The Refuge Vulnerability Assessment and Alternatives Technical Guide

Assessing Vulnerability for Refuges and Landscapes and Developing Alternatives for Management

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INTRODUCTION

Purpose of This Technical Guide

This Refuge Vulnerability Assessment and Alternatives (RVAA) Technical Guide provides the step-by-step details for conducting vulnerability assessments for refuges and their supporting landscapes and to develop strategies and alternatives for management in the face of current and future drivers of change. A companion document, *Manager's Guide to Refuge Vulnerability Assessment and Alternatives: Overview and Practical Considerations* (Manager's Guide) provides the introduction to the RVAA process and guidance for managers to understand and plan the work.

Technical Guide Objectives

The purpose and objectives of this Technical Guide are to provide user-friendly, step-by-step directions for assessing refuge vulnerability and adapting management strategies in the face of climate change and other stressors. Broadly, these steps include:

1. Assess current condition of resources within the refuge and within its regional and landscape context
2. Project and approximate future conditions as a means to determine the most pressing conservation and management issues currently and over meaningful future timeframes
3. Inform the generation of alternative strategies and future natural resource and land-use scenarios for the refuge and its partners throughout the supporting landscape
4. Facilitate a refuge's ability to meet its statutory mandates/role in the context of climate change-induced or other changes on the landscape
5. Provide the refuge with proactive management actions that it can take immediately to respond to landscape stressors in the context of climate change to manage or even preclude major landscape change and potentially maladaptive strategies.

The climate change vulnerability assessment and adaptation field is growing and evolving very rapidly; therefore, we did not attempt to be highly specific and prescriptive in the approaches. Many specific methods and tools can be applied to any of the steps outlined here. Further, this Technical Guide covers a very broad range of disciplines and methods that could not practically have a complete treatment in a single document. The foundation for the guidance is derived from existing, accepted concepts:

1. Vulnerability assessment (are resources potentially threatened by some stressor?). This incorporates climate change planning concepts of exposure, adaptive capacity, and vulnerability that will be addressed further.
2. Cumulative effects assessment, integrating climate effects (what might happen under exposure to multiple stressors?)
3. The mitigation hierarchy (avoid, minimize, restore, offset when effects found/expected)

4. Systematic conservation planning (to achieve quantitative resource retention goals in most efficient manner)
5. Ecosystem-based management (incorporates above while integrating human uses/needs in objectives)
6. Adaptive management (reassess and revise plans based on learning during implementation)

For these reasons, we provide tools and references (known as of this writing) to direct the reader to useful sources of contemporary information and guidance. The FWS climate change website can serve as an appropriate location to link to key references and general information .

Note that FWS is in the process of developing specific guidance for water resources assessment (Dar Crammond pers. comm.). While this Technical Guide is applicable to aquatic and terrestrial resources, it intentionally does not provide a detailed technical treatment of aquatic resource assessment, as that is expected to be provided in FWS' forthcoming guidance.

Useful Sources

- FWS climate change website: *www.fws.gov/home/climatechange/climate101.html*
- Climate Adaptation Knowledge Exchange (CAKE) hosts a website devoted to providing case studies profiling on-the-ground climate adaptation projects: *www.cakex.org*
- Collaborative Adaptive Management Network (CAMNet) Resources: *www.adaptivemanagement.net/resources?page=1*
- U.S. Department of the Interior (DOI). 2010. Adaptive Management Documents. *www.doi.gov/initiatives/AdaptiveManagement/index.html*
- U.S. Climate Change Science Program has a series of reports: *www.climatescience.gov/Library/sap/default.htm*
- Adger, W. N., et al. 2007. "Assessment of Adaptation Practices, Options, Constraints, and Capacity." Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M. L., et al. (eds.). Cambridge, UK: Cambridge University Press.
- 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.
- U.S. EPA Climate Ready Estuaries Program: *www.epa.gov/CRE*
- Hansen, L., Biringer, J.L., and J.R. Hoffman, editors. 2003. Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. Berlin, Germany: World Wildlife Fund Climate Change Program.

Intended Users of the Technical Guide

This Technical Guide is intended for a team that would be conducting refuge (or other unit or area) assessment and alternatives development. The Technical Guide covers a broad range of topics and thus team members will select those areas of the Technical Guide that are most pertinent to their role in the project. It is not intended to be comprehended necessarily by any single individual due to the broad range of subject matter covered. Readers desiring only a summary level treatment of the RVAA are encouraged to read the companion Manager's Guide.

How to Use this Technical Guide

This Technical Guide is arranged hierarchically in outline format to allow either a quick read of the overall flow of the steps or a detailed read of the technical substeps. An overview of the process is provided in the Manager's Guide; a process workflow diagram is provided in the section below to understand the flow of information from raw inputs to decision-support products. Because this workflow is primarily a spatial analytical process, the details are fairly technical but not prescriptive. However, they should provide sufficient guidance for a team of scientists and experienced GIS analysts to conduct or adapt them as needed. The guide is illustrated with examples from a variety of projects but primarily from two pilot RVAA pilot projects conducted during 2010 and 2011 for the Eastern Shore of Virginia National Wildlife Refuge Complex (Bulluck et al., 2011) and the Sheldon-Hart Mountain National Wildlife Refuge Complex (Crist et al., 2011).

A single Technical Guide could not provide all of the details and background related to the breadth of topics and methods described; where appropriate, "Useful Tools," "Useful Sources," and "Useful Examples" are provided along with citations for further reading on concepts. It is important to keep in mind that climate change assessment, in particular, is a highly dynamic field so the information provided in these sections should be augmented through searches of other climate change resource websites and databases.

- **Useful Tools** are primarily technological tools such as decision-support systems and models but also include guidance or methods documents. While all of the GIS processes described can be manually conducted with most GIS systems, packaged modeling and decision support tools can make such processes much easier, more efficient, and repeatable.
- **Useful Sources** are sources of more specific and detailed information to learn more about individual subjects or obtain information for the RVAA.
- **Useful Examples** are case studies and real project examples.

Refuge and regional staff and partners are often the best sources of information so these sources are not repeated except to identify specific staff roles or organizations that might be particularly important for a substep. At the conclusion of most steps is a "Revisiting Previous Steps" section which indicates when and for what purpose previous steps should be revisited based on results of the current step.

The Refuge Vulnerability Assessment and Alternatives Process

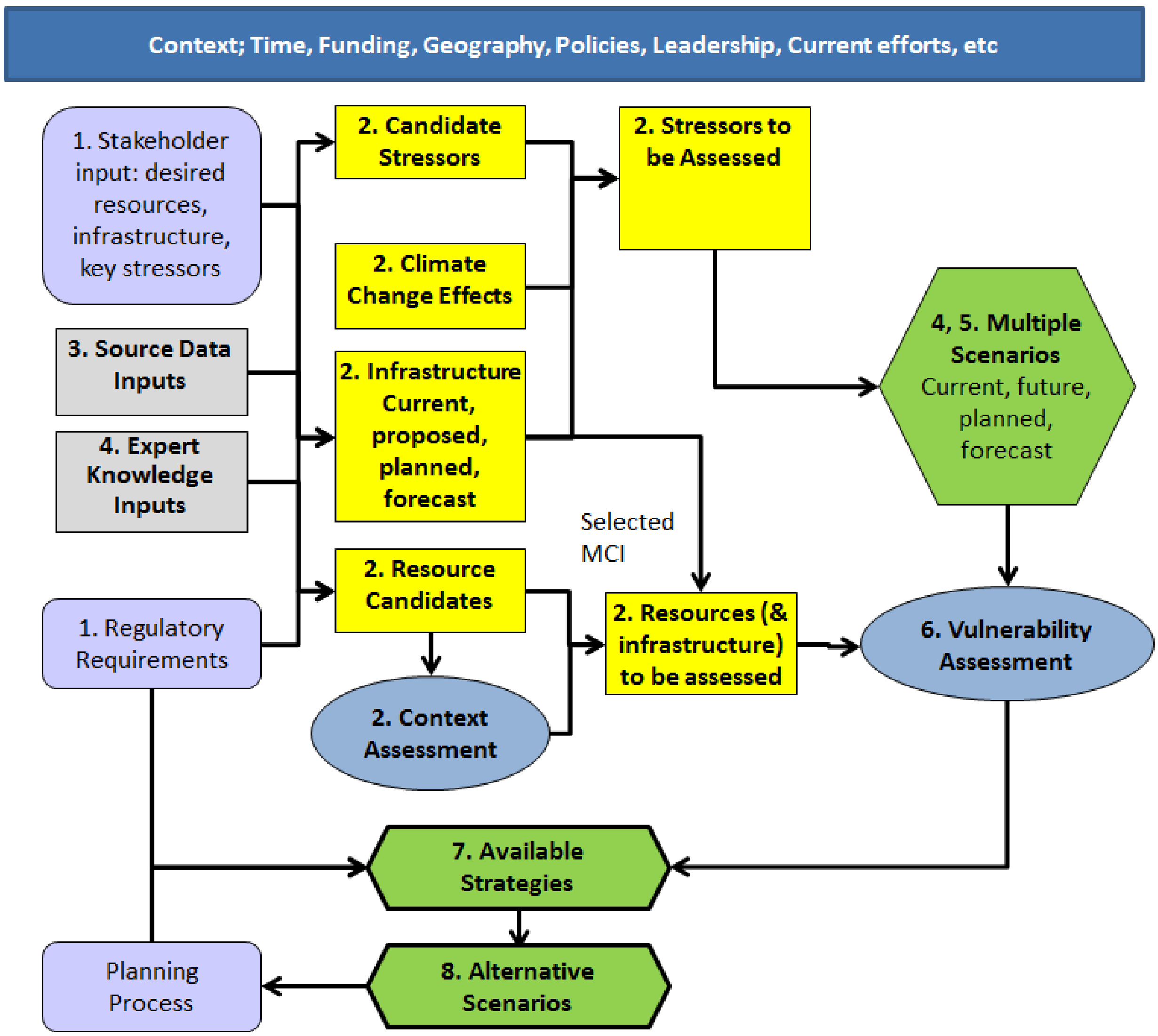
An introduction to the Refuge Vulnerability Assessment and Alternatives (RVAA) process is provided in the companion Manager's Guide along with practical information for scoping and conducting an RVAA. Here we provide additional details prior to explaining the step-by-step technical details in the next section. The RVAA process incorporates key concepts of the Structured Decision-Making (SDM) process (*www.fws.gov/science/doc/structured_decision_making_factsheet.pdf*). One key concept from SDM incorporated in the RVAA is the inclusion of logical points where previous steps can or should be revisited. These are summarized at the end of each step. The users of this guide should take particular note that while it is intended to be compatible with Structured Decision-Making, that process is not fully embedded in this guide and users should follow such guidelines to properly structure their questions and process for making decisions at each step.

The RVAA Information Workflow

The steps and major substeps of the RVAA *process* workflow are illustrated and summarized in the Manager's Guide; here we address the *information* workflow as illustrated in *Figure 1*.

Figure 1. RVAA information workflow.

Numbers in boxes refer to steps of the RVAA. Context (top blue box) provides the constraints under which the RVAA is conducted. Information or data are compiled for use as inputs or developed as interim or final outputs according to this workflow diagram. Round cornered boxes are human/policy inputs and processes; rectangular boxes are data sets, hexagons are interim and final outputs, and ovals are assessment processes.



While the RVAA steps and the information workflow in *Figure 1* describe a primarily spatial process, the RVAA can also include non-spatial assessment processes. These may be necessary to account for:

- Lack of spatial data on resources or stressors due to:
    - Fine-scale and patchy distribution that is difficult to map (e.g., small and ephemeral water resources)
    - Unpredictable patterns or timing of occurrence (e.g., severe weather events)
- Current limits of tools to model explicit spatial patterns of effects
- Future events with high uncertainty (e.g., climate-induced changes decades into the future)
- Insufficient knowledge to spatially model outcomes (e.g., habitat relationships insufficiently understood)
- Strategies with pervasive influence, such as elevated public awareness, changes in national policy, or other conditions that prevail consistently across the entire planning landscape

Some assessments may require purely non-spatial processes (e.g., assumed outcome for small ephemeral water bodies from expected future warming), while others may benefit from some spatial information (e.g., pipeline development plan for area with unmapped but expected resource connectivity needs). The following table illustrates non-spatial components and spatial counterparts.

Table 1. General non-spatial components and spatial counterparts of the RVAA process.

Non-spatial Component	Spatial counterpart
List resources known to occur in assessment area	Map/model distribution of resources
Describe resource condition according to biologist field observations	Model condition based on expert knowledge of resource responses to disturbances/practices
Express objectives as meeting desired conditions through population parameters, presence of ecosystem functions/processes, etc.	Express objectives as meeting resource quantities subject to patch size and condition thresholds and other specific parameters as feasible (e.g., demographic, landscape pattern parameters, etc.)
Express scenarios as optional plausible visions or proposals of the future at different time steps	Map current physical actions/uses/stressors on the landscape and propose/model future distribution of stressors and actions
Express management intent/plans as "if this situation occurs, we'll do this action in response"	Express management/intent plans as a spatially explicit map of "we intend to do/allow this in these locations to achieve a quantitative objective(s)"[1]

[1] Note that spatial expressions of actions can also be identified as contingent on other factors, e.g., "suppress fire in this location *if* the exotic species cheatgrass invades."

Relationship of This Technical Guide to Strategic Habitat Conservation

This topic is briefly treated in the Manager's Guide; here we provide a more thorough treatment. Refuge Vulnerability Assessment and Alternatives (RVAA) and Strategic Habitat Conservation (SHC, *www.fws.gov/science/StrategicHabitatConservation.html*) are complementary approaches for assessment and planning. SHC is a phased approach of biological planning, conservation design and delivery, and monitoring and research, all at ecoregional scales. Biological planning encompasses selection of key species and trust resources for focused analysis of habitat relationships and sustainable population size. It may include development of models that formalize and test assumptions about the amount and quality of habitat required to restore or maintain populations at desired levels. Conservation design and delivery focus on identifying clear habitat objectives and efficient configurations of habitat to meet conservation objectives. Monitoring and research phases measure and evaluate progress towards securing habitat and population objectives. SHC aims to clarify an efficient regional configuration of habitat conservation actions to maximize FWS mission success.

RVAA will support the same general phases of SHC; however, the emphasis of RVAA is to incorporate more explicit considerations of anticipated changes in habitat location, extent, and quality brought about through the most likely forms of climate-change-induced stress and interactions with other ecological stressors. RVAA explicitly takes a multi-scaled approach, linking habitat requirements for migratory species and habitat configurations at ecoregional scales with conservation options within the immediate supporting landscape for the refuge. Through RVAA, decisions regarding selection of trust resources, modeling of population-habitat relationships, statement of habitat objectives, and design and configuration of habitat for conservation have all considered the most likely interactions among current and future ecological stressors relevant to refuge resources. SHC complements these more general analyses by adding explicit consideration of population demographics and viability over species ranges.

STEPS FOR CONDUCTING RVAAS

This section provides the details for conducting the RVAA steps. The steps are arranged hierarchically beginning with a summary of the step and its inputs and outputs, and then are followed by substeps and specific details and illustrations of how those are conducted. Embedded within the details, as appropriate, are useful tools, sources, and examples. Note that this technical guidance for the RVAA does not address key processes for organization prior to beginning the work or planning processes using its outputs—those are covered in other guidance and texts. It is critical, however, to apply Structured Decision-Making principles (see previous section) to ensure that the proper questions are being formed prior to conducting the RVAA and decision making processes are in place to guide the work and make appropriate use of the results.

Climate Change Concepts in the RVAA

These concepts were briefly addressed in the Manager's Guide. Following is a more detailed description of how each of the key climate change concepts are integrated in the RVAA process (see also *Figure 2*):

Exposure

Stressors such as climate change, development, and certain management actions will lead to *exposure* of resources to stresses. Exposure is generally realized through RVAA Steps 4 and 5 to characterize scenarios that map the location and type of stressors. In Step 6, resources are intersected with scenarios to map which stressors they are exposed to. Simply being exposed to a stressor does not mean any particular resource itself is stressed.

Adaptive Capacity

Resources have individual responses to stressors that define whether they are stressed in the presence of such stressors. Their response to stressors integrates their adaptive capacity to withstand or recover from the stress. RVAA Step 4 documents resource responses to stressors.

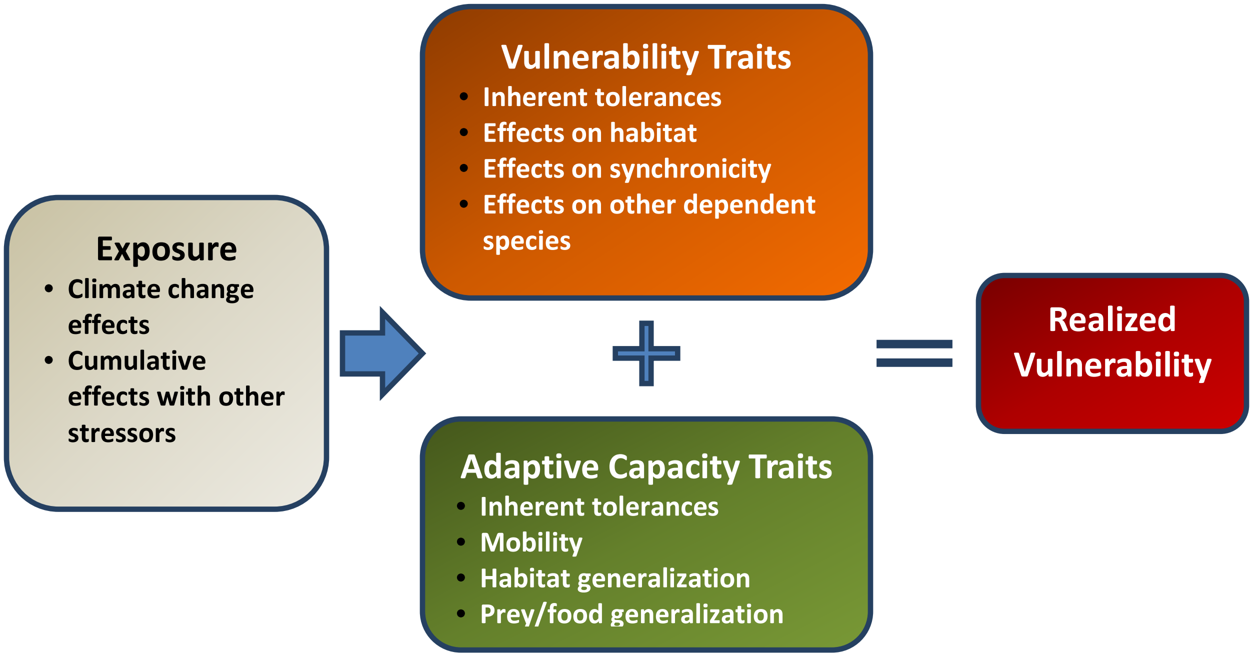
Vulnerability

Step 6 of the RVAA informs the vulnerability of resources to stressors under each evaluated scenario. By coupling the exposure of resources through the intersection of resources to stressors in Step 6 with the assessment of resource responses to stressors developed in Step 4, the effect of stressors on the resources results can be calculated.

Maladaptive Response

Certain adaptive actions that might be taken to mitigate stressor impacts on one resource may be maladaptive and cause stress to another resource. For example, engineering efforts to protect mission-critical infrastructure (e.g., primary access road to a refuge) from sea level rise, may prevent a wetland type from migrating (adapting) to the sea level rise. The impact on the wetland type would be a maladaptive response to the adaptive action taken to protect the access road. Assessing maladaptive response is equivalent to assessing vulnerability in the RVAA but happens once strategies (Step 7) are turned into alternative management scenarios in Step 8 and then reassessed for beneficial and maladaptive outcomes by revisiting Step 6.

Figure 2. Climate change concepts in vulnerability assessment.



Step 1. Characterize the refuge

This step collects, integrates, and synthesizes readily available information to characterize the refuge's regulatory and policy framework, resources, infrastructure, and current or potential stressors using a series of checklists found in the appendices. Note that if a Comprehensive Conservation Plan (CCP) has been conducted, much of this information has likely already been gathered.

The checklists are part of an information and decision workflow in which information from the first checklist (regulatory and policy framework) informs the next checklists (resources and infrastructure) which then inform the listing of stressors. Stressors in this case are any feature, action, or phenomena capable of negatively affecting a resource of interest noting that a stressor for one resource may have a neutral or even positive effect on another resource. Populating these checklists prioritizes the resources and stressors to be analyzed and informs subsequent population of the final checklist to identify data needs. This final checklist will form the basis for estimating the scope and cost of the assessment in Step 3.

Summary of Inputs

1. Existing refuge plans if any (especially CCP, *www.fws.gov/policy/602fw3.pdf*, and HMP, *www.fws.gov/policy/620fw1.pdf*)

2. If no CCP, then refuge establishment acts, purchases, stipulations
3. Refuge species checklist
4. Maintenance Management System (*www.fws.gov/policy/372fw2.pdf*)

Summary of Outputs

1. Completed checklists A–D

Detailed Substep

Populate the four theme checklists

Regulatory Framework, Resources, Infrastructure, and Stressors using existing refuge documents (e.g., CCP) and other relevant data and information from refuge staff:

a) **Regulatory and Policy Framework checklist:** What are the legal requirements for refuge management and what are the other policies and plans that the refuge currently or intends to follow? This checklist is used to inform the resource checklist and later for identifying or bounding strategies for conservation planning (see 602 FW1under Useful Sources).

   i) Complete the regulatory and policy framework checklist found in Appendix A. Also use this information to begin populating the Resources Checklist (Appendix B).

   Useful Sources

   - Handbook for Identifying Resources of Concern (Paveglio and Taylor 2010)
   - FWS 2000. 602 FW1: Chapter 1, Refuge Planning Overview. (*www.fws.gov/policy/602fw1.pdf*)
   - Much of this information will come from FWS policy guidelines and from the refuge establishment legislation. Also consult stipulations and agreements from real estate transactions.

b) **Resources checklist**: What are the resources of management interest based on the regulatory framework and other priorities (see Useful Sources for other FWS guidance). Note that analyses in Step 2 may identify additional resources for consideration. The resources checklist is designed to facilitate the tracking of candidate resources and final decisions on the inclusion of resources for RVAA.

   i) In addition to resources identified in the regulatory framework, use information from current plans and staff/stakeholder input to list resources that are of management interest or concern that should be candidates for assessment and planning. Because refuges typically occupy higher-productivity sites relative to some other protected areas in the United States, they can be relatively more diverse and require consideration of many resources. However, practical limits on time, funding, and extant knowledge of resources suggests strategic prioritization of resources for consideration.

ii) A combined habitat and species-based approach (see Habitat Evaluation Procedures Technical guide under Useful Sources) may efficiently organize ecological resource information and provide a practical focus. This is often referred to as a "coarse-filter/fine-filter approach" (Groves 2003) (see also Rapid Ecoregional Assessments and TNC ecoregional assessments and conservation projects under Useful Examples). The major upland, wetland, and aquatic habitats can be described and those that characterize the ecology of the refuge and surroundings may be used to effectively address the primary ecological patterns and processes that support most common species. A smaller number of vulnerable species assemblages or individual species can then augment this selection where habitats do not adequately account for these species.

iii) Some of the characteristics of priority resources are related to their conservation/imperilment status, their susceptibility to stressors, their adaptability, and their role or function in the refuge ecosystem. For example, a refuge might prioritize resources (species) that:

(1) Require area beyond the refuge to support viable numbers and/or life history and access to different resources/habitats. Such species would be highly susceptible to habitat changes off-refuge which could jeopardize their viability on refuge (see Landscape Conservation in Action under Useful Examples)

(2) Are likely to require a transition or dispersal from the refuge across non-refuge areas to more suitable locations in the face of climate-induced changes to which they are not adapted (see 601 FW3under Useful Sources)

(3) Are species having traits making them particularly vulnerable to climate change (Rowland, et. al. 2011; see species vulnerability assessment tools under Useful Tools for a formal approach and tools to evaluate species vulnerability). The World Conservation Union (IUCN, Foden et al., 2008) identified five biological traits indicating species' vulnerability to climate change:

a) Require specialized habitats or microhabitats

b) Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle

c) Dependence on specific environmental triggers or cues that are likely to be disrupted by climate change

d) Dependence on disturbance regimes that are likely affected by climate change such as fire, flood, and drought cycles

e) Dependence on inter-specific interactions that are likely to be disrupted by climate change

f) Poor ability to disperse to or colonize a new or more suitable range

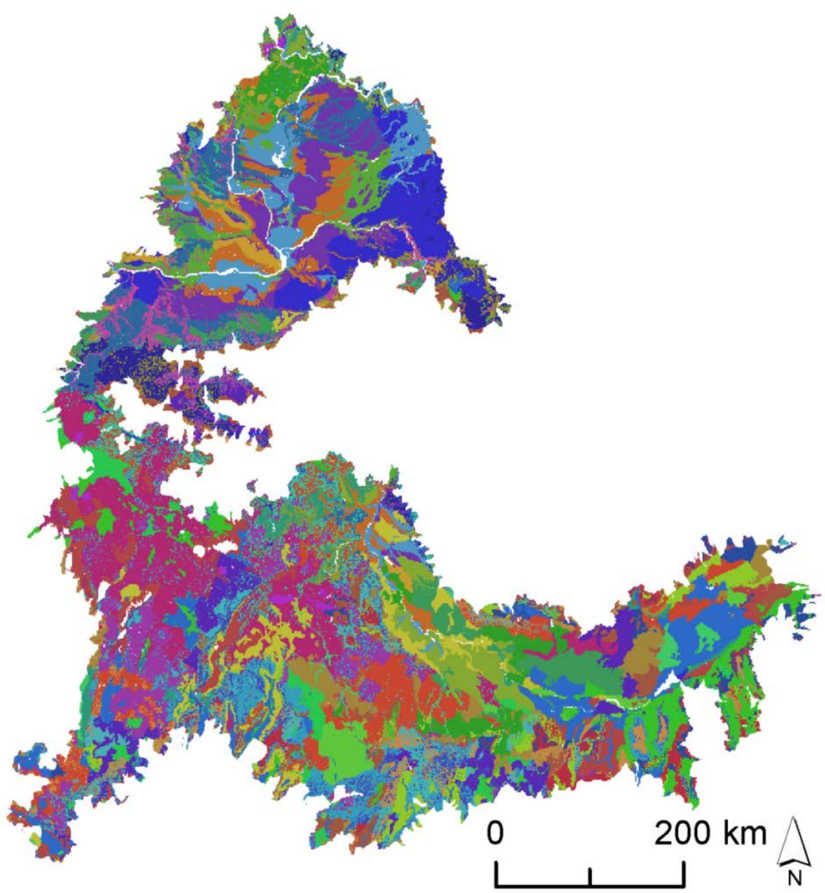
(4) Provide redundancy. In considering resource selection to promote ecosystem resiliency to climate change, consider resource redundancy (Glick et al., 2011). This concept

identifies resources that play duplicative roles in ecosystem processes (e.g., primary producers, herbivores, carnivores, and decomposers). By including these redundant resources, the assessment can detect if at least one playing each process role will be retained or not.

iv) For accommodating the uncertainty of which resources may remain within the planning area under climate change scenarios, consider utilizing abiotic features as surrogates for future habitats/niches (*Figure 3*). A number of approaches typically categorize combinations of abiotic characteristics important for differentiating habitats regardless of species composition such as soils, elevation, landscape position, hydrology, and surficial geology (e.g., Beier and Brost 2010, Iacobelli et al., 2006, Anderson 2006, Anderson et al., 2012). The abiotic groupings resulting from such categorizations have various terms such as "enduring features" (Iacobelli et al., 2006), "ecological land units" (Anderson 2006) or "land facets" (Beier and Brost 2010).

Figure 3. Example land facets map for the Colombia Plateau Ecoregion.

Mapped at a 1km resolution, designated from elevation, slope, and five soil variables. Courtesy Carrie Schloss, Josh Lawler, and Jenny McGuire, University of Washington.



Useful Tools

- NatureServe Explorer can be used to identify and query for species of importance for the area based on legal and imperilment status: *www.natureserve.org/explorer*
- The NatureServe Climate Change Vulnerability Index (CCVI) tool can provide information about species that may be especially vulnerable under climate change: *www.natureserve.org/prodServices/climatechange/ccvi.jsp*
- System for Assessing Vulnerability of Species (SAVS) to Climate Change (USFS): *www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/*
- Framework for categorizing the relative vulnerability of threatened and endangered species to climate change (EPA): *http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203743*
- Standard 7 in Higgins, J. and R. Esselman, eds. 2006. Ecoregional Assessment and Biodiversity Vision Toolbox. The Nature Conservancy, Arlington, VA. *www.conservationgateway.org/file/ecoregional-assessment-toolbox*

Useful Sources

- Refuge biologist
- Refuge species checklists
- State natural heritage program staff and databases (See *www.natureserve.org/visitLocal/index.jsp*.)
- State resource agency staff and State Wildlife Action Plans (*www.wildlifeactionplans.org*)
- FWS 2009. Draft: Identifying Refuge Resources of Concern and Management Priorities: A Handbook. United States Department of the Interior U.S. Fish and Wildlife Service National Wildlife Refuge System.
- FWS policy guidance and refuge establishment legislation
- Conservation organizations working in the area

Useful Examples

- Landscape Conservation in Action: Strategic Conservation in Action—Bringing Back the Birds: A Strategic Approach to Wetland Conservation in the Prairie Pothole Region: *www.fws.gov/midwest/science/SHC/landscape.htm*
- Rapid Ecoregional Assessments, particularly those conducted by NatureServe, that employed a rigorous approach to resource identification using the coarse filter/fine filter approach: *www.blm.gov/wo/st/en/prog/more/climatechange/reas.html*
- Ecoregional assessments conducted by The Nature Conservancy and partners: *http://east.tnc.org/*

- Conservation projects of The Nature Conservancy and partners: *http://conpro.tnc.org/*

c) **Infrastructure checklist**: What are the mission-critical infrastructure (MCI) and other infrastructure in the supporting landscape both currently and anticipated in the future?

Complete the checklist found in Appendix C. Infrastructure can be considered both as a feature to preserve (identified as MCI within refuge and otherwise important outside the refuge) as well as a stressor on resources. Infrastructure identified as a feature to preserve (MCI), albeit subject to assessment results, will be assessed as a resource; infrastructure identified as a stressor will be included as a component of a scenario to assess its impacts on resources or other MCI (see 372 FW2 under Useful Sources).

Useful Sources

- Refuge database of mission-critical infrastructure
- FWS 2002. 372 FW2: Chapter 2,Maintenance Management System: *www.fws.gov/policy/372fw2.pdf*
- Partners with interest in or mission related to infrastructure such as departments of transportation, utilities, water managers, health/sanitation, hazards, etc.

Useful Examples

- The Federal Highway Administration's literature review of case studies of climate change vulnerability assessments conducted for transportation infrastructure: ICF International 2009: *www.fhwa.dot.gov/hep/climate/ccvaraaa.htm#Toc236233834*
- The U.S. Climate Change Science Program's assessment of climate change impacts to Gulf Coast transportation and infrastructure (CCSP 2008)
- The Transportation Research Board's report on impacts of climate change to U.S. transportation (Transportation Research Board 2008)

d) **Stressors checklist**: What are the stressors on the biological resources and MCI currently and anticipated in the future? (See 601 FW3 under Useful Sources.)

i) Complete a stressors checklist (Appendix D). This information will be used to create a classification of potential stressors—land use, management practices, invasive species, climate-change effects, and other stressors that will or may appear in current and future scenarios that will be assessed for resource impacts. The list of stressors should be comprehensive; assessment will reveal which stressors are likely to be drivers of impacts and changes. The stressor table (Appendix D) also permits the identification and tracking of those stressors for which mitigation by refuge staff and/or partners is feasible. Those that cannot be mitigated may require additional management adaptation and may be tracked accordingly in the checklist.

Here we give additional specific treatment to climate change stressors. While climate change effects are continuously being discovered and documented, the key consideration at this stage is resource exposure. Exposure to climate change, coupled with a resource's sensitivity to the change as well as its adaptive capacity, determines the resource's vulnerability (see Glick et al., 2011 under Useful Sources). We address resource response to the exposure in

Step 4: Characterize current conditions, management regimes, stressors.

Climate changes have already been observed and many more are forecast to occur, but how these changes actually play out is an area of large uncertainty. Following are key aspects of exposure to consider for both spatial and non-spatial assessment approaches to determine what resources may be affected and what sort of sensitivity information needs to be developed in Step 4. Note that these are arranged from the most direct impacts (gets too hot for a species) to indirect effects (sea level rise), to more complex interactive effects. We do not explicitly list here existing stressors that are likely to be aggravated by climate change, such as fire, but modeling synergistic effects of stressors is an important part of the assessment:

Change in:

- Temperature: Basically this would expose a resource to temperatures that exceed its thresholds of tolerance in both terrestrial (air) and aquatic environments (Parmesan 2005, Root et al., 2005, Donner et al., 2006). Note that if seasonal extreme values can be forecast (e.g., coldest and hottest), these are usually more influential and meaningful than forecasts of average values (Glick et al., 2011). Understanding temperature thresholds for resources will be important to characterizing this stressor.
- Available water: For both plants and animals, this is often a function of precipitation change in conjunction with temperature change and seasonality of changes (Ryan et al., 2008; see Useful Sources)). Per above, seasonal extreme values will generally be more useful to utilize. However, if precipitation stays the same or even increases, available water can still decrease if temperature also increases enough to increase rates of evapotranspiration (see Glick et al., 2011 for references of calculation methods and useful tools).
- Environmental chemistry: This primarily affects aquatic resources, such as brackish water-adapted species that may experience decreased or increased salinity (Kennedy et al., 2002).
- Landscape position relative to hydrology: This describes changing water levels such as sea level rise, increase or decrease of lakes, streams and wetlands; and groundwater level increase or decrease. All of these changes are expected to create hydrologic conditions not tolerated by resources currently occupying affected areas (Meyer et al., 1999).
- Habitat location and/or composition change: As changes in temperature, precipitation, and hydrology impact individual species and their distributions,

ecosystems will shift and reassemble into unique compositions. Such changes can be expected to significantly affect many species adapted to current habitat compositions and locations (Fischlin et al., 2007, Arctic Climate Impact Assessment 2004).

- Prey, predators, and competitors: Changes in the composition or density of these species/habitat components have the potential to act as stressors on target resources. A key expectation is that these components will increasingly change with climate changes such that species will have trouble obtaining enough prey, will have increased predatory pressures, especially from novel predators moving in from elsewhere, or novel or increased competitors (Parmesan 2006). Invasive species are an entire class of novel competitors that are frequently expected to exert increased pressure on resources as a result of synergistic effects from climate change (Burgiel and Muir 2010).

Useful Sources

General:

- State Wildlife Action Plans that have identified key stressors: *www.wildlifeactionplans.org*
- The Nature Conservancy (TNC) Ecoregional Assessments (*http://east.tnc.org/*) and Conservation Action Plans (*http://conpro.tnc.org/*) that likewise identify key stressors on their resource targets
- Bureau of Land Management Rapid Ecoregional Assessments are also identifying and analyzing "change agents," including climate change: *www.blm.gov/wo/st/en/prog/more/climatechange/reas.html*
- FWS 2001. 601 FW3: Chapter 3, Biological Integrity, Diversity, and Environmental Health: *www.fws.gov/policy/601fw3.pdf*
- Glick et al., 2011: See their Chapter 3 for more extensive treatment of types of climate change sensitivities and references.
- For drought information, see
  - *http://drought.unl.edu/DroughtBasics.aspx*
  - *http://drought.unl.edu/MonitoringTools.aspx*
  - NOAA drought maps are available at *http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html*

Useful Tools

- The Variable Infiltration Capacity (VIC) model can be used for detailed macroscale hydrologic modeling (*www.hydro.washington.edu/Lettenmaier/Models/VIC/*)

e) Summarize each thematic area (regulatory framework, resources, infrastructure and stressors) and create an overall synthesis for the refuge report. This substep is completed in Step 2, prior to the onsite meeting in Step 2. See Appendix E. Assessment Report Outline, for content and structure.

Step 2: Identify conservation priorities and issues

This step conducts contextual spatial analyses to understand the proportion of resources managed by the refuge in the context of the ecoregion and supporting landscape. It also develops a conceptual model to understand the ecosystem functions of the supporting landscape and the relationship among resources and stressors. These activities help identify those resources for which the refuge has or could have a significant role in conserving (see FWS 2009 under Useful Sources) and the key stressors. This step concludes with an onsite meeting with refuge staff and partners to validate the information and conclusions of Steps 1 and 2 and to develop the requirements for a work plan (Step 3) for the remaining steps.

Summary of Inputs

1. Regional assessment boundary
2. Supporting landscape boundary
3. Watershed boundary (if applicable for hydrologic assessments)
4. Resource distribution data layers (with optional historic distribution if available)
5. Protected areas data layer/database
6. Conservation priority area data layers (optional)

Summary of Outputs

1. Integrated spatial database of spatial inputs
2. Report of contextual analyses, including quantitative tables characterizing proportional resource distribution in assessment regions
3. Conceptual model of the interaction of resources and stressors in the supporting landscape
4. Partner workshop to validate and document results and decisions
5. Updated checklists (Appendices A-D)

Detailed Substeps

Select the assessment region(s)

This substep provides guidance on how to determine the appropriate geographic context for assessing the refuge. The recommendation is to apply two assessment contexts: first, the planning team selects the ecoregional context (“region”) to place the resources in a broad context to understand the proportional role of the refuge(s) in maintaining resources (see Bailey 2009. Second, they select a smaller landscape context ("supporting landscape") that encompasses the refuge of interest and can sufficiently represent population and stressor dynamics in and around the refuge.

Regional context: The term "region" as used here does not prescribe any particular geographic subdivision, although we do provide practical recommendations of units from existing landscape and regional classifications. An ecoregional assessment is important because it can help clarify resource management importance based on the proportional distribution of resources on the refuge relative to other land stewards; in other words, is the refuge a significant player in the viability of a resource or could it be solely based on the proportion of a resource it contains? It also should help clarify which partners will be important for managing shared resources at the regional scale. Selecting assessment region boundaries should consider natural resource distributions currently but also may consider potential changes from climate change (e.g., incorporate areas where refuge resources may need to migrate and areas from where new resources may move into the refuge. An example of an ecoregion used for an RVAA is shown in *Figure 4*. Evaluating refuge resources at an ecoregion scale can answer questions such as:

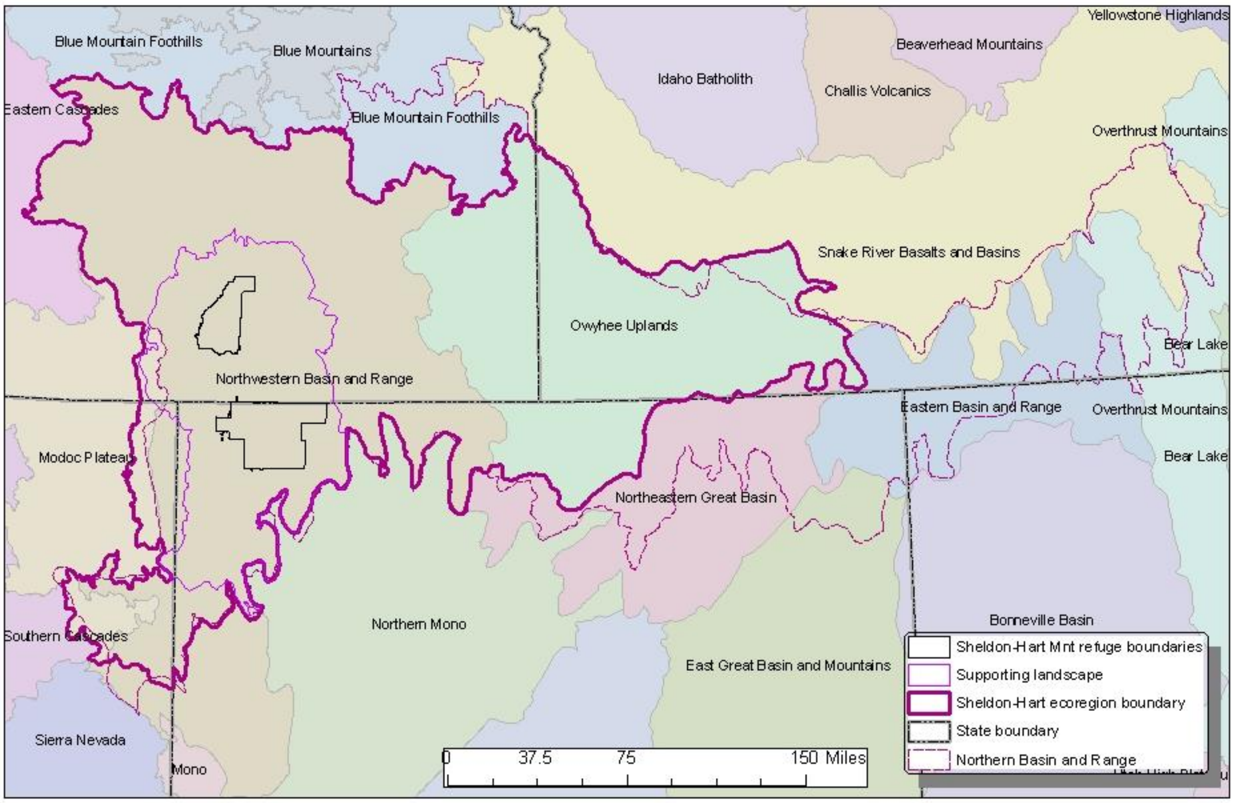
- Are there regionally significant resources that potentially occur on the refuge, but have not been documented?
- Is the refuge the only location or a key location supporting a given resource?
- How many other conservation lands do, or could, support this resource?

Future resource and land-use scenarios will then have this broader contextual information. For example, if it appears likely that future climate-induced stress will substantially degrade or eliminate habitat for certain species within the refuge over coming decades, potential alternative locations for those habitats can be identified. Note that while this substep is not particularly difficult or costly, it merely entails intersecting existing maps of resource distributions with landownership/management patterns and generating tables of results. It does not at this stage include mapping stressors or characterizing scenarios – those activities following later steps. Results of state or regional gap analyses (*http://gapanalysis.usgs.gov/*) may be able to provide suitable results for this substep.

A third possible "scale" of analysis includes migratory species, operating at continental scales (see Migratory Bird and Habitat Programs under Useful Sources). Existing species-level plans reference key migratory stopover and occupancy sites and the expected contributions from a given refuge along the migratory pathway (e.g., US FWS 1994, Canadian Wildlife Service and U.S. Fish and Wildlife Service. 2007). For an RVAA, a continental context is not feasible for spatial analyses, therefore migratory species can be considered both in a non-spatial assessment of their population condition and spatially within an RVAA by mapping the habitat features important to such species. These features typically include key stopover locations within the ecoregion-scaled assessment unit and specific habitat areas within the supporting landscape.

Figure 4. Example of an ecoregion boundary.

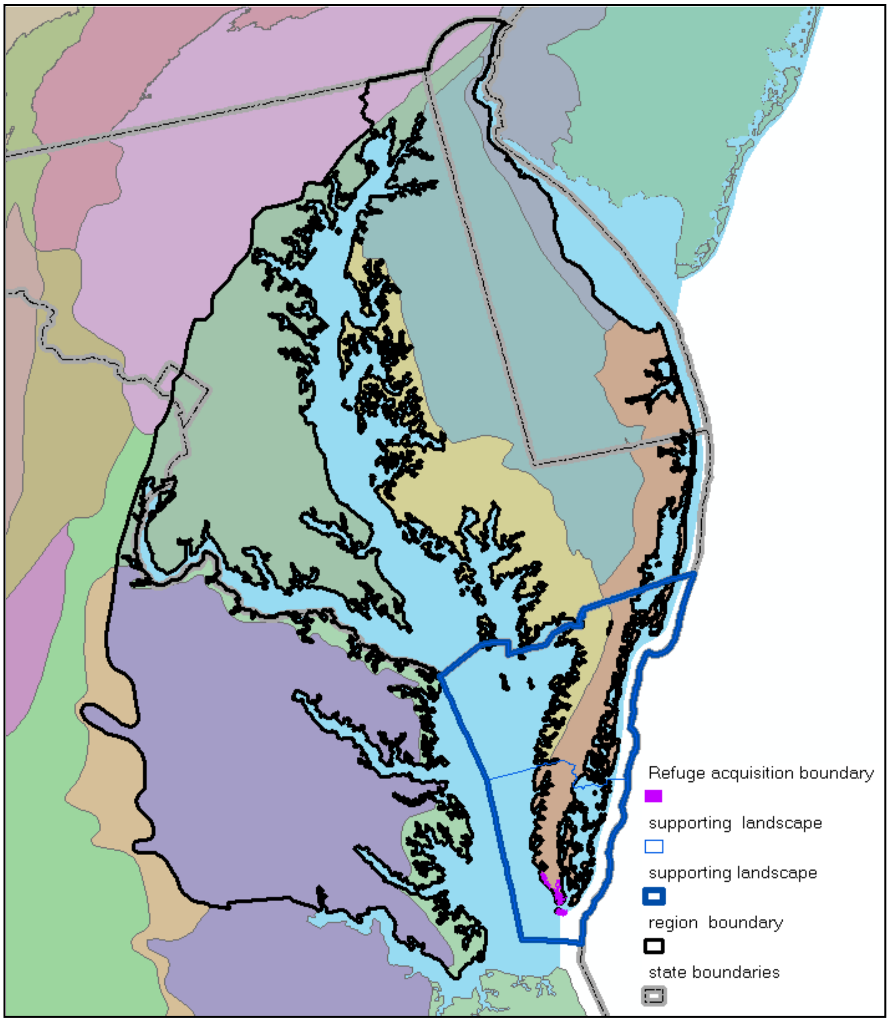
The ecoregion boundary used for the Sheldon-Hart RVAA is largely drawn from two ecological units, the Northwestern Basin and Range and Owyhee Uplands ECOMAP sections (McNab and Avers, 1994). These two sections roughly correspond with the western half of the Northern Basin and Range level III ecoregion (Omernik, 1987). The Sheldon-Hart ecoregion boundary was expanded westward into the Modoc Plateau ecological unit to improve hydrological connectivity with the rest of the region.



We define the supporting landscape context as the immediate landscape interacting with the refuge (see *Figure 5*). The interaction is defined by refuge resources use of the surrounding habitats and the effects of stressors on those resources in and outside of the refuge. Thus the supporting landscape is the boundary within which detailed mapping of resources and stressors and their interactions will be conducted. Supporting landscapes may be defined using a number of factors, a list of recommendations is provided below. Subsequent land-use scenarios and cumulative effects assessments (CEQ 1997) will be developed within the supporting landscape context.

Figure 5. Example of a supporting landscape boundary.

The supporting landscape for the Virginia Eastern Shore pilot RVAA includes the two counties of Accomack and Northampton. Besides encompassing the southern tip of the peninsula, the two counties are also the operating region for the Southern Tip Partnership, a multi-agency conservation group working with the refuge. The region boundary was derived from ECOMAP subsections, state boundaries and expert opinion.



Following are considerations and guidance for choosing the supporting landscape assessment boundary.

a) From the resource perspective, the boundary affects what proportions of resource distributions are considered and may influence proper identification of core-vs. -peripheral habitat locations and presence of important wildlife corridors or other ecosystem linkages. Consider a supporting landscape extent that contains the habitat and linkages supporting species populations or linkages to metapopulations in the ecoregion.

b) From the stressor perspective, the assessment boundary may influence whether an important stressor and its offsite effects are included in the analyses. This may be particularly important for aquatic resources affected by upstream stressors. Consider a supporting landscape extent that includes stressors with direct effects on priority resources.

c) Management implementation, including coordination of partner actions, can also influence the supporting landscape extent. Naturally defined boundaries may be augmented with those of local planning and management jurisdictions such as local governments, regional planning entities such as Metropolitan Planning Organizations (MPOs, *www.ampo.org*), and other state and federal resource-management agencies.

d) For the supporting landscape context, we recommend a terrestrial unit defined by Forest Service ECOMAP sections or subsections (depending on refuge size and location). Alternatively, Major Land Resource Areas (MLRAs) from the Natural Resource Conservation Service (NRCS) may be suitable. Also, a watershed unit may be useful to provide context for aquatic resources on the refuge. We recommend the use of HUC 8 basins depending again on refuge size and the nature of aquatic resources (e.g., stream order).

e) The boundary must be constrained by practicality of implementation. Larger boundaries inherently require more data from more data sources, geometric increases in computer processing, and often a requirement to use spatially coarsened data and dilution of the significance of individual assessments. This will present a challenge when considering the needs of migratory and wide-ranging species, large river systems, and broadly distributed/matrix-forming vegetation communities.

Useful Sources

- Forest Service ECOMAP units: *www.fs.fed.us/land/pubs/ecoregions/intro.html*
- NRCS Major Land Resource Areas (MLRAs): *www.soils.usda.gov/survey/geography/mlra/*
- HUC basins maps: *http://water.usgs.gov/GIS/huc.html*
- Migratory Bird and Habitat Programs; Migratory Bird Conservation Plans and Partnerships (*www.fws.gov/pacific/migratorybirds/conservation.htm*)

Useful Examples

- Using management considerations to inform supporting landscape boundaries: Bulluck et al., 2011. The RVAA conducted for the Eastern Shore of Virginia utilized the two-county operating region for the Southern Tip Partnership, a multi-agency conservation group working with the refuge, to help define the supporting landscape boundary (see *Figure 5*).

Conduct contextual assessments

This substep uses the assessment regions to conduct initial analyses and consultations to conclude what resources and issues should be addressed in the assessment. Because not every resource and issue can be analyzed and addressed, this substep is intended to provide an appropriate focus on priority resources and issues for which the refuge has the ability to influence outcomes. The ecoregion-scale assessment provides information to understand the distribution, status, and apparent ecological condition of refuge resources across the region and can help prioritize resources that may otherwise be overlooked without this contextual assessment. These analyses help identify resources that may warrant increased or decreased management attention. Whether they should receive more or less attention from the refuge may partly depend on the level of management they receive from other stewards of those resources. The contextual assessment will help determine whether such resources should be included for the more specific assessments within the supporting landscape. These assessments can also identify important resource management partners because of shared resource management responsibilities.

a) Obtain or model resource distribution data sets for resources identified in Step 1 within the assessment region. Distribution of a resource may be mapped as point or polygon "occurrences" (as in *Figure 6*) or as a continuous surface or grid (as in *Figure 7*) (*www.natureserve.org/prodServices/heritagemethodology.jsp*)

   Predicted distribution models for species and other resources are becoming increasingly common (e.g., USGS GAP—see Useful Sources) but they may be lacking in some resources (e.g., they are less common and reliable for many rare and imperiled species) or lack the precision desired for a landscape-scale RVAA. Fortunately software tools exist to utilize existing data and expert knowledge to derive reasonably high confidence models of probably distribution (see Useful Tools).

Figure 6. Example of resource distribution data (element occurrences, "EOs") in the Eastern Shore of Virginia NWR pilot project.

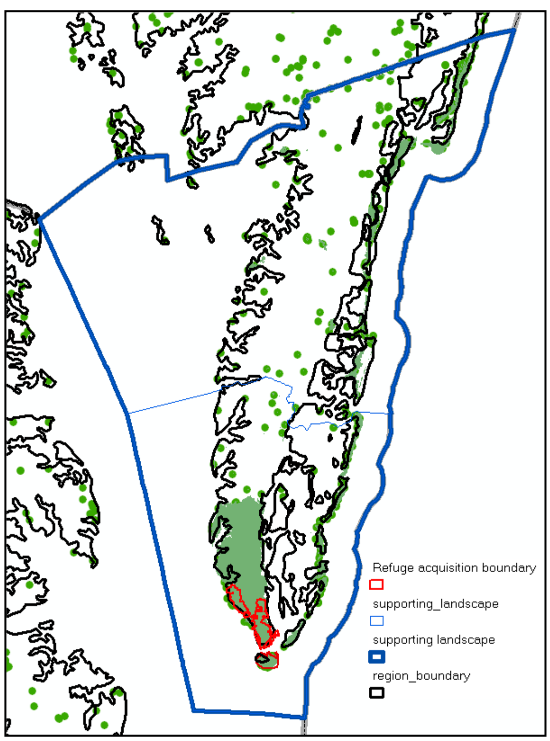
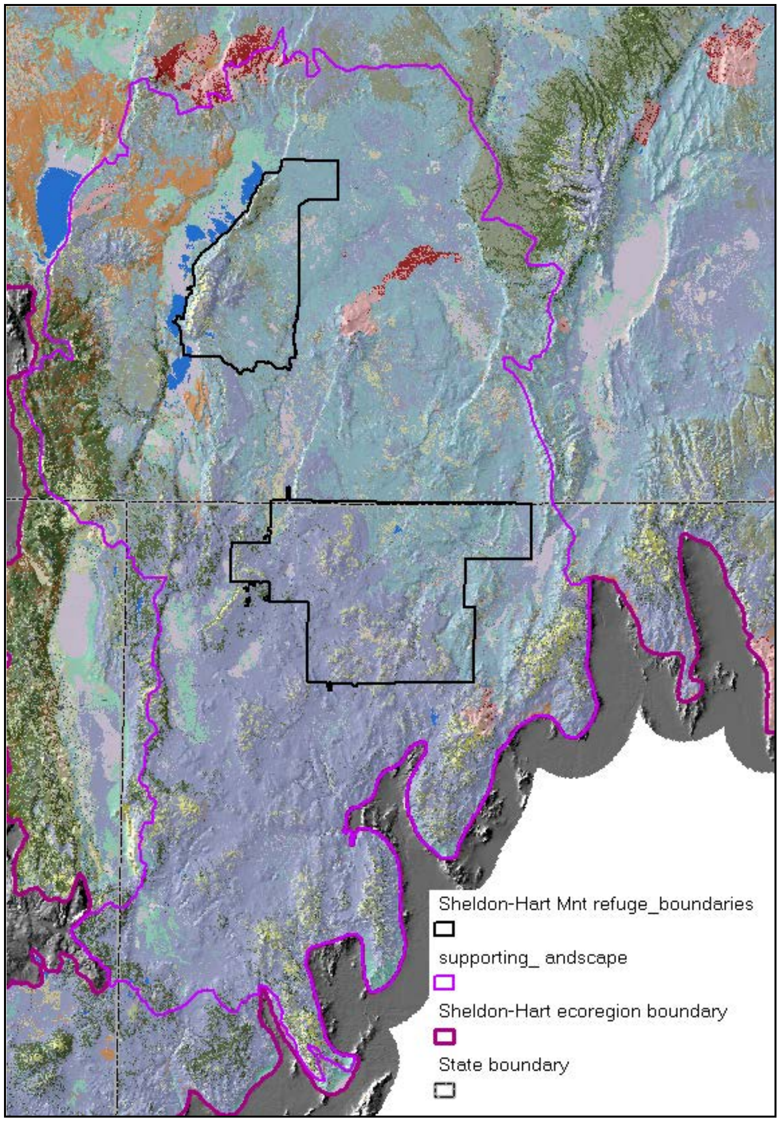


Figure 7. Example of resource distribution data (ecological systems) in the supporting landscape of the Sheldon-Hart Mountain National Wildlife Refuge Complex.



Useful Sources

- Refuge or FWS regional GIS databases (see refuge and/or regional GIS administrators)
- Ecosystem, vegetation, wetland, and aquatic resource maps from national or local sources:
    - State GIS clearinghouses, e.g., *http://gis.oregon.gov*
    - FWS' National Wetlands Inventory (NWI) Web Map Services (WMS): *www.fws.gov/wetlands/Data/WebMapServices.html*

    - NatureServe's ecological systems data: *www.natureserve.org/getData/USecologyData.jsp*
    - The GAP Analysis Program's Land Cover Viewer: *www.gap.uidaho.edu/landcoverviewer.html*

- Predicted species distribution and habitat maps (these are available for all terrestrial vertebrates in the coterminous United States and Puerto Rico through the USGS Gap Analysis Program (GAP) (*www.gap.uidaho.edu/Portal/DataDownload.html*) and often through state resource agencies and from a variety of other NGO and academic programs depending on the region). If developing your own resource distribution models, see Useful Tools.
- Natural heritage element occurrences, field observations, and map surfaces (see *www.natureserve.org/explorer/aboutd.htm* for information about the data and *www.natureserve.org/visitLocal/index.jsp* for state program contacts and links)
- State wildlife agency data and State Wildlife Action Plans (*www.wildlifeactionplans.org*)
- Other agencies' and universities' data
- Nongovernmental organizations' data; e.g., The Nature Conservancy (*www. conserveonline. org*, *http://conserveonline.org/workspaces/climateadaptation/documents/vulnerability-assessments/view.html*, *http://conpro.tnc.org*); Data Basin (*www.databasin.org*)
- In the western United States, see Bureau of Land Management Rapid Ecoregional Assessments: *www.blm.gov/wo/st/en/prog/more/climatechange/reas.html*

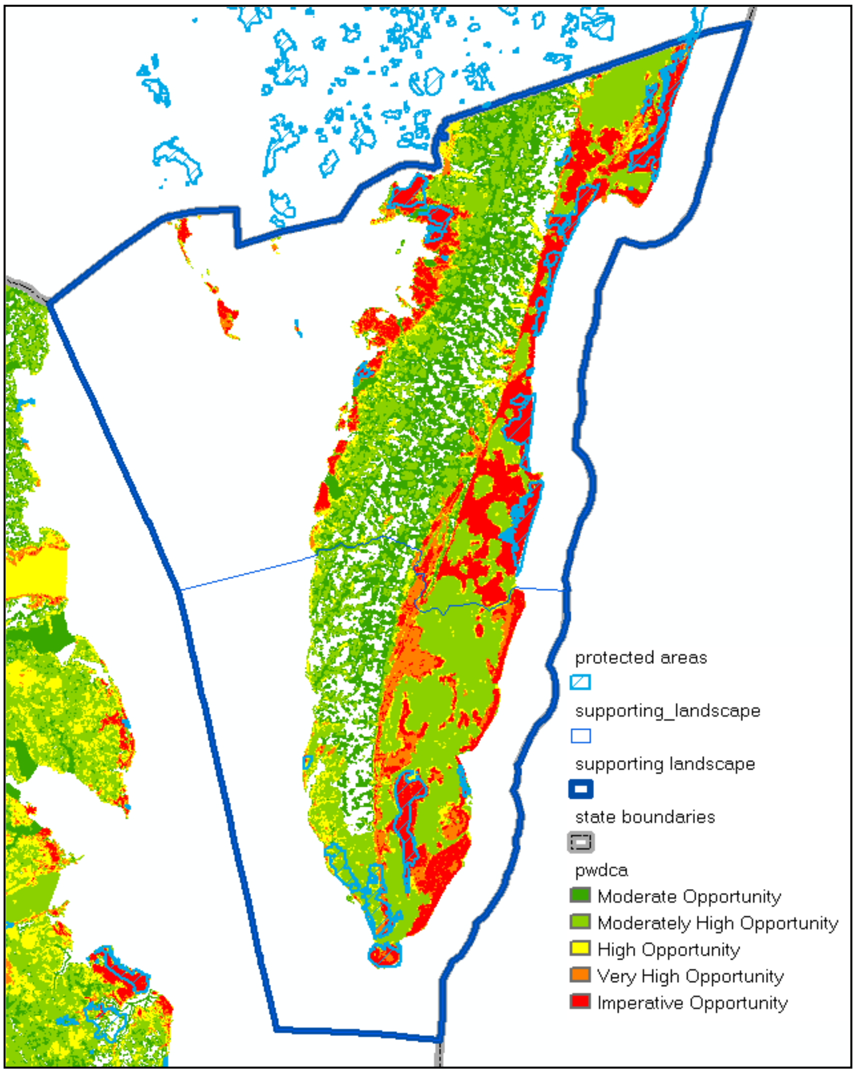
Useful Tools

- Maxent is the leading tool for modeling the current and future distribution of resources: *www.cs.princeton.edu/~schapire/maxent*

b) Obtain boundaries of existing protected and (optionally) priority conservation areas (*Figure 8*). Priority conservation areas are those not yet protected but have been identified for such need by TNC, State Wildlife Action Plans (SWAP), Audubon (Important Bird Areas), Ducks Unlimited, and other conservation planning efforts. Note that this activity compiles information on both existing *protected* areas as might be found in a protected area database (PAD) and *proposed* conservation priority areas from other assessments. While the former supports a gap analysis of current resource protection and management in the assessment region, the latter illustrates the conservation goals or intentions of other agencies and organizations in the context of the assessment area.

Figure 8. Example of conservation priority areas used as input for RVAA.

The Virginia Department of Game and Inland Fisheries created the Priority Wildlife Diversity Conservation Areas (PWDCA) dataset to guide the Department's conservation planning efforts. The PWDCA identifies priority areas for conservation. Also included in this figure are protected areas in Virginia and Maryland. These datasets were used to help refuge personnel quantify what resources are currently protected as well as what is being prioritized by other agencies and non-profit organizations.



Useful Sources

- U.S. Protected Area Database (PAD): *http://gapanalysis.usgs.gov/data/padus-data* or *www.protectedlands.net*
- National Conservation Easement Database (NCED): *www.conservationeasement.us*
- State Wildlife Action Plan (SWAP): *www.nbii.gov/portal/server.pt/community/geographic_perspectives/243*

- Data Download for GAP National Datasets: *www.gap.uidaho.edu/Portal/DataDownload.html*
- TNC ecoregion assessments and conservation action plans and existing easements: *http://conserveonline.org/workspaces/cbdgateway/era/index_html*
- Other sources for public and private protected areas and conservation priority areas include the Conservation Registry (*www.conservationregistry.org*), and LandScope America (*www.landscope.org*)

c) Conduct contextual analyses. The first analysis calculates the proportion of each resource's distribution falling into different spatial contexts (see *Table 2*) to understand the proportional responsibility of the refuge for each resource relative to the supporting landscape and ecoregional contexts. The second analysis is a gap analysis of resource conservation status (see How a Gap Analysis is Conducted, under Useful Sources). This analysis calculates the degree that a resource is conserved by other stewards relative to the refuge's proportion (see *Table 3*) to inform whether the refuge should be a significant steward for a resource (*sensu* BIDEH document; see 601 FW3 under Useful Sources). Likewise, it may determine that the refuge is currently managing for regionally common and non-threatened species at the expense of more rare or threatened species that the refuge is well positioned to maintain.

Table 2. Example resource distribution context analysis from the Sheldon-Hart Mountain National Wildlife Refuge Complex.

Note that for all resources 100% falls within the ecoregion so the values are percent of the ecoregion distribution in the refuge versus the Supporting Landscape

Resource Name	% in Refuge	% in Supporting Landscape
Deciduous Woodlands and Shrublands	1. 61	54. 87

Table 3. Example output table properties from contextual gap analysis for the Sheldon-Hart Mountain National Wildlife Refuge Complex.

For the "% in Steward" columns, utilize as many columns as needed and insert steward names (e.g., names of agencies or NGOs managing protected areas).

Resource Name	% in Refuge	% in Steward A	% in Steward B	% in Steward C	% in Steward (private)	% in GAP status 1	% in GAP status 2	% in GAP status 3	% in GAP status 4
Montane Sagebrush Steppe	1. 98	78. 51	2. 76	2. 15	12. 7	7. 96	13. 92	65. 31	12. 7

Useful Tools

- There is not currently a customized tool to perform these analyses, but they require only simple GIS intersection functions that can be automated using tools such as Model Builder in ESRI's ArcGIS. This approach is applicable to the following substep as well.

Useful Sources

- U.S. Geological Survey, National Biological Information Infrastructure, Gap Analysis Program (GAP). How a Gap Analysis is Conducted. *www.nbii.gov/portal/server.pt/community/program_info/1849/gap_how-to/7002*
- FWS 2001. 601 FW3: Chapter 3, Biological Integrity, Diversity, and Environmental Health. *www.fws.gov/policy/601fw3.html*

d) Conduct optional contextual analysis of resource distribution relative to conservation priority areas not yet designated and/or protected. This information is used to identify potential resource management partners and the degree to which their plans may support resource retention objectives. Neither pilot RVAA project did this assessment due to lack of time and resources but the information can be summarized in a table similar to that above.

e) Conduct other contextual analyses to further inform the RVAA. In many cases, contextual analyses may include both spatial and temporal dimensions. Knowledge of historical patterns in vegetation, wetlands, and habitat condition can provide useful insights for prioritizing current and future habitat management (e.g., USGS Land Use History of North America, *http://biology.usgs.gov/luhna/index.html*). Some states and local jurisdictions have developed land cover maps based on historical information (e.g., *web4.msue.msu.edu/mnfi/data/veg1800.cfm* for the State of Michigan) depicting vegetation and other land cover prior to widespread Euro-American settlement, or more recent time periods. Similar information may be derived from spatial models (see Useful Sources below). For example, the inter-agency LANDFIRE effort developed moderate- to high-resolution maps of "Biophysical Settings" for use in fire-regime assessment. These maps, available nationwide, depict the probable upland and wetland vegetation one might expect to encounter without human disturbance, but assuming natural fire-disturbance regimes. Soils maps can also be quite useful; for example, historical wetland extent may be estimated based on hydric soil distributions. Long-term trends in habitat extent relevant to the refuge can be determined with these data. Producing a simple table (or adding fields to *Table 2*) of historic vs. current areal extent of resources would be useful for informing refuge and regional priorities.

The objective of incorporating historical vegetation information in the contextual analysis is to determine whether the refuge should consider maintaining or restoring certain habitat types or ceasing some management practices that constrain or alter those types because they are significantly reduced or disturbed throughout the region *and* the refuge could play a significant role in retaining or restoring the type. It is also important, however, to understand and consider the natural disturbance scale and cycle of these habitats and whether the refuge and its immediate context can support natural disturbance or mimic it through management (Noss 2002). Further, it will be important to understand whether attempts to restore historical types are likely to be unsuccessful due to climate change (see next).

Useful Sources

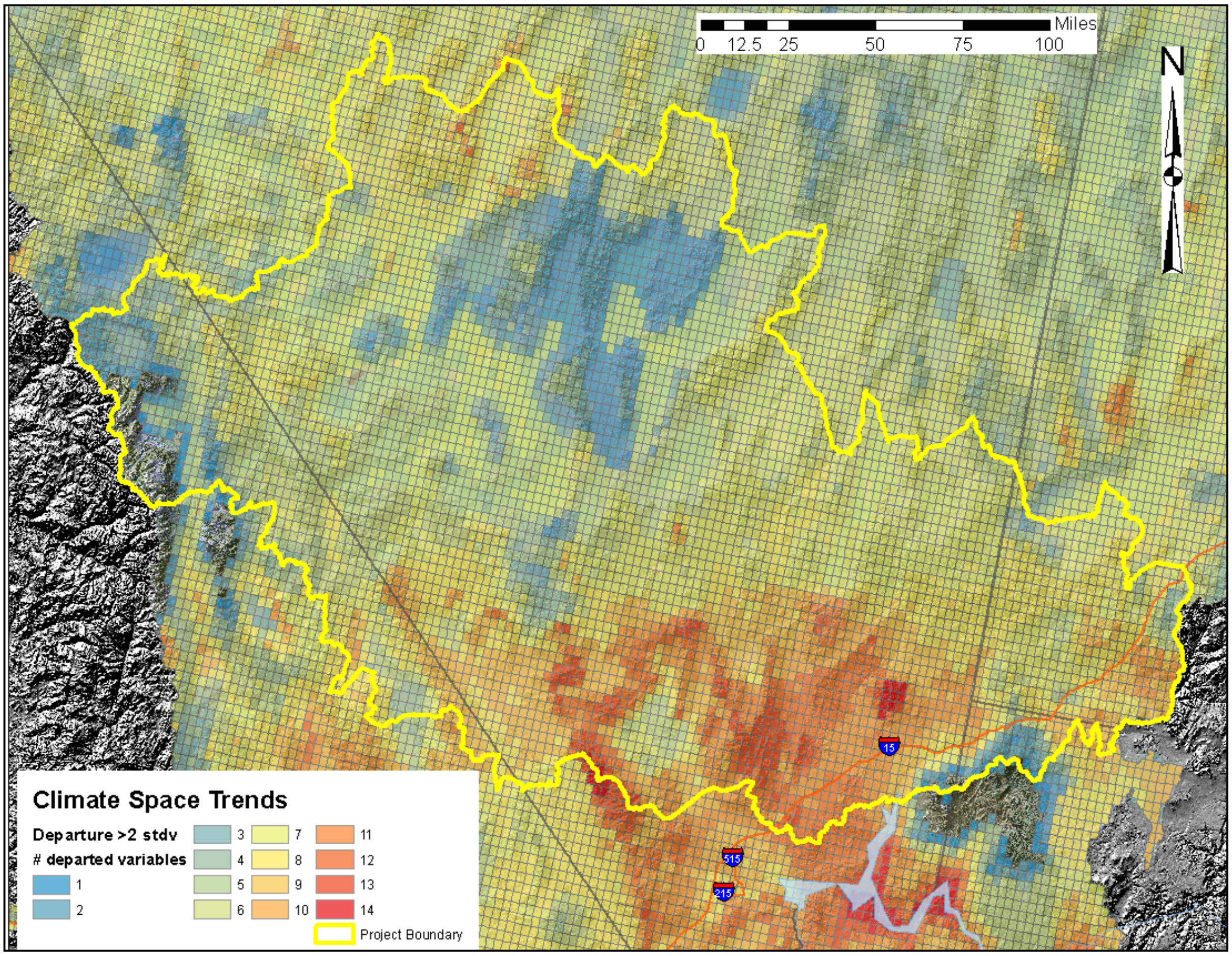
- LANDFIRE Biophysical Settings: *www.landfire.gov/NationalProductDescriptions20.php*
- USGS terrestrial ecosystem maps: *http://rmgsc.cr.usgs.gov/ecosystems/dataviewer.shtml*
- NRCS soils maps: *http://soildatamart.nrcs.usda.gov*

Characterize past and future climate

Obtain appropriate historical climate data (e.g., 20th century data at 4km resolution) (see PRISM Data, NWS, and NASA TOPS under Useful Sources) and climate forecasts (see Useful Tools and Useful Sources) and characterize the current and projected climate for the assessment area (*Figure 8*).

Figure 9. Example climate trend map.

This example is from a Bureau of Land Management study for an area of southern Nevada conducted with NatureServe and Dr. Healy Hamilton. It is an index of the number of climate variables forecast to deviate from historic climate by at least two standard deviations for the year 2060. Red areas are where the largest number of climate variables are forecast to change significantly.



As of this writing, most readily available and higher confidence forecast data are at 15 km resolution, but many downscaled products are becoming available at resolutions as fine as 1 km. It is important to understand various factors used in the models and subsequent downscaling to assess confidence in the data such as:

i) Whether an ensemble of global climate models (GCMs) was used; the use of more models tends to smooth out differences and increase confidence, although some GCMs perform better in different parts of the globe.

ii) Whether the model has been tested using "back-casting" to determine its ability to accurately predict past and/or current climate.

iii) For downscaled data, the density of weather stations is important for calibrating the GCM to finer scales (pixels). The denser the weather station data, the more accurate the downscaled climate forecasts are expected to be.

The typical variables obtained from climate data (past and future) are 1) average temperature (seasonally), 2) average precipitation (seasonally), and 3) net evapotranspiration (integrating forecasted precipitation and temperature). It is also often highly useful to have resource-relevant seasonal high and low temperatures and a variety of secondary climate effects variables.

Climate data alone simply indicate trends in these pervasive factors. For assessing refuge vulnerability, our focus is on *climate effects*—the translation of climate variables into changes in local conditions (see A Method for Incorporating Climate Change under Useful Sources). Models that link climate variables to effects might include the following:

iv) Sea-level rise (SLR) estimates over coming decades (see Vulnerability Assessment and Strategies for Management Options for the Eastern Shore of Virginia and Fisherman Island National Wildlife Refuges under Useful Examples).

v) Coastal waters salinity changes (see Webster 2007 under Useful Examples).

vi) Hydrologic models forecasting stream flow changes (see Merritt et al., 2003 under Useful Examples).

vii) Expected shifts in distribution of major vegetation type or species ranges (see Richardson et al*.,* 2009 under Useful Examples).

viii) Expected shifts in invasive species distributions (see *Figure 16*, also FWS invasives guidance under Useful Sources and BLM Rapid Ecoregional Assessments under Useful Examples).

Useful Tools

- Climate Wizard (*www.climatewizard.org/index.html*) may provide ready reference to basic climate data relevant to RVAA. Climate Wizard offers data outputs by political jurisdiction as well as for customized queries based on your regional landscape (once you upload a shape file).

Useful Sources

- The National Climate Change and Wildlife Science Centers and planned hubs are intended to be the foremost source of information: *http://nccwsc.usgs.gov*
- PRISM Data Descriptions and Terms of Use (Historical 4km US Lower 48 dataset): *www.climatewizard.org/docs/US%2048%20Historical%204km%20Climate%20Data%20%20Documentation.pdf*
- National Weather Service Climate Prediction Service (NWS): *www.cpc.noaa.gov*
- NASA TOPS is an integrated modeling platform for ecological effects of climate: *http://ecocast.arc.nasa.gov*

- Aldous, A., P. Gonzalez, and K. Popper. 2007. A Method for Incorporating Climate Change into Conservation Action Plans: An example from Oregon. The Nature Conservancy.
- FWS on-line learning module: Managing Invasive Plants: Concepts, Principles, and Practices: *www.fws.gov/invasives/staffTrainingModule*
- FWS invasive species page: *www.fws.gov/invasives/nwrs.html*

Useful Examples

- Eastern Shore of Virginia NWR RVA report. Bulluck et al., 2011
- Rhode Island Coastal Resources Management Program, Section 145: Climate Change and Sea Level Rise. Adopted 1/15/2008. *www.crmc.state.ri.us/regulations_adopted/2008-03-04_RICRMP_Section_145.pdf.*
- Webster, M. 2007. Saltwater Invasion: Climate change is causing the oceans to flow further inland, putting pressure on coastal areas to adapt. Scienceline. *www.scienceline.org/2007/06/env_webster_salt-water-global-warming.*
- Merritt, W.S., Y. Alila, M. Barton, B. Taylor, and S. Cohen. 2003. Exploring Impacts of Climate Change on the Hydrology of the Okanagan Basin, in *Proc. of the Canadian Water Resources Association*, Vancouver, BC, Canada. *http://cses.washington.edu/cig/outreach/workshopfiles/Apr03_Scenarios_water/BC_Merritt_etal_cwra2003.pdf*.
- Richardson, D.M. et al., 2009. Multidimensional evaluation of managed relocation. Proceedings of the National Academy of Sciences USA. Vol. 106 (24) pp. 9721-9724. DOI: 10. 1073/pnas. 0902327106. *www.pnas.org/content/106/24/9721.full*.
- Bradley, B., M. Oppenheimer, and D. Wilcove. 2009. Climate Change and Plant Invasions: Restoration Opportunities Ahead? Global Change Biology. Vol. 15 (6) pp. 1511–1521. DOI: 10. 1111/j. 1365-2486. 2008. 01824. *www.sciencedaily.com/releases/2009/01/090127112055.htm*.
- Some Rapid Ecoregional Assessments of the Bureau of Land Management modeled potential spread of invasive species under climate change: *www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html*

Develop a conceptual model of the interaction of resources and stressors

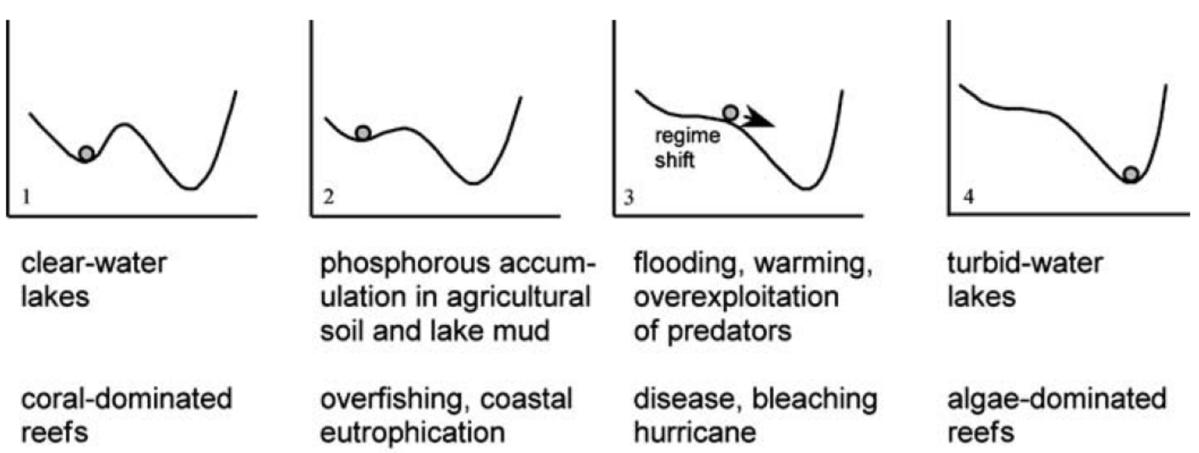
We begin the discussion for conducting this substep with concepts important for understanding ecological assessment. Given the challenges presented by climate change, it is worthwhile to review established concepts of alternative ecosystem states, including ecological resistance, and resilience. Some of these concepts, summarized by Beisner et al., (2003), use a "ball-in-cup" analogy, where the ball represents a current ecosystem or species assemblage. It may vary in its expression (e.g., in species composition and dynamic processes) but can be predicted to occur within a given range of variation due to existing biophysical constraints, intact food-web interactions, and other interacting ecological processes. It may in fact, be found to occur within multiple, apparently "stable" species assemblages or ecosystem "states." Given these "intact" conditions, when natural disturbances occur, it retains much of its typical character: it exhibits high "resistance." When severe disturbances occur, it may shift temporarily, but can bounce back: it exhibits high "resilience." In *Figure 10-1*, this is symbolized by the high central portion of the curve, keeping the ball within the "cup" on the left. However, when food-webs or key dynamic processes have been altered or disrupted (as illustrated by the lowering of the central portion of *Figure 10-2* and *Figure 10-3*), we might see dramatic and seemingly permanent shifts to alternative stable states (*Figure 10-4*).

Figure 10. Illustration of the "ball-in-cup" analogy with a hypothetical lake or coastal marine ecosystem (adapted from Scheffer et al., 1993 and Gunderson 2000).

A central challenge to wildlife conservation in the 21st century is to address current stressors that degrade natural ecological processes and decrease both resistance and resilience among natural ecosystems (see Adaptation Options under Useful Sources). By addressing these stressors today, and anticipating novel stressors introduced by climate change, we lower the risk of widespread shifts to alternative, simplified stable states characterized by lower ecosystem productivity and diversity.

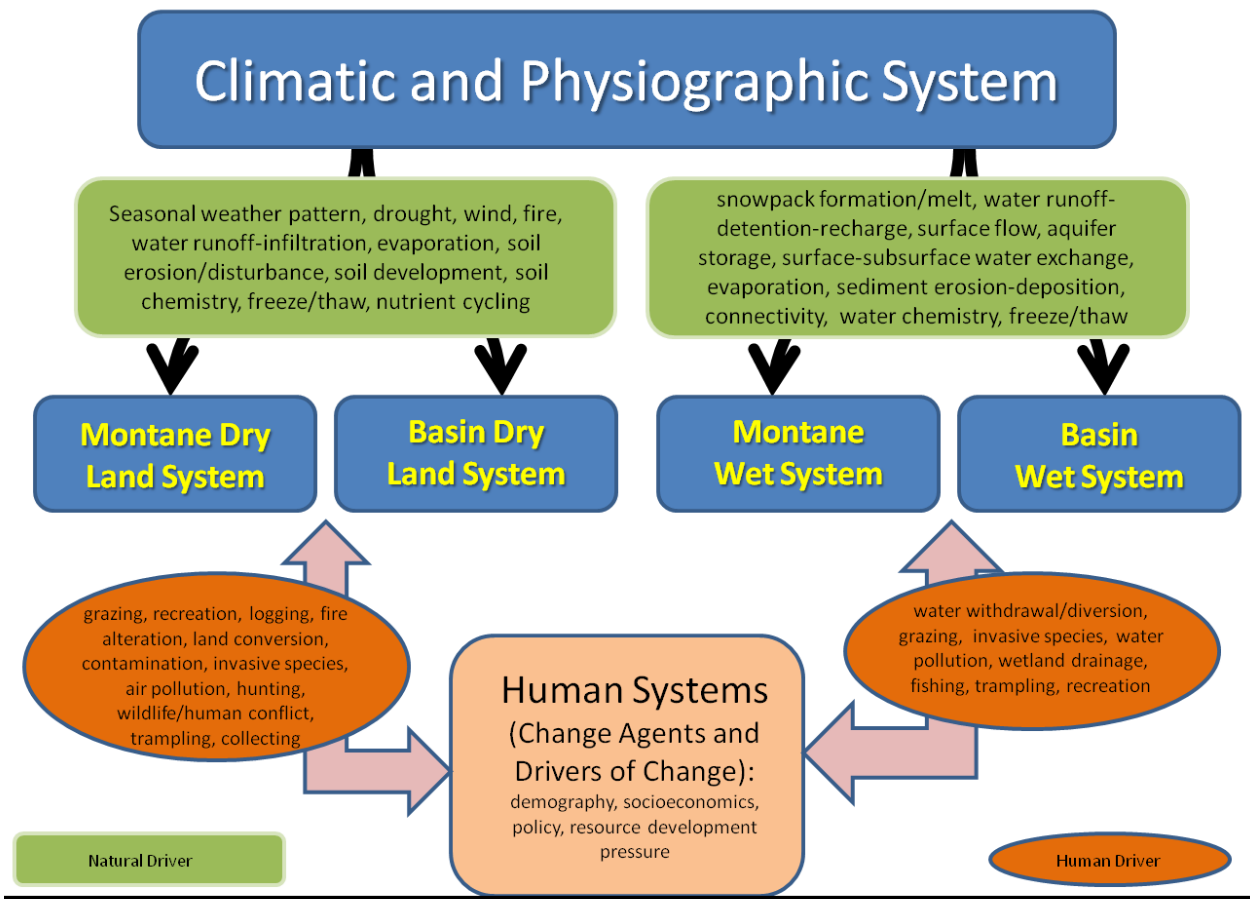
With this conceptual foundation, we turn now to the task of characterizing resource response to stressors. There is a large body of work on ecological response to environmental and anthropogenic changes to inform this step. While climate change introduces novel stressors, most existing response models can address climate change effects. Glick et al., (2011) provide a good treatment of the range of models and their conceptual application to vulnerability assessments in their Chapter 4.

To understand resource response to stressors, it is helpful to develop simple conceptual models of the resources. Conceptual models assist with organizing current knowledge and communicating key assumptions about the environmental controls and dynamics that characterize the refuge's supporting landscape. Models commonly include "box-and-arrow" diagrams, tabular summaries, and textual descriptions. We recommend review of current approaches (e.g., Gross 2005) to organize a conceptual



model for the supporting landscape and perhaps the key ecosystem types. You may be able to draw upon a wealth of existing conceptual models developed for regional applications by National Park Service Inventory and Monitoring programs (e.g., Chung-MacCoubrey et al., 2008) or for more local applications (e.g., LANDFIRE vegetation dynamics models or NRCS Ecological Site Descriptions). The purpose of these models is to articulate key assumptions about landscape pattern and process that will inform further analysis of conservation elements and stressors. An overarching description and model can also provide a framework for organizing a series of component models for the area. For example, *Figure 11* includes a conceptual model applicable at regional scales to basin and range landscapes across the cool semi-desert and warm deserts of the interior West of the United States. It articulates major environmental controls, such as the interactions with climate and regional landscape patterns (physiography), that influence major patterns in upland vegetation and aquatic ecosystems. It also depicts the human dimension, in part using common human uses, and the stressors they may introduce into the natural ecosystem types. This regional conceptual model also provides a framework for more detailed conceptual models. For example, within the Sheldon-Hart Mountain National Wildlife Refuge Complex (Crist et al., 2011), the "Montane Dry" system includes higher-elevation aspen forests and montane sagebrush steppe. The "Basin Dry" system includes the predominant, lower-elevation sagebrush shrublands and steppe. Each of these types may have more precise conceptual models developed to help articulate key assumptions about natural disturbance regimes, successional pathways, and responses to stress, such as the introduction of invasive plant species.

Figure 11. Conceptual model for regional landscapes of the interior West of the United States.



Useful Tools

- Conceptual modeling tools can be found at *http://fileheap.com/software/conceptual_data_model.html*, although a simple schematic, as in *Figure 11*, is adequate for RVAA purposes

Useful Examples

- Rapid Ecoregional Assessments of the Bureau of Land Management utilize conceptual models: *www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html*

Develop a refuge context report

This component describes contributions of the refuge to the NWR system and the refuge's supporting landscape and regional context and presents the conceptual model for how the supporting landscape's resources and stressors interact. The report will also include content from Step 1 and will contribute toward the complete final refuge report (see Appendix E for complete report outline).

Conduct a refuge/partners workshop

The primary objective of this workshop is to validate information and determine the appropriate course of work for the RVAA. It is at this point where key decisions should be made about the key necessary assessments that are required to support the information needs. Conducting a full geospatial RVAA as described in the following steps can be very time and resource intensive so participants should closely consider the necessity of each component analyses relative to decision making needs. The participants should also be aware of and contribute information about other relevant assessments (recent past, current or planned) that can provide equivalent information as some of the RVAA components.

Assuming some level of geospatial analyses is desired, the workshop participants should also identify potential futures to be analyzed (see MIT-USGS and NPS scenario planning under Useful Examples). Workshop participants can use the conceptual model to finalize which stressors should appear in which future scenarios and in particular determine those climate effects most relevant for the resources to be assessed in the scenarios.

The workshop should include planners, managers, and scientists that manage or affect the priority resources of the refuge. A suggested workshop agenda can be found in Appendix F.

Useful Examples

- National Park Service Scenario Planning: *www.nature.nps.gov/parkscience/index.cfm?Page=3*
- MIT-USGS Science Impact Collaborative Everglade Project: *www.alternativefuturestechnologies.com/everglades*
- New Mexico Climate Change Ecology and Adaptation Workshop: *http://nmconservation.org/projects/new_mexico_climate_change*

Revisit previous steps

Step 2 is inherently designed to revisit the initial candidate lists established in Step 1. Prioritization in Step 2 may require some revisiting of Step 1 issues such as policy mandates in resource selection.

Step 3: Identify data needs and develop a work plan

This step uses the results of Steps 1 and 2, including outcomes from the partner workshop, to develop the details necessary for conducting the rest of the RVAA steps. Remaining analyses will pertain to the supporting landscape, so this geographic area will now be used to determine data needs. Enough may be known during the general project scoping to accomplish this task earlier. The most challenging component of this step is securing experienced labor in conducting the technical and scientific activities required. Although large numbers of agency, academic, and NGO staff have been developing the necessary skills and experience, demand and competition for these services can be high so advance planning is encouraged.

Summary of Inputs

1. Conceptual model, reports, and tables from Steps 1 and 2
2. Result of partners workshop

Summary of Outputs

1. List of data needs and costs (see Appendix G)
2. Work plan outlining scope of work, cost estimate, and schedule for conducting remaining steps

Detailed Substeps

Complete the initial assessment and estimates

a) Complete the checklist of all potential data needed and evaluation of current data quality and improvement/development needs and costs (see Appendix G). As with all data, care must be taken to match the scale and precision of climate change data to the scale and scope of the RVAA (Glick et al., 2011). An increasing number of downscaled climate change products and climate change effects results are being created at increasingly finer resolution, so a frequent re-assessment of available data is recommended.

b) Determine exact steps and costs to complete the analysis. Work with appropriate refuge staff to confirm information and costs to complete the process. The remaining technical steps descriptions in this guide should provide sufficient detail for this process but there are a number of options to consider that can have significant impact on time and cost.

c) Develop the work plan and distribute for review to participating organizations then discuss and revise as needed.

d) Fund the assessment and secure labor and expertise commitments and contracts to conduct the work.

Conduct technical kickoff workshop

This workshop is suggested when there are multiple partners, collaborators, and contractors involved in the work. This is the opportunity for participants to get to know each other and clarify scope, roles, schedule, and mechanisms and frequency of communication.

Revisit previous steps

Evaluating available data and estimating project costs necessarily causes some revisiting of priorities and mandates from Steps 1 and 2. Refuge Vulnerability Assessment and Alternatives are highly scalable, and as in any assessment, products will need to be prioritized to fit available resources.

Step 4: Characterize current conditions, management regimes, stressors, and resource response

This step collects and integrates information to characterize the current ecological condition, land use, management practices, and other stressors on the refuge and in its supporting landscape (see IUCN-CMP 2006 under Useful Sources). It also documents how resources are known or expected to respond to the stressors and their viability requirements. It builds the baseline for Step 5 and supports the cumulative effects assessment (CEQ 1997) conducted in Step 6.

Summary of Inputs

1. Distribution data layers for resources and MCI to be assessed
2. Resource and MCI retention parameters (expert input)
3. Resource and MCI responses to stressors (expert input)
4. Updated/completed spatial data inputs for scenarios including stressors, land management, and conservation areas.

Summary of Outputs

1. Table of resource and MCI retention parameters and responses
2. Optional resource and MCI condition models
3. Final spatial data inputs for resources, MCI, and scenarios
4. Integrated baseline scenario of current uses, management, and stressors.

Detailed Substeps

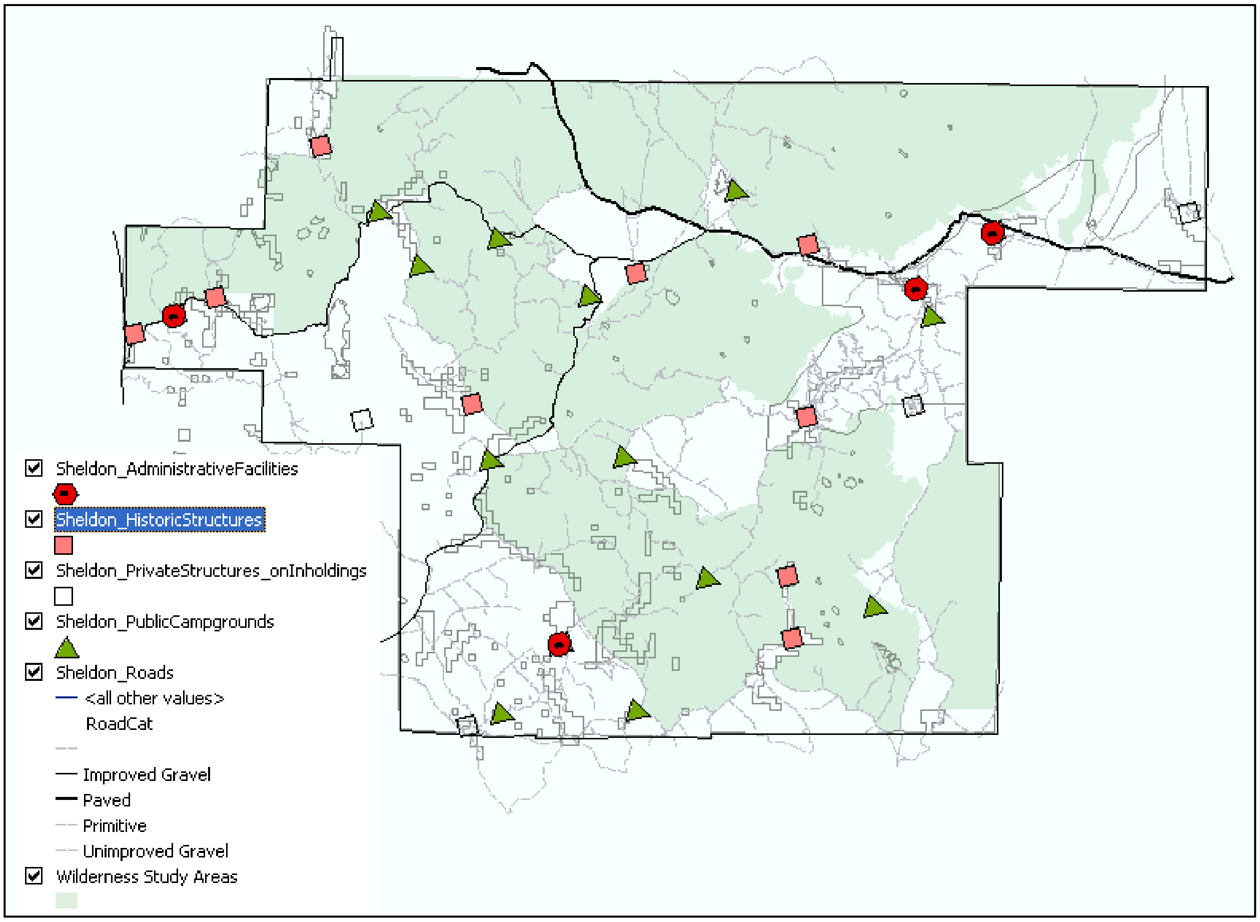
Collect or develop additional data

This substep addresses data identified in the data checklist (developed in Step 3).

Obtain or model the current distribution of resources and MCI (e.g., see *Figure 12*) to be assessed. Some of this will have been collected for Step 2. See *Figure 22* and associated text for information about modeling potential future distributions of resources under climate change. This substep completes the data acquisition identified in Step 3.

- See Useful Sources under Step 2, Conduct contextual assessments substep.

Figure 12. Support infrastructure on Sheldon National Wildlife Refuge.



b) Determine the conservation requirements for resources and MCI (as applicable). "Conservation requirements" are the quantitative and qualitative descriptions of what is needed to conserve or maintain the biological or MCI resource in the supporting landscape of the refuge. This information is important for conducting robust cumulative effects assessment and follows information requirements for systematic conservation planning approaches (see Margules and Pressey 2000 under Useful Examples). These requirements form the basis for modeling how resources respond to stressors under the different assessment scenarios and quantifying those impacts. Key inputs for conservation requirements follow and are typically gathered from resource experts using processes which can range from simple workshops, survey forms, and interviews to more complex approaches of formalized expert elicitation. For threatened and endangered species, see Useful Sources below. For resources lacking sufficient research, "Expert elicitation (EE) is a systematic process of formalizing and quantifying, typically in probabilistic terms, expert judgments about uncertain quantities" (EPA 2009). While quantifying expert opinion is a worthy objective, it is often a high bar simply to access the time of such experts to provide the minimum information necessary for assessment and planning and little empirical data exists for many resources to provide unqualified parameters for these assessments. That said, it is important to: A) understand that this information is intended for planning purposes rather than site level project environmental impact assessment, and B) capture and convey uncertainty about these conservation requirements to those tasked with applying the information. Following are key conservation requirements recommended for these analyses:

- Quantitative retention goal(s) (see Adamcik et al., 2004 under Useful Tools and Groves 2003 under Useful Sources). The retention goal is most closely related to the objectives of a CCP as it identifies the quantity of each resource/MCI feature that is desired to be retained in the project's supporting landscape and refuge. These need to be stated in a form that can be analyzed and quantified in a GIS spatial analysis. For example, habitat goals might be expressed as the "areal extent" (i.e., number of acres) of high-quality habitat conditions that would support a target population at sustainable levels. Goals can be expressed as a percentage of the existing resource (including a restoration objective) (see *Table 4*), which allows it to be applied to any spatial extent, or as a numeric quantity (i.e., the number of populations or occurrences). Goals can also be expressed as a range, e.g., minimum and preferred, or to indicate uncertainty in the appropriate goal or levels of risk of retaining the resource. For MCI, typically each feature will have a retention goal of 100% but classes of MCI (e.g., all 2-track roads) might have a smaller percentage that must be retained. Often retention goals for MCI are tied to specific infrastructure features as they perform different functions or connect different places and are not substitutable. Goals should be revisited after evaluation in Step 6, particularly after evaluating climate change scenarios which might suggest unachievable goals for certain elements or MCI features forecast to experience area reductions (e.g., Geselbracht et al., 2011). Species population goals are a key part of conducting Strategic Habitat Conservation but require considerably more data, time, and expert knowledge to develop and assess than areal habitat goals.

Table 4. Example of retention goals for biological resources.

This example is from the Creating Resilient Communities project (*http://resilient-communities.org*) in the greater Charleston, South Carolina, area. Retention goals here are described as a percentage of the resource's total area within the project area.

Resource	Justification	Retention Goal (%)
Non-riverine Swamp and Wet Hardwood Forest	Many species of concern and provides high connectivity; maintains hydrology of landscape; low threat of development.	80
Floodplain Forest	Some regulation is in place, but connectivity and indirect upstream impacts are important; medium threat level.	70
Salt and Brackish Tidal Marsh	Highly threatened by sea level rise. Must preserve as much as possible since so much will be lost.	100
Fresh – Oligohaline Tidal Marsh (transitional zone)	Highly threatened by sea level rise. Must preserve as much as possible since as much will be lost.	100
Tidal Wooded Swamp	High ecosystem value; limited distribution. Must preserve as much as possible because there is so little currently on the landscape.	100
Dry and Mesic Oak and Mixed Forest	Faces high development pressure; relatively limited distribution.	75

- Responses of resources to stressors and management practices. Responses describe how a resource or MCI type responds when coincident with a stressor. The basic relationships between stressors and resources should have been described by the conceptual model produced in Step 2. To conduct geospatial analyses of cumulative effects of stressors on resources, more detailed response models are needed. Response models can range from a simple categorical relationship (e.g., resource responds as negative, neutral, or beneficial in the presence of the scenario feature) (see *Table 5*) to more complex models such as a spatial model of ecological condition (see *Table 5*) or very complex population viability models incorporating demographics, population size and connectivity (See Useful Examples). Some condition models calculate on and off-site (i.e., distance effects) reductions in ecological/habitat condition (or infrastructure condition) expected to result from stressors and compare calculated condition to a threshold for viability (see Step 6 for examples of condition model assessment). Responses of MCI to stressors tend to be more straightforward than biological resources but could include complex relationships such as seismic threats, raising or lowering of groundwater from climate or development stressors, or user threats such as vandalism to historic features if access is increased. Responses and condition models can be set up once for each resource/MCI type or class and can be reapplied to assess many scenarios (see Useful Tools).

Table 5. Example summary of resource responses to stressors

Categorical responses to stressors were assigned for resources in the Sheldon-Hart Mountain National Wildlife Refuge Complex: negative (–), neutral (=), and positive (+) (partial table, see RVAA report for full table).

Resource	Agriculture	Invasive Grassland	Juniper Woodlands	Recently Burned	Water (aquatic species)	Roads	Transmission Lines	Mech. & Herbicide Treatmts	Seeding & Planting	Grazing (commercial)	Wind Energy Potential	Solar Energy Potential	Mining	Recreation Activities	Wild Horses & Burros
Pronghorn Primary Habitat	=	=	–	+	–	–	–	+	+	–	–	–	–	–	–
Pronghorn Corridors	=	=	–	+	–	–	–	+	+	–	–	–	–	–	–
Sage Grouse	=	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Sage Grouse Breeding Habitat	–	=	–	–	–	–	–	+	+	–	–	–	–	–	–
Sage Grouse Range	–	=	–	–	–	–	–	+	+	–	–	–	–	–	–
Pygmy Rabbit	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Greater Sandhill Crane	+	+	–	–	+	–	–	+	+	–	–	–	–	–	–
Lahontan Cutthroat Trout	–	–	–	–	+	–	–	+	+	–	–	–	–	–	–
Inter–Mountain Basins Big Sagebrush Steppe	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–
Inter–Mountain Basins Semi–Desert Grassland	–	–	–	+	–	–	–	+	+	–	–	–	–	–	–
Long–flowered Snowberry	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Hart Headquarters	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
Sheldon Headquarters	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=

This example is from the Creating Resilient Communities project in the greater Charleston, SC area and focused on development and coastal hazards. Resource responses to stressors were coded as 1 = beneficial, 2 = neutral, 3 = negative.

Resource	Urban/ Suburban	Rural Residential	Agriculture	Timber Forest	Recreational Parks	Natural Areas	Conservation Management	Habitat	Mines	Active Landfills	Local Roads	Local Roads (dirt)	State/ Inter-state Roads	Transmission Corridors	Storm Surge	Sea Level Rise
Non-riverine Swamp and Wet Hardwood Forest	3	3	3	3	3	2	1	1	3	3	3	3	3	3	2	3
Floodplain Forest	3	3	3	3	3	2	1	1	3	3	3	3	3	3	2	3
Salt and Brackish Marsh	3	3	3	3	3	2	1	1	3	3	3	3	3	2	2	2

Given the RVAA emphasis on climate change vulnerability, we provide background for evaluating resource response to climate change in particular. Resource response to climate change effects is based on three basic considerations (see Glick et al., 2011 for sources):

(1) Resource sensitivity to types of environmental changes caused by climate change.

(2) Expected exposure to climate changes (this can be characterized spatially or non-spatially). This addresses whether or not changes are expected to occur and to what degree.

(3) Resource adaptive capacity to withstand or adjust to the changes. Glick et al., (2011) provide a good treatment and references for this concept in their Chapter 3). Some key components of adaptive capacity can include:

  (a) Resource plasticity: the ability of the resource to change its physiology or behavior to adjust to climate change effects

  (b) Dispersal capability: the resources ability to relocate to more favorable locations which can be strongly influenced by its dispersal capabilities and barriers to dispersal

  (c) Evolutionary potential: species with fast generation times, inherent genetic diversity, and large, broadly distributed populations tend to have greater evolutionary potential to adapt to climate changes

(d) For MCI, “adaptive capacity” may include the ability of the feature to continue performing its function if exposed to certain climate change effects, such as whether a boat ramp was designed to accommodate rising water levels. MCI is primarily going to experience indirect effects of climate change (such as inundation, groundwater/soil changes, or erosion increases), although increased temperatures might have an effect on pavements not designed for those higher temperatures (CCSP 2008). See Useful Sources for additional information.

These responses can be documented in a tool that documents species response to climate change (Rowland, et al., 2011; see Useful Tools) and, as with other stressors, modeled in simple to complex ways. Additional details and examples of this are provided in Steps 5 and 6. Often a species response to climate change (and other stressors) is associated with its response to habitat changes and in this case, the key sensitivities of the habitat can be used as a surrogate for individual species response (Glick et al., 2011).

- Other conservation requirements can include:

(1) Minimum required occurrence size (e.g., the minimum undisturbed area surrounding nest sites to ensure nesting success, or the minimum contiguous area of vegetation required to sustain and recover from natural disturbances)(see NatureServe Ecological Integrity Assessments or Population/Occurrence Delineation under Useful Sources).

(2) Dimensional requirements (e.g., to retain a specific buffer size or connectivity corridor width) (see Boyd 2001 under Useful Examples).

(3) Dependencies on other resources, infrastructure, or management (e.g., fire dependent habitat) (see Management Methods under Useful Examples).

Useful Tools

- Maxent is the leading tool for modeling the current and future distribution of resources: *www.cs.princeton.edu/~schapire/maxent*
- The Climate Change Vulnerability Index tool can be used to document expert assumptions about how climate change may affect individual resources: *www.natureserve.org/prodServices/climatechange/ccvi.jsp*
- System for Assessing Vulnerability of Species (SAVS) to Climate Change (USFS): *www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability*
- Framework for categorizing the relative vulnerability of threatened and endangered species to climate change (EPA): *cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203743*
- Coastal Marine Ecosystem Based Management Tools (*www.ebmtools.org)* includes a searchable database with entries for a large variety of useful tools for this step in addition to some highlighted here.

- Adamcik, et al., 2004. Writing Refuge Management Goals and Objectives: A Handbook. *http://library.fws.gov/Refuges/WritingRefugeGoals_022504.pdf*.
- Miradi may be useful for documenting assumptions about resource requirements and responses: *www.miradi.org*
- The NatureServe Vista expert input guides and tools provide guidance and Excel spreadsheets for capturing and documenting input from resource experts: *www.natureserve.org/prodServices/vista/docs/Expert_inputs.xls*
- NatureServe Vista provides a database structure for gathering and documenting resource viability requirements, condition models, and response to stressors: *www.natureserve.org/vista*
- The Ecosystem Management Decision Support system (EMDS) can be used for building logic and spatial models for conducting ecological assessment: *www.spatial.redlands.edu/emds*
- FWS 1980-1. Habitat Evaluation Procedures Handbook: *www.fws.gov/policy/ESMindex.html*

Useful Sources

- For developing conservation requirements for threatened or endangered species, there are numerous FWS documents that should be consulted such as recovery plans, HCPs, critical habitat designations, listing rules, and five-year reviews. There are also numerous document related to migratory species. See *www.fws.gov/endangered/esalibrary/index.html#hcp*, *http://criticalhabitat.fws.gov/crithab*, *www.fws.gov/migratorybirds*.
- Glick et al., (2011) Chapter 3.
- IUCN – CMP 2006. Unified Classification of Direct Threats: Version 1.0 *http://science.natureconservancy.ca/salishsea/documents/Background/general/IUCN-CMP%202006b.pdf*.
- Report on impacts of climate change on transportation infrastructure: *www.climatescience.gov/Library/sap/sap4-7/final-report/sap4-7-final-all.pdf*
- Adaptation Options for Climate-Sensitive Ecosystems and Resources: Chapter 2: Introduction: *http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-Ch2-Intro.pdf*
- Guidance for developing conceptual ecological models Gross (2005): *http://science.nature.nps.gov/im/monitor/ConceptualModels.cfm*
- NPScape – Monitoring Landscape Dynamics of National Parks: *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

- LANDFIRE Vegetation Dynamics Models: *www.landfire.gov/NationalProductDescriptions24.php*
- Ecological Site Descriptions and conceptual state-and-transition models: *http://esis.sc.egov.usda.gov*
- NatureServe Ecological Integrity Assessments: *www.natureserve.org/getData/eia_integrity_reports.jsp*
- Establishing resource retention goals and responses is best accomplished by a working group of experts in the particular resources accessing relevant literature in combination with their expert judgment
- Groves, C. 2003. Drafting a conservation blueprint. Island Press. Washington, DC.
- Population/Occurrence Delineation and Viability Criteria (NatureServe): *www.natureserve.org/explorer/popviability.htm*
- Schneider, S.H., and T.L. Root (eds.) 2002. Wildlife Responses to Climate Change: North American Case Studies. Island Press, Washington, DC.

Useful Examples

- Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature. Vol. 405, pp. 243-253. doi:10. 1038/35012251, *www.nature.com/nature/journal/v405/n6783/full/405243a0.html*.
- Boyd, L. 2001. Buffer Zones and Beyond: Wildlife use of Wetland Buffer Zones and their Protection under the Massachusetts Wetland Protection Act. University of Massachusetts. *www.umass.edu/nrec/pdf_files/final_project.pdf*.
- "Management Methods: Prescribed Burning": *www.fws.gov/invasives/staffTrainingModule/methods/burning/introduction.html*
- Several Rapid Ecoregional Assessments of the Bureau of Land Management utilized condition models: *www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html*

Useful Tools

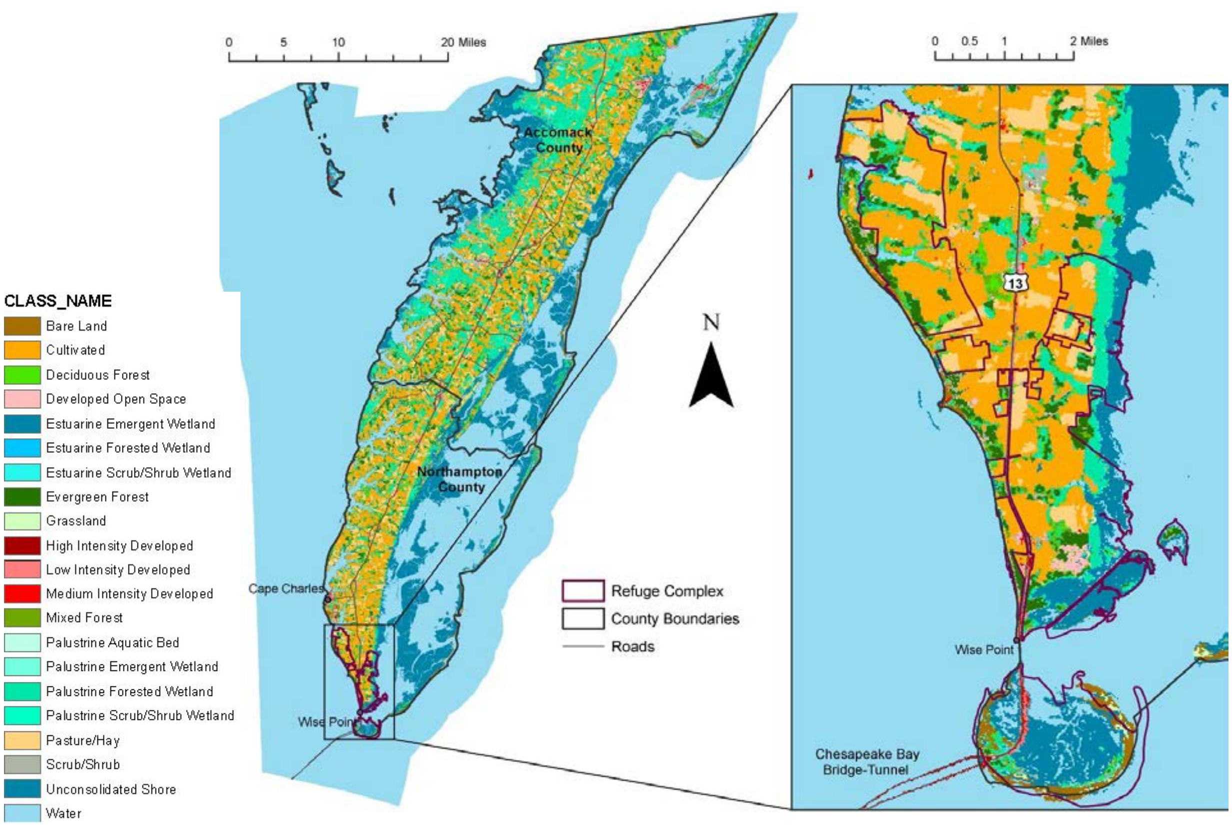
- Non-point source pollution/sedimentation modeling can be conducted in NOAA N-SPECT (*www.csc.noaa.gov/digitalcoast/tools/nspect/index.html*), SWAT (*http://swatmodel.tamu.edu*), and other hydrologic modeling tools.
- Ecological assessment of water quality effects (generated by above tools) on resources can be modeled in NatureServe Vista (*www.natureserve.org/vista*) and more generic ecological modeling tools like EMDS (*www.spatial.redlands.edu/emds*).

Characterize current conditions (the baseline scenario)

Obtain data layers of current management and stressors within the supporting landscape boundary. The resulting scenario will be a map with attributes for each location about the features that should be assessed for their effects on the resources (*Figure 13*). Being as complete as possible will render the most accurate assessment. This means including all features expected to both support and stress the resources to quantify the degree of impact as well as the location and types of stressors causing the impacts. Typical features to include can be found in Appendix D combined with supportive uses such as protected areas and mitigation banks.

a) Obtain data layers that characterize or indicate the current land uses, land management, and stressors. What features should be mapped should come out of the conceptual model and lists of stressors and scenario visioning processes (Step 2). See Useful Sources for common sources of such information.
b) Create a spatial baseline scenario of current infrastructure, uses, management, stressors, and protected areas (see BCMF 2005 under Useful Examples). This substep entails combining the maps to produce a cumulative scenario. It is important to determine if overlapping features in the maps should be combined to indicate concurrent activities or if one map/feature should override others because it excludes other uses in its presence (see NatureServe Vista under Useful Tools).
c) Stressor effects on aquatic resources require the use of hydrological models that can calculate or predict changes to stream flows and/or the transport of sediment and pollutants from upland and upstream stressors to aquatic resource locations (see FWS aquatic resource guidance or consult with experts on this substep).

Figure 13. The baseline land use scenario for Eastern Shore of Virginia NWR.



Useful Tools

- NatureServe Vista provides a tool for combining multiple data layers and crosswalking them to a common classification of land use/practices/stressors as well as characterizing policy/causal mechanisms: *www.natureserve.org/prodServices/vista/docs/UserManual_AnalyticalTools.pdf*. This results in one or more raster layers which can then be evaluated in Vista (Step 6) or exported for use in other assessment tools.

Useful Sources

- See Useful Sources under Step 2.
- Regional or local government planning bodies such as metropolitan planning organizations (MPOs) will typically have current land-use information and infrastructure. For coastal areas, NOAA's Coastal Change Analysis Program (CCAP) is a good source of current land-cover information over regions (*www.csc.noaa.gov/digitalcoast/data/ccapregional*). The 2006 National Land Cover Data (NLCD) is also frequently used.
- State Departments of Transportation (DOTs) are often the best source for transportation data, a typical input included in the baseline scenario. Local units of government may also have high quality transportation data
- Utility companies are generally the best source of data on power lines and related infrastructure, although they may or may not be able to make their data available for assessment purposes
- The USGS Protected Areas Database (US-PAD) is the most comprehensive source of protected areas data (*http://gapanalysis.usgs.gov/data/padus-data*), a standard baseline scenario input. State or local governments may also have protected areas data sets. The National Conservation Easement Database (NCED) is now available (*http://nced.conservationregistry.org*).
- Local units of government are the best sources of land use plans; if these are available spatially, they may be used for characterizing future scenarios

Useful Examples

- In the western United States, the Bureau of Land Management Rapid Ecoregional Assessments are creating scenarios of existing and future (see Step 5) stressors: *www.blm.gov/wo/st/en/prog/more/climatechange/reas.html*
- British Columbia Ministry of Forests (BCMF). 2005. Baseline Datasets for Evaluating Wildlife Tree Patches. The FRPA Evaluator, Extension Note #6. *www.for.gov.bc.ca/hfp/frep/site_files/extension/FRPA_Evaluator_Extension_Note_06.pdf.*

Revisit previous steps

Step 4 activities often reveal actual data and information limitations as well as limitations in accessing available resource expertise. Additional investigation into available data for weak areas may be revisited. At this stage, priorities established in Steps 1 and 2 must often be revisited again in the light of these limitations. This may trigger the need for a general meeting if scope change is suggested by lack of information to conduct the assessments as originally planned.

Step 5: Characterize planned and forecast scenarios

This step collects and integrates information to characterize the potential *future* land use, management practices, conservation, and stressors in the supporting landscape according to scenarios established in Step 2. It supports cumulative effects assessment in Step 6 by integrating the current scenario (Step 4) *plus* anticipated/modeled future stressors.

Summary of Inputs

1. Baseline scenario from Step 4
2. Information or data layers indicating planned, proposed, forecast management, development, and infrastructure
3. Climate change model outputs
4. Forecasts of other stressor spread or introduction

Summary of Outputs

1. Alternative future scenarios integrating baseline scenario features (to be retained) and planned, proposed, forecast management, development, infrastructure, and climate change effects

Detailed Substeps

Map and characterize future cumulative scenarios

Using specifications for alternative future scenarios identified in the workshop in Step 2 follow the same processes from Step 4 substep: Characterize current conditions. Alternative future scenarios are defined as future forecasts at different time steps (e.g., 5 years, 15 years, 30 years, 100 years) with different assumptions about trends in land use, infrastructure, management, and other stressors such as invasive species and climate change (see *Figure 14* and Bedoya et al., 2008 and MIT-USGS under Useful Examples). The use of non-spatial, qualitative, story-driven scenario definition techniques (see Useful Tools) can help imagine different futures and effects while spatial methods can reveal where and in what patterns stressors may occur and quantify their effects. Some stressors, such as climate-related variables, will be non-spatial and blanket the area while other stressors are highly location-specific.

a) To build a cumulative effects scenario for alternative futures, you must still include current stressors and conservation actions that are expected to continue. Begin by copying the baseline scenario and then adding data layers of planned or forecast future features following the combine or override approaches described in Step 4 substep: Characterize current conditions. It may be useful to create duplicate future scenarios that include and exclude stressors with greater uncertainty to understand potential futures with and without them.

Figure 14. Sheldon-Hart Mountain National Wildlife Refuge Complex areas at risk from wind energy development (shown in red).

This is an example of one of the kinds of data layers that might be incorporated to build a future scenario of cumulative effects.

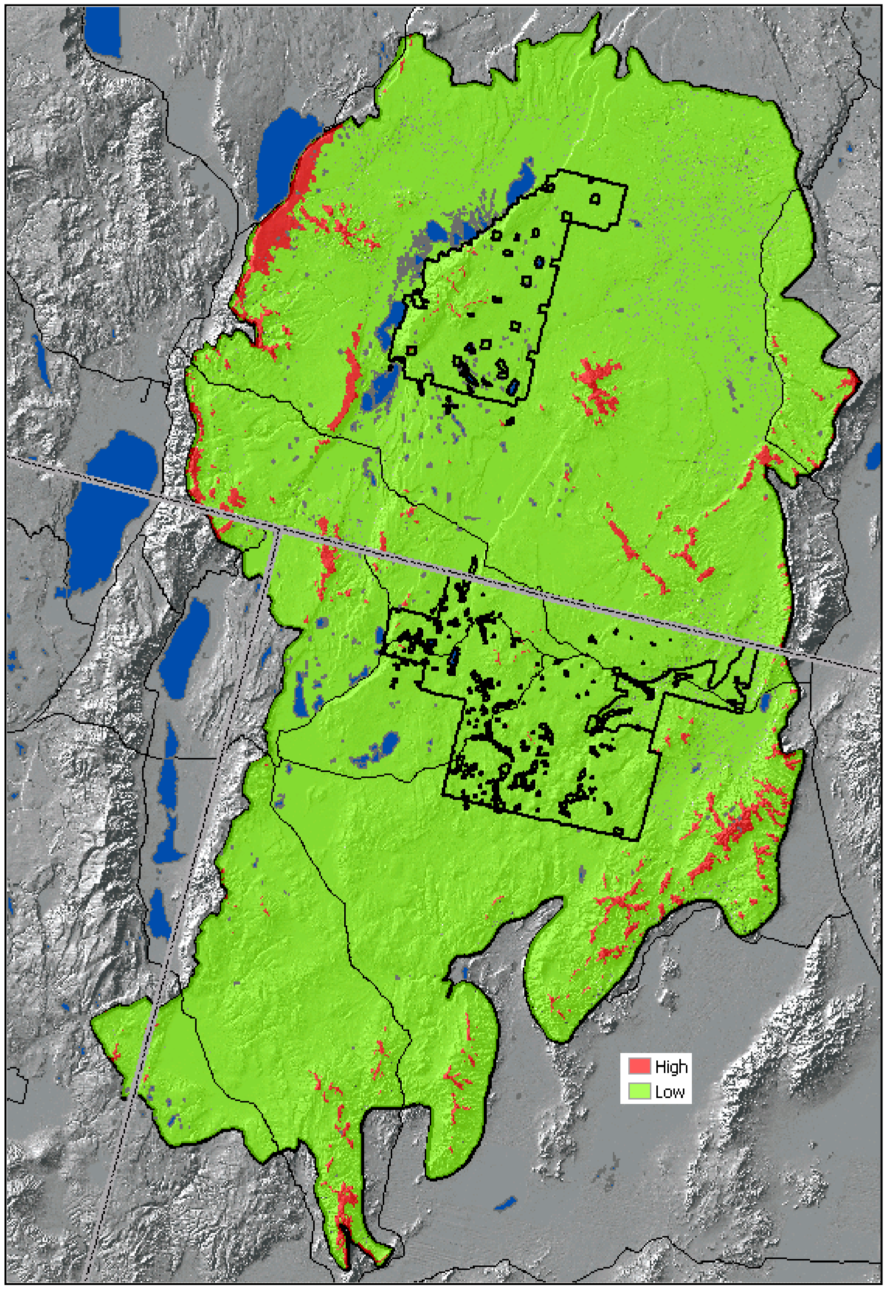
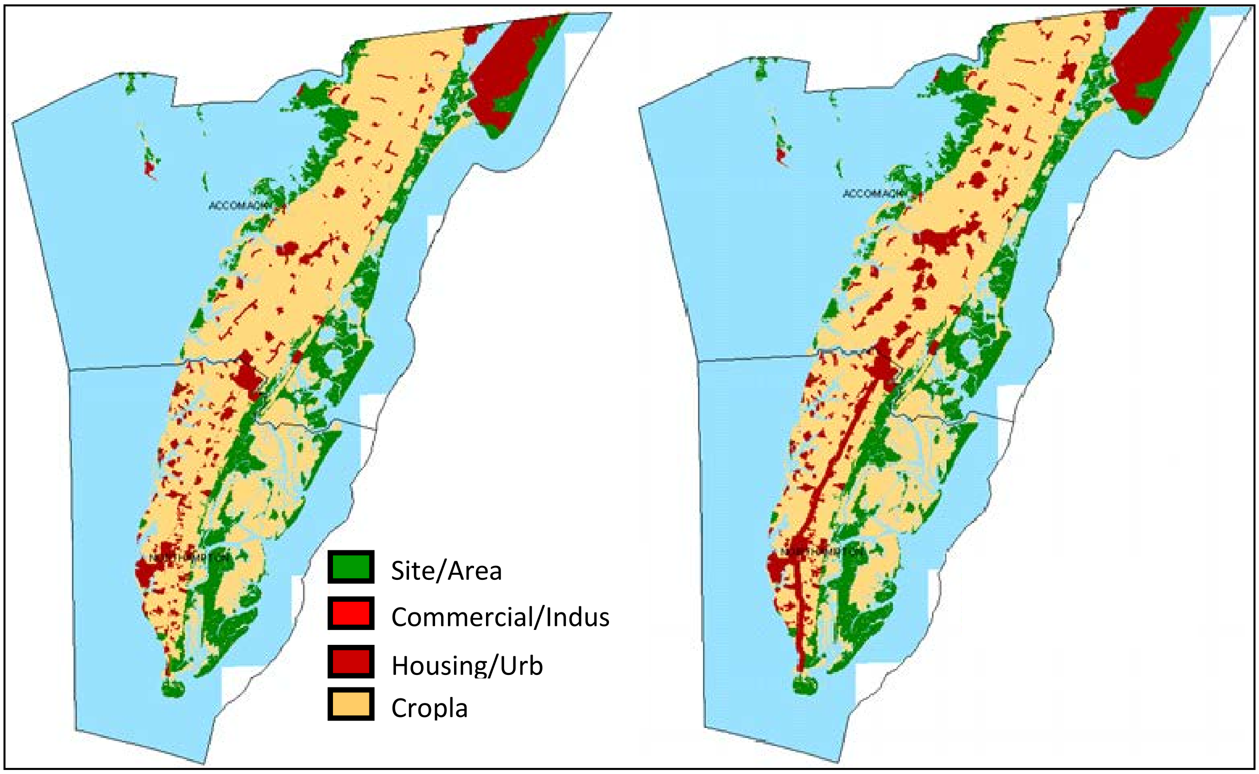


Figure 15. Comparison of baseline and future scenarios.

At left is the baseline land use scenario (from *Figure 13*). At right is a future land use scenario assuming build-out under current land-use zoning. These scenarios reflect management on managed lands, current and projected areas of urban development, and other land uses such as non-timber crops. Land use data was obtained from the county government planning departments. Accomack and Northampton counties used different classifications for land use. NatureServe Vista facilitates the "crosswalk" or reclassification of land use classes to a customized land use classification.

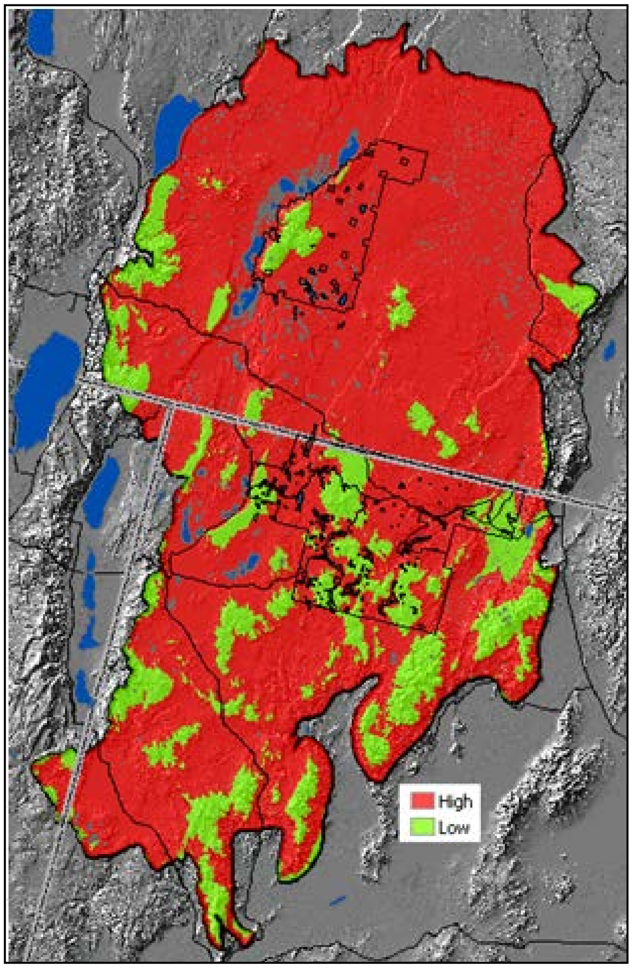


b) For scenarios that will include climate change we recommend creating different scenarios for different timeframes and different assumptions of level of climate change (see Rupp et al., 2009 under Useful Examples) (see figures this substep. Climate change data was compiled in Step 2.

   i) While Step 2 acquired basic climate data, the Step 2 process to specify scenarios to be assessed and Step 4 processes to establish resource responses may suggest additional climate change effects data. These may include secondary climate change effects model results that will be useful for selected resources such as sea level rise (*www.fws.gov/slamm*), drought risk (*http://drought.unl.edu/monitor/monitor.htm*), invasive plant risk (e.g., see *Figure 16*), changes in seasonal soil moisture (see Paul and Kimble under Useful Examples), snow cover (see NOAA under Useful Sources and Mote et al., 2005 and Nolin et al., 2006 under Useful Examples), water salinity (see Gibson et al., 2000 under Useful Examples), etc.

Figure 16. Invasive species threats in the Sheldon-Hart Mountain National Wildlife Refuge Complex.

Image shows a modeled scenario of areas at risk of invasion by cheatgrass (*Bromus tectorum*) under climate and fire change.



Useful Tools

- A variety of land use planning tools provide varying degrees of applicable functions as well as producing urban growth models that can be used directly or fed into other tools like NatureServe Vista. Some of these include:
  - CommunityViz: *www.communityviz.com*
  - What If? *www.whatifinc.biz*
  - Generally similar tools at *www.orton.org/content/tools_database*

Useful Sources

- For a variety of resources on scenario visioning approaches: *http://learningforsustainability.net/tools/scenarios.php*
- For NPS scenario approaches and case studies including climate change integration, see *www.nps.gov/climatechange/adaptationplanning.cfm*
- Downscaling Climate Data: *www.climatedecisions.org/2_Downscaling%20Climate%20Data.htm*
- NOAAs Source for Snow Information: *www.nohrsc.nws.gov*

Useful Examples

- Bedoya, M., J. Kates, E. Van Metter. 2008. A Primer on Climate Change and the National Wildlife Refuge System. Submitted to: U.S. Fish and Wildlife Service National Wildlife Refuge System.
- MIT-USGS Science Impact Collaborative Everglade Project: *www.alternativefuturestechnologies.com/everglades*
- Rupp, T.S., and A. Springsteen. 2009. Summary Report for Yukon Flats National Wildlife Refuge: Projected Vegetation and Fire Regime Response to Future Climate Change in Alaska. *www.snap.uaf.edu/downloads/reports-boreal-alfresco/FWS%Report%Yukon%Flats.pdf*.
- Paul, E.A. and J. Kimble. Global Climate Change: Interactions with Soil Properties. *www.usgcrp.gov/usgcrp/nacc/agriculture/paul.pdf*.
- Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in western North America. American Meteorological Society. Vol. 86. Pp. 39-49. doi:10. 1175/BAMS-86-1-39. *http://sciencepolicy.colorado.edu/admin/publication_files/resource-1699-2005.06.pdf*.
- Nolin, A.W., and C. Daly. 2006. Mapping "at risk" snow in the Pacific Northwest. Journal of Hydrometeorology. Vol. 7. Pp. 1164-1171. *www.prism.oregonstate.edu/pub/prism/docs/jhydromet06-snowmapping-nolindaly.pdf*.
- Gibson, J.R., and R.G. Najjar. 2000. The response of Chesapeake Bay salinity to climate-induced changes in streamflow. Limnology and Oceanography. Vol. 45(8) 1764–1772. *www.aslo.org/lo/toc/vol_45/issue_8/1764.pdf*.
- Loarie, S.R., P.B. Duffy, H. Hamilton, G.P. Asner, C.B. Field, and D.D. Ackerly. 2009. The velocity of climate change. Nature. Vol. 462, pp. 1052-1055. DOI:10. 1038/nature08649 Letter. *www.nature.com.journals.conserveonline.org:2048/nature/journal/v462/n7276/full/nature08649.html*.

- Martínez-Meyer, E. 2005. Climate change and biodiversity: Some considerations in forecasting shifts in species distributions. *Biodiversity Informatics*. Vol. 2. Pp. 42–55. *https://journals.ku.edu/index.php/jbi/article/viewFile/8/6.*

- Wiens, J.A., D. Stralberg, D. Jongsomjit, C A. Howell, and M.A. Snyder. 2009. Niches, models, and climate change: Assessing the assumptions and uncertainties. Proceedings of the National Academy of Sciences USA. Vol. 106 (2) pp. 19729–19736. *www.pnas.org/content/106/suppl.2/19729.full.pdf+html.*

- Brown, J.H., T.J. Valone, and C.G. Curtin. 1997. Reorganization of an arid ecosystem in response to recent climate change. Proceedings of the National Academy of Sciences USA. Vol. 94 (18) pp. 9729–9733. *www.pnas.org/content/94/18/9729.full.*

- Van der Putten, W.H., M. Macel, and M.E. Visser. 2010. Predicting species distribution and abundance responses to climate change: why it is essential to include biotic interactions across trophic levels. Philosophical Transactions of the Royal Society B. Vol. 365 (1549) pp. 2025-2034. doi:10. 1098/rstb. 2010. 0037

- Schreiber, E.S.G., A.R. Bearlin, S.J. Nicol, and C.R. Todd. 2004. Adaptive management: A Synthesis of Current Understanding and Effective Application. Ecological Management and Restoration. Vol. 5 (3) pp. 177–182. *www.fws.gov/bmt/documents/schreiber_et_al_2004.pdf.*

Revisit previous steps

Step 5 is fairly straightforward and revisiting previous steps would likely result from identifying the need for additional data to produce more realistic spatial scenarios or revisiting what scenarios should be characterized to express additional options for the future.

Step 6: Evaluate effects

This step maps and quantifies the cumulative effects of the current and alternative future scenarios on resources and MCI of the refuge and its supporting landscape (see Useful Sources). Generally the evaluation results communicate the degree to which the resources and MCI will achieve their retention goals under any particular scenario and correspondingly, the projected degree of loss and where the stressors are causing the loss. Uncertainty associated with the results is identified and characterized to inform Step 7. Evaluation results are then reviewed in Step 7 to identify those stressors that can be mitigated, what strategies can be employed, and whether the strategy can be expressed spatially. The following substeps cover a basic process for evaluating the current and alternative future scenarios followed by an overview of specialized assessments. In addition to specific resource evaluations, there are a growing number of landscape assessments that can inform the evaluation and subsequent strategy development; these are described under specialized assessments.

Summary of Inputs

1. Resource and MCI distribution maps from previous steps.
2. Resource and MCI retention parameters and responses from previous steps.
3. Baseline and alternative future scenarios from previous steps.

Summary of Outputs

1. Maps of each resource and MCI indicating areas retained under each scenario and areas lost (or condition values if condition modeling is used).
2. Tables of quantities of resources and MCI retained and percent of retention goal met under each scenario.

Detailed Substeps

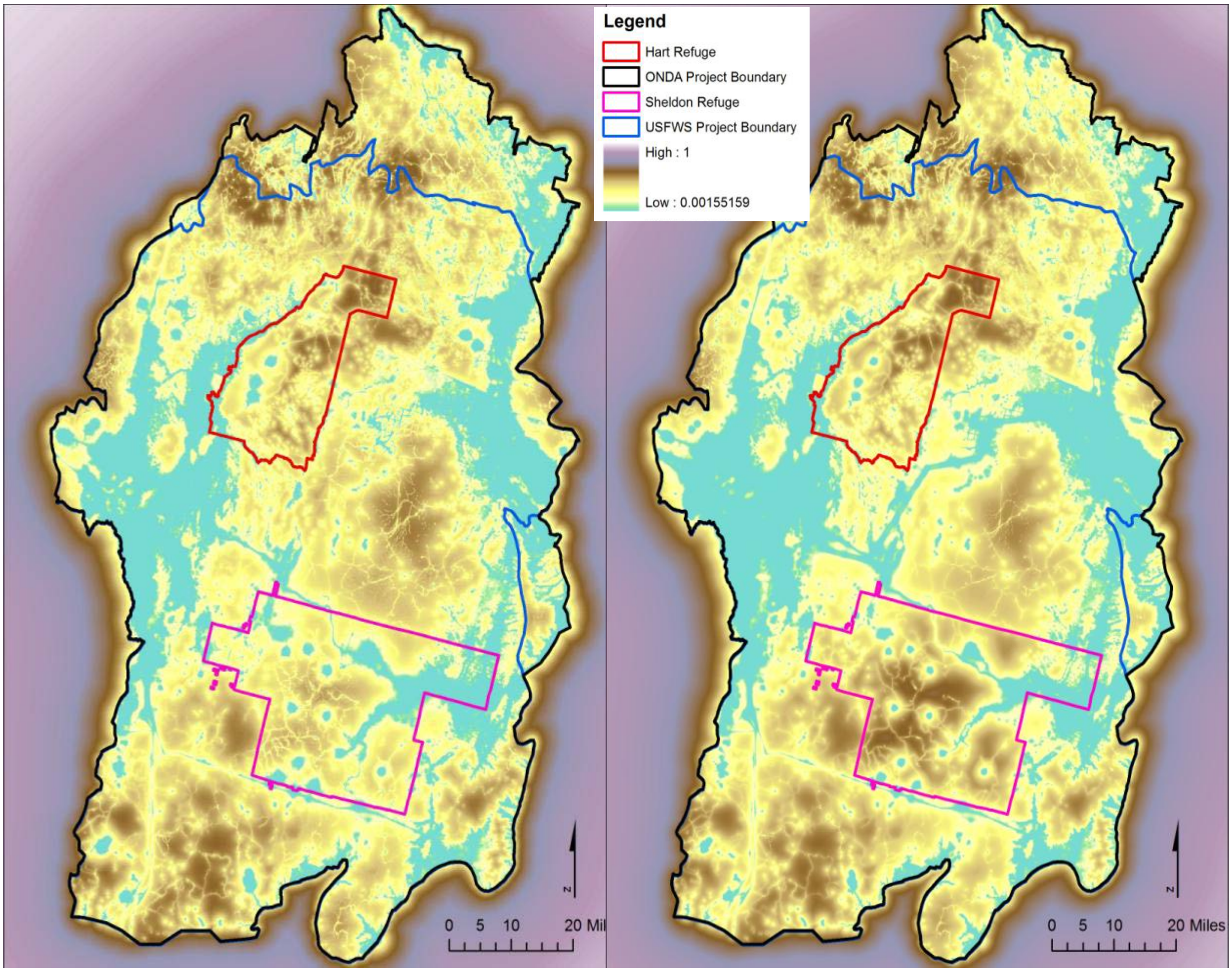
Intersect each scenario with the maps of resources and MCI

Note that infrastructure also appears in scenarios as a potential stressor, but only those infrastructure features desired for retention (e.g., "MCI") will be assessed for impacts on them. The intersection will result in GIS outputs that identify the portion of each resource and MCI type overlapped with each scenario feature.

a) Use the resource and MCI responses (developed in Step 4) to classify the portions of the resource and MCI distributions with their response to the scenario features (e.g., the portion of a habitat resource overlapped by a road in the scenario layer would be attributed with a negative response).

b) If a condition model is being used to characterize resource response in terms of impacts to its condition (versus just retention or loss), apply the condition model to the entire scenario (e.g., with the NatureServe Vista or EMDS software—see Useful Tools) to calculate the resulting condition value, including offsite stressor effects (as shown in *Figure 17*). Intersect the results with the resource/MCI distribution to quantify condition effects on the resource/MCI distribution.

Figure 17. Example landscape condition model output.



Calculate the viable proportions of the resources and MCI

The purpose of this substep is to quantify the amount of compatible area of resources and MCI to determine if retention goals are met under each scenario. Those areas of the resources and MCI that have neutral or beneficial responses (or meeting or exceeding the condition threshold value for viable condition) are considered "viable" or "retained." Next, if minimum size requirements were identified for the resources (per Step 4, substep: Characterize current conditions); evaluate the remaining viable portions against the resource/MCI minimum viable occurrence size to determine if the occurrence is still considered viable.

a) Conduct more complex assessments identified in the project scope, such as modeling loss of resources because of expected range shifts from climate change, synergistic effects of exotics and fire regimes, population viability analyses, etc. These are described further under Conduct specialized assessments below.

b) Tally viable occurrences of each resource/MCI (count of occurrences or viable area) against retention goals, for each scenario as in and create a report of resource and MCI performance against each scenario as in *Table 6*.

Table 6. Example scenario comparison of resource and MCI retention under two scenarios.

This table compares the area retained, and percent of the retention goals met, for a sample of resources and MCI under two future scenarios (2010 and 2025) for the Sheldon-Hart Mountain National Wildlife Refuge Complex. Retention goals are specified as either a percentage of the total area or as number of occurrences of the resource (in Retention goal and Goal units columns).

Type	Resource	Known area (Ha)	Known occurrences	Retention goal (%)	Goal units	% goal achieved 2010	% goal achieved 2025
Mammals	American Pika	56432	5	50	Area	55	175
	Pronghorn Winter Range	65307	6	100	Area	65	90
	Pygmy Rabbit	3255	10	50	Occ	20	20
Birds	Greater Sandhill Crane	703	1	50	Area	0	0
	Sage Grouse Breeding Habitat	648208	53	100	Area	8	25
Fish	Catlow Tui Chub	47	4	100	Area	35	37
	Catlow Valley Redband Trout	9	7	100	Occ	0	14
	Inter-Mountain Basins Juniper Savanna	37997	2538	60	Area	151	142
Communities	North American Arid West Emergent Marsh	31046	1030	60	Area	3	4
	Columbia Plateau Low Sagebrush Steppe	528016	4107	60	Area	14	47
	Rocky Mountain Aspen Forest and Woodland	14953	672	100	Area	5	7
Plants	Crosby's Buckwheat	69	13	0	Area	100	100
	Yellow Scorpionflower	36	1	50	Area	0	152
Infrastructure	Hart Boundary Fence	527	2	100	Area	100	100
	Last Chance Ranch	3	1	100	Occ	0	100
	Sheldon Headquarters	3	1	100	Occ	100	100

Generate output maps of each resource and MCI

Using results from the previous substeps, create maps that identify viable and non-viable areas of resources and MCI based on each scenario (see *Figure 18*). A summary map of areas of concentrations of conflicts (where resources that are not meeting retention goals are in conflict with the scenario) may be useful (see *Figure 19*).

Characterize uncertainty

At a minimum, qualitatively characterize the uncertainty associated with the results of the assessment and the implications for interpreting the results. If alternative future scenarios were created to determine the impact of including and excluding a future stressor with a high level of uncertainty (as mentioned in Step 5, Substep: Map and characterize future cumulative scenarios), assess the differences in results between those scenarios. Some sources of uncertainty include:

a) Quality of data on current resource distribution and/or condition: Resource distribution data may be incomplete or information on the condition of the resource in various locations may be incomplete, out of date, or otherwise of low quality. Resource maps based on predictive distribution often have commission errors which may have been quantified.

b) Quality of data / degree of certainty regarding the presence, location, extent, severity, and other factors characterizing projected stressors: all projections of future conditions have some degree of uncertainty associated with them; focus on identifying the stressor(s) having substantial degree of uncertainty.

c) Response of resources to stressors, especially novel future stressors is often based on the judgment of resource experts

Figure 18. Example resource impact map.

Below is an example output map for Sheldon-Hart Mountain National Wildlife Refuge Complex (from NatureServe Vista) indicating results of assessing current conditions of big sagebrush shrubland, montane sagebrush steppe, and pronghorn winter range. The result is a compatibility/conflict map indicating where the three resource types are responding positively or negatively to the current situation. Negative (red) areas are primarily caused by conflict with wild horse and burro grazing.

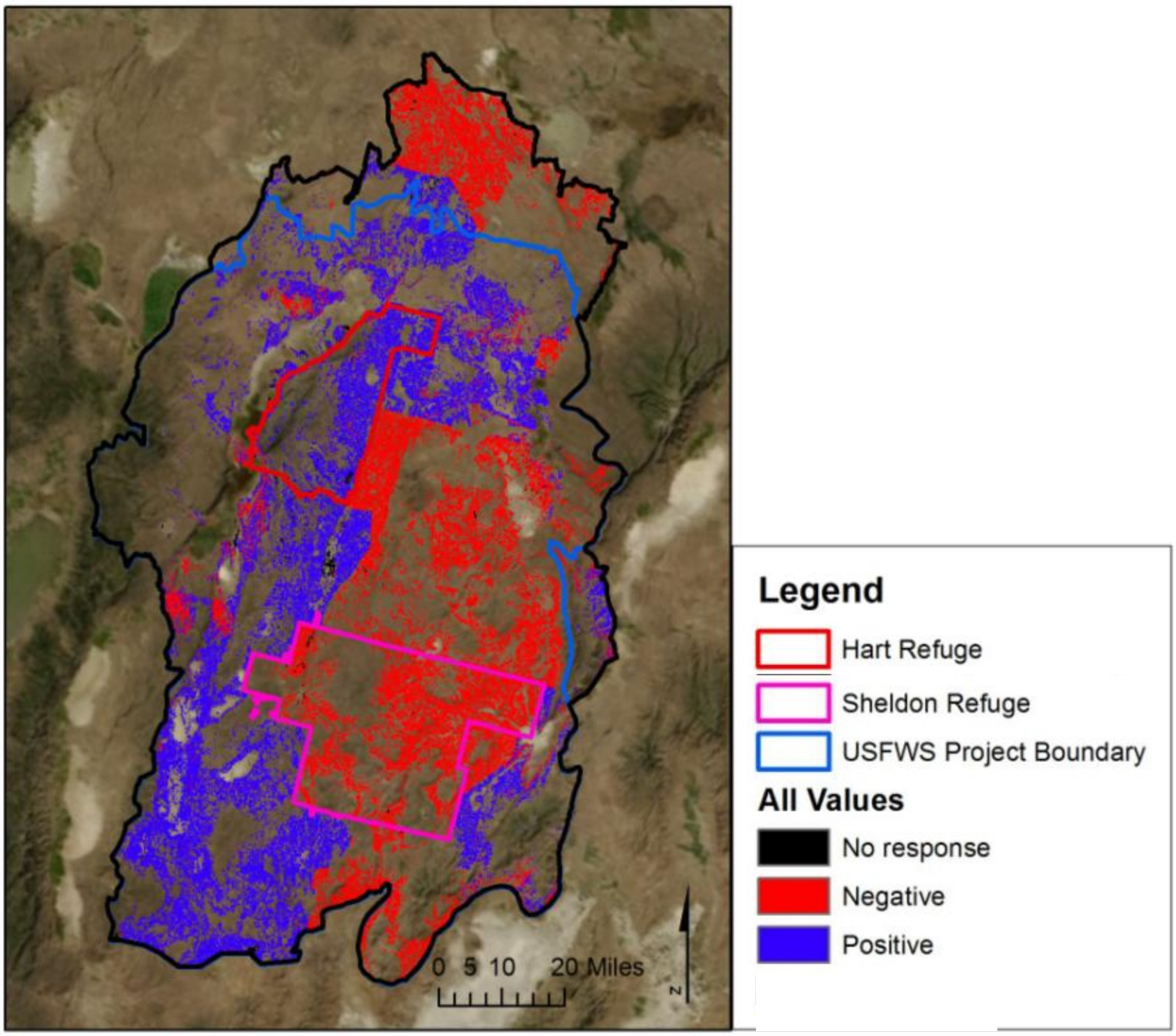
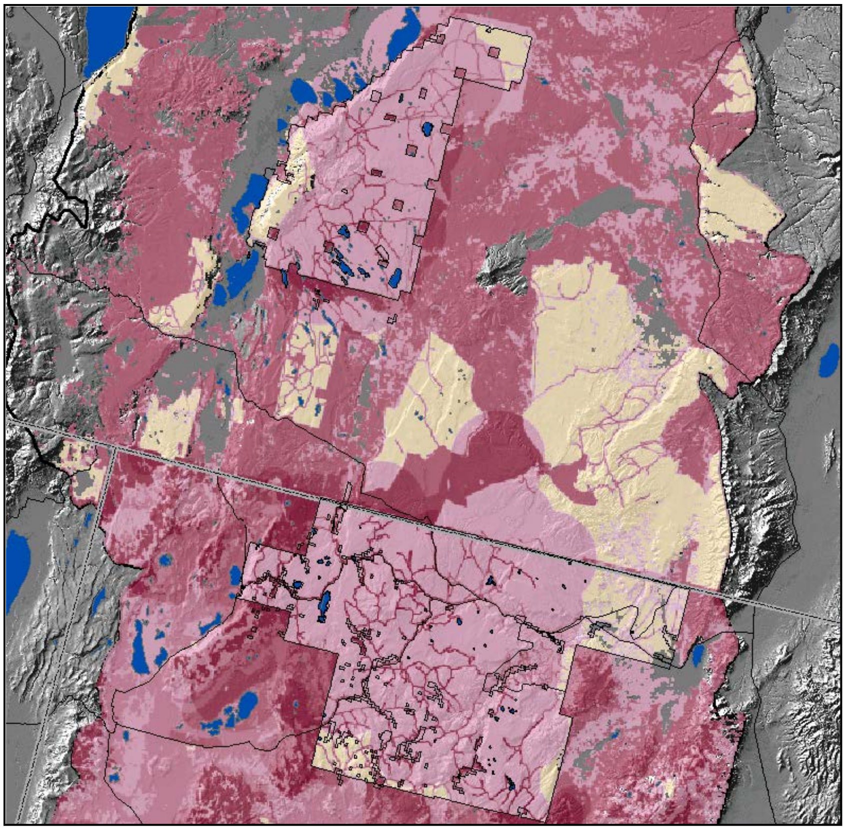


Figure 19. Example compatibility/conflict map for all resources.

Tan areas show areas where resources are compatible with land use-land cover while red areas show conflict with land use-land cover in the supporting landscape of Sheldon-Hart Mountain National Wildlife Refuge Complex. The darker red areas indicate a higher number of resources that are in conflict. Vista provides tools to select areas and see which resources and land uses are present as well as the relative contribution of a select area towards the retention goals that have been established.



Useful Tools

- The substeps described in this step are a relatively simple set of spatial analyses and calculations that can be conducted in any GIS platform. However, NatureServe Vista (*www.natureserve.org/vista*) automates evaluation of scenario impacts on resources and performs all of the substeps above. It maps and calculates area of resources impacted and compares the size (and optionally condition) of remaining, unimpacted resources to viability criteria.
- LEAM (*http://plone.rehearsal.uiuc.edu/leam*) is a tool to project land use change over time and calculate quantities of resources that might be impacted using simple assumptions about impact occurring anywhere land uses and resources intersect. It may present a simpler but not as detailed assessment as NatureServe Vista.

- EMDS (*www.institute.redlands.edu/emdsbeta/Default.aspx*) integrates the logic engine of NetWeaver to perform landscape evaluations, and the decision modeling engine of CriteriumDecisionPlus for evaluating management priorities
- N-SPECT (*www.csc.noaa.gov/digitalcoast/tools/nspect*) helps predict potential water quality impacts to rivers and streams from nonpoint source pollution and erosion. It is most accurate in medium-to-large watersheds with moderate topographic relief.
- BASINS (*www.epa.gov/waterscience/BASINS*) is a customized ArcView GIS application designed to perform watershed- and water-quality-based studies and as a system for supporting the development of total maximum daily loads (TMDLs). It supports analysis at a variety of scales and users can access national environmental information, apply assessment and planning tools, and run a variety of nonpoint loading and water quality models.

Useful Sources

- Council on Environmental Quality (CEQ) 1997. Considering Cumulative Effects Under the National Environmental Policy Act (NEPA). *http://ceq.hss.doe.gov/nepa/ccenepa/exec.pdf*.
- FWS[1] 2006. Chapter 18: Cumulative Effects. *www.fws.gov/sacramento/es/documents/PGE_O&M_draft_HCP/Ch%2018%20Cumulative%20Effects.pdf*.

Conduct specialized assessments as needed

This substep describes additional special assessments that can assess stressor effects better or more completely with an emphasis on climate effects. We begin with assessments to determine likely vulnerable resources and then provide examples of other types of assessments that may be desirable including:

- Change in resource condition from climate changes
- Integrating sea level rise and marsh migration into cumulative effects assessment
- Resource fragmentation (with or without climate changes)
- Potential resource range shifts
- Landscape refugia and resiliency assessments

Determine the resources most likely to be vulnerable to climate change effects

Vulnerability assessment typically includes resource exposure to effects, sensitivity to effects, and resiliency or adaptability to effects (see Scanning the Conservation Horizon under Useful Examples).

a) Apply a vulnerability assessment tool or method to guide the assessment and produce lists and or rankings of potential resource vulnerability (Rowland et al., 2011; see Integrating Climate Change under Useful Examples). *Table 7* shows an example of the application of NatureServe's Climate Change Vulnerability Index (CCVI); see Useful Tools.

b) Once the list of climate-vulnerable resources and MCI are identified, a number of different special analyses can be conducted.

Table 7. Example results of species climate change vulnerability assessment.

These indices were completed by the Nevada Natural Heritage Program for the state of Nevada using climate change projections for 2050 and the Climate Change Vulnerability Index tool (see Useful Tools) and used in the Sheldon-Hart Mountain National Wildlife Refuge Complex RVAA.

Resource Name	Relative Range in Nevada	Confidence	Index
American Pika	Southern edge of range	Moderate	Highly Vulnerable
American White Pelican	Southern edge of range	Very High	Moderately Vulnerable
Golden Eagle	Center of range	Very High	Presumed Stable
Greater Sage-grouse	Southern edge of range	Low	Highly Vulnerable
Greater Sandhill Crane	Southern edge of range	Very High	Presumed Stable
Lahontan Cutthroat Trout	Southern edge of range	Very High	Moderately Vulnerable
Long-eared Myotis	Center of range	Very High	Increase Likely
Preble's Shrew	Southern edge of range	Very High	Presumed Stable
Pygmy Rabbit	Southern edge of range	Moderate	Extremely Vulnerable
Snowy Egret	Northern edge of range	Very High	Presumed Stable
Spotted Bat	Center of range	Very High	Presumed Stable
Western Burrowing Owl	Northern edge of range	Very High	Presumed Stable
Western Small-footed Myotis	Entire range	Very High	Presumed Stable
Western Yellow-billed Cuckoo	Northern edge of range	Low	Moderately Vulnerable

Useful Tools

- NatureServe Climate Change Vulnerability Index (CCVI) tool (*www.natureserve.org/prodServices/climatechange/ClimateChange.jsp#v1point2*). This tool helps identify species that are particularly vulnerable to the effects of climate change. Using the Index, you apply readily available information about a species natural history, distribution and landscape circumstances to predict whether it will likely suffer a range contraction, population reductions, or both during the coming years.
- System for Assessing Vulnerability of Species (SAVS) to Climate Change (USFS): *www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability*
- Framework for categorizing the relative vulnerability of threatened and endangered species to climate change (EPA): *cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203743*

Useful Examples

- Scanning The Conservation Horizon: A Guide to Climate Change Vulnerability Assessment: *www.nwf.org/Global-Warming/Climate-Smart-*

Conservation/SafeguardingWildlife/~/media/PDFs/Global%20Warming/NWF_Scanning_the_Conservation_Horizon.ashx

- Integrating Climate Change into the Massachusetts State Wildlife Action Plan Using an Expert Panel-based Vulnerability Assessment: *www.cakex.org/case-studies/981*

Integrate sea level rise and marsh migration into cumulative effects assessment

This is a specialized case of the process of building future scenarios outlined in Step 5. The inputs for this process typically come from the Sea Level Affecting Marsh Model (SLAMM, *www.fws.gov/slamm* and *www.slammview.org*). The results from SLAMM are highly useful in their own right for understanding how different sea levels might change the distribution of marshes (salt, brackish, and fresh within the area of sea level rise). However, this model does not assess impacts to non-marsh resources, nor does it integrate other stressors. In this specialized assessment, SLAMM results are integrated into the general cumulative effects assessment to obtain a more complete picture of impacts on aquatic and upland resources and understand how retention goals for marsh resources may or may not be met in future scenarios due to migration. As carried out in the Eastern Shore of Virginia NWR RVAA, the following steps are undertaken using SLAMM results incorporated into the NatureServe Vista software:

a) Generate a time series of scenarios in Vista (e.g., current, 2025, 2050, 2075) that incorporate current and future stressors per Steps 4 and 5.

b) Augment the future scenarios with the SLAMM distributions for open water, tidal flats, and marsh types. Two of the four time scenarios for the Eastern Shore of Virginia are shown in *Figure 20* as an example of the integration of SLAMM models with other stressors. Note in this case all of these types are introduced into the scenarios as stressors; the purpose is to compare the projected distribution of these types to current distributions of other resources so we can measure the impact/loss from this conversion.

c) Incorporate into Vista the new forecast distribution of the marsh resources (as modeled in SLAMM) that correspond to the target resources for assessment (*Figure 21*). These would be labeled according to their respective scenarios (e.g., Salt Marsh 2050). The purpose is to analyze other stressor impacts upon the future distribution of these resources to determine whether their current retention goals can be met in the future. It is important to continue including protected areas in the scenario to identify whether they are able to continue their conservation mission or whether they are lost to inundation or have a potential new mission conserving different resources.

d) Evaluate the scenarios using the forecast distributions of the marsh resources that correspond with the year of the scenario (e.g., Salt Marsh 2050 assessed against the 2050 scenario) (see Step 6). This process will then inform whether current and or future distributions or resources could meet their retention goals at that timeframe. A potential limitation is that not every resource will likely have a forecast future distribution map; therefore this approach is most useful for assessing whether marsh migration is feasible and meets current retention goals and if other resources are impacted by this migration or conversion to open water or other resource types.

Note that there is now a large body of published work on applications of SLAMM to inform specific uses. Additional analyses (usually over larger extents) can help inform and refine SLAMM results such as analyzing changes of sediment inputs from upland/upstream processes and management alternatives such as dam release management (Glick et al., 2011). There are a variety of tools available for predicting hydrologic and sedimentation changes (see Useful Tools but note there are many available, most of which are oriented to hydrology experts).

Figure 20. Example sea level effects modeling of habitat change.

This pair of maps illustrates two future scenarios, 2025 (top) and 2100 (bottom), for the Eastern Shore of Virginia using SLAMM projected land cover and NOAA Coastal Change Analysis Program (C-CAP) data. Note the projected loss of land and associated habitat resources in the detail maps on the right of each figure.

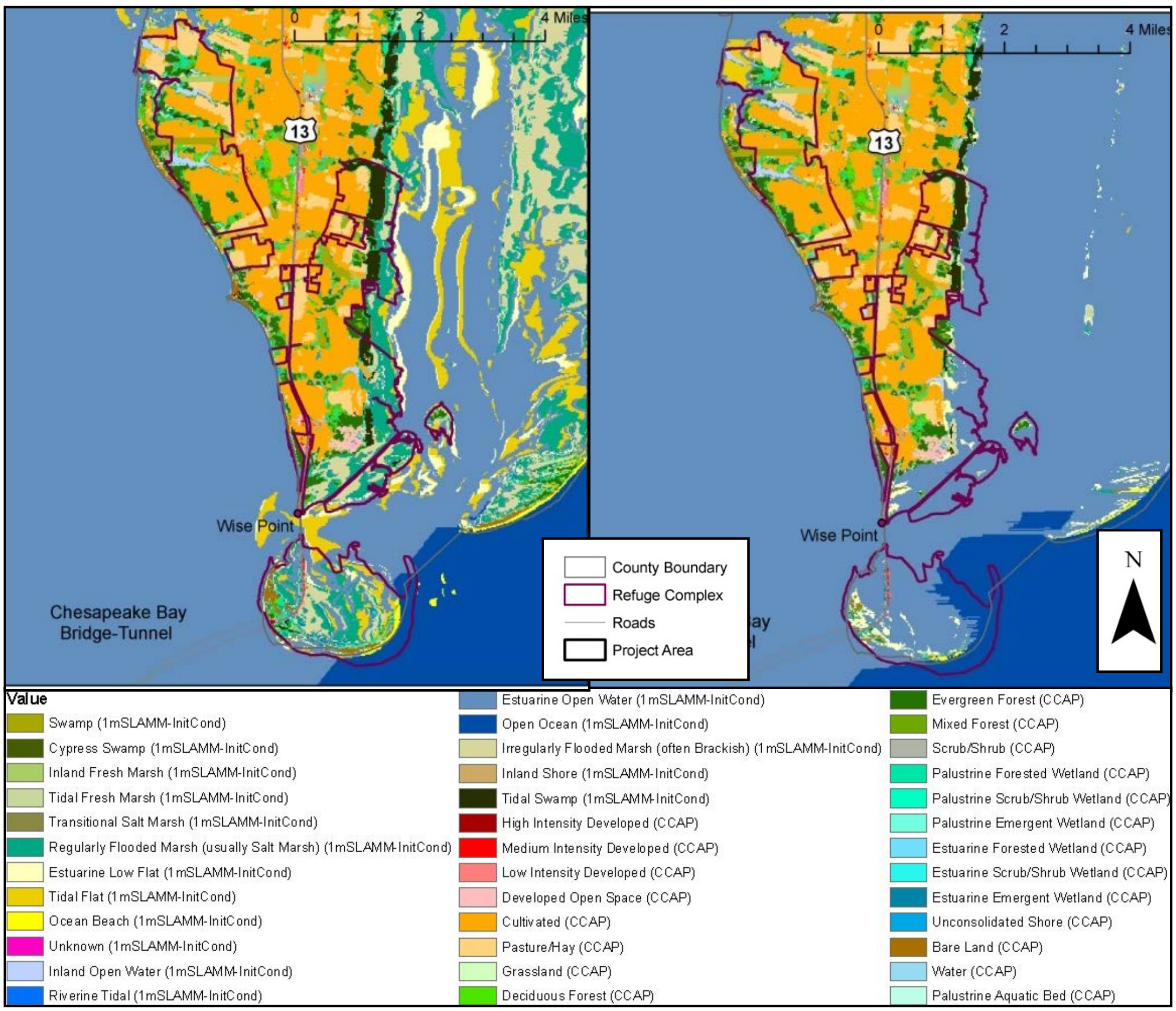
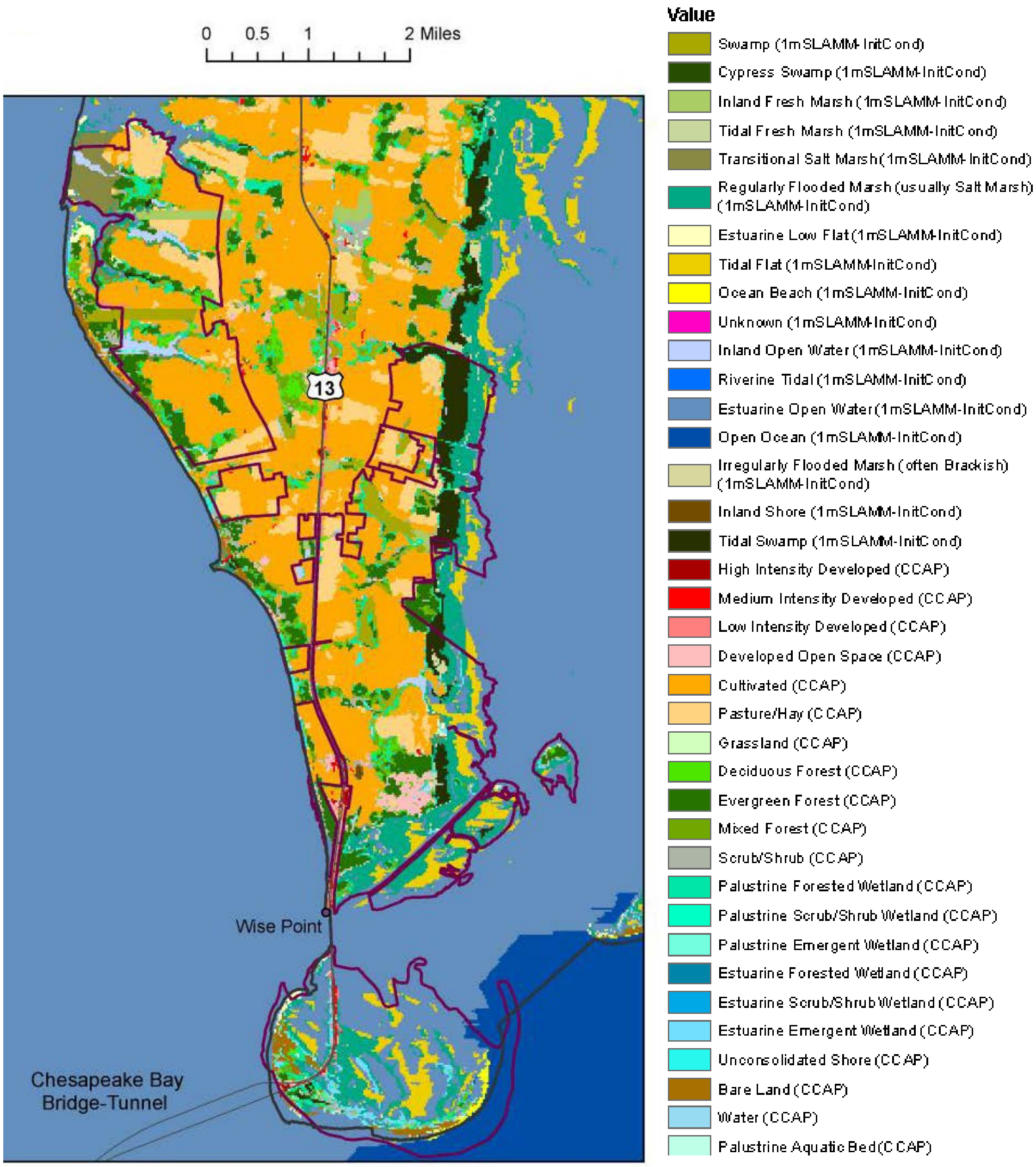


Figure 21. Example scenario with SLAMM data integrated.

2050 scenario from ESVNWR RVA pilot. Note types in legend from SLAMM used to overwrite coastal wetland types from CCAP.



Useful Examples

- Vulnerability Assessment and Strategies for Management Options for the Eastern Shore of Virginia and Fisherman Island National Wildlife Refuges (Bulluck et al., 2011)
- Scarborough, R. 2009. Application of the Sea Level Rise Affecting Marsh Model (SLAMM) Using High Resolution Data at Prime Hook National Wildlife Refuge. *www.dnrec.delaware.gov/coastal/Documents/PHNWR%20SLAMM.pdf.*

- National Wildlife Federation's Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. *www.nwf.org/~/media/PDFs/Wildlife/PacificNWSeaLevelRise.ashx*
- Gulf of Mexico Foundation's Sea Level Rise Affecting Marsh Model Runs and Conservation Planning. *www.gulfmex.org/1174/sea-level-rise-affecting-marsh-model-slamm-runs-and-conservation-planning-data-platform-development*

Analyze climate change effects on resource condition under future scenarios

This substep addresses resource condition; change in distribution is described under the next substep below. In these analyses, changes in climate variables and secondary effects such as temperature, precipitation, or soil moisture can be input to models that determine the potential future ecological condition of resources (see Post et al., 2001 under Useful Examples). Using condition thresholds, one can then assess whether climate changes might cause additional stress or even extirpation of the resource from the assessment region (see Roe and Van Eeten 2001 under Useful Examples). Some effects may require considerable additional specialized modeling such as:

- Changes to vegetation communities from changes in soil moisture, exotic species invasions, fire regime changes and resulting successional pathway changes, etc. (Crist et al., 2011)
- Changes to groundwater from precipitation and salt water intrusion
- Changes in estuary/tidal river and wetland salinity
- Changes in stream volume resulting from changes in precipitation amount, type (snow vs. rain), and timing of snow melt, etc. (see Grubin et al., 2009 under Useful Examples).

Some of these assessments can be integrated into a broad ecological response model to address ecological integrity based on changes to important ecosystem processes (Glick et al., 2011 and see Useful Tools)

Useful Tools

- NatureServe Vista (*www.natureserve/vista*). The condition modeling component of this tool allows any spatially mapped/modeled features/phenomena to be input to a condition model. The condition modeling function allows users to set and document an expected reduction in condition based on the presence of that feature (e.g., a particular range of increase in temperature).
- Complex ecological modeling can be conducted with tools like EMDS, which also assists integration and expression of uncertainty in the models: *www.spatial.redlands.edu/emds*
- Broad ecological response models include MC1 (*www.fsl.orst.edu/dgvm*) and the Regional Hydro-Ecologic Simulation System (RHESSys, *http://fiesta.bren.ucsb.edu/~rhessys*)

- SLAMM-View (*www.slammview.org*) is the FWS-supported on-line tool that allows users to compare current and future sea level conditions using SLAMM models (*www.fws.gov/slamm*) and generate summary reports summarizing changes over time for each scenario
- N-SPECT (non-point source pollution and erosion comparison tool) (*www.csc.noaa.gov/digitalcoast/tools/nspect*). This tool from NOAA CSC (*www.csc.noaa.gov*) can be used to do coarse assessment of changes in runoff volume and changes in sedimentation from expected land cover changes (e.g., from grassland to shrubland). A large number of other hydrologic modeling tools exist.
- The Vegetation Dynamics Development Tool (VDDT) and Path allow users to build state-and-transition models to simulate vegetation conditions into the future: *http://essa.com/tools*
- The Variable Infiltration Capacity (VIC) model can be used for detailed macroscale hydrologic modeling: *www.hydro.washington.edu/Lettenmaier/Models/VIC*

Useful Examples

- Post, E., M.C. Forchhammer, N.C. Stenseth, and T.V. Callaghan. 2001. The timing of life-history events in a changing climate. Proceedings of the Royal Society of London, B. Vol. 268 (1462) pp. 15-23. DOI:10. 1098/rspb. 2000. 1324. *http://rspb.royalsocietypublishing.org/content/268/1462/15.full.pdf+html?sid=1cb7801f-baca-4017-a622-4b7590d5498d.*
- Ro,e E. and M. Van Eeten. 2001. Threshold-Based Resource Management: A Framework for Comprehensive Ecosystem Management. Environmental Management Vol. 27, No. 2, pp. 195–214. DOI: 10. 1007/s002670010143.
- Grubin, E., A. Hardy, R. Lyons, A. Schmale, and T. Sugii. 2009. Conserving Freshwater and Coastal Resources in a Changing Climate. A Report Prepared for The Nature Conservancy.

Analyze potential species range shifts

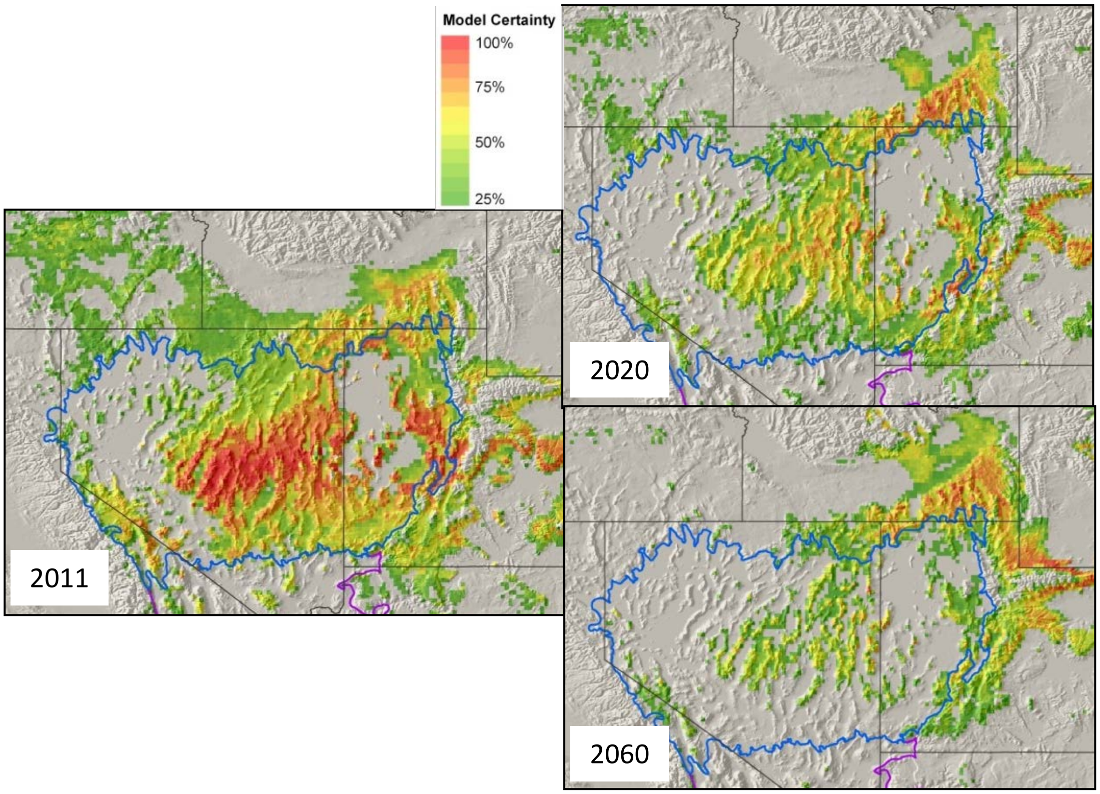
This analysis can help identify those species that may migrate in or out of the refuge due to climate change (see *Figure 22* and Hannah 2003 and Glick et al., 2008 under Useful Examples). Simple approaches can utilize existing species distribution modeling tools and methods but future ranges are not only complicated by uncertainty about future climate conditions but also how climate change would cause differential movement, reconfiguration, or extirpation of habitat components that the species depend on (see Purves and Pacala 2008 under Useful Examples and see Useful Tools). This is a newly emerging discipline best conducted over large regions using advanced methods. In some cases, however, range shifts may occur over very short distances such as marsh species moving upslope with sea level rise (see *Figure 24* and USGS 1997 under Useful Examples and Useful Tools).

i) Optionally, for longer timeframes, model potential changes in resource distribution (e.g., species range shifts) (see Loarie et al., 2009 under Useful Examples). Regional modeling of shifts in resource distribution can be useful to forecast specific resource distribution changes within the supporting landscape (see Martínez-Meyer, E. 2005 under Useful Examples). When these models are developed for multiple future time steps, they can indicate the general magnitude, direction, and rate of expected change in distribution (see Wiens et al., 2009 under Useful Examples). Depending on the strength of trends and confidence in the results, these models can be useful to 1) identify priority resources that are expected to be extirpated within the supporting landscape, 2) identify species that are expected to enter the refuge/supporting landscape that may either become a new management priority or act as an invasive stressor, and 3) inform planning for connectivity to facilitate the movement of priority species into or out of the refuge over time.

Note, however, that considerable debate exists about the ability to model accurately future distributions because ecological assemblages will, in many cases, change as their species components move independently under climate change (see Brown et al., 1997 under Useful Examples). Synergistic effects of biotic and non-biotic changes on species distribution will complicate the accurate prediction of species responses (see Van der Putten et al., 2010 under Useful Examples). For that reason, many researchers believe that such modeling should only attempt to project the future climate envelopes of resources. Climate envelopes are areas where, typically, the current range of temperature and precipitation in which the resource is found may be located at future timeframes. Climate envelopes do not utilize other habitat features and thus alone might incorporate unsuitable areas due to current land use, topography, soil, etc. Climate envelopes can be useful to understand whether current resource distributions are likely to maintain their current climates (identify where are potential climate refugia), where they may potentially expand their range, or are likely to experience significantly different climates and thus potentially be lost. Such assessments can illustrate if resources may need to migrate or otherwise be extirpated from the project area to inform adaptation planning. Climate envelope modeling is best done across an area that incorporates as much of the full expression of a resource as possible to understand its total climate niche and flexibility. If too narrow a portion of a resource's distribution is analyzed, the model results may not reflect the resource's adaptive capacity to more extreme climates in other parts of its range. *Figure 22* shows an example of climate envelope modeling used in a Rapid Ecoregional Assessment for BLM.

Figure 22. Current and projected climate envelope of a biological resource.

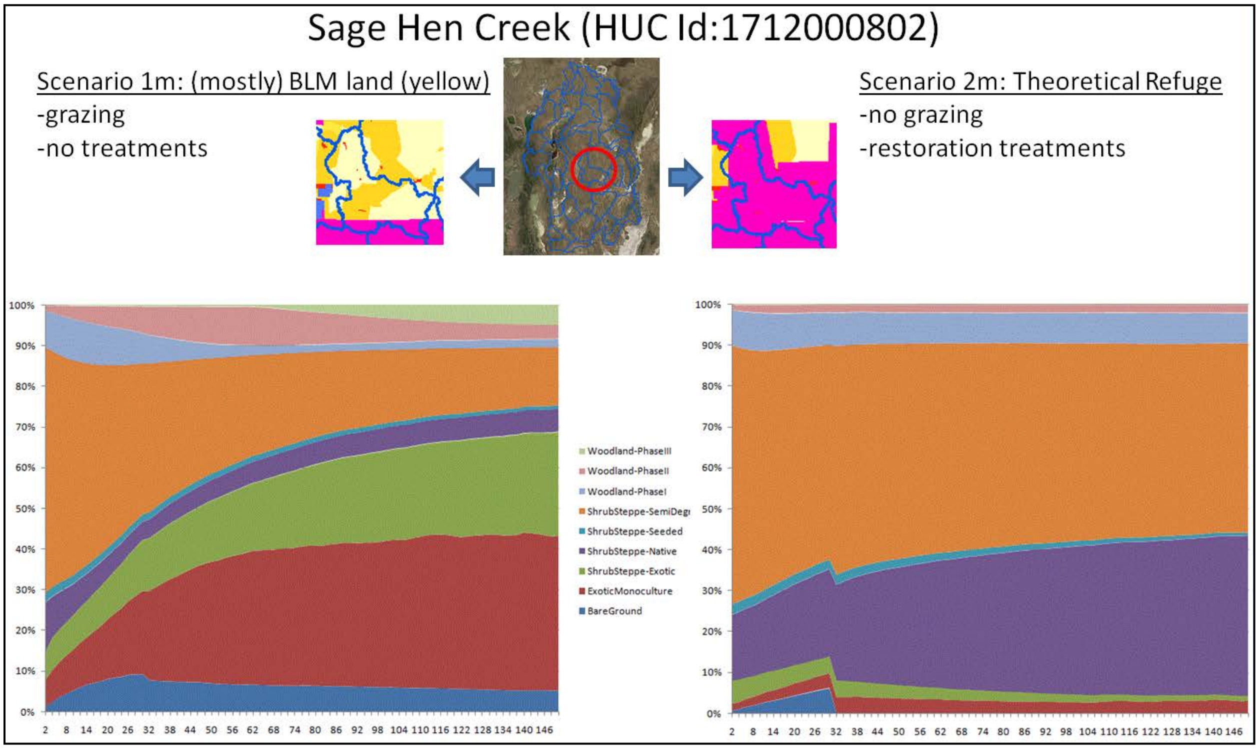
The climate envelope for Great Basin Pinyon Juniper Woodland was modeled using the variables of monthly temperature and precipitation in the Great Basin region of the U.S.



ii) Modeling the change in coastal wetlands using SLAMM software has become commonplace as illustrated in *Figure 21*. Other tools and approaches exist for quantifying the change in proportion of vegetation types within management units such as watersheds (they don't map specific distribution patterns of change); see, for example, *Figure 23*.

Figure 23. Example output of vegetation change modeling in the Sheldon-Hart Mountain RVA.

The central map indicates the watershed selected with arrows indicating areas grazed in yellow and areas of resource compatible management (removed grazing) in pink. In the graphs, the y-axis is the percent cover of the vegetation types for the example watershed and the x-axis is years from present. In this case, maintaining livestock/horse grazing is expected to result in fairly rapid dominance of invasive species whereas removal of grazing coupled with restoration management would retain current vegetation cover.



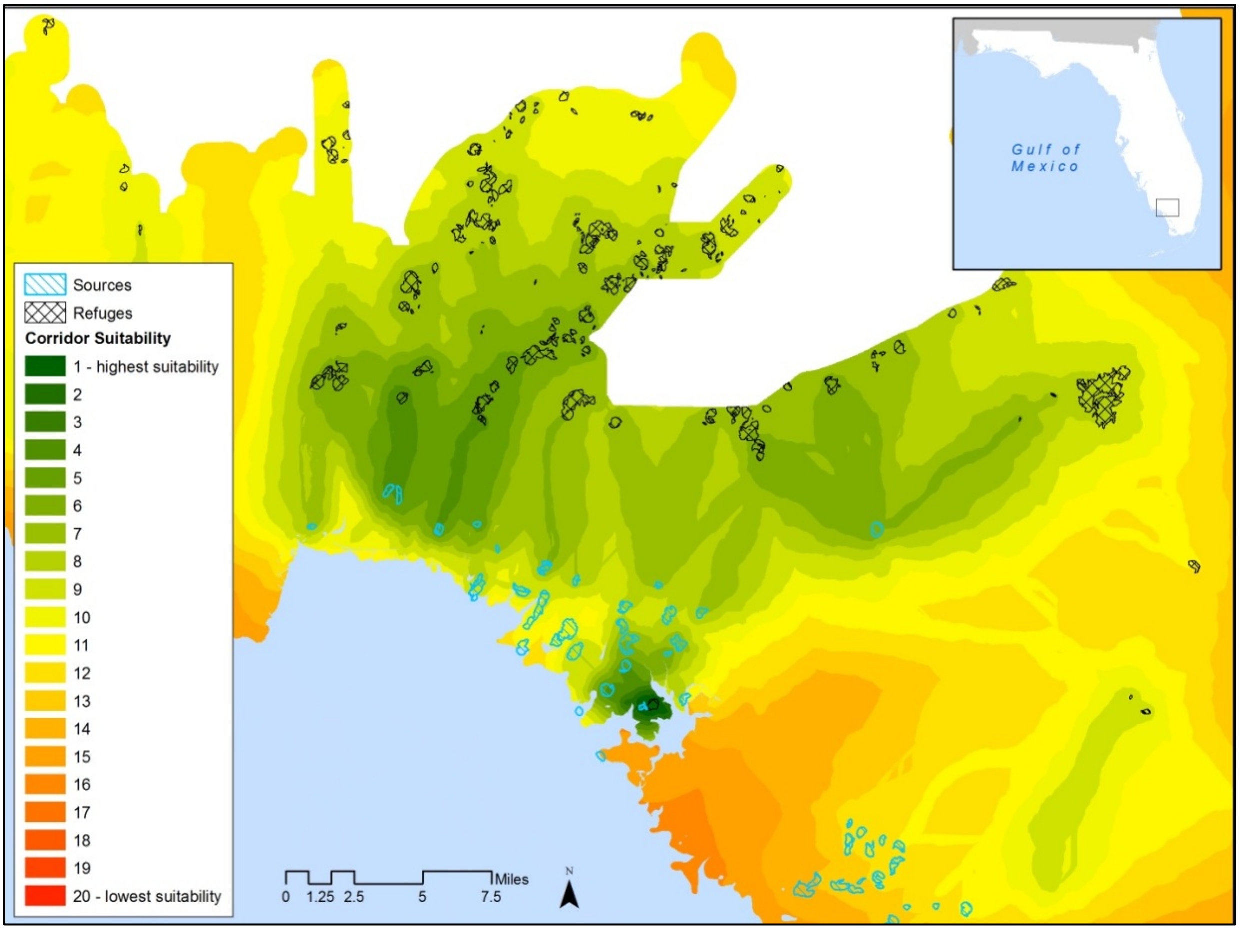
iii) Clarify focus for monitoring: Species-level modeling of distribution shifts may not be necessary to make useful management decisions for the near term, but instead can help clarify indicators for monitoring to better determine how individual resource are responding to climate change. Monitoring can inform the reliability of previous models, help improve new models, and facilitate an adaptive approach to management (see Schreiber et al., 2004 under Useful Examples).

Analyze fragmentation and connectivity for current population viability and future climate adaptation

These analyses are resource and scale-dependent. For assessment of current connectivity, some species may only require short distances to connect with necessary habitat resources or seasonal habitats while future climate adaptation may require much longer distance connectivity assessment realized over long timeframes (see Dudley and Rao 2008, Fredenberg et al., 2005 under Useful Examples). The latter may best be addressed through large regional analyses that would also consider large range shifts of species (see next item and Hannah et al., 2007 under Useful Examples). For coastal resources, often very short adaptation movements are anticipated (*Figure 24*) though topographic and built barriers may represent significant impediments. This analysis is linked to the substep below for modeling future distributions of resources and scenario evaluation (Step 6) to determine impediments to connectivity.

Figure 24. Example coastal resource movement and connectivity assessment.

Corridor suitability surface linking habitat heterogeneity hotspots in coastal Florida likely to be inundated by rising sea levels by year 2100 (sources) with hotspots expected to remain above sea level (refuges). Cost surface inputs include elevation, naturalness of land cover, and habitat heterogeneity. Florida Natural Areas Inventory 2012.



Useful Tools

- Fragmentation analyses can be conducted with a variety of tools:
  - FRAGSTATS: *www.umass.edu/landeco/research/fragstats/fragstats.html*
  - GUIDOS: *http://forest.jrc.ec.europa.eu/download/software/guidos#sec1*
  - Habitat Priority Planner: *www.csc.noaa.gov/digitalcoast/tools/hpp*
- Connectivity can also be analyzed with a variety of tools; a good summary list can be found at: *www.corridordesign.org/designing_corridors/resources/gis_tools*
- Resource distribution modeling tools:

- o Maximum Entropy (MaxEnt) (*www.cs.princeton.edu/~schapire/maxent*): This is a species distribution modeling tool that can incorporate future climate variables as well as expected future shifts in vegetation to predict possible future species distributions
- o Random Forests (*www.stat.berkeley.edu/~breiman/RandomForests*): This is another species distribution modeling tool that uses a different approach than MaxEnt
- o SLAMM (Sea Level Affecting Marsh Model) (*http://warrenpinnacle.com/prof/SLAMM*): This tool can model sea level rise and the potential shift in saltwater marsh species

Useful Examples

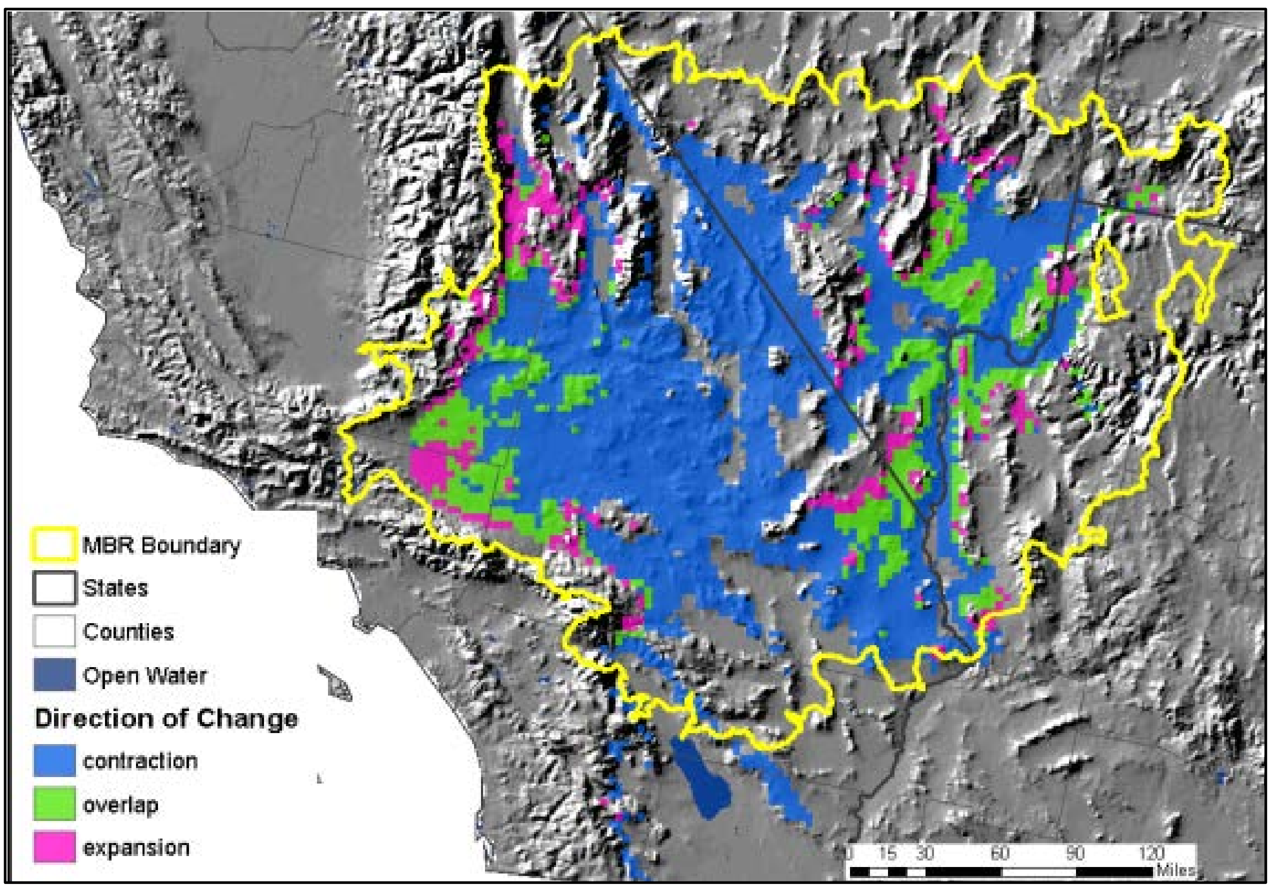
- Bureau of Land Management's Rapid Ecoregional Assessments: *www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html*
- Dudley, N. and M. Rao. 2008. Assessing and creating linkages within and beyond protected areas: A quick guide for protected area practitioners. Quick Guide Series ed. J. Ervin. Arlington VA: The Nature Conservancy. 28 pp.
- Fredenberg, W., J. Chan, J. Young, and G. Mayfield. 2005. Bull Trout Core Area Conservation Status Assessment. U.S. Fish and Wildlife Service. *www.fws.gov/pacific/bulltrout/References/BLTStatusAssessment2_22_06FINAL.pdf.*
- Hannah, L., G. Midgley, S. Andelman, M. Araújo, G. Hughes, E. Martinez-Meyer, R. Pearson, and P. Williams. 2007. Protected area needs in a changing climate. Frontiers in Ecology and the Environment. Vol. 5 (3) pp. 131–138. *www.mncn.csic.es/pdf_web/maraujo/Hannah_et_al_2007FEE.pdf.*
- Hannah L. 2003. Chapter 9 Regional Biodiversity Impact Assessments for Climate Change: A Guide for Protected Area Managers. Buying Time: A Users Manual for Building Resistance and Resilience to Climate Change in Natural Systems: 235-244.
- Glick, P., J. Clough, and B. Nunley. 2008. Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region: Technical Report. National Wildlife Federation. *www.nwf.org/GlobalWarming/Effects-on-Wildlife-and-Habitat/Estuaries-and-Coastal-Wetlands/~/media/PDFs/Global%20Warming/Reports/FullSeaLevelRiseandCoastalHabitats_ChesapeakeRegion.ashx*
- Purves, D., and S. Pacala. 2008. Predictive Models of Forest Dynamics. Science. Vol. 320 (5882) pp. 1452 – 1453. DOI: 10. 1126/science. 1155359 *www.sciencemag.org.journals.conserveonline.org:2048/cgi/content/full/sci;320/5882/1452?maxtoshow=&hits=10&RESULTFORMAT=&fulltext=Predictive+Models+of+Forest+Dynamics&searchid=1&FIRSTINDEX=0&resourcetype=HWCIT.*
- USGS. 1997. Global Warming, Sea-level Rise, and Coastal Marsh Survival. *www.nwrc.usgs.gov/climate/fs91_97.pdf.*

Conduct refugia assessment

This assessment can be relatively simple or increasingly complex. The simple approach is to analyze climate change data for a series of times and identify areas projected to experience a low degree of climate change. These areas can be expected to act as climate change refugia for the resources already occurring there as well as destinations or "stepping stones" for resources that would migrate there. The project team must determine the climate change effects variables that would be involved in assessing refugia and the thresholds or ranges that can be categorized as "low" change; those thresholds would be partly dependent on the resources being assessed. A more complex approach maps the bioclimatic envelope for a resource (*Figure 25*). In such an analysis, current climate data from the range of the resource specifies the range of climate tolerance for the resource which can then be modeled on future climate scenarios. Climate envelopes depict where climate in the future will be similar to what the climate is where the resource is currently found. It is not a future habitat map as each biotic component of habitat is expected to react individually to climate changes although additional non-biotic filters can be applied to add more precision to the climate envelope (e.g., remove incompatible soils). A refugia map can be part of the vulnerability assessment (how much of the resource distribution falls within refugia) and a layer for alternatives development to target conservation and restoration work in refugia areas and connections to them.

Figure 25. Example climate envelope analyses.

This map shows a climate envelope analyses for desert tortoise in the Mojave Desert in 2060 conducted for a Bureau of Land Management Rapid Ecoregional Assessment (by Dr. Healy Hamilton with NatureServe). Areas of contraction are expected to be incompatible with desert tortoise, green areas would retain compatible climate and act as refugia while pink areas would extend the current climate tolerances into new areas.



Conduct landscape resiliency assessment

While similar to the refugia concept above, this assessment looks at areas that are likely to be resilient to climate change rather than areas expected to experience low levels of climate change. This is a new concept and approaches are still under development, but current directions include the identification of areas with high landscape diversity measured by geophysical aspects of topographic diversity, landscape position (relative to hydrology), and elevation, although many other variables could be used (*Figure 26*). If a land facets/enduring features approach was used (*Figure 3*), such products may also support this concept. Another aspect of resiliency is landscape permeability, which measures the ability of resources to relocate to different geophysical niches as the climate changes (e.g., species requiring specific slope, aspect, and hydrologic regime can move higher in elevation as climate warms) (*Figure 27*). As with refugia assessment above, the results of this assessment can inform resource vulnerability (percent of resource distribution falling in resilient areas) as well as alternatives development to conserve and restore such locations and their connectivity/permeability.

Figure 26. Two aspects of landscape diversity used in resiliency analyses.

These examples were developed by NatureServe with Nevada State BLM under a grant from Yale University to explore factors that may make landscapes more resilient to climate change.

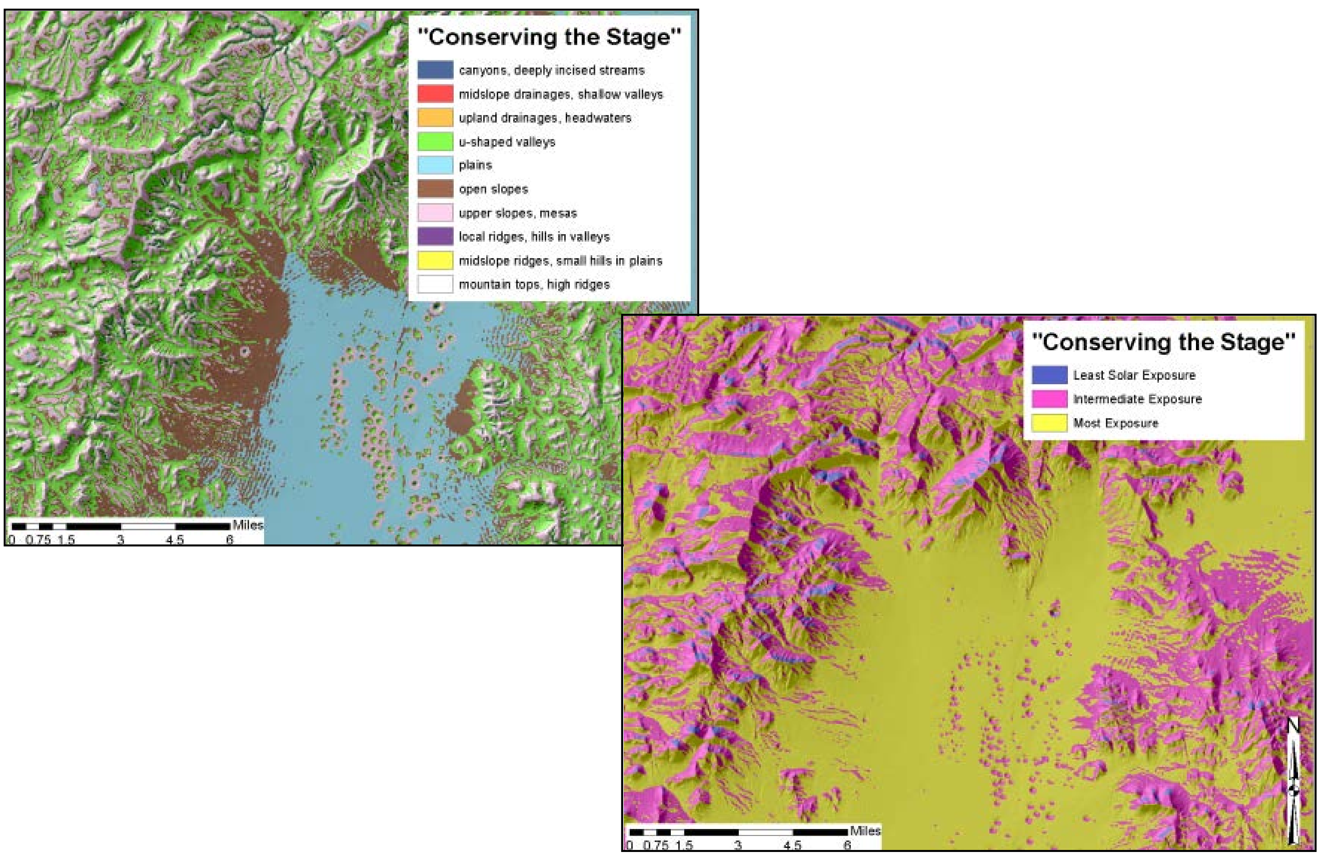
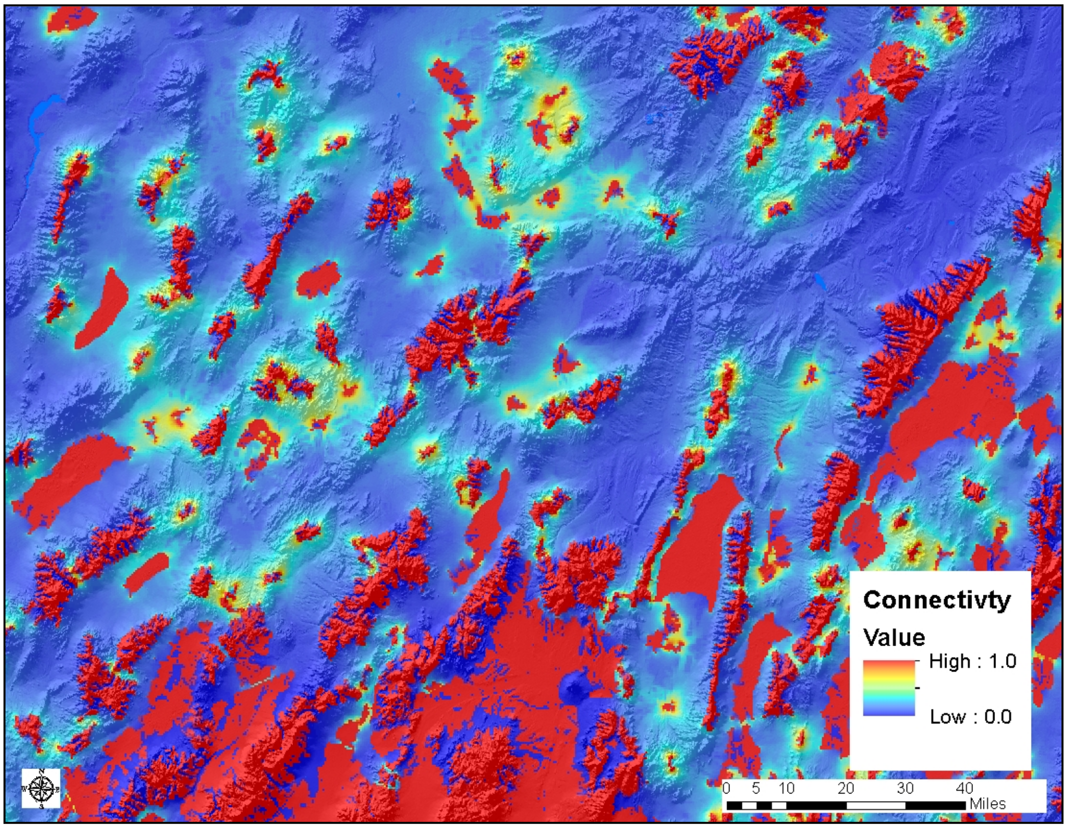


Figure 27. Landscape connectivity example.

This map depicts connectivity among intact vegetation patches (red) in the Central Basin and Range Rapid Ecoregional Assessment conducted by NatureServe for the Bureau of Land Management. Circuitscape was used to model connectivity values. Warm tones indicate higher connectivity value among patches while blue indicates low connectivity value.



Assess uncertainty

The primary limitations of the assessment process are uncertainty about climate change forecasts and lack of current knowledge about how resources will respond to climate changes (Glick 2011). Further uncertainty in adaptation action effectiveness is addressed in Step 7. As we attempt to assess scenarios further out in time, our confidence in forecasts and response models necessarily diminishes and the decision maker must decide how to react to such information. At the most fundamental level, models of resource response are simplifications of the real world and, even without considering climate change, our ability to model resource responses to stressors or management is limited. Glick et al., (2011 and embedded references such as McNulty 2002, Inouye et al*.,* 2000, and Streltzer et al*.,* 2009) note, however, that omitting climate change from cumulative effects assessments itself diminishes confidence because it is a fundamental actor of change in most landscapes so developing plans without considering climate change introduces great uncertainty as to whether the plan will, for example, preclude future options. Here we address approaches for informing managers about uncertainty in assessment results; in Step 7 we address uncertainty in developing strategies.

Providing users of assessment results with information about the confidence in the results is important. While some users may desire probability statistics and error bars, this type of uncertainty calculation is difficult to impossible and/or highly costly to produce for the large number and breadth of assessments typically conducted in an RVAA. More practical suggestions include:

- Documenting data input confidence levels (these can range from statistical accuracy assessments conducted by the data producer to qualitative statements about data confidence).
- Documenting the large amount of expert opinion in the process for source and level of confidence the experts had in their assignments.
- Documenting uncertainties about the models themselves such as limitations of excluding certain processes or information such as species population parameters.
- Conducting sensitivity analyses. This approach adds effort but tests how sensitive the model is to changes in input parameters.

Useful Examples

- NatureServe's Climate Change Vulnerability Index (CCVI; *www.natureserve.org/prodServices/climatechange/ccvi.jsp*) was applied in the state of Nevada (see case study in Glick et al., 2011). CCVI contains a Monte Carlo simulation which calculates a confidence rating of the expert-derived results.

Revisit previous steps

Reviewing the results of step 6 can generate the need to revisit most previous steps such as:

- If the climate change effects inputs are appropriate to the vulnerabilities of the resources (e.g., certain effects like changes in hydrologic regime were included)
- If the data inputs had sufficient resolution and precision for the models and purpose
- If the response models are appropriate or contain correct or appropriate parameters

In addition, resource experts will need to review outputs to determine if further model calibration is needed to get logical results.

Step 7: Identify robust strategies

In this step, strategies are proposed to adapt to or mitigate negative effects identified in the scenario evaluations. This is the single most challenging step of the RVAA as it incorporates the full set of information gathered and developed with numerous interactions, overlapping issues, and differing degrees of certainty about the results. Note that this step may be undertaken even if no spatial scenario assessments were undertaken in the previous steps. Common non-spatial scenario-based planning approaches (see forthcoming LCC guidance) also identify strategies for adaptation and mitigation and can substantially inform this step and substeps to spatially define strategies.

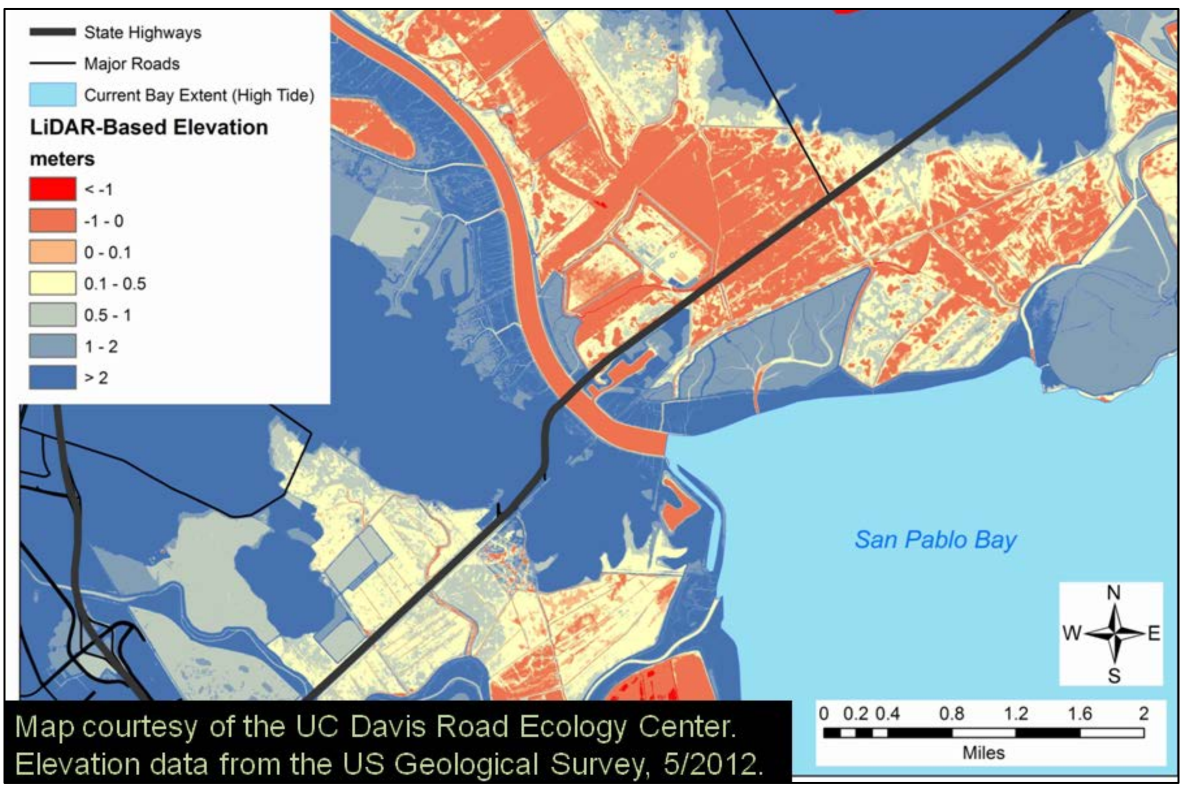
Adaptation strategies refer to actions that address current or forecast future stressors impeding key ecological processes that sustain a given resource (see Key Components and Kareiva et al., 2009 under Useful Sources) and so can include activities commonly considered "mitigation" actions. Glick et al.,

(2011) consider strategies to be robust if they result in “no regrets” outcomes even if actual climate change differs from forecast change. They note that such strategies often are designed to produce acceptable rather than optimal results as the latter may entail greater risk of getting it wrong.

Strategies can be spatial in terms of taking action to mitigate a stressor at a mapped location (e.g., conduct weed control) or non-spatial strategies that can involve activities such as coordinated planning with other stewards in the landscape or outreach activities. Non-spatial strategies may also include activities that can only be sited once a forecast stressor actually occurs (e.g., manage expected change in wildfire regime). Proposed strategies are then assessed for their potential to cause stress on non-target resources (e.g., raising a road classified as MCI to accommodate sea level rise will prevent inland migration of a marsh) also known as maladaptive responses (*Figure 28*) (Shilling et al., 2012). Such assessment can also be conducted as a non-spatial exercise or through spatial assessment.

Figure 28. Example study of mission-critical infrastructure threatened by sea level rise.

Orange areas identify segments of a critical highway that will be inundated by around 2075. Adaptation options include raising and diking which would be maladaptive to a large wetland complex.



The initial and highest confidence approach to developing strategies for climate adaptation is typically to mitigate current stressors because doing so will increase resilience to later climate stressors (Glick et al., 2011, see CASCaDE under Useful Sources). Therefore, we begin with the mitigation hierarchy (CEQ Sec 1508. 20 *http://ceq.hss.doe.gov/nepa/regs/ceq/1508.htm#1508.20*) typically employed in infrastructure project mitigation. Mitigation is typically achieved through:

1. Avoiding the stressor impacts by removing an existing stressor, preventing a future stressor, or relocating a stressor. This is the key strategy as it is typically the most effective and much easier to prevent future damage than the other approaches below. As spatial planning is primarily interested in the placement of land uses, infrastructure, and management practices in suitable locations, the planning phase is the ideal time to make these adjustments and thus avoid impacts rather than dealing with it at the project level in a piecemeal fashion. This approach may entail planning actions such as maintaining connections for species movement as they respond to climate change such as for upland areas to accommodate marsh migration from SLR.
2. Minimizing the impacts of a stressor through its design. This applies to built features and management actions that cannot be relocated through the avoidance practice above but where a variety of design and timing factors can be controlled to minimize resource impacts. For example, designing changes to MCI to maintain ecosystem processes is very important, especially in areas where water or species movement are important.
3. Restoring sites after a stressor has been removed. Refuges have long needed to conduct restoration from past activities and this strategy will remain important for restoring imperiled species populations and ecosystem processes.
4. Compensating for impacts that cannot be mitigated with any of the above approaches. In an RVAA context, compensation would meet resource retention goals in the supporting landscape through collaborative conservation. Strategies include restoring previously damaged sites or creating new conservation areas through acquisition or policy.

Climate change introduces a series of potential new stressors to ecosystems, operating directly, or interacting with other stressors to affect resource sustainability (see Obrien et al*.,* 2004 under Useful Examples). Mitigating for these climate effects (through adaptation, not climate mitigation via reduction in greenhouse gasses) may not be satisfied via the traditional mitigation hierarchy above, though those practices can be reinterpreted for climate adaptation actions.

Adaptation is addressed through three concepts: resistance, resilience, and facilitation (Heller and Zavaleta 2009, Galatowitsch et al., 2009). Resistance is the mitigation of climate change effects by, for example, reducing river water temperatures and restoring flows through increased release from dams. Resilience actions attempt to increase the ability of a resource to withstand the changes rather than mitigate the changes. Resilience actions are generally applied to an ecosystem or habitat rather than a species resource such as careful fire and weed management. Facilitation is the active assisting of species to adapt to climate change and may be a highly suitable strategy for active management such as restoring areas by planting species from, say, a warmer region that may be anticipated to migrate into the project area over time (but would currently be viable if planted).

Resilience actions are generally seen as preferred because they may be lower cost and longer lasting than the types of direct interventions needed for resistance (Heller and Zavaleta 2009) or facilitation but may necessitate acceptance of loss of particular species in exchange for a focus on ecosystem integrity.

A variety of suggestions for types of adaptation exists, though there are scant examples of their implementation in the field (and few if any for sufficient time to confirm their effectiveness, which might not be determined for decades (Heller and Zavaleta 2009)). The most common adaptation strategies include (see Useful Sources):

- Retain resource functional redundancy in ecosystems (>1 species playing same functional role such as pollination) to retain ecosystem integrity should some species be lost).
- Retain and restore resource connectivity and general landscape permeability to allow resources to migrate to areas that continue to meet their environmental requirements. This also includes retaining the areas expected to be suitable for resources in the future, e.g., upland areas for marshes to occupy under higher sea levels. Note, however, that connectivity must be examined carefully—not all resources will benefit from connectivity and some may actually experience increased stressors due to an influx of highly vagile invasive species (Game et al., 2010).
- Retain riparian corridors because these are common travel ways now and are likely to continue to be in the future. Likewise they tend to cover climate gradients within watersheds and may represent natural pathways for species to move from lower, hotter areas to higher/cooler/wetter areas (Beier and Brost 2010).
- Retain and restore riparian vegetation to promote cooler stream temperatures.
- Retain and restore climate refugia where climate changes are expected to be smallest and may retain a significant diversity of resources.
- Control the spread of exotic invasives (though examine these situations carefully to ensure that invasives native to nearby regions are not adapting by expanding into the area).
- Focus more on retention and restoration of ecosystem processes and non-biotic “niches” rather than current species composition which will change as species respond independently to climate changes. A related concept that may be especially important to species with highly limited ranges is to focus management on their current distributions with high landscape heterogeneity (e.g., a variety of topographic and hydrologic combinations) where they may persist longer by occupying niches retaining suitable microclimates.

Results from previous steps will provide the necessary information to complete this step. Note, however, that the process of examining scenario evaluation results, identifying stressors causing negative effects, and determining the best mode of mitigation can be time-consuming and complex. Whether a strategy response is expressed spatially is based on whether the evaluation results came from spatial analyses and are of sufficient certainty to propose a spatially explicit action. Depending on the location or the policy nature of the response, it will also inform whether the response is best provided by the refuge or a partner in the supporting landscape.

Summary of Inputs

1. Outputs of scenario evaluations

2. Expert interpretation and knowledge of management/adaptation options and practices
3. Partner input through a workshop
4. Optional policy and economic expertise

Summary of Outputs

1. Written description of strategies and the stressors they are intended to mitigate
2. Optional mapped locations for mitigation/adaptation actions

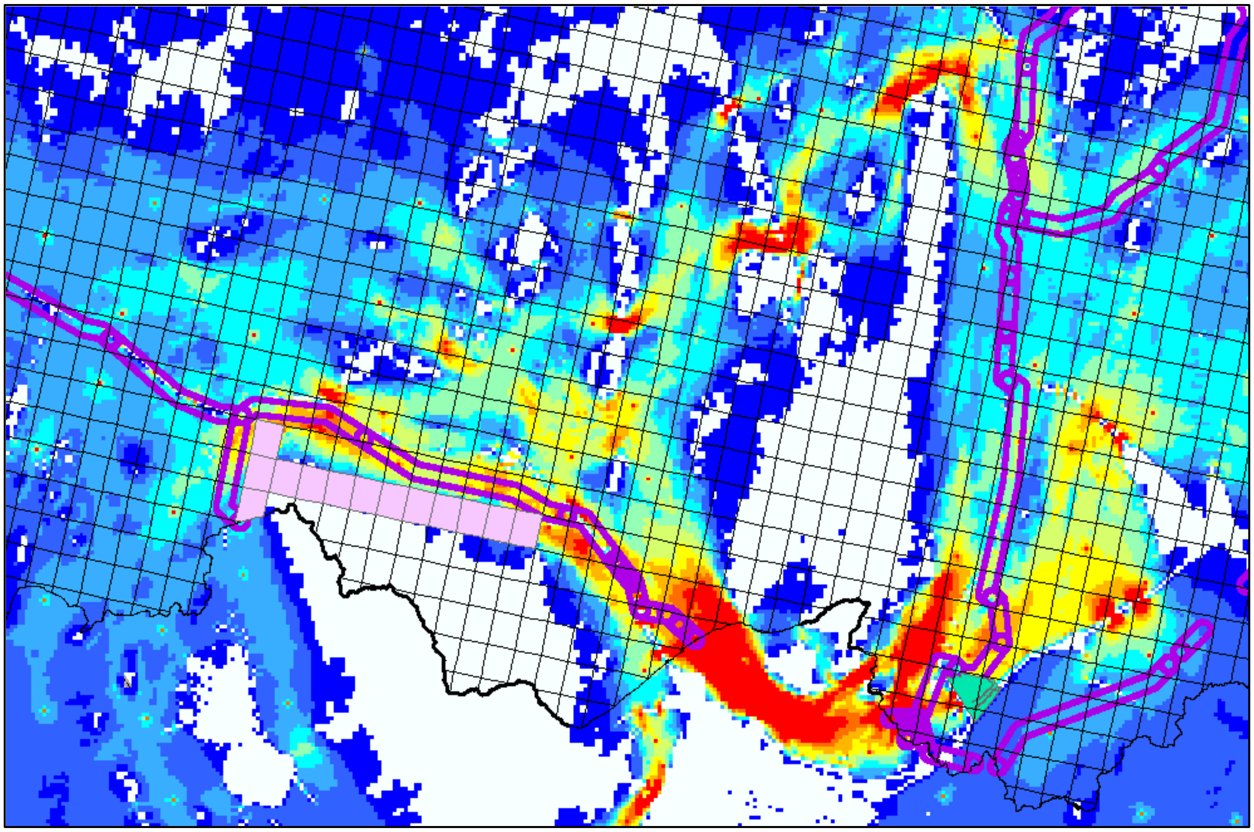
Detailed Substeps

Examine current and future near term scenarios

These scenarios, per Steps 4 and 5 represent existing and high confidence future features/actions affecting resources and thus represent the best opportunity to spatially define robust strategies that can mitigate negative effects. The first step is to determine if the stressors can be mitigated to remove/reduce the negative effects. For existing stressors their locations are known and determining feasibility of mitigation is fairly straightforward but will require coordinated efforts for stressors outside the refuge. For planned, but not yet implemented stressors such as new infrastructure, it will be easier and more effective to use avoidance (relocate the feature to a less sensitive location) to preclude future damage than to mitigate after the damage is done. It is also easier and more effective to use avoidance of future development rather than remove current stressors and conduct restoration (see Mawdsley et al., 2009 under Useful Examples). Note, however, that potential future patterns of resources should be considered in the relocation of planned development. While a current planned location may have negative outcomes, it is possible that a new location, apparently free of conflicts, may have even greater implications for future viability of resources (see, for example, *Figure 29*). This is an exploratory area because modeling future patterns of resources is an emerging field with high uncertainty and it is more important to maintain current resource viability than risk current damage for uncertain future conditions.

Figure 29. Example of avoidance mitigation for planned development.

This example (for illustration purposes only) is from a collaborative pilot project between NatureServe and Nevada BLM and funded by Yale University. It illustrates potentially relocating planned energy transmission corridors (purple lines) from areas of likely high impact to several resources including desert tortoise movement corridors (bright yellow/orange/red areas and future concentrations of climate refugia to less impactful areas. Potential relocation corridor shown in light pink squares.



Examine future longer-term scenarios

Longer term scenarios represent timeframes typically 30-100 years from present. These scenarios will contain a combination of stressors from the above scenarios, longer range forecasts of development from urban growth models for example, along with climate change effects forecasts. This combination of factors has the benefit of identifying cumulative and synergistic effects but also the range of certainty of where and whether stressors appear makes identification of appropriate strategies more complex. Following are suggestions for assessing the results and developing strategies.

a) If multiple future scenarios were assessed that represent different alternative futures for the same timeframe (e.g., based on different climate assumptions), associate strategies to each scenario so a menu of “if this happens do this” strategies is created.

b) As described for near term scenarios, strategies for mitigating longer term development plans can be readily developed but also as pointed out above need to consider potential future patterns of resources.

c) Determine if forecast climate-induced stressors can be mitigated through management (now or at such time the effects appear or trends are validated) such as managing change in weeds and fire regimes on or off the refuge and develop appropriate strategies and partnerships for such actions (see Management Methods under Useful Sources).

d) For climate change effects forecast to impact resource integrity in the medium term and distribution in the medium to long term, determine possible management adaptation strategies and timing in light of time scales and certainty. These can include regional partnerships to achieve/maintain connectivity and space for resource movement and strategies for dealing with new resource arrivals.

Identify and characterize spatial strategies

Usually spatial strategies are most appropriate for mitigating current and near term stressors due to higher confidence in stressor occurrence and effects, though considering actions that can anticipate and mitigate longer term stressor effects may be appropriate. It may be useful to assign spatial strategies by time step for when adaptation/management actions would likely be implemented and to alternative scenarios based on different assumptions about climate and or other stressor trends. It may also be useful to create multiple alternatives when and where these are available to explore what combinations may yield the best results with least maladaptive responses. Further guidance and examples of spatial strategies represented in alternative scenarios are presented in Step 8.

Useful Tools

- Miradi is useful for graphically mapping causal chains of stressors to understand the point in the chain where mitigation may be easiest and most effective (*https://miradi.org*). For example, mitigation is often focused on the end result of policies such as poorly planned urban growth whereas a focus further up the chain on the policies themselves may be much more effective in mitigating resource impacts.
- NatureServe Vista's Site Explorer function permits in-depth examination of conflicts at individual sites to understand the mix of land stewards, stressors, and resources operating there (*www.natureserve.org/vista*)

Useful Sources

- FWS. Key Components of a Fish and Wildlife Climate Adaptation Strategy: Guidance for Natural Resource Managers: *www.fws.gov/nfwcasgnrm.html*
- Kareiva, P., C. Enquist, A. Johnson, S.H. Julius, J. Lawler, B. Petersen, et al., 2009. Synthesis and Conclusions, Chapter 9. Preliminary review of adaptation options for climate-sensitive ecosystems and resources: Final Report, Synthesis and Assessment Product 4. 4. *http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-Ch9-Synthesis.pdf*.
- Heller and Zavaleta (2009) for extensive lists, examples, and critique of adaptation strategies.
- U.S. Geological Survey. CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem. *http://cascade.wr.usgs.gov.*

- FWS. Management Methods: Prescribed Burning. Online Learning Module: Managing Invasive Plants. *www.fws.gov/invasives/staffTrainingModule/pdfs/methods/burn_casestudy.pdf.*

Useful Examples

- Strategies developed for the Eastern Shore of Virginia and Sheldon-Hart Mountain NWR complex RVAA pilot projects (Bulluck et al., 2011; Crist et al., 2011)
- Climate Adaptation Knowledge Exchange (CAKE) hosts a website devoted to providing case studies profiling on-the-ground adaptation projects: *www.cakex.org*
- O'Brien, K., R. Leichenko, U. Kelkar, H. Venema,G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, and J. West. 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change. Vol. 14 (2004) pp. 303–313 doi:10. 1016/j. gloenvcha. 2004. 01. 001 *http://geography.rutgers.edu/images/stories/Leichenko_pubs/obrienetal.pdf.*
- Mawdsley, J. R., R. O'Malley, and D. S. Ojima. 2009. A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation. Conservation Biology. Vol. 23 (5) pp. 1080–1089. DOI: 10. 1111/j. 1523-1739. 2009. 01264. x

Conduct a partners workshop to review Step 6 and 7 results

The timing of this workshop is flexible; some project teams may wish to conduct this at the conclusion of Step 6 to review results of the scenario assessments, particularly if there was high uncertainty in the results of those assessments. Otherwise it is suggested that the technical and scientific team review the results and generate initial strategies and review the sum of these results with the broader team.

Address uncertainty in strategy development

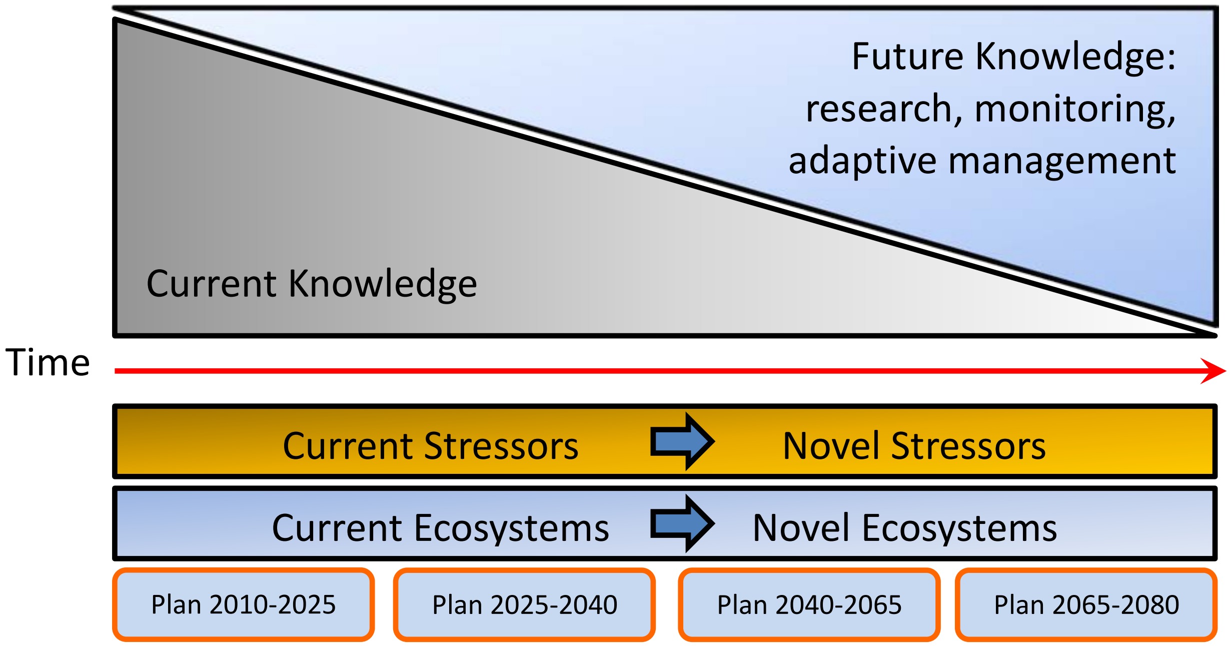
Heller and Zavaleta (2009) reviewed lengthy lists of adaptation strategies and noted that few had been implemented, let alone tested over time. As a practical matter, proactive mitigation actions to adapt to forecast climate change cannot be assessed until such climate change has come to pass. Therefore, confidence that any particular strategy will work may only be gained through field evaluation over time as the actual climate change effects it is intended to mitigate actually occur. Currently, many planners and managers are paralyzed in their decision-making due to high uncertainty about climate change and vulnerability assessment forecasts. Because changes are happening and often may occur relatively suddenly due to tipping points, exceeding thresholds, or sudden extreme events; it is important to plan adaptive actions even in the face of uncertainty. In *Figure 30*, a 15-year CCP cycle is juxtaposed with the diminishing applicability of our current knowledge as stressor impacts become dominated with novel (e.g., climate change) stressors and ecosystems transition to novel ecosystems. This lack of current knowledge must be backfilled with development of future knowledge via research, monitoring and adaptive management. A basic approach to dealing with uncertainty suggests:

- For future forecasts that are highly uncertain, utilize the forecasts to design monitoring to detect if forecast changes are happening. Use results of monitoring to calibrate and improve models to increase certainty of later forecasts. This has been likened to the cone of uncertainty common in hurricane forecasts where as time passes, more information is gathered, and the threat approaches, the cone becomes narrower and decisions (e.g., where to evacuate) can be made with higher certainty.

- For assessment of current stressors or near-term forecasts having higher confidence, develop robust strategies that result in no-regrets actions if models are incorrect (see introduction to Step 7 and Glick et al., 2011). Using the same scenario envisioning process that was used to identify scenarios in Step 5 can be useful for thinking through adaptation strategies (Glick et al., 2011).

- Consider that forecasts are typically snapshots in time and there is transition time (and often space) involved between snapshots. This means it will be important to consider, for example, how species will remain viable between now and the time they are forecast to move elsewhere. In other words, writing off a species now and deferring management action (e.g., restoration) because the species is forecast to lose viability in the study area may hasten the population's demise and its potential to adapt to changes in the future.

Figure 30. Role of research, monitoring, and adaptive management in adaptation planning.



Revisit previous steps

It is at the stage of strategy development when gaps in knowledge may become most evident and the desire to improve certainty will become pressing. These may trigger the need to revisit some aspect of most of the previous steps. If the process for previous steps has been well documented, and if automated decision support tools and models were employed, revisiting steps will be greatly simplified.

Step 8: Develop alternative scenarios and report results

This step evaluates and synthesizes strategies developed in Step 7 to develop alternative future scenarios that can then be input to the planning process. In this step the RVAA report is also compiled documenting all of the inputs, methods, and results. The following sections of this step focus on alternative scenario development; development of the report is addressed at the end of the substeps description.

In this step, mitigation/adaptation responses developed for the different scenarios (representing different time steps and assumptions) are evaluated for how they should influence alternatives development conducted in later planning phases (fundamentally CCP, SHC, and HMP, see Useful Sources). Therefore, this is a pre-planning activity that is focused on developing a variety of alternatives that feed into planning rather than creating plans or a preferred plan to be evaluated by the public and the NEPA process. Decisions about what resources and stressors ultimately are addressed by a plan and the management response also inform inventory and monitoring (*www.fws.gov/policy/701fw2.html*). For a CCP it will be important to distinguish near-term/high-confidence strategies that could be implemented over the CCP 15-year cycle from those that cannot be implemented yet due to funding constraints and those that are more speculative due to uncertainty about future stressors (development and climate change). For the latter, it is important to be cognizant of the strategies that may be necessary so that near term strategies do not aggravate potential future stressors (i.e., become maladaptive strategies) or waste funds on management/mitigations/acquisitions that do not have a reasonable chance of success in the coming decades (or serve critical shorter term needs). For example, it is important to consider whether the acquisition of salt marsh habitat (likely to be submerged within 30 years under high-confidence sea level rise scenarios) will be a wasted effort or is important for species viability in the near term to assure that species population exists in the future to have a chance at adapting to changing conditions.

Summary of Inputs

1. Strategies from Step 7
2. Scenarios from previous steps
3. Resource and MCI distribution maps and retention parameters and responses
4. Expert review of alternative scenarios
5. Optional policy and economic expert input and review
6. Documentation of all previous steps for the RVAA report

Summary of Outputs

1. Alternative management scenarios indicating changes in locations and types of management, development, infrastructure and other stressors that mitigate issues identified in the assessment
2. Evaluations of alternative scenarios quantifying expected resource and MCI retention, condition levels, and remaining areas of expected impacts
3. Alternative scenarios to forward into the planning process
4. RVAA report

Detailed Substeps

Create spatial alternatives that can mitigate stressors and meet management needs

The task in this step is to spatially represent (as feasible) strategies developed in Step 7 and integrate these into scenarios developed in Steps 4 and 5 to remove or modify targeted stressors following the process in Step 5. The result will be one or more new alternative management scenario(s) (see *Figure 31*). The methods for creating such an alternative scenario vary tremendously but choice of approach and tools (see Useful Tools) can be informed by determining if the impacts requiring mitigation are broad and systemic in the area or fairly discrete. For the latter, visual investigation and site-by-site mitigation may suffice. For the former, optimization approaches and tools such as Marxan can help develop efficient spatial solutions dealing with multiple objectives and variables (see Game et al., 2008 under Useful Examples for application of Marxan to climate change adaptation planning).

1) Evaluate proposed strategies following the process in Step 6 to determine if strategies will have the desired effects on resources/MCI and not create maladaptive stressors on other resources/MCI. If the latter occurs, iterate the process until the desired effects are achieved.

2) Create spatial management scenarios for different time steps and or assumptions of trends that include strategies that should be implemented at those times or if the trends are validated (the further out in time the more likely they need to be revisited prior to implementation).

3) Review draft scenarios in a workshop and conduct revisions as indicated by participants.

4) Forward the alternative scenarios to the planning process for further steps of assessment, stakeholder engagement, and adoption as required.

Figure 31. Example spatial opportunities for ESVNWR.

This map uses predicted 2050 land cover to identify the hatched orange areas that indicate places where future development is likely to become wetland and thus represent win-win opportunities to avoid hazards to human developments and secure locations for marsh migration.

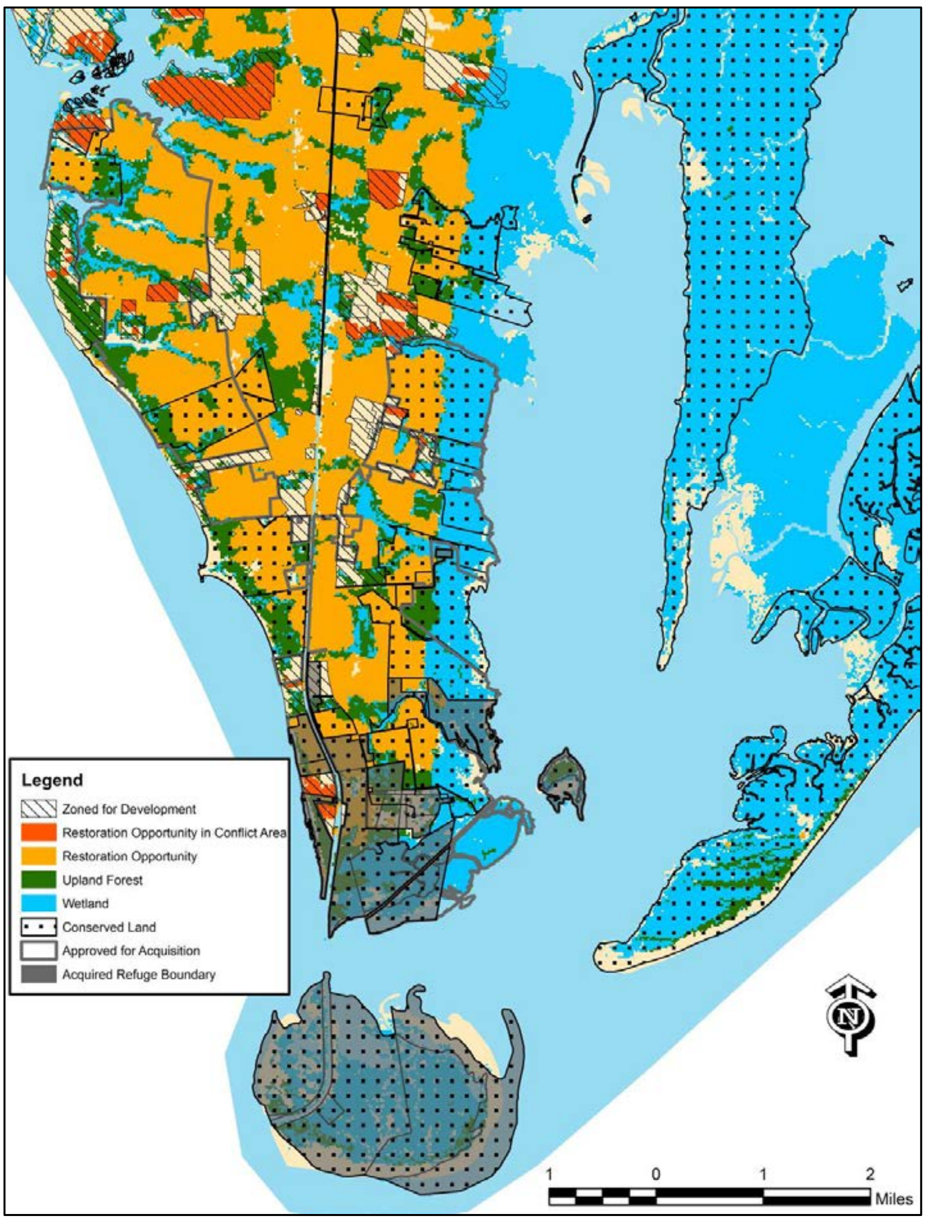
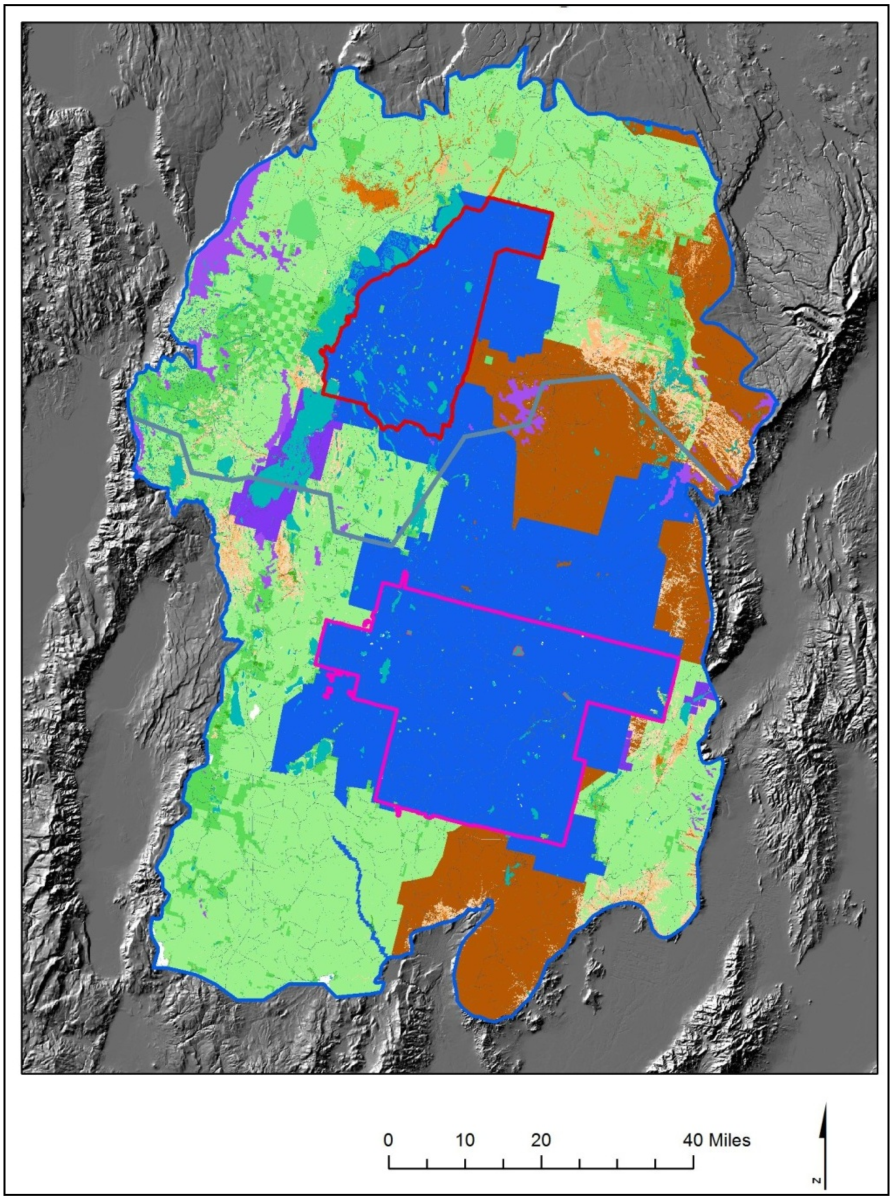


Figure 32. Example alternative management strategy for Sheldon-Hart Mountain NWRC.

This example (for illustration purposes only) explored concepts of extending conservation management around and between the refuge units (blue areas) in addition to removing horse and burro grazing from Sheldon.



Useful Tools

- NatureServe Vista's Site Explorer function facilitates proposing and analyzing the effects of changes to land use or management at sites or groups of sites and creating alternative scenarios from there: *www.natureserve.org/vista*
- Marxan can be used with Vista or independently to create near-optimal solutions to site selection problems. When used with Vista, Marxan can identify the suite of sites that can most efficiently reach resource retention goals and then Vista can be used to refine the spatial design

(e.g., properties to acquire) and the appropriate use/management and implementation mechanism for each site: *www.uq.edu.au/marxan*

- Land use planning tools (e.g., CommunityViz, *www.communityviz.com*) are important tools for proposing and examining ramifications of land use change on socioeconomic characteristics in surrounding local government jurisdictions.

Useful Sources

- CCP: *www.fws.gov/policy/602fw3.html*
- SHC: *www.fws.gov/science/StrategicHabitatConservation.html*
- HMP: *www.fws.gov/policy/620fw1.html*

Useful Examples

- Game et al., (2008) utilized Marxan (see Useful Tools above) in conjunction with climate change data to develop a reserve solution for the Great Barrier Reef. The key finding is that for only a 2% increase in the size of the reserve, areas of low to moderate forecast climate change could be prioritized for meeting resource goals.

Create the RVAA report

Creation of the report is a very similar exercise to writing assessment components of a CCP. An example outline for the report is provided in Appendix E, the pilot RVAA reports can be downloaded at *www.fws.gov/home/climatechange/climate101.html*. The report effort and product will reflect the complexity of the RVAA process conducted but experience from the pilot RVAA Projects found it challenging to convey highly complex analyses (especially unfamiliar climate change effects assessment) to refuge staff via the reports. It is suggested that conducting frequent check-ins (e.g., workshops and webinars) throughout the process will aid development and comprehension of the report. Adequate review time should be planned and producers of the report should plan for multiple revisions to address staff concerns. As is good practice with all scientific and technical reports, good documentation should be maintained throughout the process to support report development rather than trying to reconstruct methods and decisions from memory at the project conclusion.

A final workshop would be valuable to discuss needed revisions to the report as well as provide a venue for summary review of the entire project and further build partnerships for coordinated planning and management throughout the supporting landscape.

CONCLUSION

An RVAA does not end with creation of alternatives. As described in the process overview, the alternatives inform the planning phase for a CCP or other relevant planning process. After plan acceptance and implementation, the RVAA can be conducted as a continuous loop for informing adaptive management based on monitoring. Monitoring will be a critical component to validate or refute assumptions and forecasts and help calibrate models for ongoing prediction of climate change effects on resources that will then inform the next round of planning. This Technical Guide is intended to be maintained with periodic updates to capture the latest concepts and knowledge of climate change vulnerability assessment and adaptation planning and users of this guide are encouraged to check frequently for updates.

Glossary

Note that this glossary is not exhaustive. There are a large number of terms used in the RVAA Technical Guide that could not practically be defined here. It is expected that the intended technical and scientific users of the guide will be familiar with these terms or can access references to better understand terms and concepts.

Adaptive capacity: The ability of a species, ecosystem, or other feature to maintain its integrity and continue performing (or return to) its function if exposed to changes in its environment (such as climate change).

Adaptive management: A management framework founded on the concept of monitoring the outcomes or effects of management actions (and their interactions with other events) and adjusting on-going management decisions and actions based on those outcomes.

Alternatives: In RVAA use, these include spatial (mapped) and written descriptions of possible actions within the planning region to achieve resource retention goals. These are not formal alternatives for NEPA assessment but are options that can feed into formal planning processes for further assessment and consideration.

Back-casting: Using historical, empirical data to test how well a model works that is designed to make future projections.

Biological Integrity, Diversity, and Environmental Health Policy (BIDEH): This is a policy of the FWS that applies to the National Wildlife Refuge System: "The policy is an additional directive for refuge managers to follow while achieving refuge purpose(s) and System mission. It provides for the consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges and associated ecosystems. Further, it provides refuge managers with an evaluation process to analyze their refuge and recommend the best management direction to prevent further degradation of environmental conditions; and where appropriate and in concert with refuge purposes and System mission, restore lost or severely degraded components."
See *www.fws.gov/policy/601fw3.html.*

Climate envelope: The statistical and geographic area representing a set of ranges for climate variables. Typically term is used to describe the envelope of temperature and precipitation ranges of known tolerances for resources and modeling of climate envelope shift under future climates allows one to understand how climate change may affect the range of resources.

Coarse filter: A conservation planning concept that resources that occur as larger communities or ecosystems can serve as surrogates for, and provide conservation for resources that occur in smaller, discrete distributions.

Community: Interacting assemblage of organisms that co-occur in a particular environmental context with some degree of predictability and consistency.

Comprehensive Conservation Plan (CCP): The term used within FWS for conservation plans for National Wildlife Refuges. According to FWS, it describes the desired future conditions of a refuge or planning unit; provides long-range guidance and management direction to achieve the purposes of the refuge; helps fulfill the mission of the Refuge System; maintains and, where appropriate, restores the ecological integrity of each refuge and the Refuge System; helps achieve the goals of the National Wilderness Preservation System; and meets other mandates. (See more at *www.fws.gov/northeast/planning/whatareccps.html.*)

Conceptual model: A verbal or diagrammatic characterization of an object or phenomenon. Conceptual models for natural resources typically characterize resource systems in terms of their structure, function, status and change through time.

Condition model: A model representing the condition of a resource, typically in terms of the anthropogenic stressors in and around it.

Connectivity: The degree to which a landscape facilitates or impedes the movement or spatial shift of organisms between areas of suitable habitat but may also apply to general connectivity (see also *landscape permeability*).

Conservation element: A species, ecological system, plant community, habitat, or other biological or ecological feature of high conservation interest which is the focus of a conservation or resource assessment such as an RVAA.

Conservation priority areas: Areas that are of high conservation interest for one or more species or ecological systems that have been identified through some type of conservation assessment or planning process.

Conservation requirements: The quantitative and qualitative parameters of what is needed to conserve or maintain a species, ecological system or other biological resource within a geography of interest. An example of a conservation requirement is the minimum size of a resource occurrence that is needed for the occurrence to persist.

Cumulative effects assessment: An assessment of the impacts of the combined, incremental effects of the array of stressors acting on a resource. Such assessments account for past and current activities, and depending on the need, may also include planned or projected activities.

Development: A general term for anthropogenic structures and activities that includes urbanization, industrialization, transportation, mineral extraction, water development, or other human activities that occupy or fragment the landscape or that develop renewable or non-renewable resources.

Downscaling: See Scaling.

Ecological integrity: The ability of an ecological system to support and maintain a community of organisms that have the species composition, diversity, and functional organization that is expected under "natural" conditions.

Ecoregion: A geographic area with relative homogeneity in ecosystems. Ecoregions depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) differs from those of adjacent regions.

Ecosystem: A community of organisms and its abiotic or physical environment interacting as an ecological unit.

Ecosystem-based management: A holistic environmental management approach that takes into account the full array of interactions of the ecosystems and species, as well as anthropogenic activities and influences, present in the area of interest, rather than managing for resources in isolation from each other.

Element occurrence: As used by *natural heritage programs*, generally delineates the location and extent of a species population or ecological community stand, and represents the geo-referenced biological feature that is of conservation or management interest. Element occurrences are documented by voucher specimens (where appropriate) or other forms of observations. A single element occurrence may be documented by multiple specimens or observations taken from different parts of the same population, or from the same population over multiple years.

Fine filter: A focus of conservation analysis that is based upon conserving resource elements that occur at a fine (or localized) scale and that would not be adequately represented by conserving only coarse-filter elements.

Fire regime: Characterization of the pattern of fire occurrences for a given area or ecosystem in terms of frequency, size, severity, and sometimes vegetation and fire effects as well.

Fragmentation: The process of dividing habitats into smaller and smaller units through disturbance by stressors that replace the natural vegetation (e.g., road) and or introduce a persistent disturbance (e.g., electrical transmission line) causing isolation of the units of habitat from each other.

Geographic Information System (GIS): A system of computer hardware and software designed to collect, manage, manipulate, analyze, and display spatially referenced data and associated attributes.

Indicator: Components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., land health) that are too difficult, inconvenient, or expensive to measure. (USDA et al, 2005.)

Infrastructure: Buildings, roads, utilities, equipment and other structures or facilities. In an RVAA, infrastructure can be considered both as a feature to preserve as well as a stressor on resources. See also *mission-critical infrastructure*.

Landscape resiliency: The ease with which a landscape can resist or recover from the effects of stressors, particularly stressors occurring to greater extremes than "normally" experienced within the landscape.

Landscape permeability: The degree to which a landscape permits the movement of organisms through the landscape.

Marsh migration: The process of wetland communities to move in response to changes in water level and salinity; typically associated with processes of accretion and/or sea level rise.

Maintenance Management System: A system used by federal agencies to document facility and equipment deficiencies, justify requests for maintenance needs, and provide a sound basis for management decision-making. The Maintenance Management System contains four major components: property inventories, condition assessments, budget planning, and a management reporting system. (See *www.fws.gov/policy/372fw2.pdf*.)

Mission-critical infrastructure (MCI): The buildings, roads, utilities, and other infrastructure present on the refuge (or managed land) that is determined to be critical to conducting the operations and achieving the mission of the refuge. (Structures or facilities which are no longer in use or are planned for removal would not be considered mission-critical.)

Mitigation hierarchy: A framework intended to help manage risk to resources and is commonly used in assessments of environmental impacts of development projects; the four major components of the hierarchy are: 1) avoid impacts, 2) minimize impacts, 3) restore, and 4) offset when other measures are not feasible.

Model: Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models incorporate hypotheses about resource structures and functions, and they generate predictions about the effects of management actions.

Natural heritage program: An agency or organization, usually based within a state or provincial natural resource agency, whose mission is to collect, document, and analyze data on the location and condition of biological and other natural features (such as geologic or aquatic features) of the jurisdiction. These programs typically have particular responsibility for documenting at-risk species and threatened ecosystems, and they participate in the NatureServe network. (See *www.natureserve.org/visitLocal/index.jsp* for additional information.)

Occurrence: See *Element Occurrence*.

Population: Individuals of the same species that live, interact, and migrate through the same niche and habitat.

Refugia: Areas that have escaped (or are projected to escape) ecological or environmental changes occurring elsewhere and thus provide suitable habitat for species or communities that cannot tolerate those changes; often used in relation to climate change

Regulatory and Policy Framework: The content of regulations and policies under which planning and management are required to be conducted. In an RVAA it contributes to selection of resources, development of objectives and bounds available strategies and development of alternatives.

Resource: A biological, cultural, historical, or infrastructure feature that is included in an RVAA project.

Retention goal: The quantity of a resource that is desired to be retained within a specified geographic area in order to meet the conservation objective for that resource. Retention goals may be stated as the number or percent of individuals (e.g., 200 breeding pairs), occurrences or populations, or areal extent (e.g., in acres) to be maintained free of stressor conflicts or meeting a certain condition threshold or viability status.

RVAA: An assessment of the vulnerability or susceptibility of a refuge's biological and infrastructure resources (or other resources) to a range of stressors, such as development, invasive species, and climate change and the development of strategies and alternatives to mitigate stressor effects so as to meet resource retention goals.

Scaling: The process of converting information or data to different spatial scales. *Upscaling* is the process of transferring information from a finer resolution to a coarser resolution. Conversely, *downscaling* is the process of transferring information from a coarser resolution to a finer resolution (e.g., from 15 km pixels to 4 km pixels), commonly conducted when converting global climate model outputs to regional climate change data.

Scenario: In RVAA terms, a description (can be both written and mapped) of the full set of conditions affecting resources at a specified point or period in time and under a specific set of assumptions. It typically depicts the full set of stressors and conservation practices in an area and is used to determine the extent that resources can meet their retention goals at that time or under those assumptions. In an RVAA, a current scenario is compared with at least one future scenario.

Step-down management plan: A detailed management plan containing specifics on how to meet goals and objectives identified in a more general management or conservation plan, such a Habitat Management Plan step down from a Comprehensive Conservation Plan as used by FWS. (See more at *www.fws.gov/northeast/planning/stepdown.html* and *www.fws.gov/policy/602fw4.html*.)

Strategies: In RVAA use, written descriptions of actions that are proposed to mitigate the effects of stressors on resources.

Stressor: Any feature, action, or phenomena capable of negatively affecting a resource. Factors causing such impacts may or may not have anthropogenic origins. (Note that a stressor for one resource may not be a stressor on another.)

Supporting landscape: In an RVAA, describes the immediate landscape interacting with the refuge (or other area being assessed). It is the area that contributes to the viability of the refuge's biological resources or influences those resources due to the stressors present within it.

Upscaling: See Scaling.

Viability: The ability of a species or ecological system to persist

Vulnerability assessment: In this context, an assessment of whether and to what degree resources are potentially threatened by some stressor, such as climate change.

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APPENDIX A. REGULATORY AND POLICY FRAMEWORK

The primary purpose of this Appendix is to identify those regulations guiding resource management on the refuge and what specific resources can be identified or inferred from those regulations. Broader guidance for identifying refuge purpose and authority is covered in the Technical Guide on Preplanning Guidance for Comprehensive Conservation Plans (FWS[2] 2006). The following is an example from the Sheldon-Hart Mountain NWRC RCAA pilot project.

Regulation, Policy, or Plan	Policy/Plan Intent	Resource (E-explicit/I-inferred)	Management Influence
1994 Hart Mountain CCP	Establish management plan for the refuge	Refuge resources	Little for this study as it is being revised
Migratory Bird Conservation Act		Migratory birds (E)	
Charles Sheldon Wild Life Refuge, Nevada (Executive Order [EO] 5540, Jan 26, 1931)		Wild animals and birds (E)	
Enlarging Charles Sheldon Wildlife Refuge, Nevada (EO 7364, May 6, 1936)		Migratory birds (E)	
Charles Sheldon Pronghorn Range, Nevada (EO 7522, Dec 21, 1936)		Pronghorn and other "secondary" species necessary for a balanced wildlife population (E)	
National Wildlife Refuge System Administration Act		Fish, wildlife, and plant resources (E)	
Mineral Withdrawal of a Portion of the Sheldon National Wildlife Refuge; Nevada (PLO 7761, Apr 26, 2011)	Removed mining as an allowable use until April 21, 2031		This stressor no longer allowed except in the special designated mining district
Endangered Species Act	Recover endangered species populations	At-risk species (E)	Aligns with refuge management priorities for wildlife and wildlife habitats
Transfer of Certain Real Property for Wildlife Conservation Purposes Act	Conserve species habitat	Wildlife (E)	Collaboration with land trusts, neighboring agencies
Refuge Recreation Act	Allows recreational use of refuges, when such uses do not interfere with the area's primary purposes	Refuge resources (I)	

Regulation, Policy, or Plan	Policy/Plan Intent	Resource (E-explicit/I-inferred)	Management Influence
National Wildlife Refuge System Improvement Act	Ensures that the Refuge System is managed as a national system of related lands, waters, and interests for the protection and conservation of Nation's wildlife resources	Refuge resources (E)	
National Environmental Policy Act	Prevent or eliminate environmental damage	Habitats (I)	Aligns with refuge management priorities for wildlife and wildlife habitats; provides EIS framework
North American Waterfowl Management Plan 1994, Intermountain West Joint Venture		Waterfowl (E) but lacks population goals for Sheldon	
Partners in Flight (PIF), Sheldon Refuge Plan			
Pacific Flyway Plans	Protection of habitat for migratory birds	Canada Geese, Greater White-fronted Geese, Snow Geese, Ross' Geese, Swans: Pacific Trumpeter, Rocky Mountain Trumpeter, Western Tundra, Eastern Tundra; Sandhill Cranes, Mourning Dove (E)	Provides resting habitat only, little habitat so little influence on the assessment.
Intermountain West Regional Shorebird Conservation Plan	Protection of shorebird populations	long-billed curlew, mountain plover and upland sandpiper, snowy plover, black-necked stilt, American avocet, long-billed curlew, long-billed dowitcher, and Wilson's phalarope (E)	Aligns with refuge management priorities for wildlife and wildlife habitats
Draft Intermountain West Region Waterbird Conservation Plan	Protection of additional waterbirds not covered by other plans	41 species but not area-specific	Aligns with refuge management priorities for wildlife and wildlife habitats
Species Recovery Plans			Aligns with refuge management priorities for wildlife and wildlife habitats

Regulation, Policy, or Plan	Policy/Plan Intent	Resource (E-explicit/I-inferred)	Management Influence
Nevada Wildlife Action Plan		Species of Greatest Conservation Need identified in the plan	
Nevada Partners in Flight			
Nevada Management Plans for various species		Mule Deer, Big Game Status, Elk Species Management, Bat Conservation, Pronghorn Ecology, Management and Conservation, and Greater sage-grouse Conservation (E)	
National Historic Preservation Act			
Landscape Conservation Cooperative			
Important Bird Area (entire complex sagebrush obligates)			

APPENDIX B. RESOURCES CHECKLIST

This checklist identifies the candidate resources to be considered for the assessment phase of this study. Results of the assessment may suggest removal of some resources from further assessment and justification for this. If work has already been done to identify refuge resources, those results can be input to this table (also see an excellent table in the draft technical guide on Identifying Refuge Resources, FWS 2009).

Definition of fields and instructions

1. Resource Name: should appear as desired for the intended planning document. Note that the recommendation is to list the habitat types (also can be defined as ecosystems, or community types) as the primary units of assessment and the identify species (possibly through the SHC process) that a) could be presumed to be treated through these habitats or b) need to be considered separately. Appendix B2 provides for the listing of indicator species for each habitat type. Indicator species, through their presence, indicate the presumed quality of habitat.
2. Identified by: insert name from the regulatory and policy framework checklist or other process by which the resource was identified as a candidate.
3. Assess in non-spatial only or also spatial: identifies the expectation of how the resource can/should be assessed.
4. Adequate expertise: Y/N determines if adequate knowledge to conduct the assessment exists for the resource.
5. Purpose/rational for inclusion: narrative of why the resource is important to assess.
6. Assessment status is a dynamic field that will be updated throughout the course of the study. Any resource first listed is a candidate for assessment; those selected to be assessed are then identified for assessment; and finally the results of the assessment will inform those that are to be identified as a management focus resource to receive specific treatment in planning. In this way, the table maintains a record of the resources considered. The optional purpose category is for comment on the purpose the resource would serve in the refuge management, e.g., “fulfill regulation,” “provide recreation,” etc. and again, can be treated dynamically to form a record of the considerations for each resource.

Resource Name	Identified by (establishing order, regulation, non-regulatory policy/plan, group, individual)	Assess in non-spatial only or also spatial	Adequate expertise	Purpose/rationale for inclusion	Assessment status: candidate for this study, assessment, management focus
Habitat Types					
Priority Species					

Following is an example from the ESVNWRC RVAA pilot project:

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Habitat Types					
Early Successional Upland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Freshwater Emergent Marsh*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Upland Forest - Pine Dominated*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Dune Grassland	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Grassland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Dune Scrub	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Scrub*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Maritime Dune Woodland	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Woodland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Upland Forest - Deciduous Dominated*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Wet Grassland G1	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Maritime Wet Grassland G3	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Salt Flat	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Seaside High Flat^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside High Marsh^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside Lagoon^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside Low Marsh^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Tidal Mesohaline Polyhaline Marsh G4	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Tidal Mesohaline Polyhaline Marsh G5	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Tidal Polyhaline Marsh Complex*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Upper Beach Overwash Flat	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Upper Beach-Overwash Flats*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Active beach intertidal	3			Candidate	
Agricultural land	3	NRCS	Tina Jerome	Candidate	
Aquaculture sites (clams & oyster) existing vs. potential	3	DEQ	Marcia Berman- VIMS, Hank Badger- VMRC	Candidate	
Freshwater ponds	3	NWI		Candidate	
Freshwater streams	3	NHD+		Candidate	
Grasslands	3	NOAA-C-CAP		Candidate	
Hydric forest	3	NWI & NOAA-C-CAP		Candidate	
Impoundments (fresh and salt)	3	NWI		Candidate	
Interdune pond	3	NWI		Candidate	
Open water (Chesapeake Bay/ Atlantic)	3	DEQ	Bryan Watts -W&M - CCB	Candidate	
Oyster reefs	3	DEQ	Mark Luckenback - VIMS	Candidate	
Sea level fen	3	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Candidate	
Seagrass meadows	3	DEQ	Bob Orth- VIMS	Candidate	
Birds					
American black duck	3		Gary Costanzo - DGIF	Candidate	High marsh potential habitat (breeding)

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
American oystercatcher	3		Pam Denmon (FWS), Alexandra Wilke (TNC) and Ruth Boettcher (DGIF); AMOY working Group studying winter distribution via breeding season banding.	Candidate	Beach Nester requiring to have feeding and nesting adjacent. Requires marshes for foraging in winter. Sandy habitat for nesting in spring/ summer.
American woodcock	3		Pam Denmon (FWS), Barry Truit (TNC), Bryan Watts (CCB), David Krementz (U of Arkansas)	Candidate	Upland forest bird, winters on ES
Bald eagle	3		Bryan Watts (CCB), VA NHP	Candidate	
Beach nesters	3			Candidate	Species guild containing at least priority species
Beach shorebirds	3			Candidate	Species guild containing at least priority species
Black rail	3		Bryan Watts (CCB)	Candidate	High marsh nester
Clapper rail	3		Bryan Watts (CCB); Pam Denmon (FWS) may have some survey data	Candidate	Marsh nester
Eastern towhee	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate songbird
Field sparrow	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate songbird
High marsh birds	3			Candidate	Species guild containing at least priority species
Low marsh birds	3			Candidate	Species guild containing at least priority species
Mudflat shorebirds	3			Candidate	Species guild containing at least priority species
Northern bobwhite	3			Candidate	Upland species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Peregrine falcon	3		Libbey Mojica (CCB)	Candidate	Not a resident on the shore, but representative of raptor species that use the ES during fall migration.
Piping plover	3			Candidate	Beach nester
Prairie warbler	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate species
Raptors	3			Candidate	
Salt marsh sharp tail sparrow	3	Study underway during RVA. Data available from mist netting at sites on Refuge Complex and in far north of supporting landscape.	Fletcher Smith (CCB); Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Indicator of effects of SLR on preferred marsh habitat(s).
Sanderling	3		Bryan Watts (CCB)	Candidate	
Seaside sparrow	3		Fletcher Smith (CCB)	Candidate	
Waterbirds	3			Candidate	
Waterfowl	3			Candidate	
Whimbrel	3		Fletcher Smith (CCB)	Candidate	
Yellow billed cuckoo	3		Bryan Watts (CCB) via banding data from the ES	Candidate	Species breeds and migrates on the ES
Yellow-rumped warbler	3		Bryan Watts (CCB) via banding data from the ES	Candidate	Upland shrubland, maritime dune indicator. Migrant on uplands of Eastern Shore.
Insects					
Ghost tiger beetle	3		Barry Knisley	Candidate	
Monarch	1	Virginia Natural Heritage Data	Lincoln Brower and Larry Brindza (Monarch Migration Program)	Assessment	Important Migration Roosts on southern tip of Eastern Shore
Northeastern beach tiger beetle	1	Virginia Natural Heritage Data	Barry Knisley Mike Drummond -FWS	Assessment	Federally endangered
Rare bees	3		Sam Droege - USGS PWRC	Candidate	
Mammals					

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Delmarva fox squirrel	3		Karen Twilliger and Ray Dueser	Candidate	
Marine mammals (harbor seal haulout site)	3		Mark Swingle, Virginia Aquarium Stranding Center (VAQS)	Candidate	
Plants					
Sea beach amaranth	3			Candidate	Federally Threatened
Other state listed rare plants	3			Candidate	
Reptiles					
Diamondback terrapins	3			Candidate	
Loggerhead sea turtles	3		Ruth Boettcher - DGIF Mark Swingle, Virginia Aquarium Stranding Center (VAQS)	Candidate	
Cultural resources					
Chesapeake Bay Harbor Defenses	3			Candidate	Consists of public use resources
Fort John Custis remains	3			Candidate	Consists of public use resources
Historic Farm Homestead	3			Candidate	Consists of public use resources
Mission Critical Infrastructure					
Bridge -Tunnel through Fisherman Island	1	Virginia Geographic Information Network (VGIN) Road Centerline Program Data		Assessment	
Building - Maintenance	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Refuge Headquarters	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Building - Refuge Residence	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Visitor Center	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Workamper	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Canoe - Kayak Launch	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Communications Tower	1	Extracted from layer (Virginia_08_towers) provided by Les Vilchek at Blackwater NWR		Assessment	
Parking - Asphalt	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Parking - Concrete	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Parking - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Road - Asphalt	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Road - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Road - Native	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Trail - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Trail - Mowed	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Wise Point Boat Ramp and Dock	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Coastal Changes Due to Sea Level Rise					
Current Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--Initial Condition		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.
Year 2050, future Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--2050		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.
Year 2100, future Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--2100		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.

* derived habitat element at the refuge level ^ derived habitat resource at the supporting landscape level

Appendix B2: Indicator Species by Habitat Type

The suggested table format will facilitate the use of habitat types to represent species of interest (coarse filter approach). In addition to trust resources, refuges and other land management units are increasingly interested in managing for their full diversity. However, detailed information on the breadth of species occurring on any one unit is typically inadequate to treat them individually so a habitat approach is increasingly popular.

Habitat Name	Presumed Species Addressed	Key Processes	Key Indicator Species

APPENDIX C. INFRASTRUCTURE CHECKLIST

The purpose of this checklist is to identify those infrastructure features/types within the refuge acquisition boundary that should be considered in assessment as features to be retained (Mission Critical Infrastructure or MCI) and assessed for their response to stressors, and within the entire supporting landscape to be assessed as stressors on other resources. If the feature is not a retention target it will only be used to assess impacts on other resources. Generally, most features would be considered as a stressor on resources but a feature could be attributed as not a stressor if it is already planned for removal or it is confidently believed to not stress any other resources. Any refuge building that is used should be listed as MCI; those not used and are identified as an historic structure should appear on the resource list if they have no associated stresses. Following is the example from the Sheldon-Hart Mountain NWRC RVAA Pilot Project (Crist et al., 2011).

Feature Name/Type	Retention Target	Stressor on Resources	Comment or feature name(s)	Data?
Paved and improved gravel roads	Y	Y		Y
Improved road native material roads	Y	Y		Y
2-tracks	Some	Y	Some on refuge will be closed.	Y
Visitor contact station	Y	Y	(Sheldon)	Y
Visitor center	N	N	Off refuge	
Campgrounds	Y	Y	Some may be closed/relocated	Y
Communications tower	Y	Y	Small facility	Y
Fire lookout tower	Y	Y		N
Refuge headquarters	Y	Y	Hart and Sheldon headquarters included as both stressors and resources	Y
Administrative buildings	Y	Y		Y
Maintenance buildings and barns	Y	Y		Y
Refuge residences	Y	Y		Y
Surplus buildings	N	Y	Planned for removal	N
Kiosks	Y	Y		N

Feature Name/Type	Retention Target	Stressor on Resources	Comment or feature name(s)	Data?
Non-motorized travel routes (Desert Trail and currently closed 2-tracks used as trails)	N	Y	Hiking routes designated by recreation groups, not established or maintained by the refuge. Decision to move to stressors.	N
Trail (Degarmo Cyn Trail)	Y	Y	Built by volunteers	N
Overlook Trail	Y	Y		N
Water control structures	Some	Y	NWR will ID specific ones. Have data for Sheldon.	Y
Gates	N	Y		N
Interior Fences	N	Y	Currently being removed	N
Exterior Fences and cattle guards	Y	Y	Hart and Sheldon boundary fences included as both stressors and resources	Y
Signs	N	N		N
Constructed ponds/reservoirs (controlled)	Some	Y		Y - Sheldon
Constructed ponds/reservoirs (uncontrolled)	Some	Y	some data from bat foraging locations off-refuge	Y - Sheldon
Utility lines (overhead)	Y	Y	have data for major lines off-refuge	Y
Utility lines (buried)	Y	Y	Ruby Pipeline off-refuge. Hart has buried lines, but no data for these.	Y
Gravel pits	Y	Y		N
Air strips	Y	Y		N
Inholdings structures	Y	Y		N
DOT rest area	Y	Y		N
Fishing docks	Y	Y	Have spatial data for fishing areas, not docks specifically	Y

Appendix D. Stressors Checklist

This checklist identifies those stressors currently known or assumed to be occurring and those reasonably anticipated in the future. The checklist will be used to obtain maps or develop models for those stressors to include them in scenarios to be assessed for impacts on resources. The "Interactions" column can be used to identify or rank the climate interactions or other synergies among stressors. The "Future" column indicates if the stressor is expected (under current plans) to continue into the future or is not currently in the assessment region but anticipated to be in the future. Current stressors will be assumed to continue unless mitigated. Checking the "included" box indicates the stressor will be used as an input to scenarios to assess impacts and is a target for data collection. Checking the "Mitigable" box indicates that FWS and or its partners may be able to mitigate impacts from the stressor. Following is a generic listing, after which we provide the example from the Sheldon-Hart Mountain NWRC RVAA Pilot Project.

Stressor name/type	Effects	Interactions	Current	Future	Included	Mitigable by FWS/partners
Agriculture						
agriculture contaminants (incl active spraying)	Sedimentation, Toxins—kill invert and food sources, direct toxicity to resources					
Conversion of land use to agriculture	Habitat conversion, offsite impacts					
Biotic Sources						
Invasive species	Outcompete native species, prey up on native species, introduce diseases					
Elevated predation	Population impacts on imperiled wildlife					
Wildlife disease	Population impacts on imperiled wildlife					

Stressor name/type	Effects	Interactions	Current	Future	Included	Mitigable by FWS/partners
Energy						
Solar development	Habitat removal, water use					
Wind development	Habitat alteration, direct mortality--collision					
Geothermal development						
Oil/gas drilling pads	Habitat removal, surface and water pollution, hydrologic changes					
Open pit mines	Habitat removal, surface and water pollution, hydrologic changes					
Shaft mines	Surface and groundwater pollution, hydrologic changes					
Mining spoils	Habitat removal, surface and water pollution, hydrologic changes					
Infrastructure						
Communications tower	Bird impact					
Water diversion and alteration	Stream flow regime, habitat alteration					

Stressor name/type	Effects	Interactions	Current	Future	Included	Mitigable by FWS/partners
Auto traffic	Wildlife fatalities, air pollution, noise pollution, increased wildlife avoidance/fragmentation					
Oil/chemical spills along roadways	Toxic runoff into water bodies					
Above ground cable transmission						
Below ground transmission						
Management/Recreation						
Conflicting habitat management (on refuge and by state agencies—parks, natural heritage programs, DGIF, TNC (owned and easements)	Promotion of some habitats/species over others					
hunting/trapping/fishing	Overuse, Baiting, Human conflicts					
Human pedestrian and dogs activity (trespass and permitted)	Chasing wildlife, disturbing the wildlife behavior, displacing wildlife					
Urbanization/Industry						

Stressor name/type	Effects	Interactions	Current	Future	Included	Mitigable by FWS/partners
Suburban growth	Loss of refuge expansion opportunity, encroachment, introduction of invasive plants and free ranging introduced mesopredators (e.g., house cats)					
Non-point source water pollution	Nitrification and toxins in water bodies					
Former toxics sites	Toxins in soil and toxic runoff into water bodies					
Air pollution deposition e.g., mercury	Inhibition of breeding success					
Climate Change Stressors						
Extreme weather events (frequency/intensity)						
Change in Net Evapotranspiration (precip and temp interaction) (spring, summer, fall, winter)						
Increased air temperature (spring, summer, fall, winter)	Heat stress on vegetation and wildlife, decreased soil moisture, drought intensity					
Decreased air temperature (spring, summer, fall, winter)	Drought frequency/intensity					
Increased precipitation (spring, summer, fall, winter)	Raised groundwater levels, alteration of soil moisture, nest flooding					

Stressor name/type	Effects	Interactions	Current	Future	Included	Mitigable by FWS/partners
Decreased precipitation (spring, summer, fall, winter)	Drought frequency/intensity, fire frequency					
Changed phenology	Uncoupling of wildlife-vegetation-prey relationships, impacts on feeding and reproduction					
Key interacting Stressor names/types						

Here is an example from the Sheldon-Hart Mountain NWRC RVAA Pilot Project (Crist et al., 2011):

Stressor name/type	Effects	Current	Future	Included	Data Available
Feral horses and burros (Sheldon)	Herbivory, soil disturbance/erosion, water source disturbance and development	Y	?	Y	Y
Feral horses and burros (surrounding lands, not on Hart)	Impact to surrounding wildlife habitats	Y	Y	Y	Y
Altered fire regime	Altered plant composition, promotion of invasive species, soil erosion, altered nutrient cycling	Y	Y	Y	Y
Juniper expansion and infill	Habitat replacement, avian predator distribution Connectivity	Y	Y	Y	Y
Mining (Sheldon and off refuge)	Plant and soil disturbance/removal	Y	Y	Y	Y, Sheldon

Stressor name/type	Effects	Current	Future	Included	Data Available
Off-road vehicle use not on tracks	Plant and soil disturbance, erosion, wildlife disturbance, hydrologic disturbance, promotion of exotic/invasive species	Y	Y	Y	N
Roads/auto traffic (see infrastructure list)	Wildlife fatalities, air pollution, noise pollution, increased wildlife avoidance/fragmentation	Y	Y	Y	N
Wildlife poaching	Wildlife removal	Y	?	N	N
Campgrounds	Localized trampling, wildlife disturbance, trash	Y	Y	Y	Y
Resource Collecting	Fossil hunting, etc	Y	Y	N	Y
Day Use Areas, Fishing	Disturbance to wildlife, vehicle traffic	Y	Y	Y	Y
Communications towers	Bird and bat impact, disturbance to sage grouse	Y	Y	Y	Y
Agriculture contaminants (including active spraying)	Sedimentation Toxins: kill invertebrates and food sources, direct toxicity to resources as assumed output of intensive agricultural areas	Y	Y	Y	N
Agricultural (cropped) development (off-refuge, SSURGO model).	Habitat clearing, fragmentation, increased contaminants	Y	Y	Y	Y
Chained cleared pasture development (private, contact NRCS if they have a projection, utilize SSURGO?)	Habitat clearing, wildlife disturbance	Y	Y	N	N
Other private undefined land use	Habitat conversion, structures, agriculture, grazing possible	Y	Y	Y	Y
Water diversion and alteration (wildlife/cattle tanks, drinkers, water appropriation in Virgin Valley)	Stream flow regime, groundwater reductions, spring draw down, habitat alteration, increase in mesopredators	Y	Y	Y	Y (Sheldon)
Conflicting habitat management (on refuge and by state agencies—parks, natural heritage programs, DGIF, TNC (owned and easements)	Promotion of some habitats/species over others	Y	Y	Y (part)	Y
Livestock and horse grazing (off refuge, BLM, USFS, private and state land)	Habitat degradation, weed vectors, riparian impacts, wildlife disturbance	Y	Y	Y	Y

Stressor name/type	Effects	Current	Future	Included	Data Available
Invasive native species (Artemisia; excludes juniper)	Plant composition changes, fire regime changes, loss of forage	Y	Y	N	N
Invasive exotic plants (cheatgrass and medusahead)	Plant composition changes, fire regime changes, loss of forage	Y	Y	Y	Y
Invasive exotic animals (guppies, bullfrogs)	Loss of diversity, hybridization, endangered species loss	Y	Y	N	N
Introduced wildlife diseases (e.g., WNV assoc with feral horses—non spatial assessment example)	Population stress or extirpation	Y	Y	N	N
Hunting (sage grouse and pronghorn)	Site disturbance from trampling, general localized wildlife disturbance, introduction of exotic species	Y	?	N	N
Inholdings development (possibly treat same as generic private development/clearing)	Habitat clearing, fragmentation, introduction of invasive plants and free ranging introduced mesopredators (e.g., house cats)	Y	Y	Y	Y
Overhead utility lines (current and proposed—see western energy corridor website for a route between refuges)	Bird collision, vegetation clearing, soil disturbance	Y	Y	Y	Y
Buried utility lines (maintained corridor—ex and proposed)	Vegetation clearing, soil disturbance	Y	Y	Y	PART
Non-point source water pollution	Nitrification and toxins in water bodies	Y	Y	N	N
Oil/chemical spills along roadways	Toxic runoff into water bodies	Y	Y	N	N
Former toxics sites	Toxins in soil and toxic runoff into water bodies	Y	?	N	N
Elevated predation	Population impacts on imperiled wildlife. Consider as response to development	Y	Y	Indirect	N
Human pedestrian and dogs activity (trespass and permitted)	Chasing wildlife, disturbing the wildlife behavior, displacing wildlife	Y	Y	Indirect	N
Light pollution	Disturbance to nocturnal animals	Y	Y	N	N
Air pollution deposition e.g., mercury	Inhibition of breeding success	Y	Y	N	N
Energy development (wind)	Habitat alteration, direct mortality—collision	Y	Y	Y	Y
Energy development (solar)	Habitat alteration, disturbance, traffic/roads	N	Y	Y	N

Stressor name/type	Effects	Current	Future	Included	Data Available
Energy development (geothermal)	Habitat alteration, disturbance, traffic/roads	Y	Y	Y	Y
Wildlife disease	Increased mortality or decreased fitness	Y	?	N	N
Predator control (outside refuge)	Decreased predation stress, decreased predator populations	Y	?	N	N
Extreme weather events (frequency/intensity)	Increased stress to habitats	Y	Y	N	N
Increased air temperature (annual average and seasonal extreme?)	Heat stress on vegetation and wildlife, decreased soil moisture, drought intensity	Y	Y	Y	Y
Air temperature change (seasonal)	Phenology change, drought stress	Y	Y	Y	Y
Decreased air temperature	Drought frequency/intensity	N	?	N	N
Increased precipitation	Raised groundwater levels, alteration of soil moisture, nest flooding	Y	?	Y	Y
Decreased precipitation (annual average)	Drought frequency/intensity, fire frequency	N	?	Y	Y
Change in precipitation timing	Reduced snowpack	?	Y	N	N
Altered phenology	Uncoupling of wildlife-vegetation-prey relationships, impacts on feeding and reproduction	Y	Y	N	N
Cheatgrass invasion	Change and reduction in distribution of sage and desert scrub ecosystems	Y	Y	Y	Y

Appendix E. Assessment Report Outline

This outline is structured to directly support content of a CCP (see Appendix B of Preplanning Guidance for Comprehensive Plans technical guide) though it will have broader application and thus may be restructured for other applications as necessary. As with that technical guide's Appendix B, this outline is formatted as a table to manage content development. Chapter numbers are associated with those in the CCP technical guide Appendix B to allow easy navigation but sections and subsections (indented headings) may be unique to this outline. Sections/subsections unique to this outline are indicated in bold. In the comments section is specific guidance for this Technical Guide on relevant content. Some headings are provided only as context for where this study's content should be located; in those cases the comments will indicate N/A. Experience from the RVAA pilot projects indicated that reordering of content will be important for comprehension of the RVAA but the headings can still be useful for associating content to a CCP.

Chapter/Section/Subsection	Date Complete	Comments
Chapter 1. Introduction and Background		Specific introduction and background for this study
Purpose of and Need for Plan		N/A
Application		Application for which this study is done, e.g., CCP, HMP, etc.
Refuge Purposes		Aspects of refuge purpose that guided this study
Legal and Policy Guidance		Laws and policy under which this study was conducted
Existing Partnerships		Partners that engaged in this study
Chapter 2. Planning Process		N/A
Planning Issues		The issues that initiated and guided this study
Chapter 3. Refuge Environment		
Geographic/Ecosystem Setting		Per CCP guidance
Refuge Resources, Cultural Resources, and Public Uses		N/A
Resources of Management Priority		
Infrastructure of Management Importance		
Resource Stressors		
Chapter 4. Management Direction		N/A
Cumulative Vulnerability Assessment		
Scenarios Evaluated		
Resources Assessment		
Infrastructure Assessment		
Refuge Management Direction: Goals, Objectives, and Strategies		If this study is updating or stepping down an existing CCP or if this information has been developed for the current study it should be described

Strategy Development Process and Options		Should describe steps taken to investigate and identify strategies based on scenario evaluations
Refuge Options and Recommendations		Maps and describes alternative futures based on strategies
Chapter 5. Implementation and Monitoring		N/A
Resource and Stressor Monitoring Recommendations		Utilizes scenario evaluation and strategies results to recommend resources, stressors, and approaches for monitoring

Appendix F. Suggested Workshop Agenda and Checklist

This is a generic agenda that can be tailored to individual sites. The objectives of this meeting are:

1. Validate the initial NWR characterization and identify needed changes or additions
2. Decide, based on the information what should be the key resources and MCI to include in the assessment
3. Decide, based on the information what should be the key stressors to include in the assessment
4. Identify the appropriate data to be used and data gaps to be filled (complete Appendix G checklist)
5. Conclude what assessment products are desired and how they should be transferred to the refuge including training/capacity building for ongoing use and adaptation of the data and tools.

Day 1

9:00a Host NWR welcome and participant introductions

9:15a Meeting objectives and participant roles

9:30a Overview of overall project objectives, pilot role, and assessment steps/workflow

10:15a Break

10:30a Presentation of NWR characterization, discussion, validation (ID deficiencies/corrections). Plan on approximate 20 min discussion per item; break as needed

- Regulatory framework guiding resource selection
- Initial resource candidate list
- Infrastructure
- Stressors

12:00p Lunch Break

1:00p Presentation of regional context assessment

- Assessment objective and methods
- Results
- Q&A

3:00p Context assessment discussion

- Validation of results
- Deficiencies/corrections
- Implications

Day 2

9:00a Recap items from Day 1, review agenda

9:15a Prioritize initial characterization (Steps 1 and 2) deficiencies for remediation

9:30a Break

10:00a Overview remaining assessment steps and prioritize for pilot demonstration purposes and value to the refuge

10:30a Detailed discussion of remaining steps, data needs, availability and sources
12:00p Lunch break
1:00p Complete detailed steps discussion as needed or proceed to next item (here can focus on climate change issues if not already covered)
2:00p Discussion of next steps and process for further review and product transfer

- Data and expert knowledge gathering and simple modeling for resources, infrastructure, stressors
- Analyses and outputs
- Expected final products for phase 1 pilots
- Transfer of content to the refuge (interest in receiving as Vista project)

3:00p Wrap up

Workshop Checklist

In this checklist, items that are revised within products (e.g., a checklist is revised) can just be noted as such. Additional action items can be noted as a comment.

Item	Addressed/Comment
Regulatory framework	
Resource candidate list	
MCI retention list	
Stressors	
Regional contextual analyses reviewed	
Next evaluation steps reviewed	
Climate change assessment discussed	
Data needs and sources identified	
Final products discussed	
Form of tech transfer to refuge discussed	

Appendix G. Data Needs and Costs Checklist

The following data checklist is a suggested start and should be modified for individual projects. See also the Manager's Guide for a sample budget for the entire RVAA technical work.

Data Theme	Source	Secured	Quality/improvement needs	Cost
Boundaries				
Regional				
Watershed				
Supporting Landscape				
Acquisition				
Refuge ownership				
Resource Distribution Maps				
Ecosystems/habitat types				
Multi-Species Assemblages				
Species				
Resource Viability Requirements				
Minimum occurrence size				
Condition threshold				
Supporting landscape retention goal				

Responses to stressors/management				
Infrastructure Type/Location Maps				
Roads and rail				
Buildings				
Power/transmission				
Water control structures				
MCI Viability Requirements				
MCI type minimum occurrence size if applicable				
MCI type minimum condition threshold (e.g., might estimate degree of integrity in the face of storm surge)				
MCI type retention goal (e.g., if there is redundancy of an MCI type and less than 100% is required to be retained)				
Scenario Input Maps				
Current protected areas (e.g., GAP status I and II)				
Current public land and private conservation land stewards				
Proposed conservation areas (e.g., SWAP, TNC, Audubon, DU, etc.)				
Current land use				
Future zoned or modeled land use				

Current infrastructure				
Planned or proposed infrastructure				
Current management practices				
Planned/proposed management				
Current invasive species				
Modeled invasives spread				
Current flood/storm surge limits and depths				
Modeled future flood/storm surge limits and depths				
Modeled wildfire risk areas				
Modeled sea level rise limits and depths				
Other modeled future climate changes (temp, soil moisture, salinity, pH, etc)				