. M., Jetten, T. H., & Focks, D. A. (1997). SENSITIVITY OF MALARIA, SCHISTOSOMIASIS AND DENGUE TO GLOBAL WARMING. *Climatic Change*, *35*(2), 145–156. http://doi.org/10.1023/A:1005365413932

Martens, W. J., Niessen, L. W., Rotmans, J., Jetten, T. H., & McMichael, A. J. (1995). Potential impact of global climate change on malaria risk. *Environmental Health Perspectives*, *103*(5), 458–464.

Meffe, G. K. (2001). Crisis in a Crisis Discipline. *Conservation Biology*, *15*(2), 303–304. http://doi.org/10.1046/j.1523-1739.2001.015002303.x

Menne, B., & Ebi, K. . L. (2003). European Climate Change Health IMpact and Adaptation Asessment. *Epidemiology*, *14*(5). Retrieved from http://journals.lww.com/epidem/Fulltext/2003/09001/EUROPEAN_CLIMATE_CHANGE_HEALTH_IMPACT_AND.282.aspx

Moll, P., & Zander, U. (2006). Managing the interface. *München: Oekom*. Retrieved from http://www.ufz.eu/export/data/1/30553_managing_the_interface_en_kurz.pdf

Monserud, R. A., Tchebakova, N. M., & Leemans, R. (1993). Global vegetation change predicted by the modified Budyko model. *Climatic Change*, *25*(1), 59–83. http://doi.org/10.1007/BF01094084

NAS, U. (2000). *Climate Change Impacts on the United States The Potential Consequences of Climate Variability and Change. National Assessment Synthesis Team, US Global Change Research Program. HTUhttp*.

Nicholls, R. J., & Leatherman, S. P. (1995). *Potential impacts of accelerated sea-level rise on developing countries*. Coastal Education and Research Foundation.

O’Brien, K., Eriksen, S. E. H., Schjolden, A., & Nygaard, L. P. (2004). *What’s in a word? Conflicting interpretations of vulnerability in climate change research* (Working paper). CICERO Center for International Climate and Environmental Research - Oslo. Retrieved from http://brage.bibsys.no/xmlui/handle/11250/192322

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. *Nature*, *367*(6459), 133–138.

Scheraga, J. D., & Furlow, J. (2001). From Assessment to Policy: Lessons Learned from the U.S. National Assessment. *Human and Ecological Risk Assessment: An International Journal*, *7*(5), 1227–1246. http://doi.org/10.1080/20018091094961

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), 9.

Smithers, J., & Smit, B. (1997). Human adaptation to climatic variability and change. *Global Environmental Change*, *7*(2), 129–146. http://doi.org/10.1016/S0959-3780(97)00003-4

Timmerman, P. (1981). Vulnerability, resilience and the collapse of society. *A ReviewofModels and Possible Climatic Appli-Cations. Toronto, Canada. Institute for Environmental Studies, University of Toronto*. Retrieved from http://www.ilankelman.org/miscellany/Timmerman1981.pdf

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., … others. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, *100*(14), 8074–8079.

Vogel, C., Moser, S. C., Kasperson, R. E., & Dabelko, G. D. (2007). Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. *Global Environmental Change*, *17*(3–4), 349–364. http://doi.org/10.1016/j.gloenvcha.2007.05.002

Wellstead, A. M., Howlett, M., & Rayner, J. (2013). The neglect of governance in forest sector vulnerability assessments: Structural-functionalism and “black box” problems in climate change adaptation planning. *Ecology and Society*, *18*(3), 23.

Williams, S. E., Shoo, L. P., Isaac, J. L., Hoffmann, A. A., & Langham, G. (2008). Towards an integrated framework for assessing the vulnerability of species to climate change. *PLoS Biology*, *6*(12), e325.

Young, B., Byers, E., Gravuer, K., Hall, K., Hammerson, G., & Redder, A. (2010). Guidelines for using the NatureServe climate change vulnerability index. *NatureServe, Arlington, VA*. Retrieved from http://www.cakex.org/virtual-library/guidelines-using-natureserve-climate-change-vulnerability-index

APPENDIX 3. Constraints of Climate Change Vulnerability Assessments and Recommendations for Overcoming Them

Executive Summary

The purpose of this paper is to provide a brief overview of the literature regarding the constraints facing the creation and use of climate change vulnerability assessments (CCVAs or VAs) in terms of successfully informing climate change adaptation policy. There are several types of constraints, which are categorized as follows:

- Issues associated with scientists and the scientific enterprise
- Institutional barriers facing users of climate science
- Shortcomings in the communication process between scientists and users
- Technical limitations on scientific validity of CCVAs and their lack of usability

This paper will also address some of the proposed measures to ameliorate these problems.

Constraints

Issues Associated with Scientists and the Scientific Enterprise

Scientists' Perception of What Their Job Is and Their Desire to Stay Away from Politics

One commonly cited barrier between scientists and users of climate science is the culture in science that encourages a distance from politics or policy making. For ethical and professional reasons, scientists typically desire to keep their work separate from the vagaries of politics (e.g. McNeely, 1999; Brooks, 2001; Freyfogle and Newton, 2002). Dilling and Lemos (2011) note that the scientific enterprise often views its role as producing knowledge with little consideration as to whether it is useful in decision making. They quote one senior official of the United State Global Change Research Program as saying "whether that [knowledge] can translate into actions…is not really the business of the Subcommittee on Global Change Research. That is where our job ends, and, thank God, in some sense, other people's job starts" (p. 684). Likewise, Vogel et al. (2007) describe communication as being either an afterthought of scientists or something not in their job description.

Scientists' Incentives

There are numerous conflicts between the career incentives of scientists and providing users of climate change science with useful information. They include:

- The incentive to engage in basic, rather than applied, science since applied science is accorded less prestige and rewards than basic science (Moll and Zander, 2006).
- Academic scientists operate in a system where publication and grant income, rather than communication with resource managers, is rewarded (Gibbons et al., 2008; Arlettaz et al., 2010). In addition, effective communication with practitioners is time-intensive, is not prestigious, and can even be penalized in some scientific circles (Chappell & Hartz, 1998; Jacobson et al., 2004).
- Relatedly, Meffe (2001) observes that the time frames of journal publication may be incompatible with urgent conservation needs. As well, scientists typically desire to err on the

side of caution and have their results reviewed in the peer-review process while decision makers want information quickly (Van der Vink, 1997; Blockstein, 2002; Cash et al., 2002).
- Furthermore, the scientific knowledge production process is relatively conservative in terms of rewarding established methods and making incremental improvements upon knowledge rather than using uncertain, innovative strategies (Travis & Collins, 1991; Wessely, 1998).
- There are disincentives within research institutions to conducting multidisciplinary research despite its necessity in developing realistic adaptation strategies (Ludwig et al., 2001; Knight et al., 2008).

Neglecting Politics: Doing Science in a Vacuum

Related to the issue of the science-politics divide addressed above, even when scientists desire to inform the policy creation process with good science, they often overlook the nature of the political decision making. Vogel et al. (2007) argue that scientific knowledge has a political and strategic nature and is produced in a political context. For scientists to make science useful, but not used in unjustifiable manners, they must be mindful of the practitioner interface. As well, for vulnerability assessments that make recommendations regarding adaptation, having a sense of the policy process and social science will make their conservation recommendations more useful. Watson (2005) notes that most conservation recommendations neglect social science and are primarily focused on ecological data despite the importance of human behavior and preferences in determining outcomes. Indeed, most vulnerability assessments are made without any explicit acknowledgement of the policy-making process, treating it as a "black box" into which VAs are an input and (hopefully) the correct policies are the output (Wellstead et al. 2013).

Institutional Barriers Facing Users of Climate Science

Resource managers face both formal and informal barriers that prevent them from making full productive use of climate science. Dilling and Lemos (2011) provide examples of formal barriers, a major one being inflexible decision making. Examples of this include water allocation decision making in the Pacific Northwest, wildland fire management, and mitigating flood risk (Callahan et al., 1999; Corringham et al., 2009; Morss et al., 2005; Pulwarty & Redmond, 1997). Informal institutional barriers include things such as organizational cultures that favor established practices and are apprehensive about changing policy in accordance with uncertain forecasts. The incentives within resource management bureaucracies discourage risk-taking in embracing new ideas, but encourage sticking with what is established (Dilling & Lemos, 2011). Young and Van Aarde (2011) state that the cultures of organizations that use climate science often do not promote the use of science when implementing strategies.

When asking resource managers and other decision makers about impediments to their use of climate science, a pattern emerges. They mention the disconnection between scientists and practitioners, such as the lack of alignment between the scientific research and the information needed by policy makers (Fazey et al., 2005; Young & Van Aarde, 2011), as well as the difficulty in accessing and interpreting the scientific information (Pullin & Knight, 2005; Arlettaz et al., 2010). In a study that interviewed federal land managers from the US Forest Service, Bureau of Land Management, National Park Service, and the Fish and Wildlife Service in Colorado, Utah and Wyoming regarding barriers to the implementation of climate change adaptation efforts, Archie et al. (2012) found the following issues:

- Competing priorities within the agency
- Lack of relevant data
- Lack of clear governmental roles
- Lack of agency direction
- Lack of funding
- Unfavorable public sentiment
- Conflict among stakeholders

It is especially this last point that highlights the importance of the insights found in Healy and Ascher (1995). In studying the effects of new sources and methods of applying information on the forest planning policy process, Healy and Ascher found that the new information did not have the positive, unifying effect that many had hoped it would have. Rather, stakeholders would attempt to use the information in such a way to justify their pre-existing policy positions. Thus, Healy and Ascher concluded that no matter how valid scientific information is, it cannot fully answer questions regarding competing values. Therefore, we should not expect climate change vulnerability assessments or other forms of climate science to solve all or even the majority of problems facing implementation of adaptation policy.

Shortcomings in the Communication Process between Scientists and Users

No matter how relevant or robust the climate science is, it will not translate into efficacious adaptation if it is not properly communicated to the relevant parties. One of the primary communication barriers, as mentioned above, is not presenting scientific information in ways that are both accessible and can readily be incorporated into existing decision making procedures (e.g., Hall & Paradice, 2005; Morss et al., 2005). A further barrier is that scientists and decision makers often have different ideas of what types of knowledge should be considered legitimate, such as the latter group's consideration of stakeholder values and non-scientific knowledge (Vogel et al., 2007).

Due to several factors, such as the frequent one-way communication from scientist to science consumer, the perception that scientists are driven by personal agendas and lack consensus (Young & Van Aarde, 2011), and the fact that scientists and practitioners have very few opportunities for regular face to face interaction (Dabelko, 2005), a lack of trust between scientists and practitioners can arise. This lack of trust obviously presents a communication barrier, and it can also affect practitioners' trust in the legitimacy of the science itself (Dilling & Lemos, 2011). This trust is important, and methods for fostering it will be discussed in the recommendations section.

Another avenue of communication that should not be neglected is communication with the public. If relevant scientific information is not presented in ways that do not attract political and public support (perhaps because it does not create a sense of urgency or conflicts with deeply held values) it may not even factor in the policy making process (e.g., Ogunseitan, 2000, 2003; Schreurs et al., 2001; Pielke, 1997; Gerhard, 1994). A difficulty is that scientists are not trained to communicate with the media and are unlikely to report their findings in a way that interests the typical media consumer. Furthermore, due to other pressing and more visible concerns, climate change issues are less able to hold central public attention (Vogel et al., 2007).

Technical Limitations on Scientific Validity of CCVAs and Their Lack of Usability

Issues with CCVAs abound. A significant one, mentioned in more detail in "Defining Vulnerability and Vulnerability Assessments," is the differences in how scientists conceptualize vulnerability and the factors associated with it. Due to the complexity of the systems at issue and the number of different scientific disciplines involved, confusion is often the result. As well, the precise use of terms such as resilience or adaptation can be a challenge when handled by members of separate disciplines (Thomalla et al., 2006). In addition to the many ways one can conceptualize a term, one can also operationalize a concept in myriad different ways, and with climate science, there are an almost infinite number of options in forecasting at different spatial and time scales. Most seasonal forecasting is more accurate at larger scales, but users perceive smaller scales as much more useful (Broad & Agrawala, 2000); Broad et al., 2002; Leetmaa, 2003; Patt & Gwata, 2002; Rayner et al., 2005; Letson et al., 2001).

Patt et al. (2005) are highly critical of climate change vulnerability assessments, particularly in terms of their uncertainty. They claim that they are different from other types of vulnerability assessments for three reasons:

- The complexity of the system under analysis is greater.
- There is no way to scientifically validate the integrative models and test whether the various parts of the system interact in the way that is proposed. Thus, only the most basic of statements can be made with confidence.
- The predictive accuracy over the long term must be greater. CCVAs require projecting possible outcomes many decades into the future with enough accuracy to differentiate between the effectiveness of competing present policy options.

One implication of these three points is that while narrowly framed VAs may improve the quality of long-term investment decisions, the inherent uncertainty in broader types of CCVAs may not be any more useful than in their capacity to suggest no-regrets strategies. However, Patt et al. (2005) are skeptical of CCVAs being much more useful beyond this. Indeed, they find that a CCVA with little or no useful information may be worse than no assessment at all because they may crowd out some other type of assessment that is more useful. Thus, the contribution of CCVAs to the policy process is not in identifying the most effective ways of reducing future vulnerability, but rather in creating a dialogue where impacts can be elucidated and no-regrets adaptations explored.

One final issue of usability that is especially salient given the transition in the expectations of CCVAs to provide adaptation policy assessment (Füssel & Klein, 2006) is the frequent lack of specificity in regard to adaptation recommendations. This is true not only of CCVAs but all conservation recommendation literature. In a review of 22 years of recommendations, Heller and Zavaleta (2009) found that the majority of recommendations in the published journal literature are very general (e.g., “Integrate climate change into planning exercises (reserve, pest outbreaks, harvest schedules, grazing limits, incentive programs,” p. 18) and “have been reiterated frequently without the elaboration necessary to operationalize them” (p. 29).

Recommendations

Create an iterative process that facilitates communication between scientists and decision makers

A frequently cited problem in the enterprise of creating actionable climate science for decision makers is the communication process. Vogel et al. (2007, p. 352):

> Where the science-practice interaction is not taken seriously or carefully designed, a number of disconnections can emerge that frustrate otherwise well-meaning measures to reduce vulnerability and enhance resilience: the scientific output is more likely to be mismatched to user requirements…it may not be delivered in time or in appropriate formats; those

interacting do not communicate well; scientists feel their credibility is negatively affected by collaborating with practitioners; stakeholders do not feel their legitimate concerns are addressed; and so on.

In consideration of these issues, Vogel et al. (2007) recommend conceptualizing the science/practice interaction as "'spider webs' of connectivity and exchange in which there are nodes and complex linkages" rather than "'bridges' or 'highways of connectivity'" (p. 360). The communication process should not be linear or a one-off event, but instead there should be an iterative arrangement involving continued interaction between scientists and science users (Dilling & Lemos, 2011). The following are some types of institutions that can facilitate such communication:

- The establishment of Vulnerability Assessment Committees (VACs) to serve as relatively permanent institutional forums for communication between scientists and stakeholders (Owens, 2005; Maunder & Wiggins, 2007).
- Boundary organizations (e.g. Cash, 2001; Guston, 2001; Miller, 2001)
- Miles et al. (2006) suggest that the usual 2 or 3 year project cycle funded by US agencies may be inadequate for building trust and relationships between scientists and stakeholders.
- Embedding research scientists in resource management agencies or creating formal links between decision makers and scientists at research-focused institutions (Dilling & Lemos, 2011; Cook et al., 2013).

Dilling and Lemos (2011) present an example from the private sector that may serve as a useful model: "The use of SCFs [seasonal climate forecasting] in agribusiness and weather derivatives demonstrates that when private interests see a benefit and can afford to invest in personnel, SCFs are incorporated into business decisions through sophisticated modeling and interpretation of climate data" (p. 685). This example illustrates Palmer's (2012, p. 6) recommendation to "[turn] the tables" and ask decision makers what they need from the scientific community, rather than to have the scientific community do related research that may or may not be useful. Indeed, Sarewitz and Pielke (2007) argue that equilibrating the supply of and demand for scientific research could improve the usefulness of science for the management of public lands.

Improving the usefulness of CCVAs

In order to deal with the uncertainty of CCVAs, Patt et al. (2005) recommend that scientists either perform a narrower form of CCVA, such as evaluating a single decision or less complex system (e.g. a building or infrastructure project), or if they choose to conduct a broader form of CCVA, they should present their findings in a less aggregated manner. By combining projections for future climate change impacts and predictions regarding socioeconomic variables, they are multiplying uncertainties. Rather, scientists should consider future risks to a given system as that system exists today instead of how they expect that system to exist in the future.

As mentioned above, another shortcoming of CCVAs about which practitioners frequently complain is the lack of specific recommendations about adaptation. Therefore, Heller and Zavaleta (2009) state that conservation recommendations should be concrete, specific, and involve case studies that illustrate how to link research agendas to conservation strategies, as well as take into account the actions of humans and how they will relate to other species that cohabitate lands with them.

Dilling and Lemos (2011) further suggest evaluating the success of VAs and other forms of climate science in terms of their usability, focusing on measures of outcomes such as clarity of the results and relationships developed with stakeholders. Relatedly, Kerr (2011) provides what may be the most useful definition of “actionable science” in any context involving a user of scientific research: a result is actionable if you would spend your own money on it.

Conclusion

Climate change vulnerability assessments face a number of constraints to maximizing their usefulness in informing adaptation practices. This paper has highlighted some of the largest constraints, as well as the most commonly cited. In addition, it has also provided recommendations on how to overcome these barriers. Some of these constraints may be surmounted by institutional changes and conscientiousness by scientists and stakeholders. Other criticisms of CCVAs, however, suggest that expectations of what vulnerability assessments can accomplish may be too great and that more modest goals should replace the current aims of predicting the state of complex systems of social and natural variables far into the future. For the usefulness CCVAs to be maximized, these issues must be confronted and addressed.

REFERENCES

Archie, K. M., Dilling, L., Milford, J. B., & Pampel, F. C. (2012). Climate Change and Western Public Lands: a Survey of U. S. Federal Land Managers on the Status of Adaptation Efforts. *Ecology and Society*, *17*(4), 20.

Arlettaz, R., Schaub, M., Fournier, J., Reichlin, T. S., Sierro, A., Watson, J. E. M., & Braunisch, V. (2010). From Publications to Public Actions: When Conservation Biologists Bridge the Gap between Research and Implementation. *BioScience*, *60*(10), 835–842. http://doi.org/10.1525/bio.2010.60.10.10

Blockstein, D. E. (2002). How to Lose Your Political Virginity while Keeping Your Scientific Credibility. *BioScience*, *52*(1), 91–96. http://doi.org/10.1641/0006-3568(2002)052[0091:HTLYPV]2.0.CO;2

Broad, K., & Agrawala, S. (2000). The Ethiopia Food Crisis--Uses and Limits of Climate Forecasts. *Science*, *289*(5485), 1693–1694. http://doi.org/10.1126/science.289.5485.1693

Broad, K., Pfaff, A. S. P., & Glantz, M. H. (2002). Effective and Equitable Dissemination of Seasonal-to-Interannual Climate Forecasts: Policy Implications from the Peruvian Fishery during El Niño 1997–98. *Climatic Change*, *54*(4), 415–438. http://doi.org/10.1023/A:1016164706290

Brooks, H. (2001). Autonomous science and socially responsive science: A search for resolution. *Annual Review of Energy and the Environment*, *26*(1), 29–48.

Callahan, B., Miles, E., & Fluharty, D. (1999). Policy implications of climate forecasts for water resources management in the Pacific Northwest. *Policy Sciences*, *32*(3), 269–293. http://doi.org/10.1023/A:1004604805647

Cash, D. W. (2001). “In Order to Aid in Diffusing Useful and Practical Information”: Agricultural Extension and Boundary Organizations. *Science, Technology & Human Values*, *26*(4), 431–453. http://doi.org/10.1177/016224390102600403

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., … Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, *100*(14), 8086–8091.

Chappell, C. R., & Hartz, J. (1998). The challenge of communicating science to the public. *Chronicle Higher Educ*, *87*, B7.

Cook, C. N., Mascia, M. B., Schwartz, M. W., Possingham, H. P., & Fuller, R. A. (2013). Achieving Conservation Science that Bridges the Knowledge–Action Boundary. *Conservation Biology*, *27*(4), 669–678. http://doi.org/10.1111/cobi.12050

Corringham, T. W., Westerling, A. L., & Morehouse, B. J. (2008). Exploring Use of Climate Information in Wildland Fire Management: A Decision Calendar Study. *Journal of Forestry*, *106*(2), 71–77.

Dabelko, G. D. (2005). Speaking Their Language: How to Communicate Better with Policymakers and Opinion Shapers – and Why Academics Should Bother in the First Place. *International*

Environmental Agreements: Politics, Law and Economics, *5*(4), 381–386. http://doi.org/10.1007/s10784-005-8329-8

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689. http://doi.org/10.1016/j.gloenvcha.2010.11.006

Fazey, I., Fischer, J., & Lindenmayer, D. B. (2005). What do conservation biologists publish? *Biological Conservation*, *124*(1), 63–73. http://doi.org/10.1016/j.biocon.2005.01.013

Freyfogle, E. T., & Newton, J. L. (2002). Putting Science in its Place. *Conservation Biology*, *16*(4), 863–873. http://doi.org/10.1046/j.1523-1739.2002.01042.x

Füssel, H.-M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*, *75*(3), 301–329.

Gerhard, L. C. (1994). Farming policies on resources and the environment. *Geotimes*, *39*(5), 20–25.

Gibbons, P., Zammit, C., Youngentob, K., Possingham, H. P., Lindenmayer, D. B., Bekessy, S., … Wintle, B. (2008). Some practical suggestions for improving engagement between researchers and policy-makers in natural resource management. *Ecological Management & Restoration*, *9*(3), 182–186. http://doi.org/10.1111/j.1442-8903.2008.00416.x

Gregory E. van der Vink. (1998). Scientifically illiterate vs. politically clueless. *Optics & Photonics News*, *9*, 22–23.

Guston, D. H. (2001). Boundary Organizations in Environmental Policy and Science: An Introduction. *Science, Technology, & Human Values*, *26*(4), 399–408.

Hall, D. J., & Paradice, D. (2005). Philosophical foundations for a learning-oriented knowledge management system for decision support. *Decision Support Systems*, *39*(3), 445–461. http://doi.org/10.1016/j.dss.2004.01.005

Healy, R. G., & Ascher, W. (1995). Knowledge in the policy process: incorporating new environmental information in natural resources policy making. *Policy Sciences*, *28*(1), 1–19.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, *142*(1), 14–32.

Jacobson, N., Butterill, D., & Goering, P. (2004). Organizational Factors that Influence University-Based Researchers' Engagement in Knowledge Transfer Activities. *Science Communication*, *25*(3), 246–259. http://doi.org/10.1177/1075547003262038

Kerr, R. A. (2011). Time to adapt to a warming world, but where's the science? *Science*, *334*(6059), 1052–1053.

Knight, A. T., Cowling, R. M., Rouget, M., Balmford, A., Lombard, A. T., & Campbell, B. M. (2008). Knowing But Not Doing: Selecting Priority Conservation Areas and the Research–Implementation Gap. *Conservation Biology*, *22*(3), 610–617. http://doi.org/10.1111/j.1523-1739.2008.00914.x

Leetmaa, A. (2003). Seasonal forecasting: innovations in practice and institutions. *Bulletin of the American Meteorological Society*, *84*(12), 1686–1691.

Letson, D., Llovet, I., Podestá, G., Royce, F., Brescia, V., Lema, D., & Parellada, G. (2001). User perspectives of climate forecasts: crop producers in Pergamino, Argentina. *Climate Research*, *19*(1), 57–67.

Ludwig, D., Mangel, M., & Haddad, B. (2001). Ecology, Conservation, and Public Policy. *Annual Review of Ecology and Systematics*, *32*, 481–517.

Maunder, N., & Wiggins, S. (2007). Food security in southern Africa: Changing the trend? Review of lessons learnt on recent responses to chronic and transitory hunger and vulnerability.

McNeely, J. A. (1999). Strange bedfellows: why science and policy don't mesh and what can be done about it. *The Living Planet in Crisis: Biodiversity, Science and Policy. Columbia University Press, New York*.

Meffe, G. K. (2001). Crisis in a Crisis Discipline. *Conservation Biology*, *15*(2), 303–304. http://doi.org/10.1046/j.1523-1739.2001.015002303.x

Miles, E. L., Snover, A. K., Binder, L. C. W., Sarachik, E. S., Mote, P. W., & Mantua, N. (2006). An approach to designing a national climate service. *Proceedings of the National Academy of Sciences*, *103*(52), 19616–19623. http://doi.org/10.1073/pnas.0609090103

Miller, C. (2001). Hybrid Management: Boundary Organizations, Science Policy, and Environmental Governance in the Climate Regime. *Science, Technology & Human Values*, *26*(4), 478–500. http://doi.org/10.1177/016224390102600405

Moll, P., & Zander, U. (2006). Managing the interface. *München: Oekom*. Retrieved from http://www.ufz.eu/export/data/1/30553_managing_the_interface_en_kurz.pdf

Morss, R. E., Wilhelmi, O. V., Downton, M. W., & Gruntfest, E. (2005). Flood Risk, Uncertainty, and Scientific Information for Decision Making: Lessons from an Interdisciplinary Project. *Bulletin of the American Meteorological Society*, *86*(11), 1593–1601. http://doi.org/10.1175/BAMS-86-11-1593

Ogunseitan, O. A. (2000). *Framing vulnerability: global environmental assessments and the African burden of disease*. Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University. Retrieved from http://belfercenter.hks.harvard.edu/publication/2762/framing_vulnerability.html

Ogunseitan, O. A. (2003). Framing environmental change in Africa: cross-scale institutional constraints on progressing from rhetoric to action against vulnerability. *Global Environmental Change*, *13*(2), 101–111. http://doi.org/10.1016/S0959-3780(03)00004-9

Owens, S. (2005). Making a difference? Some perspectives on environmental research and policy. *Transactions of the Institute of British Geographers*, *30*(3), 287–292. http://doi.org/10.1111/j.1475-5661.2005.00171.x

Palmer, M. A. (2012). Socioenvironmental sustainability and actionable science. *BioScience*, *62*(1), 5–6.

Patt, A., & Gwata, C. (2002). Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. *Global Environmental Change*, *12*(3), 185–195. http://doi.org/10.1016/S0959-3780(02)00013-4

Patt, A., Klein, R. J., & de la Vega-Leinert, A. (2005). Taking the uncertainty in climate-change vulnerability assessment seriously. *Comptes Rendus Geoscience*, *337*(4), 411–424.

Pielke, R. A. (1997). Refraining the U.S. hurricane problem. *Society & Natural Resources*, *10*(5), 485–499. http://doi.org/10.1080/08941929709381046

Pullin, A. S., & Knight, T. M. (2005). Assessing Conservation Management's Evidence Base: a Survey of Management-Plan Compilers in the United Kingdom and Australia. *Conservation Biology*, *19*(6), 1989–1996. http://doi.org/10.1111/j.1523-1739.2005.00287.x

Pulwarty, R. S., & Redmond, K. T. (1997). Climate and Salmon Restoration in the Columbia River Basin: The Role and Usability of Seasonal Forecasts. *Bulletin of the American Meteorological Society*, *78*(3), 381–397. http://doi.org/10.1175/1520-0477(1997)078<0381:CASRIT>2.0.CO;2

Rayner, S., Lach, D., & Ingram, H. (2005). Weather Forecasts are for Wimps: Why Water Resource Managers Do Not Use Climate Forecasts. *Climatic Change*, *69*(2-3), 197–227. http://doi.org/10.1007/s10584-005-3148-z

Sarewitz, D., & Pielke Jr., R. A. (2007). The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science & Policy*, *10*(1), 5–16. http://doi.org/10.1016/j.envsci.2006.10.001

Schreurs, M., Clark, W. C., Dickson, N., & Jager, J. (2001). Issue attention, framing, and actors: an analysis of patterns across arenas. *Learning to Manage Global Environmental Risks: A Comparative History of Social Responses to Climate Change, Ozone Depletion and Acid Rain. The MIT Press, Cambridge, MA*, 349–364.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G., & Rockström, J. (2006). Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, *30*(1), 39–48. http://doi.org/10.1111/j.1467-9523.2006.00305.x

Travis, G. D. L., & Collins, H. M. (1991). New Light on Old Boys: Cognitive and Institutional Particularism in the Peer Review System. *Science, Technology & Human Values*, *16*(3), 322–341. http://doi.org/10.1177/016224399101600303

Vogel, C., Moser, S. C., Kasperson, R. E., & Dabelko, G. D. (2007). Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. *Global Environmental Change*, *17*(3–4), 349–364. http://doi.org/10.1016/j.gloenvcha.2007.05.002

Watson, R. T. (2005). Turning science into policy: challenges and experiences from the science–policy interface. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *360*(1454), 471–477. http://doi.org/10.1098/rstb.2004.1601

Wellstead, A. M., Howlett, M., & Rayner, J. (2013). The neglect of governance in forest sector vulnerability assessments: Structural-functionalism and "black box" problems in climate change adaptation planning. *Ecology and Society*, *18*(3), 23.

Wessely, S. (1998). Peer review of grant applications: what do we know? *The Lancet*, *352*(9124), 301–305.

Young, K. D., & Van Aarde, R. J. (2011). Science and elephant management decisions in South Africa. *Biological Conservation*, *144*(2), 876–885. http://doi.org/10.1016/j.biocon.2010.11.023

APPENDIX 4. Notes for the Operational Component of Vulnerability Assessments of Climate Change for Natural Resource Managers

---

The assessment of natural resources vulnerability to climate change is of great importance today as the environment is altering, yet the demand for resources stays the same. Resource managers are not operating in a vacuum and therefore a system of assessment is needed that can best prepare them for what *may* happen in the future as a result of climate change.

Vulnerability assessments offer stakeholders the possibility of becoming better decision-makers even though they are faced with uncertainty. This is done primarily by assessing which species or systems are likely to be affected by projected changes to climate, then, determining how and why these resources are vulnerable (Glick, Stein, Edelson. 2011. Pg.1). Following, are notes on how vulnerability assessments are presently being employed in regards to climate change by a sample of stakeholders. I shall address the processes by which they are conducting their assessment and, thus, highlight the differences between the approaches chosen.

The 3 Components: Sensitivity, Exposure, and Adaptive Capacity

Glick et al. highlight the three main components of a vulnerability assessment that impact the design and application of all vulnerability assessment. The three core components are: sensitivity, exposure, and adaptive capacity (2011. Pg.2).

> "*Sensitivity* generally refers to innate characteristics of a species or system and considers tolerance to changes in such things as temperature, precipitation, fire regimes, or other key processes. *Exposure,* in contrast, refers to extrinsic factors, focusing on the character, magnitude, and rate of change the species or system is likely to experience. *Adaptive capacity* addresses the ability of a species or system to accommodate or cope with climate change impacts with minimal disruption". (Glick et al. 2011. Pg. 2).

Now, once these key concepts have been brought to mind, Glick et al. describes four key steps that need to take place:

1. Determine objectives and scope.
2. Gather relevant data and expertise.
3. Assess components of vulnerability.
4. Apply assessment in adaption planning.

As mentioned earlier, the primary role of vulnerability assessment is to aid decision making for a certain stakeholder/actor. The very first step, therefore, always needs to clarify what the stakeholder wants from the assessment and therefore what is the necessary scope to include.

"Vulnerability to climate change refers to the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change impacts". (Schneider et al. 2007).

The Goal: Adaptation Management

Adaptation can be a responsible, well-informed, and highly effective response to climate change assessments that can be adopted (unlike mitigation) on a local level. The primary focus of adaptation planning is to reduce a system's vulnerability to the effects of climate change.

Preparing for the effects of climate change is known as climate change adaptation, which is quickly becoming the most popular response to climate change from stakeholders with a conservation mindset. Globalization complicates climate change assessments further – conservation efforts are needed on a scale that crosses political and social borders and barriers. Jurisdictions are also problematic as natural resources like rivers and species of birds cannot be contained and their assessment often demand collaboration of a variety of stakeholders. Therefore, reach needs to be

considered and define in the creation of an assessment. Managers need to address whether collaboration is even a possibility, and if it is, they need to determine the level of influence and commitment required from each stakeholder.
Adaptation principles:

1. Reduce Existing Stressors.
2. Manage for ecosystem function.
3. Protect refugia and improve habitat connectivity.
4. Implement proactive management and restoration.

(Glick et al. 2011. Pg. 9.)
Adaptation plans take into consideration both resistance and resilience. Both of these concepts, when considered, will influence an adaptation plan. Within climate change adaptation literature, resistance is used to refer to the "ability of a system to withstand disturbance or change without significant loss of ecological structure or function" (U.S. CCSP 2008b; Heller and Zavaleta 2009; Nyström et al. 2008; Williams et al. 2008; Walker et al. 2004; Easterling et al 2004; Hansen and Biringer 2003), and resilience is used to refer to the "ability of a system to recover from a disturbance or change without significant loss of function or structure, and to return to a given ecological state, rather than shift to a different state" (Glick et al. 2011. Pg. 9).
Although vulnerability assessments can help resource managers prepare for the future, it is important to note the limitations of vulnerability assessments. The assessments themselves will yield results us to how resource will fair under the weight of climate change. The decision on how to interpret the assessment results, and how to prioritize limited resources are decisions that the managers make.

Assessment Case Studies
Deciding which tools to use for a vulnerability assessment is by no means a straightforward process, but rather the decision depends heavily upon the management questions being asked, the target natural resource, finances available, the degree of stakeholder engagement and the level of confidence that is demanded (Johnson, 2014. Pg.3). As shown here in a selection of vulnerability assessments, the resource in question heavily influences the methodology. Therefore, this report is organized by sections that reflect the types of resources being assessed.

Species Vulnerability Assessments to Climate Change
In the realm of species vulnerability assessments, the most widely adopted method of assessment is NatureServe's Climate Change Vulnerability Index (CCVI). In the southwestern United States, another form of assessment that has been adopted is the US Forest Service System for Assessing Vulnerability of Species (SAVS). Researchers in Florida have developed the Standardized Index of Vulnerability and Value (SIVVA), which has been applied to cases local to the Florida Area (Johnson, 2014). There exist two types of species-specific vulnerability assessments: course-filter approach assessments and fine-filter assessments. The first looks at a suite of species and the effects of climate change, while the latter is species specific.

Examples of Coarse-Filter Approaches:
Climate Change Vulnerability Index (NatureServe) integrates a species' projected exposure to climate change with three additional factors that contribute to climate change sensitivity: indirect exposure to climate change, species specific factors, and documented responses to climate change. This data is then integrated with a scoring system. (Johnson, 2014. Pg.5). "Vulnerability is calculated by numerically summing values for exposure, sensitivity, and adaptive capacity and then awarded a categorical score based on threshold values" (Lankford et al. 214. Pg.388). The numerical value then ranks the species in a 1-6 category according to the extent of their vulnerability.

A System for Assessing Vulnerability of Species to Climate Change, SAVS (US Forest Service) is a tool designed to be administered, interpreted and used by managers. First, managers can complete a questionnaire of 22 criteria that creates vulnerability scores. The scores generated pertain to specie's potential vulnerability or resilience associated with projections for their region. The questionnaire not only points towards overall vulnerability, but it also breaks down the sources of vulnerability: habitat, physiology, phenology or biotic interactions.

The US Environmental Protection Agency has developed a framework categorizing the relative vulnerability of threatened and endangered species to climate change. First, module 1 "categorizes baseline vulnerability to extinction or major population reduction" (Johnson, 2014. Pg. 9). Then, module 2 takes into consideration the species' potential physiological, behavioral, demographic and ecological responses to climate change and gives a species a likely score of vulnerability. Module 3 combines the results of modules 1 and 2 to produce a score of a species' vulnerability. Finally, module 4 "is a qualitative determination of uncertainty of overall vulnerability based on evaluations of uncertainty done in the first 3 modules" (Johnson, 2014, Pg. 10).

Standardized Index of Vulnerability and Value, SIVVA developed by Reese and Noss (2014) aims to utilize pre-existing methods in combination with one another, while also highlighting the differences between systems. The advancement from all other pre-existing methods include, (1) the ability to pull data and incorporate criteria from previous assessments, (2) pay attention to SLR, (3) the system of scoring is very flexible, (4) it produces metrics for both vulnerability and conservation values, and (5) quantitative and transparent accounting of multiple sources of uncertainty (Johnson, 2014. Pg.10).

Climate Change Vulnerability Assessment Framework CCV AF (IUCN) This method incorporates the measurements of exposure, sensitivity, and adaptive capacity to then rank a species in one of four classes of climate change vulnerability. Each class has attached to it different implications for conservation. (Johnson, 2014. Pg.12).

Case Study Example of a Species Vulnerability Assessment: The U.S. Forest Service Rocky Mountain Research Station (RMRS) in Albuquerque has been working to create a tool by which managers can assess the vulnerability of terrestrial species to climate-related changes. The tool is a process by which species are given a score, assigned from synthesized information that indicates the probability of climate-related population declines. Many factors are considered, all of which could affect a population decline, such as: natural disturbances, breeding requirement, dispersal potential. The scores of these individual species are then combined to create an overall prediction of vulnerability to climate change. The advantage to this process (which has been especially designed for managers to use) is that the scoring system focuses on simple predictive criteria and therefore it allows for managers to plug in whatever data they have, from a variety of sources.

Side Note: "Climate change vulnerability assessments will not provide an estimate of extinction risk or provide the sole basis for determining whether a species ought to receive protection under the Endangered Species Act (ESA). The types of information used in climate change vulnerability assessment can, however, provide information useful in considering the status of a species in relation to the ESA's requirements," (Glick et al. Pg. 17).

Fine-Filter Approaches:
Modeling aims to address the vulnerability of species to future climate change. Mechanistic modeling seeks to incorporate mechanisms, which are physiologically limiting to a specific species tolerance to shifting environmental changes. This modeling approach is problematic in the fact that it

requires a very detailed and extensive understanding of a species. The primary focus of such assessment is to estimate the best future environmental conditions for a certain species. “The central premise of this approach is that the observed distribution of a species provides useful information as to the environmental requirements of that species,” (Pearson, 2007).

Habitat Vulnerability Assessments

Within the area of habitat vulnerability assessments, both coarse-filter and fine-filter methods are used. Course-filter approaches are used to generate using indices to give qualitative categorizations of vulnerability and fine-filter approaches use models to “determine where and how species may be vulnerable to climate change,” (Johnson, 2014. Pg.31).

Examples of coarse-filter approaches include:

1. Climate Change and Massachusetts Fish and Wildlife, Manomet Center for Conservation Science and Massachusetts Division of Fisheries and Wildlife.
2. Northeast Association of Fish and Wildlife Agencies Regional Habitat Vulnerability Model, Manomet.

Habitat Climate Change Vulnerability Index (HCCVI) created by NatureServe combines both quantitative expert categorizations of habitats with numerical index scores (that take into consideration sensitivity and resilience) to generate an estimate of climate change vulnerability by the year 2060 for a specific community within a given ecoregion.

Climate Change Vulnerability Assessment for Shorebird Habitat (CC-VASH) was created by the Manomet Center for Conservation Science in partnership with the US Fish and Wildlife Service Northeast Region Division of Refuges. It is an Excel-based assessment and decision-making tool that uses three categories (effects of sea-level rise, effects of other climate-change variables, and effects of storms) to assess the vulnerability of coastal shorebird habitats.

Examples of fine-filter approaches include:

1. Sagebrush ecosystems in the state of Nevada (Bradley, 2010).
2. Forest restoration in a mixed-ownership landscape under climate change (Ravenscroft et al. 2010).

A Framework for assessing the vulnerability of wetlands to climate change (RAMSAR) This framework has the following elements: (1) establishing the present status, conditions, trends and pressures, (2) determines the sensitivity and adaptive capacity of the wetlands to a multitude of pressures, (3) determines the likely impacts and the likely responses to these impacts, (4) monitoring adaptive management (Johnson 2014, Pg. 39). Case study example: A geospatial assessment on the distribution, condition, and vulnerability of Wyoming’s wetlands (Copeland et al. 2010).

Coastal Vulnerability Index (CVI) (USGA) ranks geomorphology, regional coastal slope, rate of relative sea-level rise, historical shoreline change rate, mean tidal range, and mean significant wave height in terms of their physical contribution to coastal change. The ranking of each variable is then used to create an index value that represents a 1-kilometer grid cell. Each cell can then be compared to one another to highlight which locations need attending to first. Case study example: Coastal Vulnerability Assessment of the Northern Gulf of Mexico to Sea-level Rise and Coastal Change (Pendleton et al. 2010).

Place-Based Approaches

Place-based approaches require combining methods that address the vulnerability of all resources in a given area. This could include assessments of certain species, water sources, habitats, infrastructure

and cultural resources. Such an approach is often adopted by National Parks – an institution that is responsible for managing a geographical location that houses multiple resources. For example, a vulnerability assessment of Badlands National Park in South Dakota draws from literature and professional literature to make estimates on the vulnerability of species, plant communities and other natural resources in light of evaluating fire, grazing and erosion. (Amberg et al. 2012).
Case Study: Hameed et al. (2013) are highly critical of not adopting assessments that consider vulnerability at multiple ecological levels. Assessing vulnerability at different levels demands comparing and evaluating multiple sources of information – a greater attention to the reliability of information is an advantage of this approach. Hameed et al. (2013) create an example of a multifaceted climate change vulnerability assessment (CCVA) and apply it to a protected area with diverse biological communities and management concerns (Point Reyes National Seashore). Their approach consists of four facets that were created to complement one another:

1. Expert judgment that incorporates information from current observations, past responses to climate changes, species interactions, and complicating stressors.
2. Predictive vegetation models that rely on information from global circulation models (GCMs) and observations of associations between plant communities and climate niches.
3. Predictive geophysical models such as those predicting future sea level rise and glacial melt.
4. Species-level vulnerability assessments for species of interest.

Throughout the process, park managers were collaborated with and the collection of knowledge and expertise meant that an impressive 12 biological communities and 41 species of management interest were identified. It is important to note that populations respond to climate change in a very context-specific way and therefore the input of experts on regional and local activities/ history can be invaluable. Hameed et al. comments, "incorporating expert judgment into a CCVA is a great way to create a bridge between mangers and scientists with relevant knowledge for management," (2013. Pg.39). In this particular case study, expert opinions were collected through surveys with open ended questions and then filtered through the Delphi method, and additionally synthesized with literature reviews. The multifaceted study then combined this data with predictive vegetation models, predictive geophysical models and species-level vulnerability assessments to produce a region-wide comprehensive vulnerability assessment.

Ecosystem Vulnerability Assessments

Assessing the vulnerability of an entire ecosystem is a huge undertaking and the process can often prove problematic – how does one balance the vulnerability of multiple resources and interests simultaneously while also maintaining an understanding of the ecosystem as whole? The San Francisco Estuary Partnership (SFEP) was faced with this challenge when assessing the vulnerability of an entire estuary. They chose to collaborate with the Environmental Protection Agency (EPA) and the San Francisco Bay Conservation and Development Commission to hold workshops gathering together experts to elicit judgments from them in two key areas: sediment retention in salt marshes and community interactions in mudflats. Then, a coding scheme was used that characterized the type and sensitivity of each influence under both present and future climate change pressures according to the experts opinions.

Watershed and Water Resource Vulnerability Assessments

The US Forest Service, US EPA and State Departments of Water Resources are just some of the actors to use vulnerability assessments to assess both the exposure and sensitivity of their resources to climate change. The US EPA and CA Department of Water Resources enlisted the help of consulting firm CDM in 2012 to assess regional water vulnerability. The approach taken by CDM addressed characterizing the region, identifying climate change impacts, identifying key indicators of potential vulnerability and then prioritizing vulnerable water resources.

Complications / Conclusion

The selection of what type of vulnerability assessment to adopt is greatly dependent upon the resource in question. The methodology of a vulnerability assessment is also dependent upon the outcome that is sought – what exactly does the resource manager want to know? A concern of Lankford et al. is that "the degree of similarity between vulnerability assessments is unclear," (2014. Pg. 386) and while there are similarities between methodologies, different assessments of the same resource in the same location yield different results. The biggest problem is that there are no demands on how a vulnerability assessment must be administered in order for it to be called a "vulnerability assessment." In other words, a resource manager could ask five experts for their thoughts concerning the vulnerability of sage grass to climate change, or, they could complete a data analysis with numerical values to represent the alterations of sage grass behavior over the last thirty years, and call both "vulnerability assessments." The lack of clarity and consistency in this area of climate change research and natural resource management could potentially hinder conservation efforts.

References

Amberg, S., K. Kilkus, S. Gardner, J.E. Gross, M.Wood and B. Drazkoski. 2012. Badlands National Park: climate change vulnerability assessment. Natural Resources Report NPS/BADL/NRR-2012/505, National Park Service, Fort Collins, Colorado.

Copeland, H.E., S.A. Tessman, E.H. Girvets, L/ Roberts, C. Enquist, A. Orabona, S. Patla, and J. Kiesecker. 2010. A Geospatial Assessment on the Distribution, condition, and Vulnerablity of Wyoming's Wetlands. Ecological Indicators 10: 869-879.

Glick, P., B.A. Stein, and N.A Edelson, editors. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment.* National Wildlife Federation, Washington, D.C.

Hameed, S. O., Holzer, K. A., Doerr, A. N., Baty, J. H., & Schwartz, M. W. (2013). The value of a multi-faceted climate change vulnerability assessment to managing protected lands: Lessons from a case study in Point Reyes National Seashore. *Journal of environmental management, 121*, 37-47.

Johnson, K. A. (2014). Climate Change Vulnerability Assessment for Natural Resources Management: Toolbox of Methods with Case Studies.

Lankford, A. J., Svancara, L. K., Lawler, J. J., & Vierling, K. (2014). Comparison of climate change vulnerability assessments for wildlife. *Wildlife Society Bulletin, 38*(2), 386-394.

Pendleton, E. A., E. R. Thieler, and S.J. Williams. 2010. Importance of Coastal Change Variables in Determining Vulnerability to Sea-and Lake- Level Change. Journal of Coastal Research 26: 176-183.

Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez, and F. Yamin. 2007. Assessing key vulnerabilities and the risk from climate change. p. 779-810. In *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Liden, and C.E. Hanson (Eds.) Cambridge University Press, Cambridge, UK.