NatureServe

Camas NWR

Ecological Integrity Assessment, Watershed Analysis and Habitat Vulnerability Climate Change Index

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12/11/2012

Left to right: Sagebrush Steppe, Wet Meadow and Riparian Shrubland habitats at Camas NWR.

This project was made possible through a USFWS I&M grant # F11PX04463

This report is the second part of a vegetation mapping project for Camas NWR, the first report is:

Miewald, Tom, G. Kittel and E. Stockenberg. 2012. Vegetation and Habitat Mapping: Lessons Learned from Camas National Wildlife Refuge. Internal Report to Region 1 USFWS Inventory and Monitoring Program.

Acknowledgements: NatureServe would like to thank Tom Miewald and Erin Stockenberg for their comments of earlier manuscripts.

Full citation:

Kittel, G., Don Faber-Langendoen and Pat Comer. 2012. Camas NWR: Ecological Integrity Assessment, Watershed Analysis and Habitat Vulnerability Climate Change Index. Report to USFWS under contract # F11PX04463. Prepared by NatureServe, Boulder, CO.

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Executive Summary

This report is the second part of a pilot study to map the vegetation of Camas National Wildlife Refuge and determine the overall ecological integrity of the refuge, how it compares to other wetlands in the surrounding watershed, and a look into the degree of vulnerability to climate change of key habitat types found on the refuge. The first part yielded a vegetation classification, map and database using the Federal Standard National Vegetation Classification System (see Miewald et al. 2012). The second part included three complementary analyses: 1) Ecological Integrity Assessment of the vegetation resource as mapped at Camas National Wildlife Refuge, 2) Watershed analysis of the abundance and condition of wetlands across the immediate Beaver-Camas watershed and larger surrounding Upper Snake River watershed to determine the relative importance of Camas NWR wetlands from a watershed perspective, and 3) Application of the Habitat Climate Change Vulnerability Index on four habitat types throughout their range of distribution within the Snake River Plain ecoregion that are also found on the refuge.

Ecological Integrity Assessment employs a set of measures of ecosystem structure, function and composition, referenced to the range of natural variation and resistance to perturbation. The major components of the model typically include 6 major ecological factors (or attributes) of landscape, buffer, size, vegetation, hydrology (for wetlands), fire regime (for uplands) and soils. The Ecological Integrity Analysis (EIA) was conducted at two scales at Camas: individual point locations and wetland complexes. Thirty percent of the wetland condition ranked excellent to good (A/B) while 69% ranked moderate to poor (C/D) categories. Upland vegetation was not much different with 27% ranked as excellent to good (A/B) and 74% as moderate to poor. Much of the refuge is overrun with invasive non-native species (cheat grass, sow and Canadian thistle, plus many others). However several pockets of excellent condition native vegetation were located and are examples of native functioning communities. These can be used as references for restoration efforts on the refuge.

The larger wetland complexes (Ray's Lake, Camas Creek Riparian Corridor, Big Pond and Center Pond) incorporated the point conditions with surrounding landscape metrics including hydrology and buffer metrics. Overall wetlands ranked from poor (C) to good (B-) on the EIA 5 point scale. The lowest component scores come from the vegetation metrics due to abundant non-native invasive plant species. In some areas non-native species have completely replaced the native communities. Wetland buffers scores were also low for Center Pond and Ray's Lake due to roads immediately adjacent, contributing to sediment runoff and impeding flows between wetlands. Hydrologic connectivity metric scored low for Camas Creek as it has become disconnected from its floodplain except for the highest flood years, as seen in 2011. The high scores were given for the surrounding Landscape context where native upland habitats surround the refuge wetlands, which serve as buffers to neighboring agricultural fields. The report includes management recommendations for improving the ecological integrity of Camas.

The watershed analysis is an overlay of the 90 m Landscape Condition Model (a spatial model of current human land use intensity) with the current 30 m distribution map of wetlands, creating a profile of wetlands by type and condition. Profiles were generated for the immediate local Beaver-Camas watershed and for the surrounding larger Upper Snake watershed. These profiles shows that lower elevation riparian and marsh areas are in the poorest condition relative to other wetland types. Opportunities for mitigation should include the restoration of these areas. Camas NWR has some of the best condition low elevation wetlands within the local watershed. And in fact has some of the best base-of-the-foothills positioned wetlands in the entire Upper Snake River watershed, especially along the

northern edge of the topographic Snake River Plain. The location of Camas' wetland and riparian areas within a largely agriculturally converted landscape as well as its position within an interior arm of the Pacific Flyway make it strategically important for supporting wildlife movement and long term conservation of wetland dependent species.

Climate Change Vulnerability Index (HCCVI) The HCCVI aims to implement a series of measures addressing climate change sensitivity and ecological resilience for each community type for its distribution within a given ecoregion (in this case, the Snake River Plain). Since quantitative estimates may not be feasible for all measures, both numerical index scores (*normalized 0.0-1.0 scores*) and qualitative expert categorizations may be used in the HCCVI. The combined relative scores for **sensitivity** and **resilience** determine the categorical estimate of climate change vulnerability by the year 2060 (i.e., 50 years into the future) for a community type. While the overall index score for each community should be useful for regional and national priority-setting and reporting, the results of these individual analyses should provide insight to local managers for climate change adaptation. Index measures are organized within categories of **direct effects**, **indirect effects,** and **adaptive capacity**. A series of 3-5 measures, each requiring a separate type of analysis, produces sub-scores that are then used to generate an overall score for **sensitivity** (*from direct effects*) vs. **resilience** (*indirect effects + adaptive capacity*).

Direct effects can be addressed through several measures, depending on the natural characteristics of the community type. For example, analysis of downscaled global climate forecasts for temperature and precipitation variables provides an indication of the relative intensity of climate-induced stress. Dynamic simulations of fire regime or hydrologic regime may be used to forecast trends in the alteration or 'departure' from expected conditions for upland vs. riparian/aquatic communities, respectively.

Indirect effects include trends in ecological integrity. These can indicate the potential for resilience to climate change. Analyses may include spatial models aiming to characterize the degree of landscape fragmentation or other anthropogenic impacts (such as invasive species) in the landscapes supporting a given community type. Dynamic simulations of fire regime or hydrologic regime may be used here, not for forecasting, but instead to characterize the past and current degree alteration or 'departure' from expected conditions for upland vs. riparian communities, respectively.

Adaptive capacity includes inherent characteristics of a natural community that make it more or less resilient to climate change. Attributes can include diversity within groups of species playing key functional roles. Additionally, the relative breadth of bioclimatic and elevation range that characterizes a communities natural distribution can indicate inherent capacity to cope with climate change.

For the HCCVI, climate-change vulnerability is expressed in four categories, including Very High, High, Moderate, and Low vulnerability. Therefore, the index ratings are quite general, but this is because predictive uncertainty is often high, and our overall intent is a generalized indication of vulnerability. This is analogous to a scoring of "endangered" or "threatened" for a given species, but here focused specifically on climate change vulnerability, and applied to community types.

Scores for each community type are summarized for each applicable ecoregion of their natural distribution. For this project, we focused on the distribution of four habitats within the Snake River Plain ecoregion: Vancouverian & Rocky Mountain Montane Wet Meadow Group (wet meadow habitat), Intermountain Dry Tall Sagebrush Shrubland & Steppe Group (sagebrush steppe habitat), Western North American Temperate Interior Freshwater Marsh Group (marsh habitat) and the Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland Group (riparian shrubland habitat). One might apply the same analyses and gauge vulnerability for narrower or broader distributions of a given community type, but this level of ecoregionalization was selected because it likely reflects regional pattern of climate-change exposure and effects. It therefore should provide a practical starting point for efforts to systematically document climate change vulnerability at national or regional scales.

Similarly, one must explicitly consider the temporal dimension of climate change vulnerability, as the magnitude of climate exposure varies over the upcoming decades. By utilizing forecasts of climate exposure and sensitivity over a 50-year timeframe (e.g., between 2010 and 2060) provides a practical time period where realistic climate trends can emerge within acceptable bounds of uncertainty.

Component scores are summarized on a 0-1 (high to low stress) scale for direct effects and a 0-1 (low to high resiliency) scale for indirect affects and adaptive capacity. Within the Snake River Plain climate exposure will be considerable, with warmest temperatures forecasted to occur during the growing season by 2060, so scores for climate stress were high (0.3). Past landscape condition with significant agricultural conversion along with hydrological alteration to support that agriculture resulted in low scores for indirect effects for all communities past and present (0.5 - 0.35). The Snake River Plain has not escaped the onslaught of invasive species, which has altered fire regimes and community structure for three of the 4 communities assessed, both current status and the projected change with time and warming with the marsh community having the higher score (0.7 - 0.25). The adaptive capacities of the four types are relatively unconstrained by elevation or soils so these scores were in the high range (0.73 - 0.8). Indirect effects combined with adaptive capacity scores gave moderate resilience scores, which when combined with the high climate sensitivity scores, gave a final high vulnerability score for each of the community types.

Resulting Habitat Climate Change Vulnerability scores ranged from 0.38 for sagebrush steppe to 0.45 for the wetland communities. High climate change exposure with an expected continued change in the already altered dynamic processes of hydrology and fire regimes leads to these Highly Vulnerable scores.

Climate Change Adaptation includes actions that enable species, systems and human communities to better cope with or adjust to changing conditions. There is also critical temporal dimension to climate-change adaptation. While traditional natural resource management has been ‘retrospective’ – utilizing knowledge of past and current conditions to inform today’s management actions – planners are increasingly required to rigorously forecast future conditions. It is no longer sufficient to assess “how are we doing?” and then decide what actions should be prioritized for the upcoming 5-15 year management plan. One must now ask “where are we going, and by when?” and then translate that knowledge back into actions to take in the near-term, or medium-term, or those to monitor and anticipate taking over longer planning horizons.

We can readily identified components of indirect effects scores (e.g., landscape condition, invasive species, dynamic process alteration) as forming the focus of many “no regrets” adaptation strategies that could be pursued by managers. In most cases, these factors relate to the stressors that are best known and are currently being addressed within managed areas. Where indirect effects stressors were less well known, and/or interactions with climate change were less clear, strategies tended to be categorized as “anticipated actions” within the 5-15 year timeframe, where additional information will be required to move forward, but participants could foresee their implementation.

Direct effects, such as climate stress, challenges us to identify novel climate-change stressors for each community type, such as effects of heat stress or changes in seasonality of precipitation and their potential effects on functional species groups, such as pollinators. Given the limits to current knowledge in these areas, the strategies identified tended to fall in the “wait and watch” category, where research questions are specified and investment will be required over upcoming decades in order to determine appropriate management actions.

The geographic location of Camas NWR within the Snake River Plain may prove to play an important role in the resilience of these communities. Camas is located in some of the least altered part of the ecoregion. While much agriculture occurs close by, models show that this part of the ecoregion has the lowest risk for invasive species complete alteration and the least degree of fire departure. While invasive species are already present at Camas, there are areas on the refuge and on neighboring lands that have not been completely altered and transformed by invasive species. The effort to eradicate or control the spread of invasive species at Camas becomes an important management tool for increasing the resilience of native ecosystems. Additional “no-regrets” management recommendations designed to increase the resilience of Camas ecosystems are: restore shallow groundwater, retire surface diversion and groundwater pumping permits, aggressively control invasive species and protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff.

1 Introduction

This is a report on a pilot project to assess the potential of three tools for Refuge I&M to consider in their “toolkit” of assessment approaches. First is the Ecological Integrity Analysis (EIA), which provides a rapid and flexible approach to assess the ecological condition of refuge habitats. The second tool is a watershed analysis which looks at what contribution refuge wetlands make towards conservation and connectivity of wetlands from a watershed perspective. The third tool is the Habitat Climate Change Vulnerability Index, which provides an approach to assess how sensitive or vulnerable habitats are to near future (2060) predicted climate change at the scale of the ecoregional setting of a refuge.

We conducted these analyses at Camas National Wildlife Refuge, in southeastern Idaho, in conjunction with a vegetation mapping project (Miewald et al. 2012) that incorporated the new revised US National Vegetation Classification (USNVC) standard (FGDC 2008). Goals of the project were to determine the best approach to vegetation mapping on refuges, learn how to apply the USNVC standard (a USFWS requirement) and to crosswalk USNVC hierarchical terminology with USFWS habitat types.

With the application of the USNVC, the project resulted in a standardized list of vegetation types present at Camas. The next logical management question is how are they doing? What is their current status or ecological condition? Are they functioning at full capacity or is the ecological health compromised in some way? How do the ecosystems at Camas compare to those in the surrounding watershed? And, how will Camas ecosystems respond to future climate change?

The Ecological Integrity Assessment presented here summarizes the condition by vegetation/habitat type and by wetland complex. The wetland watershed analysis approach profiles the abundance, type and condition of wetlands across the local watershed (USGS 8th level Hydrologic unit) and compares these data with the profile of wetlands from the larger, surrounding watershed (USGS 6th level Hydrologic unit).

The Habitat Climate Change Vulnerability Index was applied to four habitat types that occur on the refuge: Wet Meadows, Sagebrush Steppe, Emergent Marsh, and Riparian Shrublands [1]. The index assesses the vulnerability of these habitats across their entire distribution within the Snake River Plain Ecoregion (EPA level III ecoregion, Wiken et al. 2011). We used downscaled Global Circulation Models (GCM) provided by Climate Wizard (Girvetz et al. 2009) for predicted future (circa 2060) temperature and precipitation (annual and monthly means and totals) relative to historic base line data. The assessment looks at direct climate stress, indirect effects, and the adaptive capacity of the ecosystem/habitat.

2 Ecological Integrity Assessment

2.1 Introduction

Building on the concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting of the condition of habitats on the refuges. Ecological integrity can be defined as “an assessment of the structure, composition, and function of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historic disturbance regimes” (adapted from Lindenmayer and Franklin 2002, Young and Sanzone 2002, Parrish

[1] See Appendix A for a crosswalk of USFWS habitat type names to USNVC nomenclature.

et al. 2003). Critical to the assessment is an understanding of the hydrological and fire regimes operating within the refuges, be they natural or manipulated, relative to their historic patterns. Also important is an understanding of reference conditions for habitats in the refuge.

A general conceptual model for Ecological Integrity Assessments (EIA) provides a general set of ecological factors found across ecosystem types, and then encourages the identification of individual key ecological attributes for individual system types (Noon 2003, Faber-Langendoen et al. 2008, Unnasch et al. 2009) (Figure 1). The model also provides a means to assess stressors or agents of change to the ecological factors. The major components of the model typically include 6 major ecological factors (or attributes) of landscape, buffer, size, vegetation, hydrology (for wetlands), fire regime (for uplands) and soils. Together these are the components that capture the structure, composition and processes of a system. Understanding the characteristics and processes of these attributes will contribute not only to understanding current ecological integrity but to the resilience of the ecosystem in the face of climate change and other causes of stress. The model can be refined, as needed, based on increasing specificity of ecosystem types, as described by the NVC and NatureServe's Ecological Systems (Faber-Langendoen et al. 2008).

Ecological Integrity is a set of measures of ecosystem structure, function and composition, referenced to the range of natural variation and resistance to perturbation. Ecological integrity measures also link with management goals. The analysis of acceptable ecological conditions can help refuge planners establish and document their desired resource conditions. For example, a protected area like Craters of the Moon NP, which was explicitly established to protect natural resources, may have goals to meet reference standards, and an EIA assessment informs managers on the status of the ecological condition relative to reference standards. In contrast, other areas such as Minidoka National Historic Site, established to preserve the historic setting of an internment camp, an ecological integrity assessment reports on the current condition along an successional pathway relative to reference conditions, which informs management how well they are meeting management goals to maintain the grounds in various historic states. This makes ecological integrity a flexible tool for meeting the needs of a variety of management goals of parks, wildlife refuges and other natural areas. Along with this flexibility comes a responsibility to be transparent about exactly how current conditions are determined.

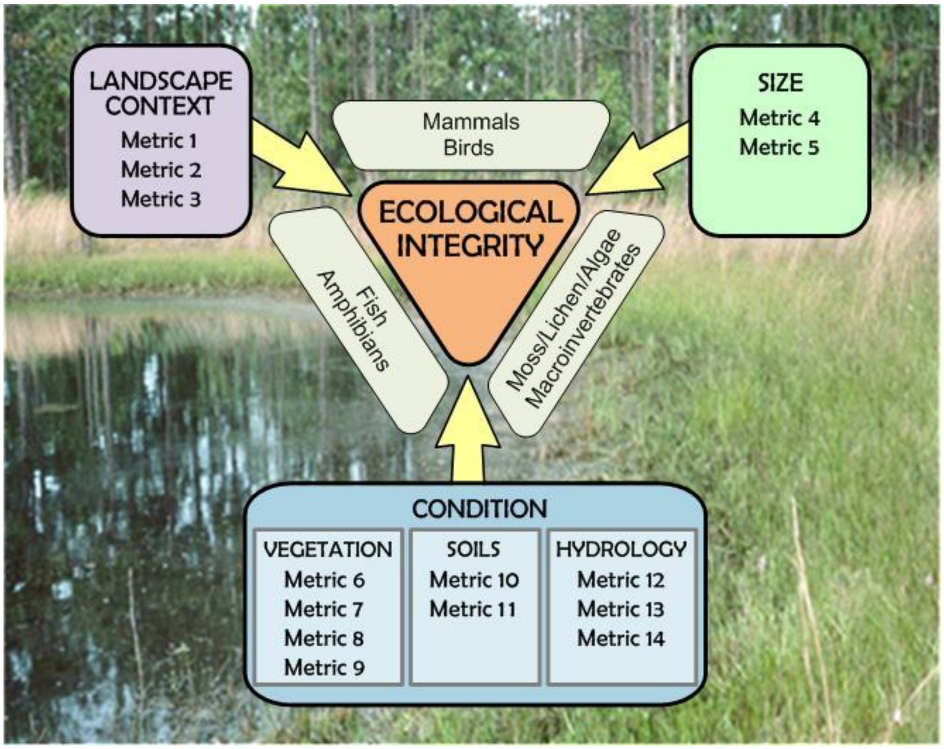


Figure 1. General conceptual model for Ecological Integrity Assessments (EIA).

2.2 Rating Ecological Integrity

Earlier we stated that ecological integrity assessments can be defined as "the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size." We can expand that definition by providing a narrative set of guidelines on the kinds of structural, compositional, and ecological functions (or processes) that are core to the assessment. Using a scorecard approach (where A = excellent integrity and D = poor integrity), we can define an A-rated example as an…

> "…Occurrence believed to be, across the range of a type, among the highest quality examples with respect to key ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include 1) the landscape context contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no stressors; 2) the size is very large or much larger than the minimum dynamic area; 3) vegetation structure and composition, soil status, and hydrological function are well within natural ranges of variation, exotics (non-natives) are essentially absent or have negligible negative impact; and 4) a comprehensive set of key plant and animal indicators are present." (Faber-Langendoen et al. 2012).

These ratings help guide the recognition of reference ecosystems, from reference standards (A-ranked wetlands or uplands) to degraded (D-ranked wetlands or uplands). Assignment of a rating presumes that a particular type is still recognizable at some level as "the type," despite varying levels of degradation. At some point, a degraded type will "cross the line" (or be "transformed," *sensu* SER 2004) into a separate, typically semi-natural, ruderal or cultural type. In some state-and-transition models, these examples may be treated as shifts to an "alternative state." As a matter of practicality, the current ecosystem under transformed conditions is considered lost. Using a scorecard approach requires working with a set of diagnostic classification criteria, based on composition, structure, and habitat (see "Level 2 Assessments" below) to distinguish "transformed" ecosystem states from degraded conditions of a particular ecosystem type.

A scorecard approach depends on a consistent scaling of the indicators or metrics, such that their ratings are comparable with respect to levels of integrity. It is then reasonable to summarize the metric ratings and roll them into aggregate scores, including an overall Index of Ecological Integrity, based on a weight of evidence approach (Linkov et al. 2009). Details of the scorecard are provided in Faber-Langendoen et al. (2012).

Metrics measure the direct level of stress or the response of a stress that may cause the system to shift away from its natural range of variability. In other words, type, intensity, and duration of these stressors is what moves a system's ecological integrity rank away from the expected, natural condition (e.g. A rank) toward degraded integrity ranks (i.e. B, C, or D). A score of B-rank indicates that stressors are present, and impacts can be observed but they are not intensive or wide spread. A C-rank indicates that stressors are heavy enough to show moderate degradation. A D-rank score indicates heavy impact, greatly altering the system. The score of A/B indicates minimal impact.

The EIA method is flexible that can be applied at three intensities: Level-1 metrics are applied via remote data in the office, Level-2 metrics are conducted by rapid field visits, and/or Level-3 metrics which involves intensive data collection, each level requires more field time. EIA is also flexible in the selection of metrics at all levels, depending on the type of habitat being assessed and the level of resources available.

At Camas we conducted Ecological Integrity of individual habitat types with Level-2 field based metrics appropriate for uplands, depressional and riverine wetlands. We also conducted an Ecological Integrity Analysis of refuge wetland complexes using a combination of Level-1 metrics and Level-2 data metrics.

2.3 Methods

For Camas NWR field work, plot data were used to meet two project goals: vegetation mapping and Ecological Integrity Assessments (EIA). Plot locations were chosen by a stratified random method, stratified by soil types identified by earlier studies (Germino 2010). This provided for samples to be located in an unbiased way on both uplands and wetland habitats on the refuge. At each point we applied a selection of Level-2 EIA metrics appropriate for the type of ecosystem. Each metric was rated by comparing measured values with values expected under relatively unimpaired (reference standard) conditions, and the ratings were aggregated into a total score.

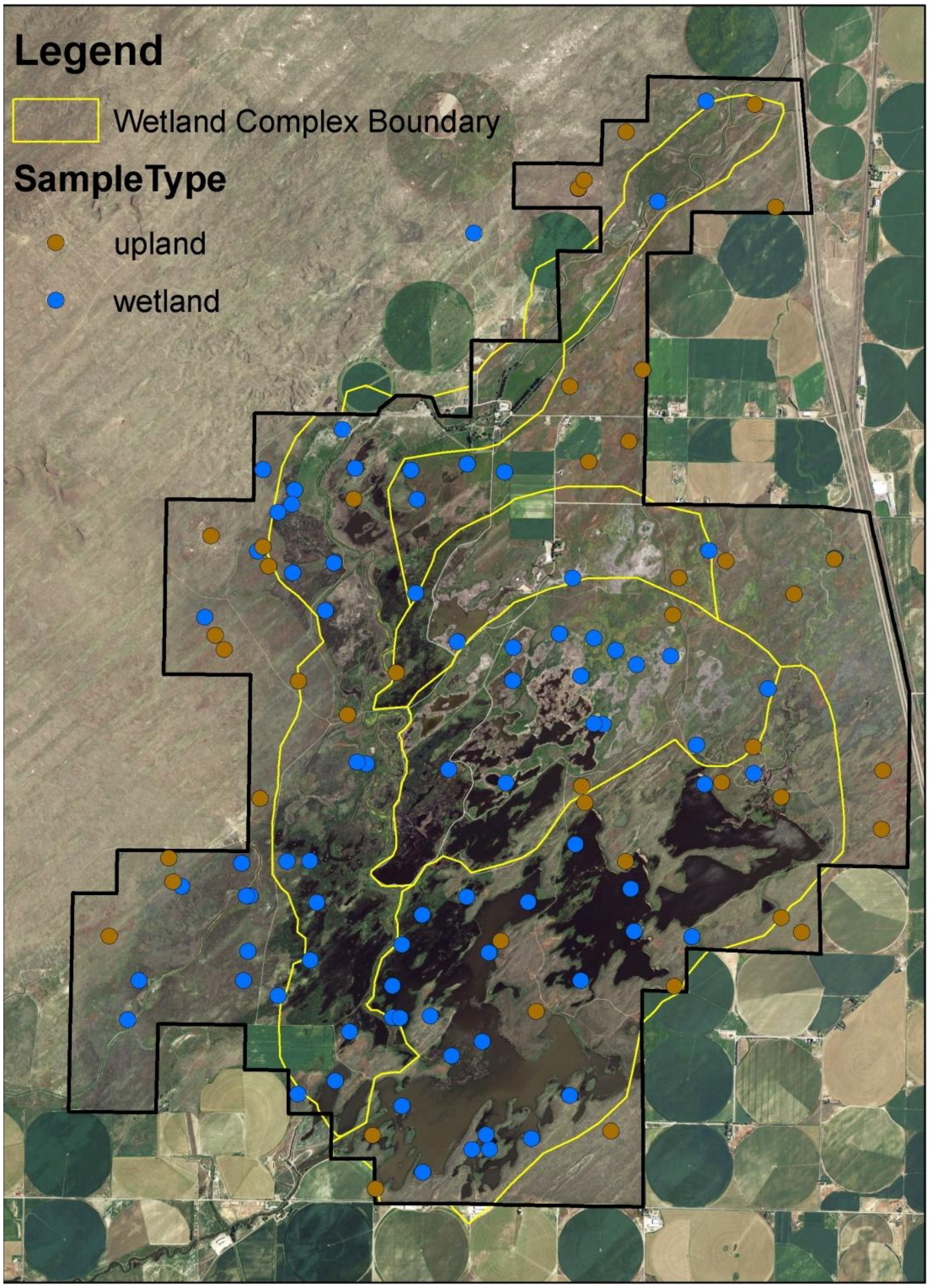


Figure 2. Camas 2009 and 2011 sample locations.

At each point we determined the US NVC type (Group, Alliance or Association), collected vegetation data (species and percent cover) within a circular plot (0.1 ha, 1000 m^2, 0.25 acre), centered on the GPS verified point, and assessed a larger, surrounding area for a total assessment area of 0.8 hectare (7854 m^2, 1.94 acres). In this surrounding area we assessed the vegetation for homogeneity, in order to determine if the vegetation at the point is representative of the larger wetland or upland area; this observation is an important field notation for mapping vegetation.

At each location we conducted Level-2 Ecological Integrity Assessment using 5 metrics (cover of native plant species, cover of non-native plant species, vegetation composition, soil surface condition, patch diversity) on wetland sites and an additional 3 metrics (native bunch grass cover, fire-sensitive shrub cover, biotic soil crust condition) at upland sites. Vegetation data collected by Germino (2010) were assessed for the first three metrics, bringing the total number of EIA sample points to 127 (Figure 2). A brief definition for each metric is outlined below.

2.4 Level-2 Condition Metric Definitions and Score Criteria

Each of the 8 metrics measures a different physical or biological aspect of the site and the scores rank how well the site is performing relative to an undisturbed, reference condition. Brief definitions and final score rollup methods are provided here. More detailed definition, rational, scoring criteria and literature references for these metrics are available in Appendix B. See Faber-Langendoen (2012) for the protocols on all EIA metrics. Example field forms are available in Appendix C.

1. **Relative Cover of Native Plant Species**--A measure of the relative percent cover of all plant species that are native to the region.
2. **Cover of Non-Native Invasive Plant Species**--A measure of the percent cover of a set of exotic plant species that are considered invasive. Invasive species can cause a substantial management effort to control and reduce condition.
3. **Vegetation Composition**--An assessment of the overall species composition and diversity, including by layer, and evidence of specific species diseases or mortality.
4. **Native bunchgrass abundance** (for shrub steppe uplands)—Abundance of native bunchgrasses.
5. **Biological soil crust** (for shrub steppe uplands)—Abundance of biological soil crust.
6. **Fire Sensitive Shrub composition** (for shrub steppe uplands)—Composition of fire sensitive shrubs relative to references conditions.
7. **Soil Surface Condition Definition**: An indirect measure of soil condition based on stressors that increase the potential for erosion or sedimentation of the soils, assessed by evaluating intensity of human impacts to soils on the site.
8. **Physical Patch Types** (Patch Diversity) A checklist of the number of different physical surfaces or features that may provide habitat for species.

2.5 Individual Site EIA Condition Score

All data were entered in the Ecological Integrity database. Each metric rank letter score is converted to a numerical score and these are averaged to create combined, Vegetation Condition Score (native cover, non-native cover, and vegetation composition for wetland sites + native bunchgrass, biotic soil crust and fire-sensitive shrubs for upland sites) and Soils Condition Score (Soil and patch diversity). These two scores were then averaged for a single EIA Condition score for each assessed location. Ecological Integrity is scored on a 1 to 5 scale, where 5 represents reference conditions in a completely undisturbed state, that is, where the ecosystem is experiencing very little to no stressors, has full buffering capacity and is able to resist or fully recover from disturbance. EIA score of 1 is a highly altered ecosystem that has high level of stress, little buffer or resistance capacity, and may not recover at all from continued application of stressors. Each of the 127 field sites receive a single, EIA Condition score based on the 5 to 8 metrics, depending on if the site was a wetland or upland, respectively.

2.6 Wetland Complex Ecological Integrity Assessment

In addition to site-level condition assessments, we also applied landscape-scale Level-1 metrics to wetland complexes at Camas: Big Pond, Center Pond, Ray's Lake and Camas Creek & Floodplain. Upland areas were not subject to level-1 metrics, as that was not the focus of this project. The additional Level-1 metrics include Landscape Connectivity, Land Use Index, Buffer metrics (buffer length, width, and condition) and Hydrology metrics (water source, hydroperiod and hydrologic connectivity) (defined below).

Four wetland complexes were delineated by the project's NatureServe ecologist with the assistance of the refuge manager. These complexes encompass ponds that are linked by water source and direction of flow, creating a suite of interconnected ponds and their surrounding lowlands (Figure 3a). Landscape Scale metrics are assessed within three concentric areas surrounding each wetland, starting with the nearest- buffer area (100 m from wetland edge), then core area (250 m from wetland) and finally supporting landscape area (500 m from the wetland) (Figure 3b). Hydrology metrics was assessed for each wetland complex based on management information provided by the refuge manager.

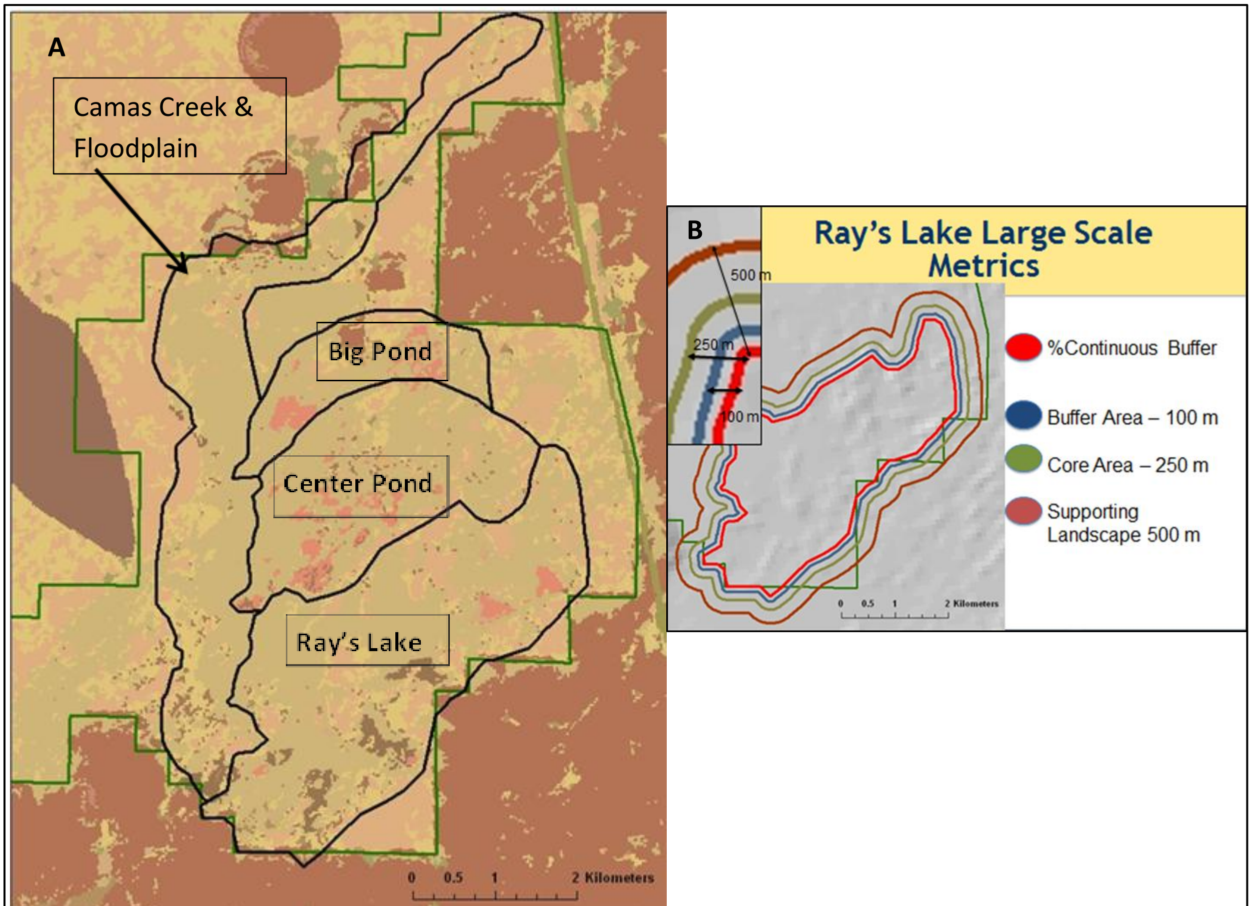


Figure 3. Map of Wetland Complex areas (A) and Landscape scale metrics (B). Landscape scale metrics measure the amount of human activity within 3 concentric areas surrounding the assessment area: within the Buffer Area (100 m), the Core Area (250 m) and the Supporting Landscape area (500 m), as well as the length or continuity of a natural wetland buffer. The dark green line is the refuge boundary.

2.7 Level-1 Landscape, Buffer & Hydrology Metrics

Level-1 Ecological Integrity Assessment of Camas wetlands included 8 metrics applied using remote sensing with GIS with field verification. Brief definitions are provided here. More detailed definition, rational, scoring criteria and literature references for these metrics are available in Appendix B.

1. **Landscape Connectivity** A measure of connectivity assessed using the percent of natural habitat in the surrounding landscape beyond the 100 m buffer, based on an additional 150 m width for the core landscape and an additional 250 m width for the supporting landscape.
2. **Land Use Index-** This metric measures the intensity of land uses in the surrounding landscape beyond the 100 m buffer, based on an additional 150 m with for the core landscape and an additional 250 m width for the supporting landscape. This process done via a Geographic Information System (GIS) by which the amount of area by land use category is calculated. Each land use is given a coefficient of land use intensity on a scale of 0-1. For example Parking lots and Industrial areas score 0.0, intensive till crop agriculture 0.2, tree plantations 0.5, logged forests 0.8, natural areas/ land managed for native vegetation 1.0. See Appendix B for more land use coefficients.
3. **Buffer Index**-- A measure of the overall area and condition of the buffer immediately surrounding the assessment area (100 m radius). Wetland buffers are defined as vegetated, natural areas that surround a wetland. See Appendix B for list of appropriate buffer types and slope modifiers. Buffer Index is measured in three sub-metrics: Buffer Length--length of the wetland perimeter with a natural buffer of at least 5 m in width; Buffer Width – average width of appropriate buffer area; Buffer Condition – amount of native vegetation, disruption to soils, signs of reduced water quality, amount of trash or refuse, and intensity of human visitation or recreation. Overall buffer index score integrates the three sub-metrics where the condition sub-score is given half the weight of the other two, as its importance to overall buffer performance is not as strong (see Appendix B for buffer index formula).
4. **Water Source**--An assessment of the kinds of direct inputs of water into, or any diversions of water away from, the wetland and the magnitude or extent of any additions, removal or blockages of the wetland water source. Scoring example is for depressional wetlands. See Appendix B for additional criteria for other HGM types (such as riverine).
5. **Hydroperiod**. An assessment of the characteristic frequency and duration of inundation or saturation of a wetland during a typical year. Scoring example is for depressional wetlands, see Appendix B for additional criteria for other HGM types.
6. **Hydrologic Connectivity**-- An assessment of the ability of the water to flow into or out of the wetland, or to inundate adjacent areas. Scoring example is for depressional wetlands, see Appendix B for additional criteria for other HGM types.
7. **Absolute Size--** A measure of the current absolute size (ha) of the entire wetland type polygon or patch. The metric is assessed with respect to expected patch sizes for the type across its range.
8. **Relative Size--** A measure of the current size of the wetland (in hectares) divided by the historic wetland size (within most recent period of intensive settlement or 200 years), multiplied by 100.

2.8 Wetland Complex EIA Overall Score

Individual metric scores were entered in the Ecological Integrity database. Each metric rank letter score is converted to a numerical score and these are averaged to create combined roll-up scores for Landscape Context (average of the Landscape Connectivity, Land Use Index and Buffer Index), Condition (Vegetation, Soils and Hydrology (Water Source, Hydroperiod, and Hydrologic Connectivity)) and Size (absolute and relative size) for each wetland. A final EIA score for each wetland is a roll-up (numeric average) of each component score (Landscape Context, Size, and Condition). The overall EIA score is scored on a 1 to 5 scale, where 5 represents reference conditions in a completely undisturbed state, that is, where the ecosystem is experiencing very little to no stressors, has full buffering capacity and is able to resist or fully recover from disturbance. EIA score of 1 is a highly altered ecosystem that has high level of stress, little buffer or resistance capacity, and may not recover at all from continued application of stressors. Each of the four wetland areas received a final Ecological Integrity Score based in the Level-1 and Level-2 metrics.

2.9 Results and Discussion

2.9.1 *Individual Assessment Sites*

The 2009 and 2011 assessment areas covered 102 hectares (252 acres) of Camas NWR. Points fell on wetlands and upland areas, while open water was not sampled. Of the 127 sample points 28% scored in good to excellent condition and 74% in fair to poor condition (15% scored “A” excellent, 13% “B” good, 17% “C” fair and 57% “D” poor) (Figure 4).

2.9.1.1 Wetlands

For the 93 wetland samples, one third of the plots ranked excellent to good integrity (EIA score A-B, 3.1 – 5.0), while the remaining two thirds ranked fair to poor integrity (EIA score C-D, 1.0- 3.0) (Table 1) (Figure 5). Lower scores at Camas NWR are largely due to the abundance of non-native invasive plant species on the refuge. Soils showed very little direct physical damage, no soil compaction, excessive erosion or off-road vehicle damage. More of the refuge is in poorer condition due to the areas that have completely transformed into ruderal types (areas that are dominated entirely by non-native species and are now beyond the natural variation of the native vegetation community once present).

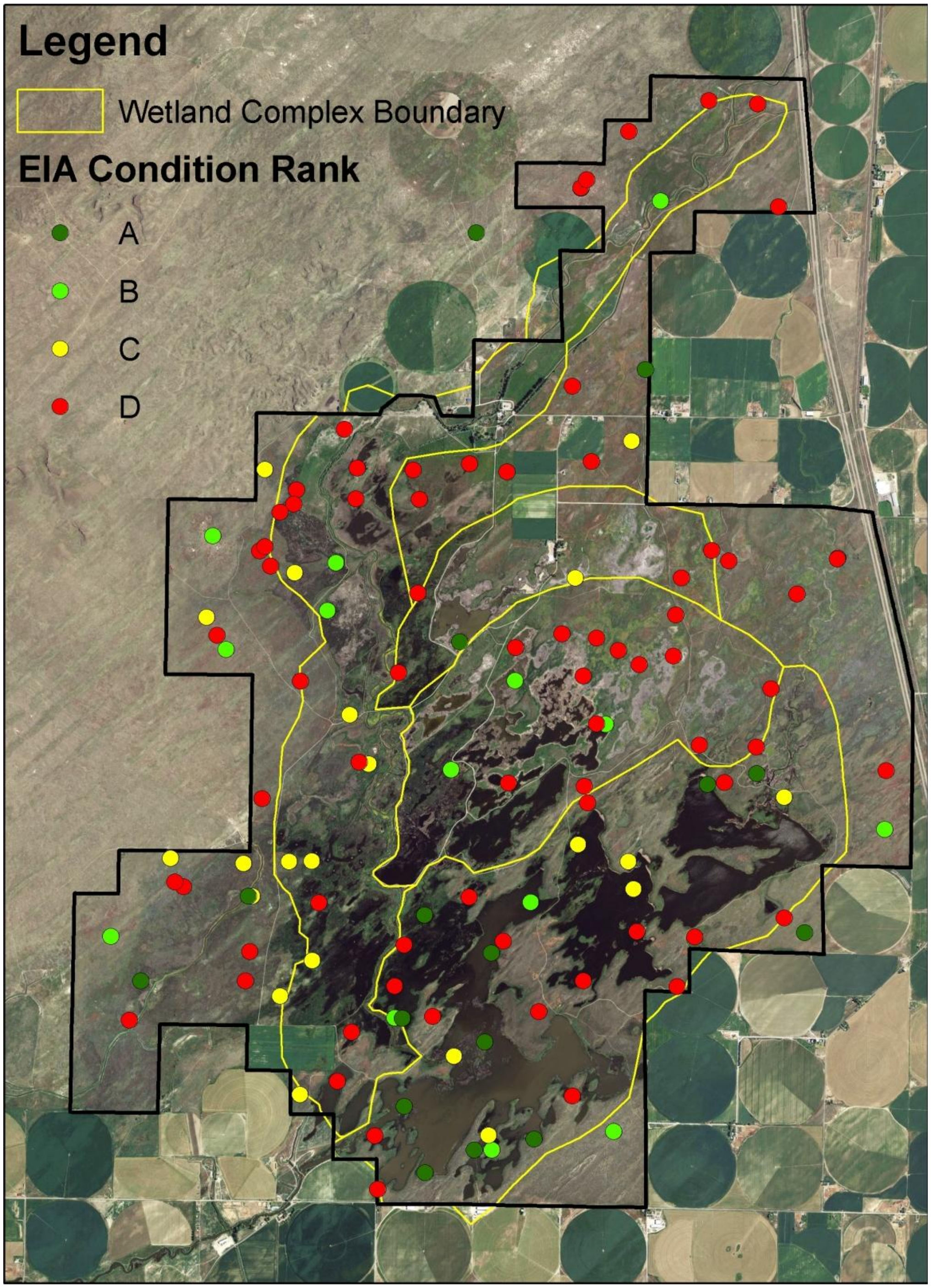


Figure 4. Sample locations color coded to their EIA rank score. Dark Green = A (Excellent), Pale Green = B (Good), Yellow = C (Moderate), Red = D (Poor).

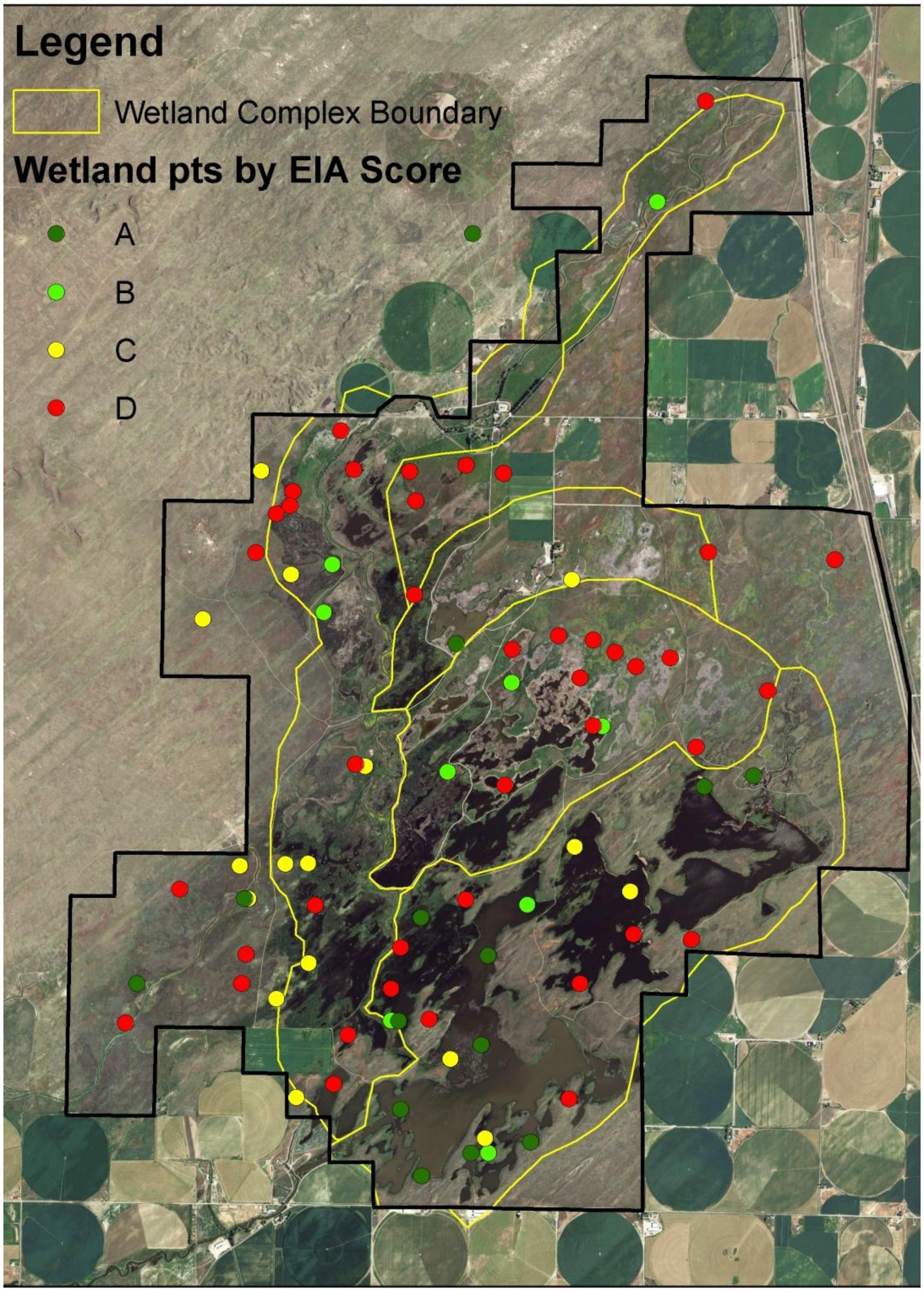


Figure 5. Wetland sample points color coded by their EIA rank score. Dark Green = A (Excellent), Pale Green = B (Good), Yellow = C (Moderate), Red = D (Poor).

Table 1. Wetland individual point EIA scores. Scores are on a 1-5 scale, where 5 represents undisturbed, full capacity ecological integrity ecosystem, and a score of 1 means completely altered ecosystem with very little ability to buffer or resist stressors.

EIA Score	EIA Rank	# Points	% by Rank
4.5 – 5.0	A	14	15%
3.1 - 4.4	B	15	16%
1.9 - 3.0	C	26	28%
1.0 - 1.8	D	38	41%
	Total	**93**	

Looking at the Ecological integrity scores summarized by their vegetation classification, by the US NVC Group type, we can tease out the condition of remaining native, non-ruderal habitats. The Freshwater Marsh Group (US NVC G518 Western North American Temperate Interior Freshwater Marsh Group) consists of emergent wetland vegetation dominated by tall reeds such as hardstem bulrush (*Schenoplectus acutus*) and cattails (*Typha latifolia*) or the much shorter spike rush (*Eleocharis palustris*). These wetlands remain saturated or with standing water for much of the growing season and are therefore often nearly devoid of invasive weed species. About half of the Freshwater Marsh areas sampled were in excellent condition (47%), 21% in good condition, 21% in Fair condition and 11% in Poor condition (Figure 6). Poor condition sites were often located at the drier fringes of the wetland where invasive weeds gain greater foothold.

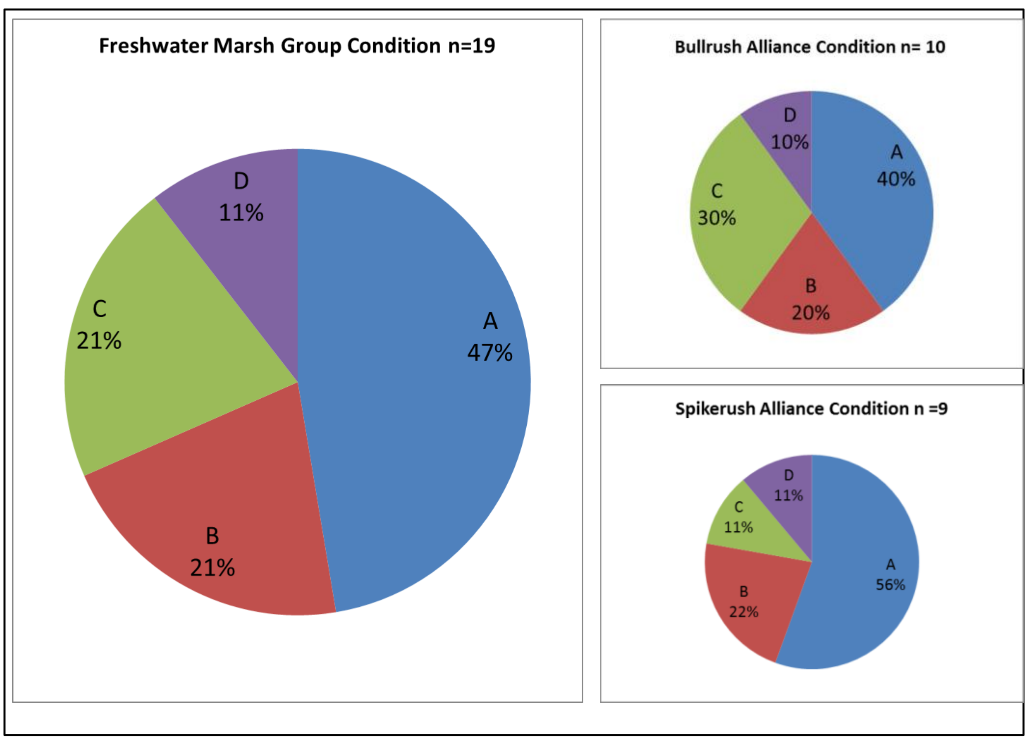


Figure 6. Ecological Integrity Assessment Scores for Freshwater Marsh Group. Level-2 field-based scores summed by US NVC Group (G518 Western North American Temperate Interior Freshwater Marsh Group, also known as “Freshwater Marsh Group”) and two nested component alliances, Hardstem Bulrush Alliance (*Schoenoplectus acutus* Alliance) and the Spike rush Alliance (*Eleocharis palustris* Alliance).

The Wet Meadow Group (USNVC G521 Vancouverian & Rocky Mountain Montane Wet Meadow Group) was sampled 28 times and shows 12% in excellent condition, 17% in good condition, about half of the areas in fair condition, and a quarter in poor condition (Figure 7). Breaking this down by alliance, we find more poor condition Baltic rush (*Juncus balticus*) alliance than the montane sedge alliance. The Baltic Rush alliance had more samples where quack grass (*Agropyron repens*) was co-dominant, whereas the montane sedge meadow alliance had stands with not as abundant invasive species.

Riparian shrublands Group (USNVC G526 Rocky Mountain & Great Basin Lowland & foothill Riparian & Seep Shrubland Group) had only a few samples but these are in better condition than their meadow neighbors, with three-quarters in excellent to good condition and a quarter in poor condition (Figure 8).

The Ruderal wet meadow & Marsh Group is by definition dominated by non-native invasive species and the assumption in applying EIA ranking criteria is that these areas were once the native wet meadow type that has now been completely transformed into a novel ruderal type. The EIA score of "D" or poor, is consistent with the classification of these areas, i.e. they are no longer functioning as (and are outside the natural range of variation of) their native counterparts (Figure 8).

Additional sample points from freshwater and alkaline flats continue the similar trend with 20% in good condition and 80% in fair to poor condition (Figure 9).

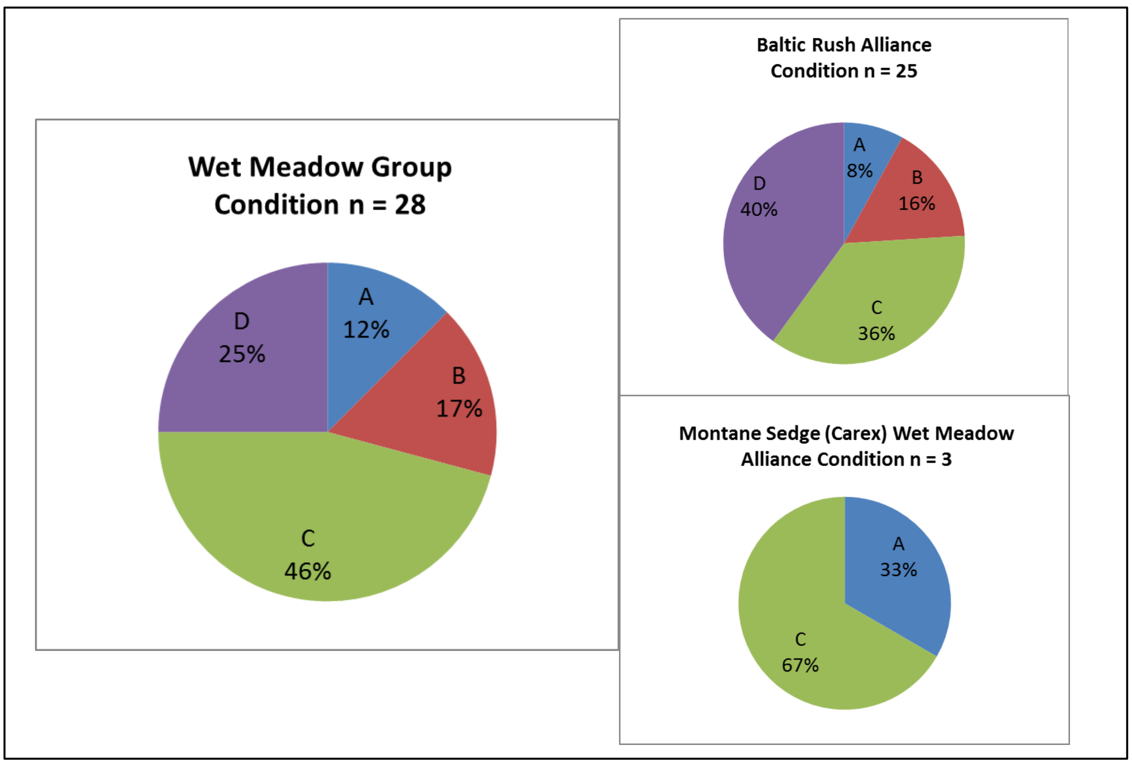


Figure 7. Ecological Integrity Assessment Scores for Wet Meadow Group. Level-2 field-based scores summed by US NVC Group (G521 Vancouverian & Rocky Mountain Montane Wet Meadow Group, also known as "Wet Meadow Group), and the nested component alliances (Baltic Rush Alliance) and Montane Sedge (Sedge (wheat, clustered field, Northwest Territory) Wet Meadow Alliance.

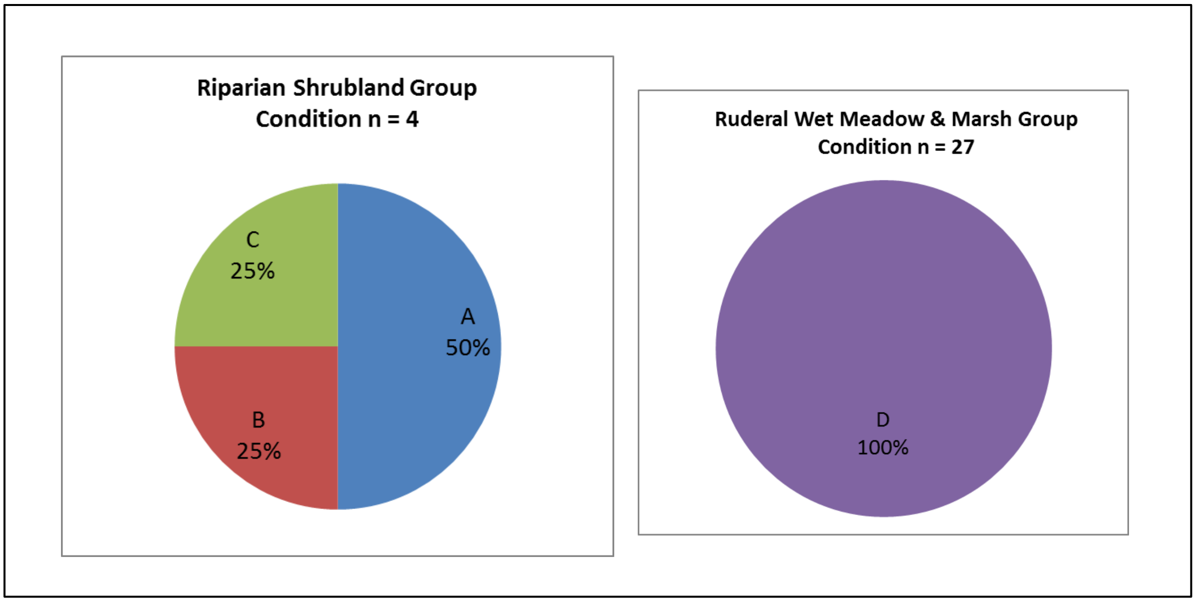


Figure 8. Ecological Integrity Assessment Scores for Riparian Shrubland Group and the Ruderal Wet Meadow & Marsh Group.

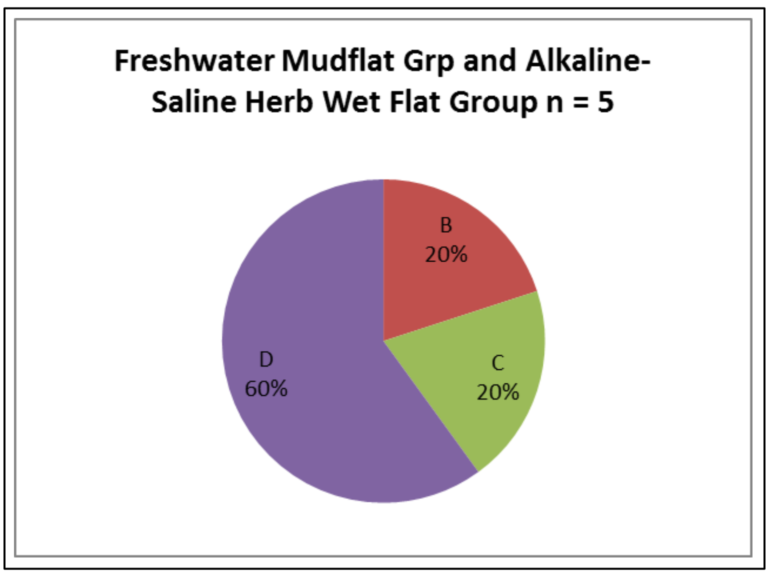


Figure 9. Ecological Integrity Assessment Scores for Freshwater and Alkaline Mudflat Groups.

One of the important techniques of the ecological integrity assessment is that the field observers not only collect data from sample points but also from throughout the entire assessment area. In the process of walking and driving to each random point, ecologists also noted the condition and species composition of areas they passed through. While the number of samples points per US NVC type was low, when combined with general field observations of the entire refuge, we can confirm that the sample points are representative of the overall condition of these types throughout the refuge.

The unbiased, random sampling found with nearly 25% of the native wetland types in "A" excellent condition. This means that these and other reference examples of the native wetlands occur within refuge boundaries. Goals for future conditions of specific areas of wetland types can be set based on references sites on the refuge. Further studies of these references areas can increase understanding of soils, topography, hydrology and historic land uses that maintain these sites. This type of information will be invaluable in restoration and weed control efforts for wetlands on the refuge.

Camas can improve its ecological health through the removal and reduction of invasive weeds via non-chemical methods. Short-term intensive grazing by goats or cows, applied at the right time of year, can be very efficient form of weed control (Wilson and Pärtel 2003, De Bruijn and Bork 2006). Restoration of areas by introduction of native species, especially through native seeds collected locally, will increase the resiliency of the refuge habitats.

2.9.1.2 Uplands

Upland sites EIA scores overall about one third (27%) rank excellent to good (A –B), 74% rank fair to poor (C- D), with the largest proportion (65%) falling within the "D" rank category (Table 2, **Figure 10**). The best sites had the least amount of invasive species while the lowest scoring sites are from upland areas converted to crested wheatgrass, a non-native grass planted to prevent soil erosion.

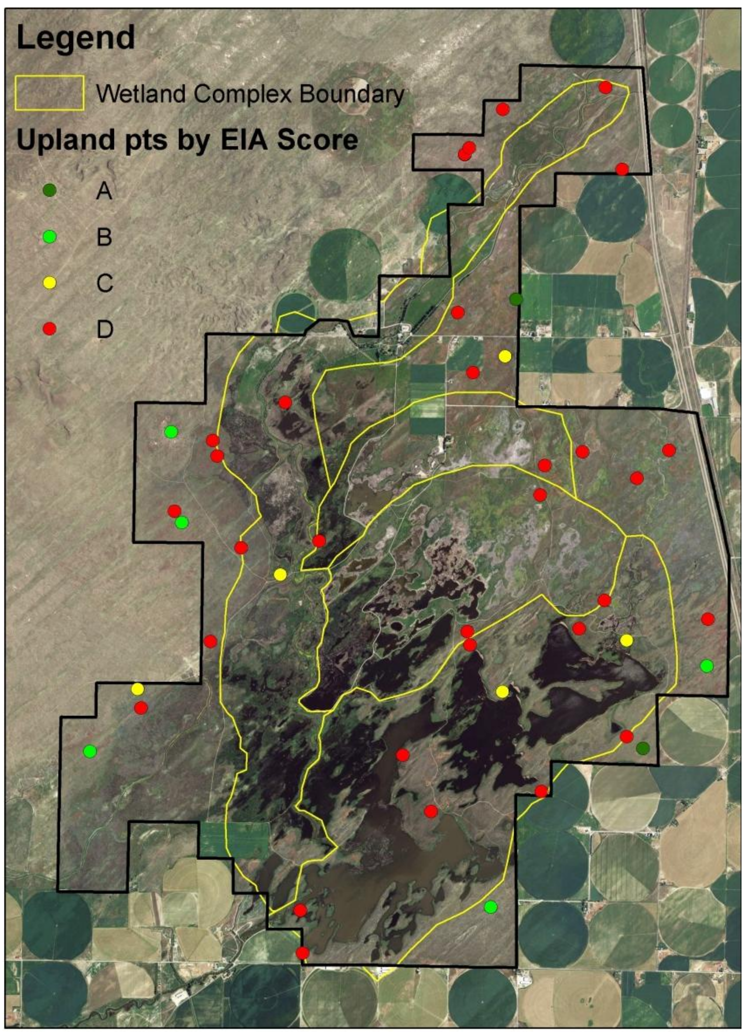


Figure 10. Upland sample points and their EIA scores. Dark Green = A (Excellent), Pale Green = B (Good), Yellow = C (Moderate), Red = D (Poor).

Table 2. Upland individual points EIA scores**.** Scores are on a 1-5 scale, where 5 represents undisturbed, full capacity ecological integrity ecosystem, and a score of 1 means completely altered ecosystem with very little ability to buffer or resist stressors.

EIA Score	EIA Rank	# Points	% by Rank
4.5 – 5.0	A	3	9%
3.1 - 4.4	B	6	18%
1.9 - 3.0	C	3	9%
0.0 - 1.8	D	22	65%
	Total	**34**	

When we examine the uplands by their USNVC Group type a more nuanced picture of how well the native upland habitats are doing on the refuge emerges. Between 20% and 40% of the native upland habitats sampled are in good to excellent condition (Figure 11). Rabbitbrush shrublands are areas that have been burned within the last 10-20 years, and that disturbance has allowed for a greater influx of non-native invasive grasses such as cheat grass (*Bromus tectorum*), which, along with the history of grazing, may explain the higher proportion of "D" ranked areas within this type. The Sagebrush steppe and desert grasslands habitats had excellent weed free examples in the northwest corner of the refuge (Figure 10). Many areas of Sagebrush Steppe have an understory of non-native invasive grasses, and were scored "D". These points correspond to areas mapped as "Sagebrush Steppe, ruderal" to distinguish from areas of sagebrush steppe with native understory grasses. The map unit "Sagebrush Steppe, native" corresponds with points ranked of A, B and C.

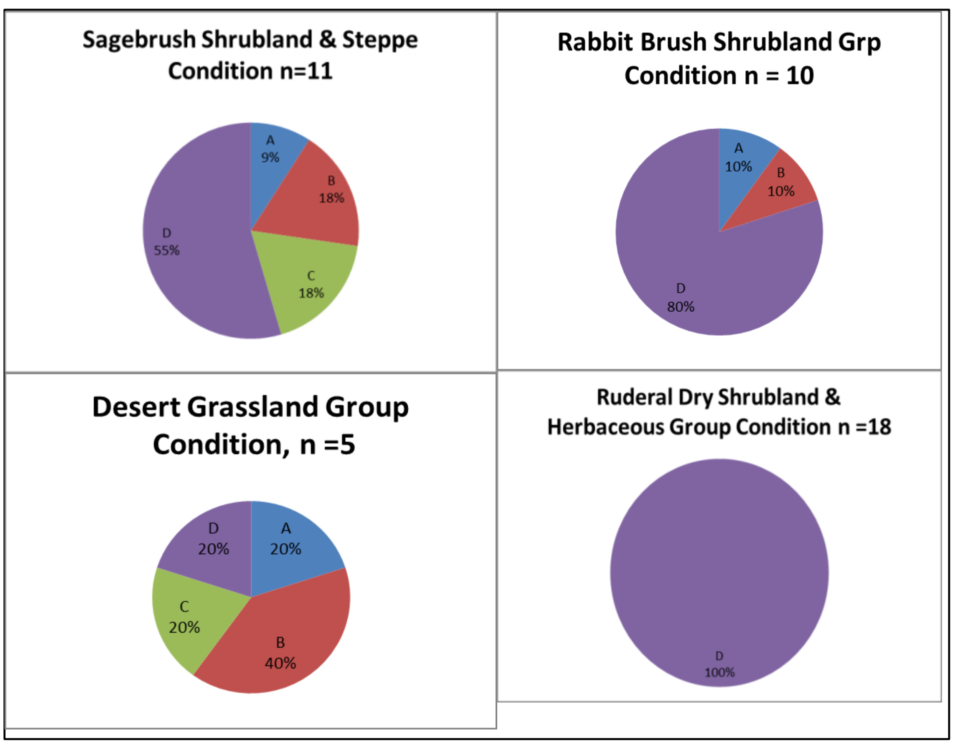


Figure 11. Ecological Integrity Assessment Scores for Upland habitats. EIA Level-2 field-based scores summed by US NVC Group: G303 Intermountain Dry Tall Sagebrush Shrubland & Steppe Group "Sagebrush Shrubland & Steppe Group", G310 Intermountain Semi-Desert Shrubland Group

"Rabbitbrush Shrubland Group", G311 Intermountain Semi-Desert Grassland & Steppe Group "Desert Grassland Group", and the G600 Great Basin & Intermountain Ruderal Dry Shrubland & Grassland Group "Ruderal Dry Shrubland & herbaceous Group".

Upland sample points ranked "A" and "B" can be used as reference sites for these habitats on the refuge. Goals for future conditions of specific upland habitats and designated restoration areas can be based on conditions found at these references sites. Further studies of the references areas should reap additional understanding of soils, topography and historic land uses that maintain these sites. This type of information will be invaluable in restoration and weed control efforts on uplands on the refuge.

Weed control and restoration of crested wheat grass areas will improve Camas upland habitat ecological integrity and improve resiliency to other stressors such as Climate Change.

2.9.2 *Wetland Complex Assessments -- Results and Discussion*

The Ecological Integrity Assessment score for each wetland complex combines the Level-1 Landscape metrics of surrounding land use context, wetland buffer index, hydrology index, and size (reviewed in section 2.7) with the Level-2 field based assessments (condition scores from wetland sample points that geographically fell within each wetland complex were averaged together). Landscape context scored well as the refuge is large enough to have natural uplands surrounding much of the wetland areas. Buffer index scores were fair to poor due to refuge roads that are immediately adjacent to wetlands. The wetlands are relatively large examples of riparian corridor, marsh and wet meadow habitats, so the size metrics scored well. Each wetland complex contains both good and poor condition vegetation metrics (as seen in the individual assessments, above). The hydrology scores are fairly high because while the source of water is artificial, the hydrologic regime follows a pattern of high spring flows with a fall drawdown period, which may be similar to the historic hydroperiod. The neighboring lands have seen enormous growth in irrigated agricultural increasing the demand for groundwater. This use of groundwater is higher than the annual recharge rate such that the groundwater table has dropped 10 feet. Wells that used to keep a high water table under Camas have had reduced flows or have dried up altogether. Current refuge management pumps groundwater and directs the flow onto the wetlands has essentially replaced the historic water table levels. The hydrology metric scores document that hydrology is highly managed but the result of this is a continued shallow water table and hydrologic continuity between the wetlands. Without the artificial water additions to the refuge wetland areas would shrink dramatically. Hydrology scores for Camas Creek however scored much lower due to alterations of in-channel flows (diversions)(Figure 12), channel dredging and elevation and steepening of channel banks.

Metric scores were entered into the EIA Access database which provides a 'scorecard' summarizing all metrics into a single overall score for each wetland complex (Table 3). The overall scores reflect the low vegetation and buffer metrics, balanced against the higher scores for landscape context, hydrology and size metrics. Total scores ranged from poor (C) to good (B-). In the following sections we explore the details of each wetland complex score for the four wetland complexes: Camas Creek (Figure 13), Big Pond (Figure 14), Center Pond (Figure 15), and Ray's Lake (Figure 16). Some of the metrics listed on the scorecard were not used and are left blank[2].

[2] Metrics "Vegetation Structure" and "Vegetation Regeneration" were not assessed, as these are more appropriate for forested vegetation types. Metrics "Native Bunchgrass", "Biological Soil Crust" and "Fire-sensitive shrubs" are specifically designed for upland vegetation and were not applied to wetland complex scores.

Table 3. Wetland Complex EIA scores**.** Scores are on a 1-5 scale, where 5 represents undisturbed, full capacity ecological integrity ecosystem, and a score of 1 means completely altered ecosystem with very little ability to buffer or resist stressors.

Wetland Complex	EIA Score	EIA Rank	# Level 2 plots	% of Plots
Camas Creek & Floodplain	2.3	**C**	39	42%
Center Pond	3.1	**C**	16	17%
Big Pond	3.3	**B -**	6	6%
Ray's Lake	3.3	**B -**	32	34%

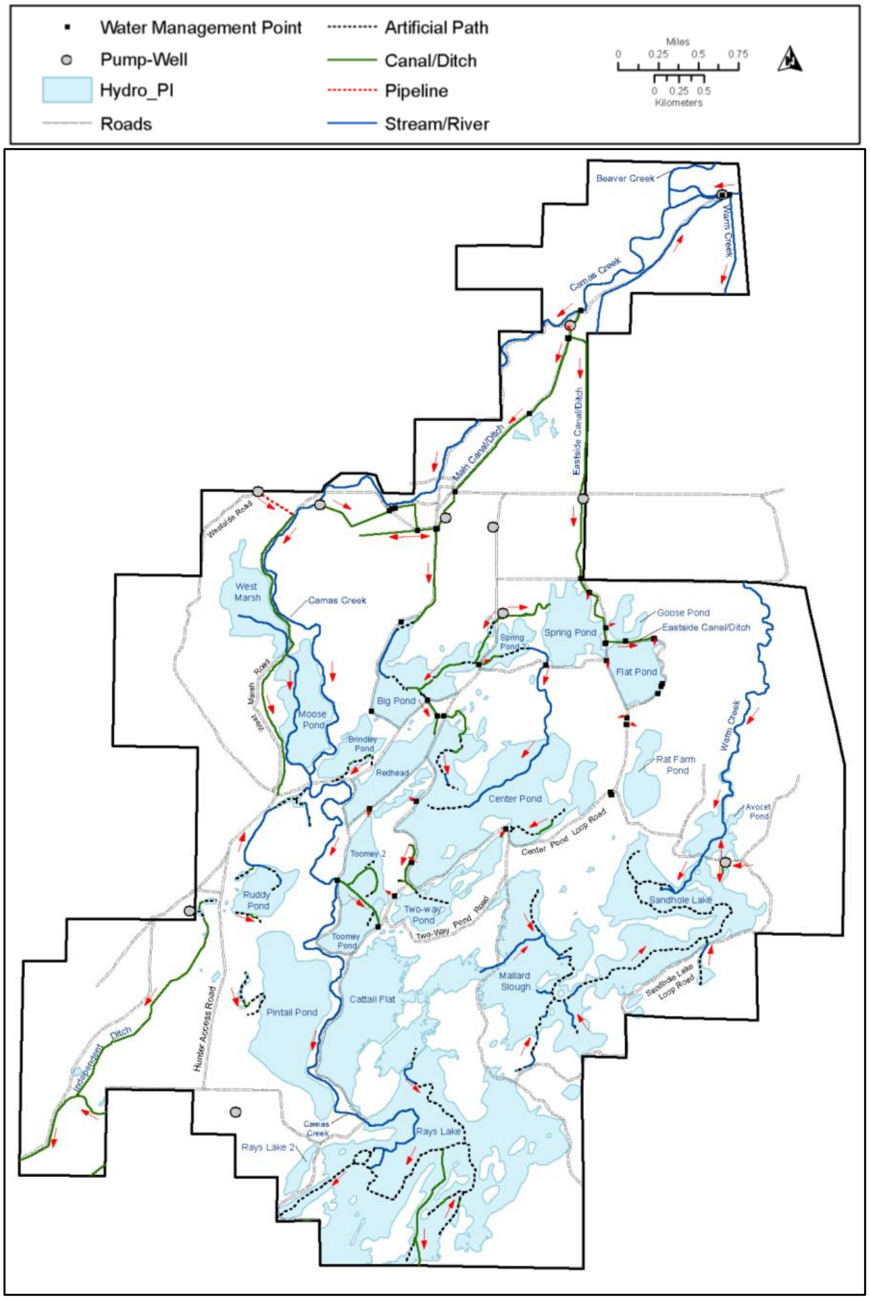


Figure 12. Water Resource Inventory Camas NWR. Red arrows are direction of flow.

2.9.2.1 Camas Creek & Floodplain EIA Score and Discussion

The Camas Creek riparian area and floodplain received few excellent scores and several poor scores for a total EIA score of “C” or fair (Figure 13). The landscape context is good for the riparian corridor as natural uplands and adjacent wetlands surround the corridor (an “A” score). The buffer index is poor as the buffer is interrupted by roads, ditches, and agricultural use, mostly on the north and west sides, less so on the south and east side, and the buffer width is constricted by the refuge utility compound, roads, agriculture that occur within the 100 m buffer, and there are areas of continuous weedy vegetation (a buffer Index score of “D”). The overall Landscape Score combines the Landscape Context and Buffer Index Scores, into a “C” score.

The absolute size of the riparian corridor is a healthy 6 mile plus corridor and ranked an “A” score. However the relative size has been reduced through alteration of stream banks and floodplain, narrowing the riparian corridor, the relative size ranking is “C” or Fair, so the total Size ranking is a “B” score.

Condition score is comprised of vegetation, hydrology and soil condition scores. Vegetation condition in the floodplain of Camas Creek is highly altered. There are areas where the land has been leveled and cleared and quackgrass (*Agropyron repens*) planted, and contains areas with abundant weeds such as Canada thistle (*Cirsium arvense*). There are areas of native woody riparian shrub cover along the river banks, and areas with very few weeds. However these weed-free areas are tiny relative to the amount of altered land within the Camas Creek floodplain. Vegetation scores therefore averaged out to a “D” or poor, score. The hydrology of the river channel has been altered in several ways: ditches remove water from the stream channel both upstream, midstream and downstream of the refuge (Figure 12), reducing the natural water source of in-stream waters and changing the hydroperiod (timing and duration of seasonal high and low flows). The immediate channel has been dredged and the stream banks augmented in height that reduces the hydrologic connection of the channel with the floodplain, so that overbank flooding happens less frequently. Hydrology scores are all very low (D for hydro connectivity, hydroperiod and water source). Current soil condition is good, with little evidence of compaction or churning, no off-road vehicle damage or excessive erosion. Finally physical alterations to the channel and bank have changed the physical patch diversity in the channel itself (reduction in channel sinuosity, pool to riffle ratios and that of the stream bank, higher in many places (Physical Patch Type score D). The total Condition score is an average of these components and comes out as a “D” or poor score.

The Camas Creek & Floodplain wetland complex Ecological Integrity Assessment score is an average of the Landscape Context, Size and Condition component scores for a final Ecological Integrity score of 2.3, “C” or fair.

Management recommendations focus on the greatest room for improvement, namely the condition of vegetation, patch diversity and hydrology. Management recommendations are to 1) bring the channel and stream bank physical configuration back to historic ratios to allow for natural flows and to re-connect the floodplain with channel flows; 2) reduce and eradicate non-native invasive weeds from fields through the use of non-chemical methods such as intensive, area-controlled grazing by goats or cows; 3) conduct restoration of abandoned agricultural fields in order to convert them back to native wet meadow vegetation.

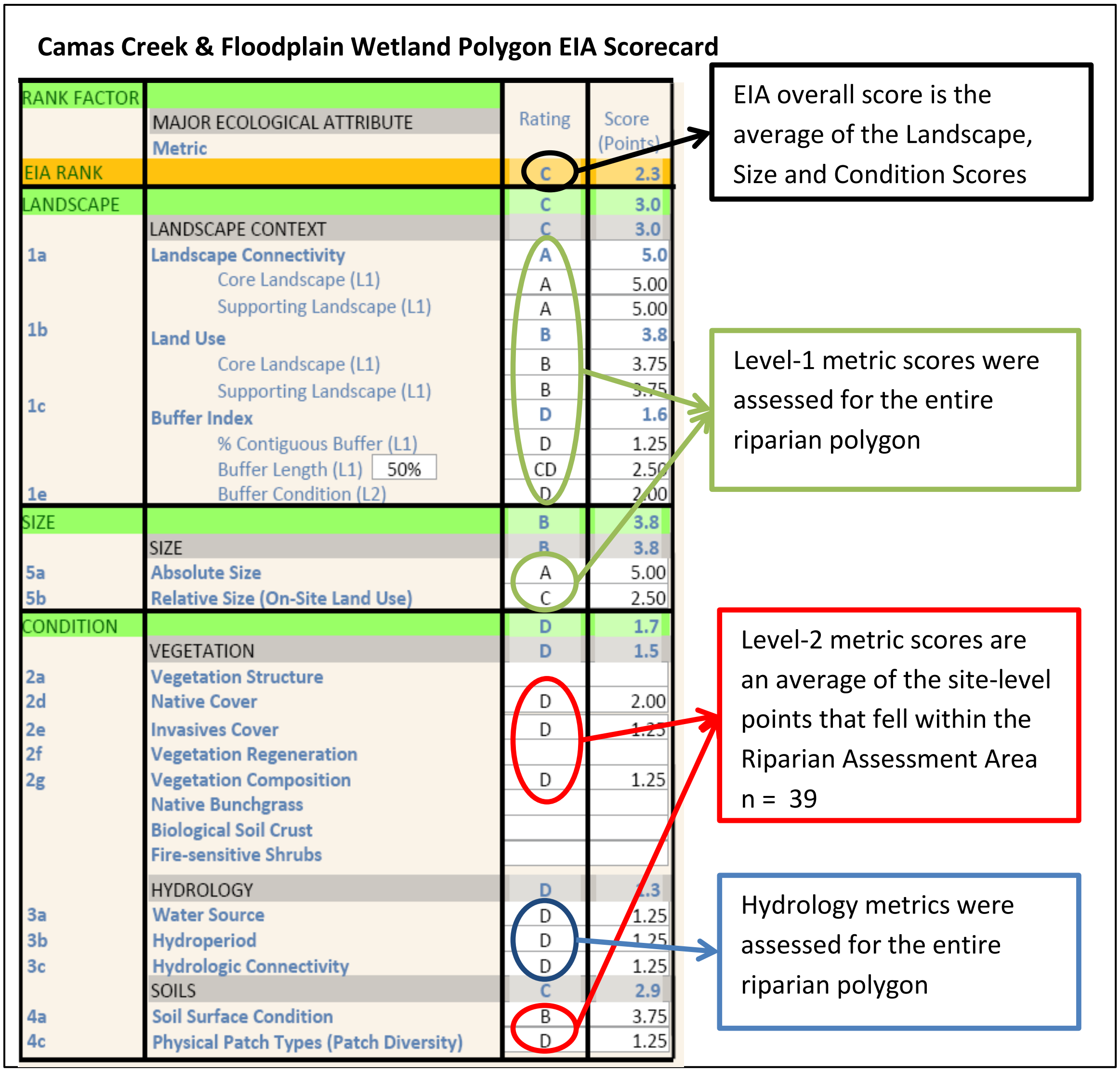


Figure 13. Camas Creek & Floodplain EIA Scorecard. Level-1 Landscape and buffer metrics applied to the area illustrated in **Figure 3** with combined scores from 39 level-2 field points. Condition is a summary of the Soils, hydrology and vegetation metrics (red & blue circles). Vegetation and Soil metrics were averaged across the 39 level-2 points that fell within the riparian area boundary. Size and Landscape rankings are based on GIS mapping information with field verification. Hydrology was assessed both in the field and from expert knowledge (refuge management and historical records). Not all metrics were applied to wetland complexes, see footnote 1.

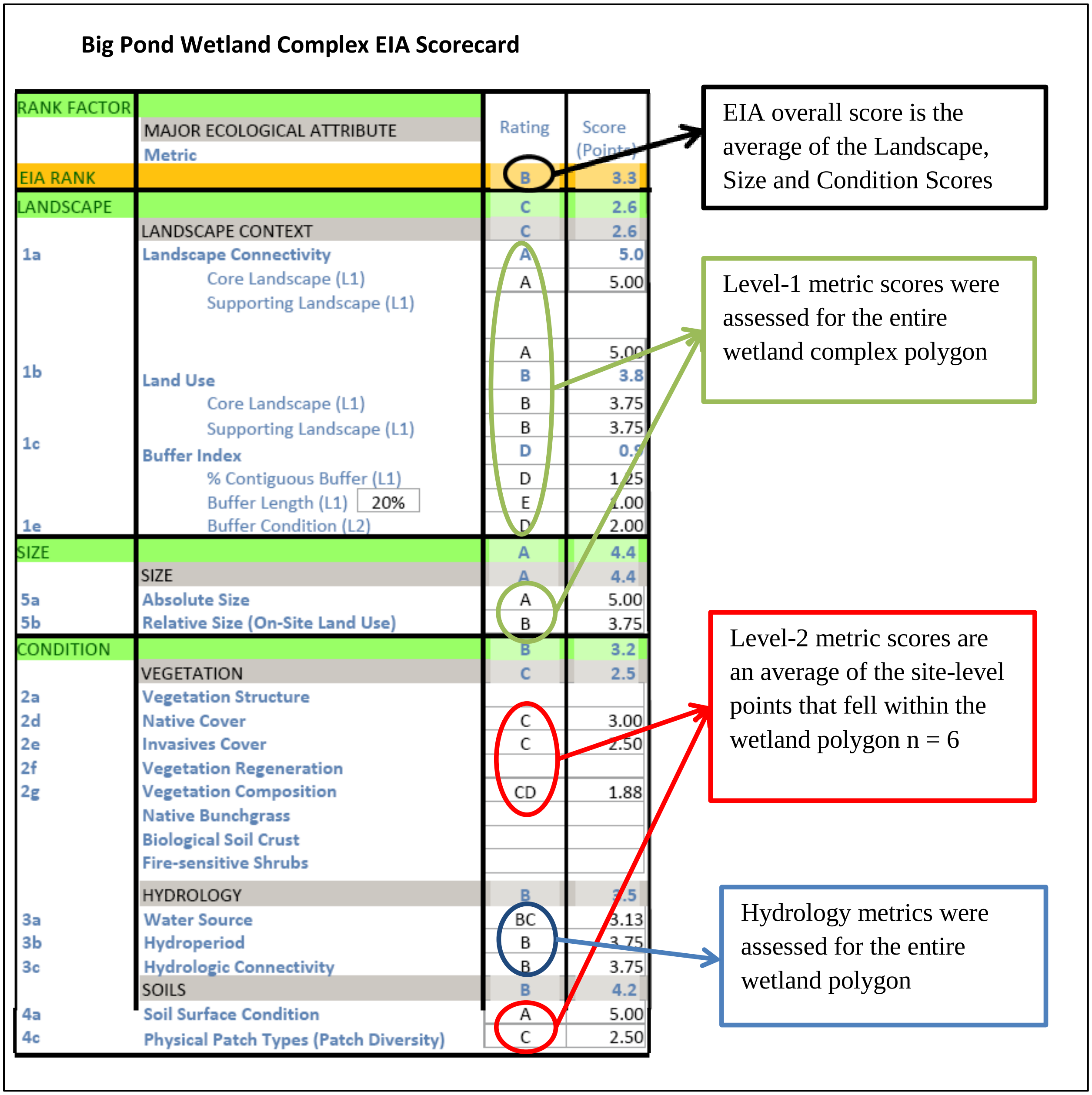
2.9.2.2 Big Pond Wetland Complex EIA Score and Discussion

Big Pond wetland Complex (Figure 3) included Big Pond, Spring Pond, Flat Pond and Brindley Pond (Figure 12). Component metric scores included some excellent and poor rating scores for a total Ecological Integrity Assessment score of 3.3, "B-" or fair/good (Figure 14). The Landscape context is very good being for the most part surrounded by other wetlands, natural vegetative cover, with only a small amount of irrigated agriculture (score "A") . The immediate buffer area surrounding the wetland contains a 15-20 m wide dirt road on a raised dike that nearly surrounds the wetland, while the rest is native or weeded vegetation (Buffer Index score "D"). The total Landscape score is then a "C" or Fair score.

The size of Big Pond wetland Complex is typical and relatively large for this type of wetland (score "A"), but the loss of an artesian well due to a drop in the ground water table has reduced the historic extent of this wetland area, giving a relative size score "B". The total Size score still averaged out to an "A", excellent score.

The vegetation condition within Big Pond has areas of entirely native emergent marshes of bulrush and cattail cover and native wet meadows of Baltic rush. However it also contains large areas of non-native invasive weeds that have transformed formerly native wet meadows into ruderal vegetation, likely due to the loss of groundwater upwelling in the northeast corner of the wetland. The average of the 6 field based level-2 sites for vegetation condition metrics comes to a "C" or fair rating. The hydrology metrics are scored as good as the refuge management is actively replacing lost groundwater upwelling with pumped water (Figure 12), and the hydroperiod as managed may be replacing the historic pattern of high spring flows with late fall drawn downs. In addition, the water management allows for hydrologic connectivity between Big Pond and Center Pond wetland complexes, total Hydrology Score is "B" or good. Current soil surface conditions appear excellent with little compaction, erosion, damage or off-road vehicle use: score "A". However the physical patch type or Patch diversity has been altered as the ponds are deeper and there is more open water than was historically present for a score of "C". The total Condition score combines the vegetation condition, hydrology condition and soils condition which averages out to a "B" or good score. We did not use the vegetation structure and regeneration metrics as they are not applicable for herbaceous communities and the native bunchgrass, biological soil crust and fire-sensitive shrub metrics apply only to uplands.

The overall Ecological Integrity Assessment score for Big Pond wetland Complex is 3.3, "B-" or fair/good, the numeric score just inside the "B" category. Suggested management recommendations are: 1) to control invasive weeds through non-chemical methods such as short-duration high intensity grazing by goats or cows and 2) improve the buffer capacity to convey water and nutrients to surrounding areas by adding culverts to road berms.



Big Pond Wetland Complex EIA Scorecard

RANK FACTOR	MAJOR ECOLOGICAL ATTRIBUTE / Metric		Rating	Score (Points)
EIA RANK			B	3.3
LANDSCAPE			C	2.6
	LANDSCAPE CONTEXT		C	2.6
1a	Landscape Connectivity		A	5.0
	Core Landscape (L1)		A	5.00
	Supporting Landscape (L1)			
			A	5.00
1b	Land Use		B	3.8
	Core Landscape (L1)		B	3.75
	Supporting Landscape (L1)		B	3.75
1c	Buffer Index		D	0.9
	% Contiguous Buffer (L1)		D	1.25
	Buffer Length (L1)	20%	E	1.00
1e	Buffer Condition (L2)		D	2.00
SIZE			A	4.4
	SIZE		A	4.4
5a	Absolute Size		A	5.00
5b	Relative Size (On-Site Land Use)		B	3.75
CONDITION			B	3.2
	VEGETATION		C	2.5
2a	Vegetation Structure			
2d	Native Cover		C	3.00
2e	Invasives Cover		C	2.50
2f	Vegetation Regeneration			
2g	Vegetation Composition		CD	1.88
	Native Bunchgrass			
	Biological Soil Crust			
	Fire-sensitive Shrubs			
	HYDROLOGY		B	3.5
3a	Water Source		BC	3.13
3b	Hydroperiod		B	3.75
3c	Hydrologic Connectivity		B	3.75
	SOILS		B	4.2
4a	Soil Surface Condition		A	5.00
4c	Physical Patch Types (Patch Diversity)		C	2.50

Figure 14. Big Pond EIA Scorecard. Level-1 Landscape and buffer metrics applied to the area illustrated in **Figure 3** with combined scores from 6 level-2 field points. Condition is a summary of the Soils, hydrology and vegetation metrics (red & blue circles). Vegetation and Soil metrics were averaged across the 6 level-2 points that fell within the wetland area. Size and Landscape rankings are based on GIS mapping information with field verification. Hydrology was assessed both in the field and from expert knowledge (refuge management and historical records).

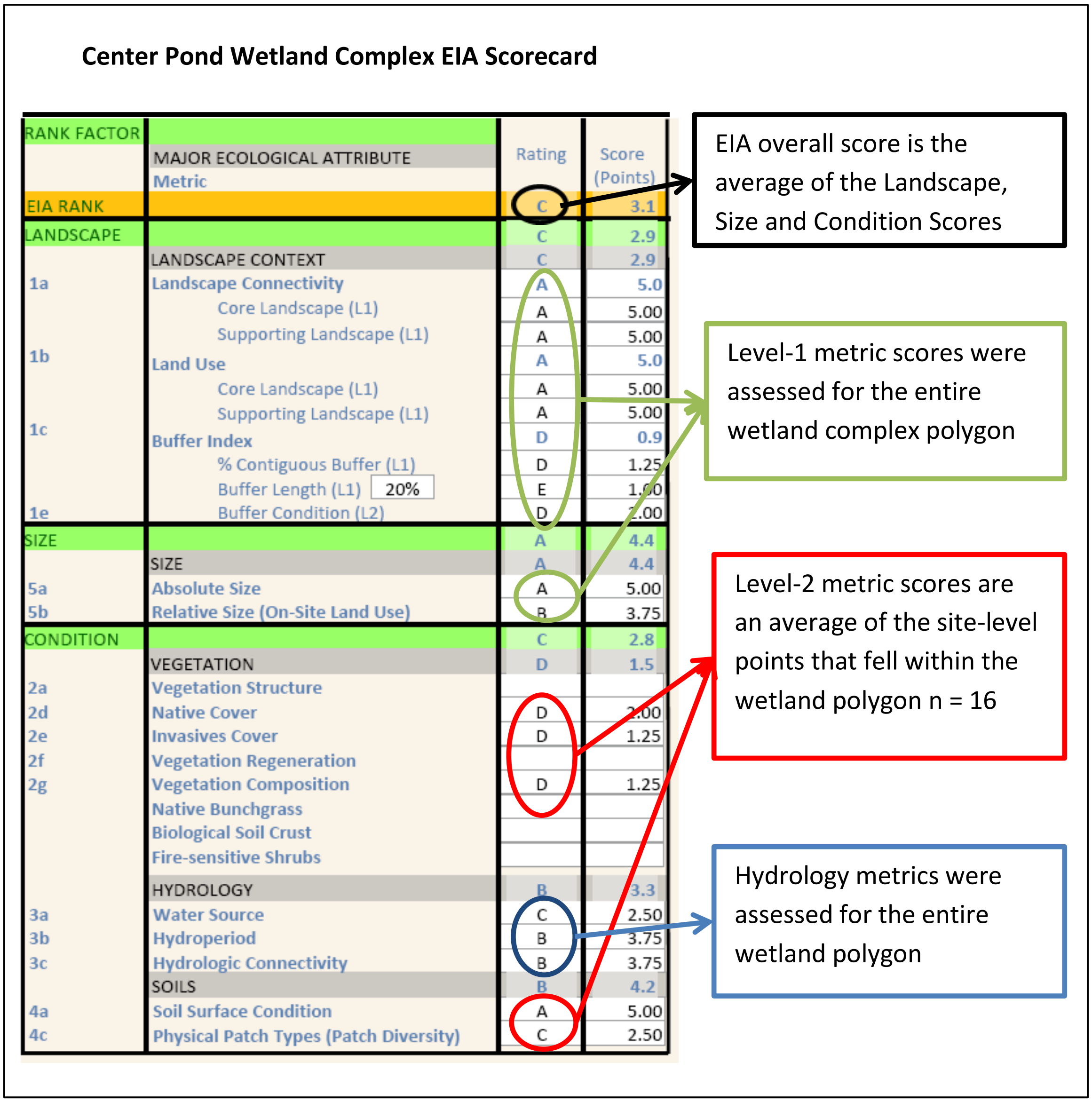
2.9.2.3 Center Pond Wetland EIA Score and Discussion

Center Pond Wetland Complex (Figure 3) consists of Center Pond, Two-way Pond, Toomey Pond, Redhead Pond and Rat Farm Pond(Figure 12). Component metric scores included some excellent and poor rating scores for a total Ecological Integrity Assessment score of 3.1, “C” or fair (Figure 15). As Center Pond Complex is located in the heart of Camas NWR, so the surrounding Landscape beyond the wetland buffer to 500 m is nearly all natural land cover with little human footprint, scoring “A” excellent for both landscape continuity and land use. The immediate wetland buffer however is nearly entirely composed of the refuge access roads, such that the 15-20 m wide dirt road on raised berm nearly surrounds the wetland, so the wetland does not have a natural buffer and condition of the limited area with natural buffer has mostly non-native weedy vegetation, so the Buffer Index score is “D”. The combined Landscape Context (Buffer Index, Land Use and Landscape Connectivity) score is “C”.

The size of Center Pond wetland Complex is typical and relatively large for this type of wetland (score “A”), but the loss of an artesian well due to a drop in the ground water table has reduced the historic extent of this wetland area, giving a relative size score “B”. The total Size score still averaged out to an “A”, excellent score.

The vegetation condition within Center Pond has areas of entirely native emergent marshes of bulrush, cattail and spike rush and native wet meadows of Baltic rush and native sedges. However it also contains large areas of non-native invasive weeds that have transformed formerly native wet meadows into ruderal vegetation likely due to the loss of groundwater upwelling. The average of the 16 field based level-2 sites for vegetation condition metrics comes to a “D” or poor rating. The hydrology metrics are scored as good as the refuge management is actively replacing lost groundwater upwelling with pumped water (Figure 12), and the hydroperiod as managed may be replacing the historic pattern of high spring flows with late fall drawn downs. In addition, the water management allows for hydrologic connectivity between Center Pond and other wetland complexes, total Hydrology Score is “B” or good. Current soil surface conditions appear excellent with little compaction, erosion, damage or off-road vehicle use: score “A”. However the physical patch type or Patch diversity has been altered as the ponds are deeper and there is more open water than was historically present for a score of “C”. The total Condition score combines the vegetation condition, hydrology condition and soils condition which averages out to a “B” or good score. We did not use the vegetation structure and regeneration metrics as they are not applicable for herbaceous communities and the native bunchgrass, biological soil crust and fire-sensitive shrub metrics apply only to uplands.

The overall Ecological Integrity Assessment score for Big Pond wetland Complex is 3.3, “B-” or fair/good, the numeric score just inside the “B” category. Suggested management recommendations are to 1) control invasive weeds through non-chemical methods such as short-duration high intensity grazing by goats or cows and 2) improve the buffer capacity to convey water and nutrients to surrounding areas by adding culverts to road berms.



Center Pond Wetland Complex EIA Scorecard

RANK FACTOR	MAJOR ECOLOGICAL ATTRIBUTE / Metric	Rating	Score (Points)
EIA RANK		C	3.1
LANDSCAPE		C	2.9
	LANDSCAPE CONTEXT	C	2.9
1a	Landscape Connectivity	A	5.0
	Core Landscape (L1)	A	5.00
	Supporting Landscape (L1)	A	5.00
1b	Land Use	A	5.0
	Core Landscape (L1)	A	5.00
	Supporting Landscape (L1)	A	5.00
1c	Buffer Index	D	0.9
	% Contiguous Buffer (L1)	D	1.25
	Buffer Length (L1) 20%	E	1.00
1e	Buffer Condition (L2)	D	2.00
SIZE		A	4.4
	SIZE	A	4.4
5a	Absolute Size	A	5.00
5b	Relative Size (On-Site Land Use)	B	3.75
CONDITION		C	2.8
	VEGETATION	D	1.5
2a	Vegetation Structure		
2d	Native Cover	D	2.00
2e	Invasives Cover	D	1.25
2f	Vegetation Regeneration		
2g	Vegetation Composition	D	1.25
	Native Bunchgrass		
	Biological Soil Crust		
	Fire-sensitive Shrubs		
	HYDROLOGY	B	3.3
3a	Water Source	C	2.50
3b	Hydroperiod	B	3.75
3c	Hydrologic Connectivity	B	3.75
	SOILS	B	4.2
4a	Soil Surface Condition	A	5.00
4c	Physical Patch Types (Patch Diversity)	C	2.50

Figure 15. Center Pond EIA Scorecard. Level-1 Landscape and buffer metrics applied to the area illustrated in **Figure 3**, with combined scores from 16 level-2 field points. Condition is a summary of the soils, hydrology and vegetation metrics (red & blue circles). Vegetation and Soil metrics were averaged across the 16 level-2 points that fell within the wetland area. Size and Landscape rankings are based on GIS mapping information with field verification. Hydrology was assessed both in the field and from expert knowledge (refuge management and historical records). Vegetation structure and regeneration metrics are not applicable for herbaceous communities and the native bunchgrass, biological soil crust and fire-sensitive shrub metrics apply only to uplands.

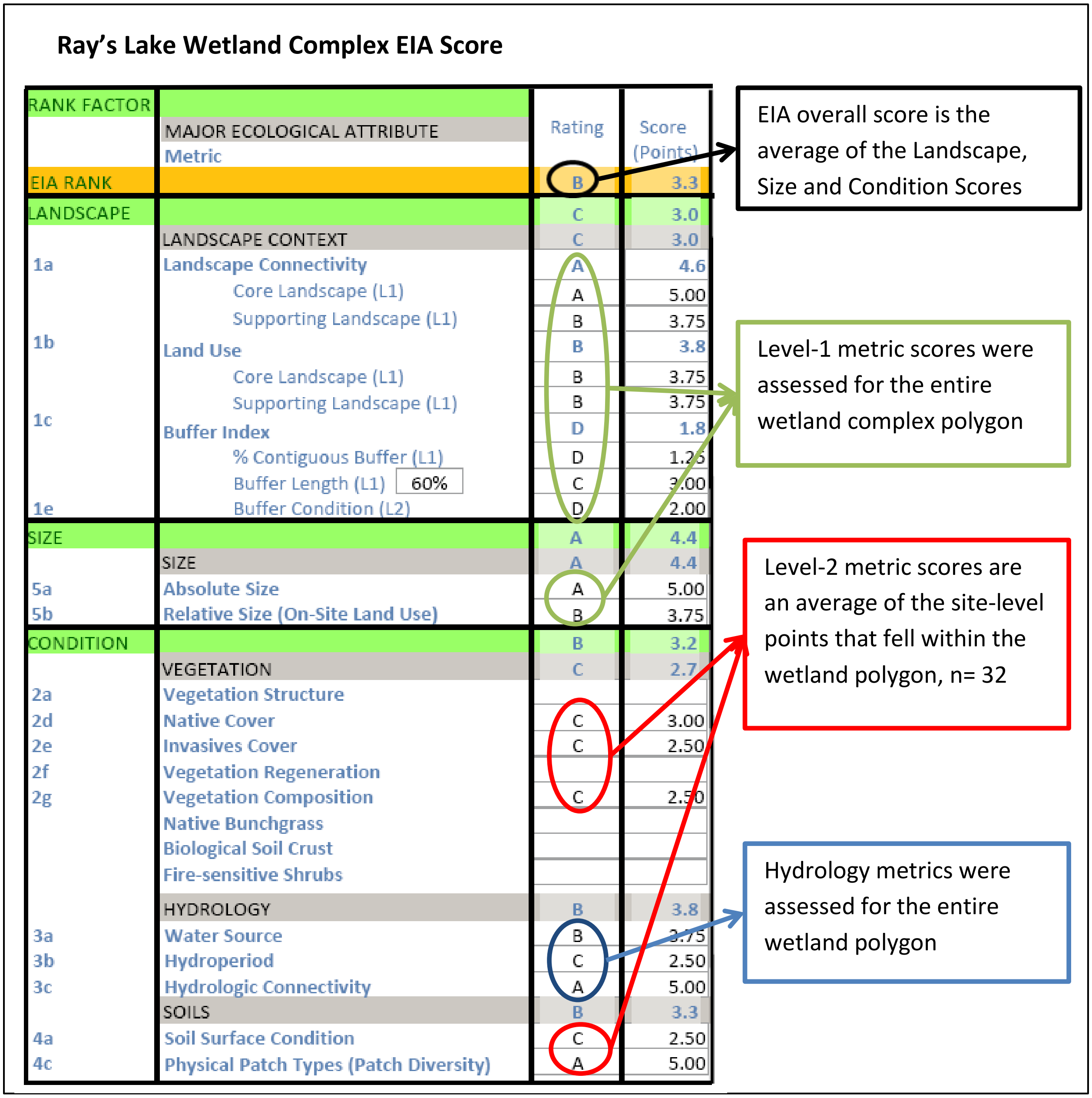
2.9.2.4 Ray's Lake Wetland Complex EIA Score and Discussion

The Ray's Lake wetland complex (Figure 3) included Ray's Lake, Sandhole Lake, Mallard Slough and Cattail Flat areas (Figure 12). Component metric scores included some excellent and poor rating scores for a total Ecological Integrity Assessment score of 3.1, "C" or fair (Figure 16). Ray's Lake Complex is surrounded by neighboring wetland and upland habitats within the 500 m surrounding landscape with little human footprint, scoring "A" excellent for both landscape continuity and land use. The immediate wetland buffer is composed for about half of its length by refuge access roads, such that the 15-20 m wide dirt road on raised berm occurs around about half of the buffer area of, so those areas of the wetland does not have a natural buffer and condition of the rest of area with natural buffer has mostly non-native weedy vegetation, so the Buffer Index score is "D". The combined Landscape Context (Buffer Index, Land Use and Landscape Connectivity) score is "C".

The size of Ray's Lake wetland Complex is typical and relatively large for this type of wetland (score "A"), but the loss of both Camas Creek inflows and artesian wells due to a drop in the ground water table has reduced the historic extent of this wetland area, giving a relative size score "B". The total Size score still averaged out to an "A", excellent score.

The vegetation condition within Ray's Lake has areas of entirely native emergent marshes of bulrush, cattail and spike rush and native wet meadows of Baltic rush and native sedges. However there are large areas of non-native invasive weeds that have transformed formerly native wet meadows into ruderal vegetation; likely due to the loss of groundwater upwelling. The average of the 32 field based level-2 sites for vegetation condition metrics comes to a "C" or Fair rating. The hydrology metrics are scored as good as the refuge management is actively replacing lost groundwater upwelling with pumped water (Figure 12), and the hydroperiod as managed may be replacing the historic pattern of high spring flows with late fall drawn downs. In addition, the water management allows for hydrologic connectivity between Ray's Lake, Camas Creek and other wetland complexes, total Hydrology Score is "B" or good. Current soil surface conditions appear fair with some areas with compaction, erosion, damage or off-road vehicle use: score "C". However the physical patch type or Patch diversity shows what appears to be a natural gradient between shallow marsh and uplands. The Patch diversity appears a near historic pattern for this type of wetland complex for a score of "A". The total Condition score combines the vegetation condition, hydrology condition and soils condition which averages out to a "B" or good score. We did not use the vegetation structure and regeneration metrics as they are not applicable for herbaceous communities and the native bunchgrass, biological soil crust and fire-sensitive shrub metrics apply only to uplands.

The overall Ecological Integrity Assessment score for Ray's Lake wetland Complex is 3.3, "B-" or fair/good, the numeric score just inside the "B" category. Suggested management recommendations are: 1) to control invasive weeds through non-chemical methods such as short-duration high intensity grazing by goats or cows and 2) improve the buffer capacity to convey water and nutrients to surrounding areas by adding culverts to road berms.



Ray's Lake Wetland Complex EIA Score

RANK FACTOR	MAJOR ECOLOGICAL ATTRIBUTE / Metric	Rating	Score (Points)
EIA RANK		B	3.3
LANDSCAPE		C	3.0
	LANDSCAPE CONTEXT	C	3.0
1a	Landscape Connectivity	A	4.6
	Core Landscape (L1)	A	5.00
	Supporting Landscape (L1)	B	3.75
1b	Land Use	B	3.8
	Core Landscape (L1)	B	3.75
	Supporting Landscape (L1)	B	3.75
1c	Buffer Index	D	1.8
	% Contiguous Buffer (L1)	D	1.25
	Buffer Length (L1) 60%	C	3.00
1e	Buffer Condition (L2)	D	2.00
SIZE		A	4.4
	SIZE	A	4.4
5a	Absolute Size	A	5.00
5b	Relative Size (On-Site Land Use)	B	3.75
CONDITION		B	3.2
	VEGETATION	C	2.7
2a	Vegetation Structure		
2d	Native Cover	C	3.00
2e	Invasives Cover	C	2.50
2f	Vegetation Regeneration		
2g	Vegetation Composition	C	2.50
	Native Bunchgrass		
	Biological Soil Crust		
	Fire-sensitive Shrubs		
	HYDROLOGY	B	3.8
3a	Water Source	B	3.75
3b	Hydroperiod	C	2.50
3c	Hydrologic Connectivity	A	5.00
	SOILS	B	3.3
4a	Soil Surface Condition	C	2.50
4c	Physical Patch Types (Patch Diversity)	A	5.00

Figure 16. Ray's Lake EIA Scorecard. Level-1 Landscape and buffer metrics applied to the area illustrated in **Figure 3**, with combined scores from 32 level-2 field points. Condition is a summary of the soils, hydrology and vegetation metrics (red & blue circles). Vegetation and Soil metrics were averaged across the 32 level-2 points that fell within the wetland area. Size and Landscape rankings are based on GIS mapping information with field verification. Hydrology was assessed both in the field and from expert knowledge (refuge management and historical records). Vegetation structure and regeneration metrics are not applicable for herbaceous communities and the native bunchgrass, biological soil crust and fire-sensitive shrub metrics apply only to uplands.

2.10 Summary EIA Findings

Camas wetland complexes ecological integrity scores ranged from poor condition (2.3 or "C") to good condition (3.1 or "B minus") on the EIA 5 point scale. The lowest component scores come from the vegetation metrics due to abundant non-native invasive plant species. In some areas non-native species have completely replaced the native communities. Wetland buffers scores were also low for Center Pond and Ray's Lake because they have roads within their immediate buffer area, contributing to sediment runoff and impeding flows between wetlands. Hydrologic connectivity metric scored low for Camas Creek as it has become disconnected from its floodplain except for the highest flood years, as seen in 2011. The high scores were given for the surrounding Landscape context where native upland habitats surround the refuge wetlands, which serve as buffers to neighboring agricultural fields.

Several pockets of high condition native vegetation were located on the refuge and are excellent examples of native wetland and upland community types. These areas can be used as references points for restoration efforts of the more degraded habitats on the refuge.

The greatest stressors to wetlands at Camas are: loss of a shallow groundwater table, weed infestations, and roads that inhibit water flow between wetlands. The greatest of these is the loss of the shallow water table, which currently is being compensated through ground water pumping by refuge management. Parts of the refuge show significant loss of wetlands that were once supported by the spring fed Warm Creek (Figure 12). This area is currently predominantly covered in non-native invasive species. The hydrologic seepage between the wetland complexes is important to maintain the shallow marsh and wet meadow habitats found between the deeper ponds.

The ecological integrity of Camas can be increased through:

- Aggressively control invasive species
- Restore ruderal areas to appropriate native plant communities
- Retire surface diversion and groundwater pumping permits on surrounding lands
- Protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff
- Increase capacity and number of culverts in roads that block hydrologic flow between wetlands
- Return Camas Creek stream banks to their historic configuration, restore stream channel sinuosity to re-connect the channel with an active floodplain

Weed control is the primary need on the refuge. It appears that many native plant communities may be able to increase in area with adequate weed removal. One very abundant alliance, the Baltic Rush Alliance, is dominated by a native species that increases with disturbance, such as heavy grazing pressure. Several areas sampled were classified to this type, but had many other native graminoid species present. It may be possible through management such as intensive localized grazing (high intensity low frequency) to reduce the abundance of Baltic rush and other less desirable species such as Canadian thistle, and increase the abundance of more desirable grasses and forbs (Wilson and Pärtel 2003, De Bruijn and Bork 2006).

Maintain the hydrologic seepage between the wetland complexes to sustain the shallow marsh and wet meadow habitats found between the deeper ponds. These shallow marsh, wet meadow and alkaline meadow areas are representative of the historic wetland plant communities, and support the greatest biodiversity at Camas. Maintaining the diversity of all habitats will be important in the future to increase the refuge's ability to resist and respond to stressors, such as climate change prediction of longer, warmer and drier growing seasons and further drop in the ground water table level.

3 Camas NWR Watershed Analysis

3.1 Introduction

Now that we have an idea of the level of ecological integrity of the vegetation at Camas NWR (previous section) how does the heath and integrity compare to other wetlands within the watershed? A watershed analysis builds a profile of wetlands throughout the local and surrounding watersheds, and allows us to compare the ecological integrity and rarity of wetlands from a watershed perspective (Kittel and Faber-Langendoen 2011).

3.2 Methods

We develop a profile of wetlands and their condition for two nested watersheds, the local Beaver-Camas watershed and the larger Upper Snake watershed (Figure 17). To determine the condition of each wetland we intersected NatureServe's ecosystem map (NatureServe 2012) with the Landscape Condition Model (Comer and Hak 2009). While Camas NWR was mapped using the National Vegetation Classification standard (FDGC 2008), we used NatureServe's Ecosystem map because it is available nationwide, and NVC Groups are very close in scale to NS Ecosystems (Comer et al. 2003) (see appendix A for crosswalk between classification systems).

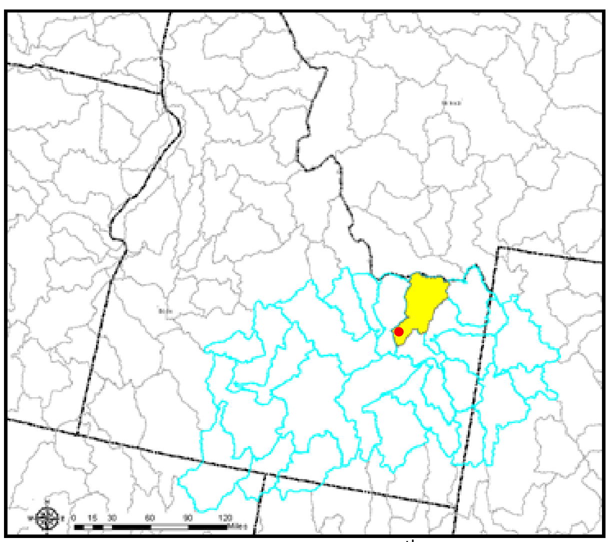


Figure 17. Watershed Map. Upper Snake watershed, USGS 6th level HUC 170402 (blue) and local Beaver-Camas watershed, USGS 8th level watershed 1704214 (yellow). Red dot is approximate location of Camas NWR.

The Landscape Condition Model (LCM) provides a single integrated index of the stressors surrounding a wetland. It is a by-pixel (90 m) model of the degree of impact based on the type and level of impact from human activities such as mines, roads, towns, industrial areas. High impact activities such as a divided highway with heavy traffic are weighted more heavily than lower impacted activity such as a single lane dirt road. A distance decay function extends the impact outward from the point of stress to adjacent areas, based on the relative strength of the stressor. For example, the distance decay function weight for agricultural hay fields is 0.9 (rapid decay) and the decay function weight for a divided highway with heavy traffic is 0.1 (slow, extensive decay) (more detailed methods are available in Appendix D). We intersected the Landscape Condition Model with wetland distribution across the entire watershed to show the range of conditions, from high levels of stressors (e.g., urban areas, roads, mines) to low levels of stressors (e.g., natural, unfragmented land cover, low impact land uses) (Figure 18).

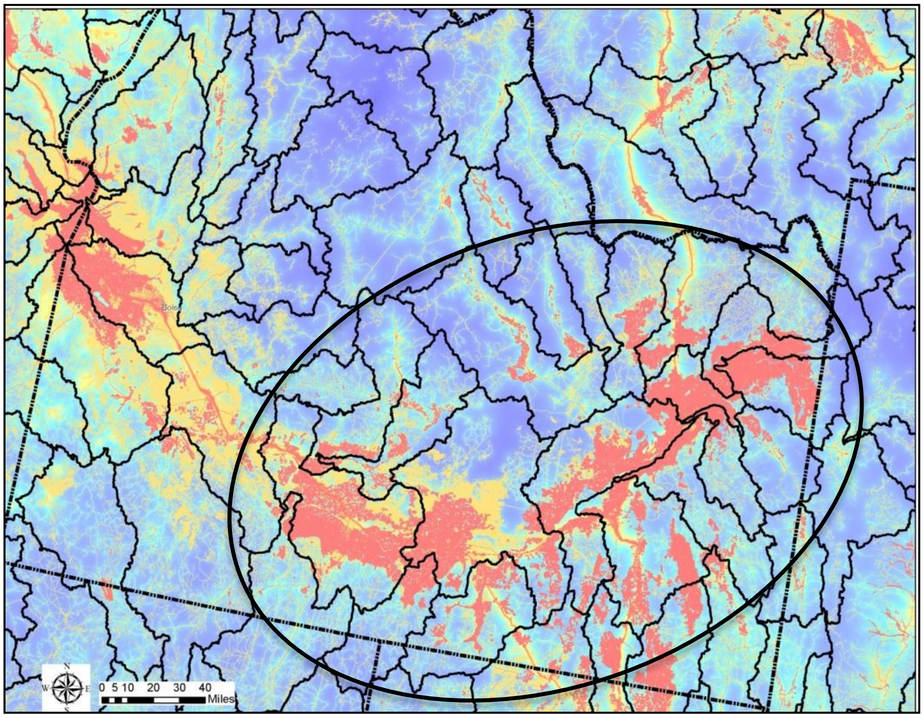


Figure 18. Landscape Condition Model for Southern Idaho. Red are areas of greatest impact, yellow/orange less impact to dark blues least impact from human development including agriculture, transportation corridors, urban and rural development. Circle highlights the Upper Snake Watershed (6th level HUC). Smaller watersheds (8th level HUC) are outlined in back.

3.3 Results

An intersection of NatureServe ecosystems (filtered on wetlands) map with the Landscape Condition model provides an estimate of the condition of each wetland pixel (Figure 19). In this figure we changed the color ramp to appear only on pixels containing wetlands. The color ramp is changed to a green to red scale where green = no impacts, blue minimal impact, orange/yellow = moderate impact levels and red = greatest impact. In Figure 20, we can see just the wetlands and their LCM rating for the entire Upper Snake watershed.

We tallied these results by the number of acres of each wetland by type (Figure 21) and by the overall average LCM score for each type (Figure 22). The Upper Snake watershed contains many montane watersheds and many acres of good condition riparian habitat. The lower elevation riparian type (the "Great Basin Foothill and lower Montane Riparian Woodland and Shrubland") has an overall lower LCM score of 57 “poor condition” because it occurs in and around more agricultural areas. The higher elevation riparian system (the “Rocky Mountain Subalpine-Montane Riparian Shrubland”) has a higher LCM score of 73 “good condition” because it occurs in less impacted areas, although often paralleled by roads.

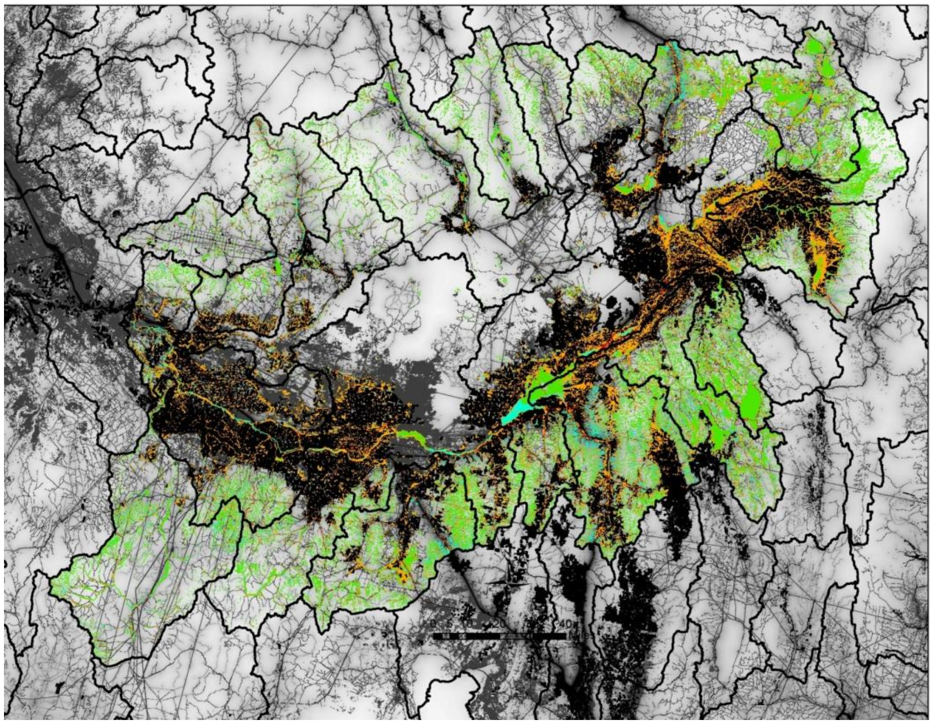


Figure 19. Landscape condition model intersected with wetlands. Color ramp is visible only where wetlands occur, and continues on a black-grey-white scale for uplands. Black is the greatest impact, white the least. For wetland pixels, colors green and blue = least development impact, orange/red highest impact.

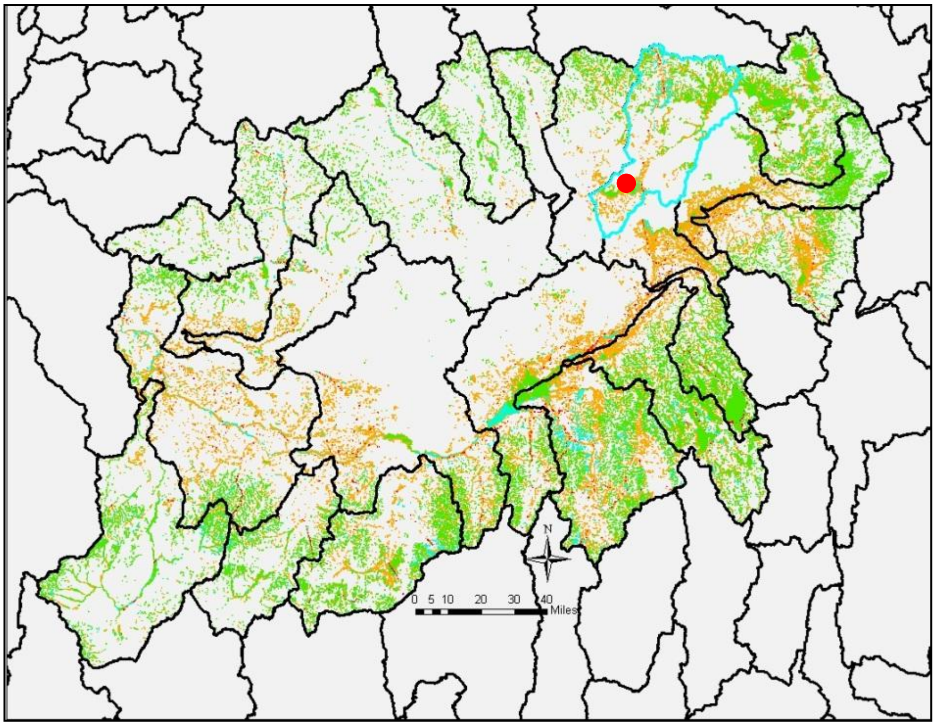


Figure 20. Condition and distribution of wetlands within the Upper Snake Watershed. Green & blue = wetlands with low impact from human development, orange = wetlands moderate levels of development, and red = wetlands with highest level of impact from development. Blue outline is the Beaver - Camas watershed. Red dot is approximate location of Camas NWR.

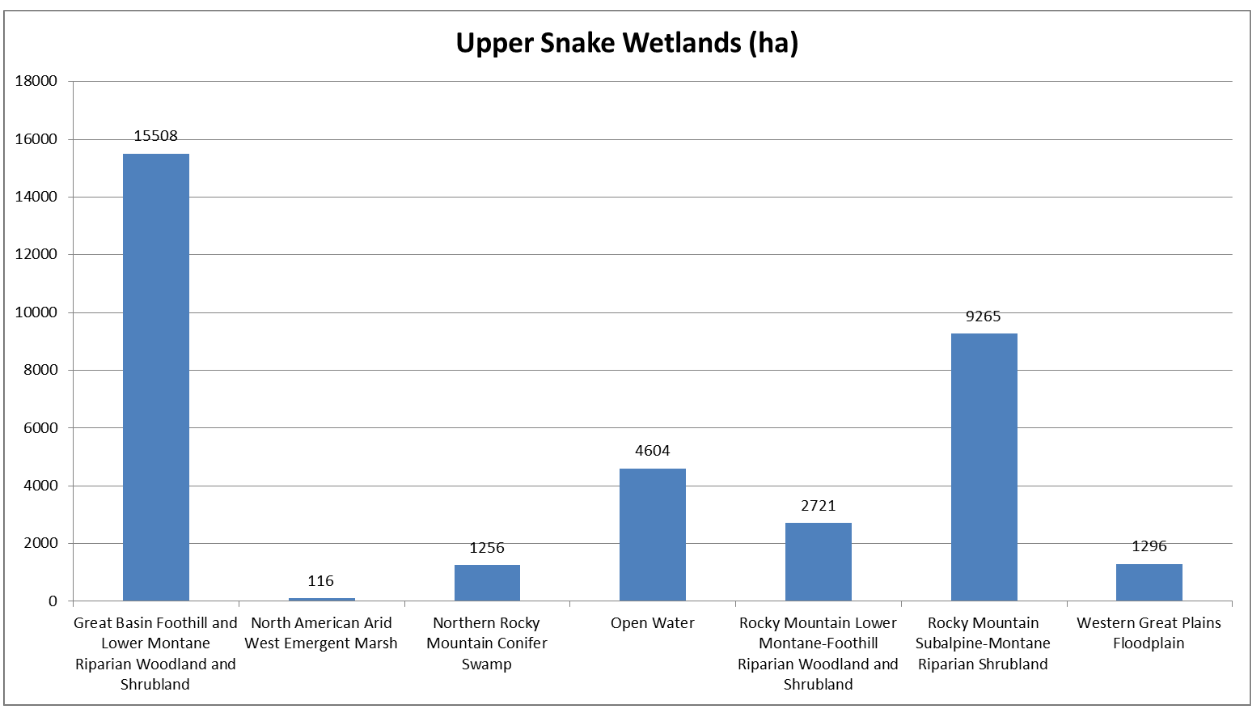


Figure 21. Abundance of wetlands by type (NatureServe Ecosystems Classification) within the Upper Snake Watershed.

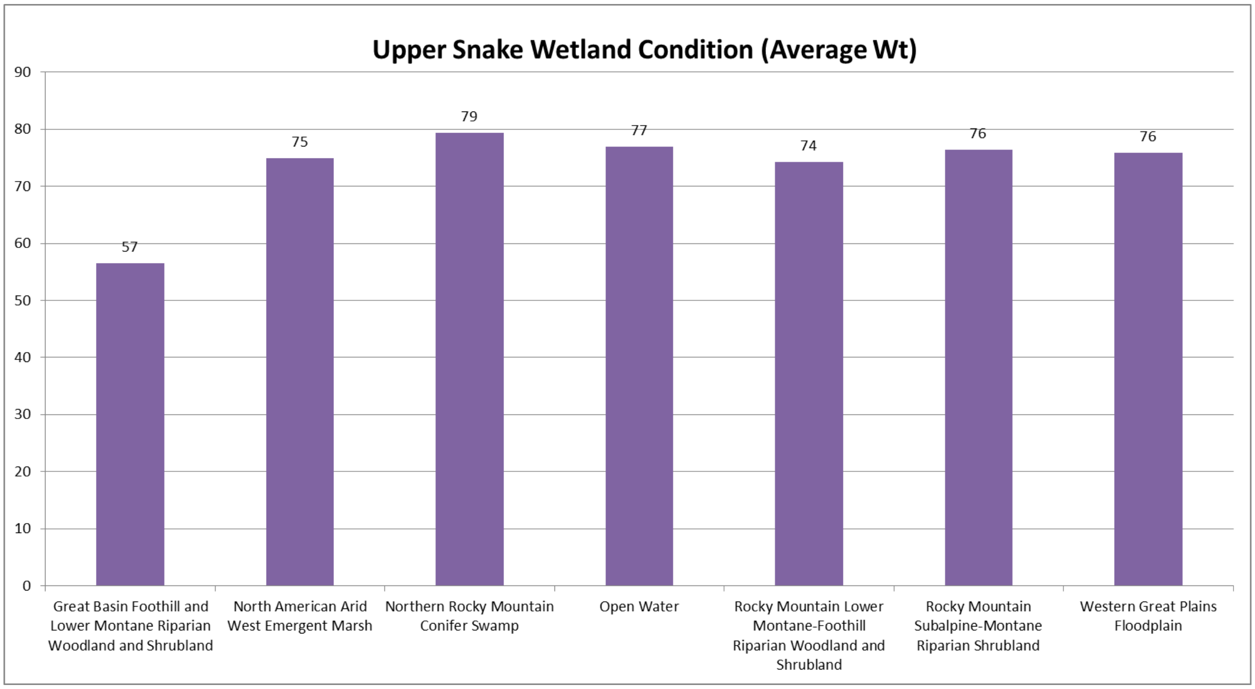


Figure 22. Landscape Condition rating of each wetland, averaged over entire distribution within the Upper Snake watershed. Landscape Condition Model rating range from 0-100, 100 is best score with least impact and 0 is the lowest score with greatest impact.   High condition wetlands rank 75-100, Moderate Condition wetlands rank 50-75, Low condition wetlands rank 25-50, Very low condition wetlands rank <25.

In the local Beaver-Camas watershed, there is similar suite of wetland types as it contains both upper montane areas as well as valley floor areas (Figures 23, 24). The lower elevation riparian type (the “Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland”) is in better condition overall than in the entire Upper Snake (LCM of 61) as there is less agricultural impact. Unfortunately the limited amount of freshwater marsh (the “North American Arid West Emergent Marsh”) is heavily impacted as it only occurs in the lowest elevations in and amongst the highest agricultural usage in the watershed (Figure 25).

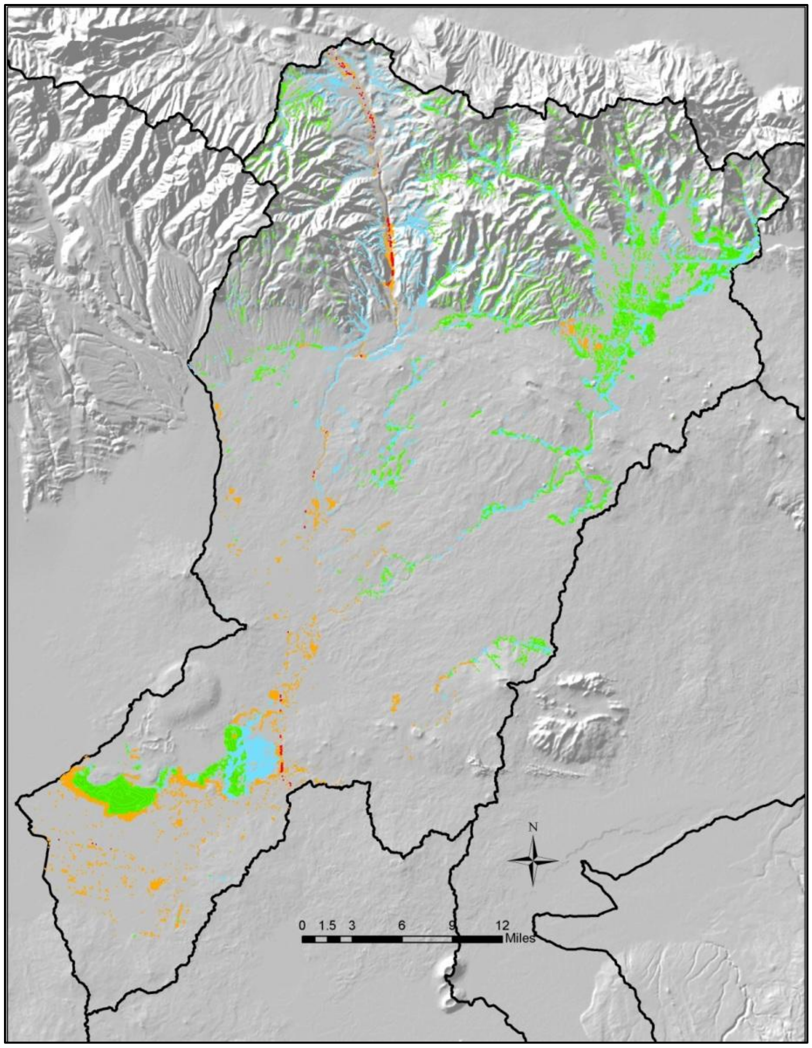


Figure 23. Wetlands by condition within the Beaver-Camas Watershed. Green & blue = high condition, yellows = moderate condition and red = low or poor condition.

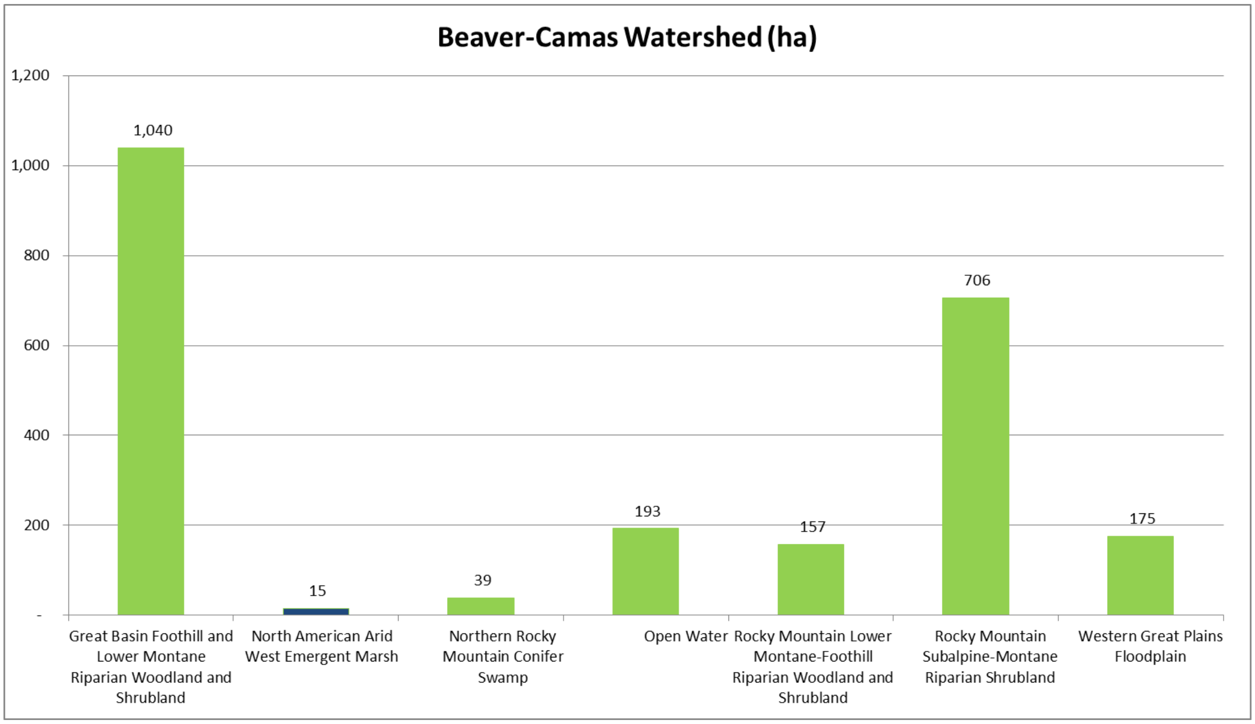


Figure 24. Abundance of wetlands by type (NatureServe Ecosystem Classification) within the Beaver-Camas watershed.

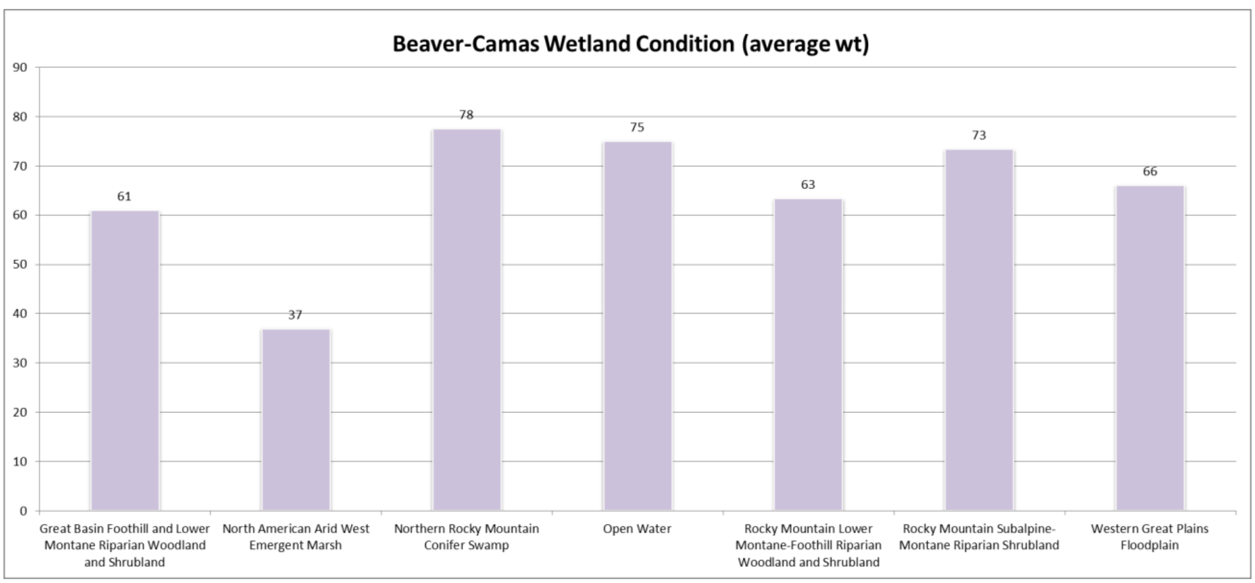


Figure 25. Average condition ranking for wetlands by type across their distribution within the Beaver-Camas watershed.

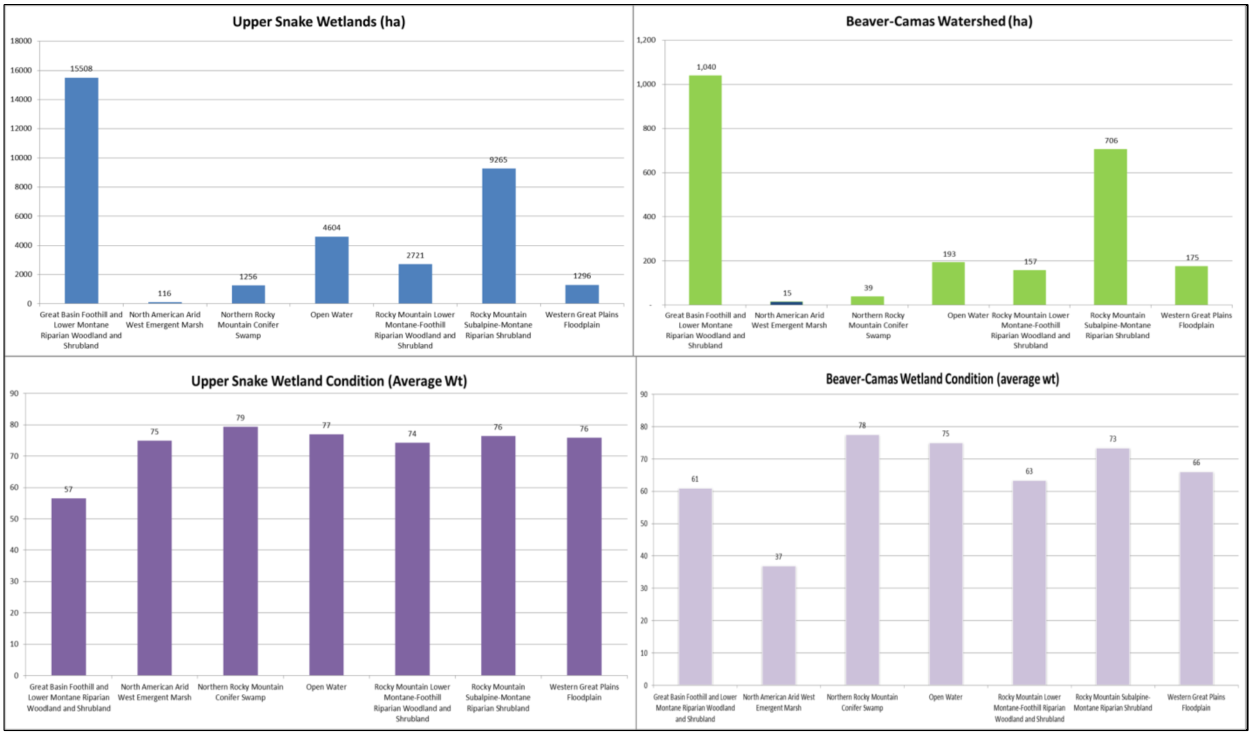


Figure 26. Abundance (upper) and condition (lower) of wetland by type for the Upper Snake (left) and Beaver-Camas (right).

3.4 Discussion

Side-by-side comparison of the larger Upper Snake with the local Beaver-Camas watershed shows that the Beaver-Camas has the full representation of wetland types in a similar relative abundance. Beaver-Camas watershed also appears to have lower LCM scores for nearly all types (Figure 26). This is because the Upper Snake has greater areas of less developed upper watersheds. Keep in mind that what these maps do not show is the loss of riparian and other wetland types due to agricultural conversion in the valley bottoms. This analysis shows the current condition on existing wetlands. Not the cumulative loss of wetlands.

This watershed profile indicates that lower elevation riparian and marsh areas are in the poorest condition relative to other wetland types. Opportunities for mitigation should include the restoration of these areas.

Camas NWR has some of the best condition low elevation wetlands within the local watershed. And in fact has some of the best "base of the foothills" wetlands in the entire Upper Snake River watershed, especially along the northern edge of the topographic snake river plain (Figure 20). The location of Camas' wetland and riparian areas within a largely agriculturally converted landscape as well as its position within an interior arm of the Pacific Flyway make it strategically important for supporting wildlife movement and long term conservation of wetland dependent species (**Figure 27**).

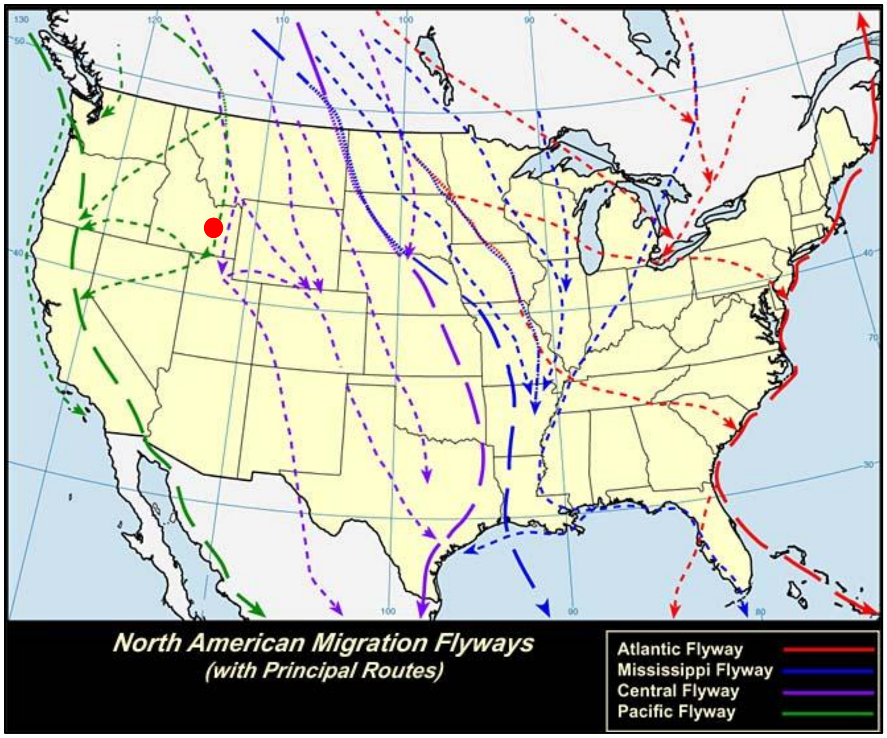


Figure 27. Waterfowl flyways of North America, showing the areas of south eastern Idaho as an important area for the interior portion of the Pacific Flyway. Red dot is approximate location of Camas NWR.

4 Habitat Climate Change Vulnerability

4.1 Introduction

The Habitat Climate Change Vulnerability Index (HCCVI) was developed and refined by NatureServe and partner organizations (Comer et al. 2012b). An overview and summary of the method is outlined here.

Climate change represents a globally pervasive stress on natural ecosystems. Temperature and precipitation regimes drive ecosystem productivity and natural dynamics, such as the rate of plant growth, the frequency of natural wildfire, and the seasonal flow of streams. Paleoecology has shown that past episodes of climate change triggered ecosystem change at regional and local scales with varying speed and intensity (e.g., Wells 1983, Betencourt et al. 1990). As the current rate of global change increases, society can expect profound shifts in key ecological processes to cascade through natural systems, resulting in altered productivity, changes to species composition, local extinctions, and many instances of ecological degradation or collapse (IPCC 2007).

We are scarcely prepared for these changes. While the modern scientific study of ecosystems dates back over a century, we do not sufficiently understand the many linkages between key climate variables and ecosystem dynamics across diverse landscapes. Nor do we fully understand the effects of other stressors, such as those tied to land use, that have already reduced the resiliency of many natural ecosystems. One certain conclusion that we can draw from our experience is that *ecosystems will not simply 'move'* as climate changes, *but will instead transform* in unprecedented ways because of the controlling link between climate and many ecosystem processes (Fagre et al. 2009); including the individualistic responses of species (Gleason 1926, Finch 2012). In any given place, we need to better understand and assess the relative vulnerability of ecosystems, natural communities, and habitats to the specific climate-induced stressors that are most likely to occur there. We also need to integrate this assessment with knowledge of other existing stressors, such as land & water use change, non-native species invasions, and pollution effects. An integrated assessment will be needed to directly inform investments in adaptation strategies by all stakeholders.

Assessment of climate change vulnerability for ecosystems and habitats can directly inform key conservation and resource management decisions in the 2012-2060 timeframe. It helps to determine those ecosystem types that, in all or part of their distribution, are most at risk of specific climate change effects; and assist with targeting species-based assessments. This information provides the baseline for developing scientifically grounded strategies for climate change adaptation. It also provides decision makers with the information to determine which adaptation options might have a higher probability of maintaining ecosystem resilience.

4.1.1 *Defining Climate-Change Vulnerability and Adaptation Strategies*

The societal response to climate change involves much new science. Along with new science, comes new terminology. Here we define and summarize some key terminology and concepts applied in this assessment. First, the notion of vulnerability to climate change has been succinctly defined by the Intergovernmental Panel on Climate Change (IPCC 2007) as:

Climate Change Vulnerability - The degree to which a system is susceptible to - and unable to cope with - adverse effects of climate change; including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007).

This overall definition points to several contributing components of climate change vulnerability commonly used in current science. These include concepts of climate-change exposure, sensitivity, and adaptive capacity. These terms have been defined as:

- **Exposure** – The degree of climate stress upon a particular unit analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events.
- **Sensitivity** – The degree to which a system will be affected by, or responsive to climate stimuli.
- **Adaptive Capacity** - the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences.

Gauging climate change exposure involves evaluation of climate information, including past, current, and forecasted future conditions, in areas relevant to the resource of concern. These analyses may be applied at continental, or more local, spatial scales tailored to the distribution of the resource of concern. Gauging climate change sensitivity requires knowledge of the ecology of communities, and/or biology of component species, in order to measure the potential effects of climate change exposure. Gauging adaptive capacity builds on knowledge of the ecology of communities to consider factors that may – or may not – mitigate climate change sensitivities that have been identified.

By understanding the components of climate change vulnerability for a given resource of concern, resource managers and decision makers are better positioned to evaluate alternative actions to respond to climate change, even in the face of considerable uncertainty (Nichols et al. 2011). These alternative actions are known as climate change adaptation strategies.

4.1.2 *Climate change adaptation strategies*

Climate Change Adaptation includes actions that enable species, systems and human communities to better cope with or adjust to changing conditions. These strategies may take a number of forms. Some have categorized strategies into three areas, including resistance, resilience, and facilitated transformation (Biringer et al. 2003, Millar et al. 2007, and McLachlin et al. 2007). *Resistance* strategies for adaptation aim to prevent the direct effects of climate change. Frequently cited examples include building sea walls and coastal hardening to prevent effects of coastal sea-level rise (Klein and Nicholls 1999). Preventive measures to head off effects of invasive species, or uncharacteristic landscape-scale fires, could also fall into this category. *Resilience* strategies aim to secure the capacity to cope with the effects of climate change by ensuring that critical ecological process – as currently understood – are restored to a high level of function or integrity. For example, by securing large and interconnected natural landscapes, patterns of species dispersal and migration are secured to protect food-web dynamics. *Facilitated Transformation* strategies anticipate the nature of climate-change induced transitions and, working with these anticipated trends, include actions that facilitate transitions that are congruent with future climate conditions, while minimizing ecological disruption. Somewhat radical expressions of these strategies might include assisted migration of sensitive species from current habitats to locations where changing climates might provide new habitat into the future (McLachlin et al. 2007, Milly et al. 2008). Some have characterized these *resistance* and *resilience* strategies as 'retrospective' because they emphasize utilization of knowledge about historical or current ecological pattern and process; i.e., protection and restoration of natural conditions as they are currently understood. *Facilitated Transformation* is therefore a 'prospective' set of strategies in that they are based on the hypothesis of future conditions (Magnuss et al. 2011).

Finally, there is a critical temporal dimension to adaptation strategies. Conservation decisions are made by people, often within the policy constraints of current law and institutions. While traditional natural resource management has been 'retrospective' – utilizing knowledge of past and current conditions to inform today's management actions – planners are increasingly required to rigorously forecast future conditions (see e.g., Comer et al. 2012a). This forecasting must strive to determine the nature and magnitude of change likely to occur, and translate that knowledge to current decision-making. It is no longer sufficient to assess "how are we doing?" and then decide what actions should be prioritized for the upcoming 5-15 year management plan. One must now ask "where are we going, and by when?" and then translate that knowledge back into actions to take in the near-term, or medium-term, or those to monitor and anticipate taking over multiple planning horizons. Considerable new science and policy will be required to support this new type of natural resource decision making.

4.1.3 *Scales of Ecological Organization*

Climate change vulnerability assessments can be aimed at different scales of ecological organization, including species, communities, or landscapes, just as conservation planning can target these same scales (Groves et al. 2002). Species, as well as subspecies, varieties, and populations, are concepts intuitively understood by the conservation community despite academic disagreement over just what they represent (de Quieroz 2007). Communities could include a variety of units (e.g., habitats for one or more species, vegetation communities, aquatic communities, etc.) that have been defined in different ways but generally refer to assemblages of species that co-occur in space and time and interact with each other and their local environment. Landscapes (as units of analysis) typically describe recurrent patterns of communities and occupy geographical areas of varying size.

Regardless of the scale of ecological organization, climate change vulnerability assessments can and should address exposure, sensitivity, and adaptive capacity; the three main components of vulnerability. Different approaches are called for depending on the level in question. The **species** is perhaps the most common focus for vulnerability assessment and consequently has received extensive attention in the literature (e.g., Thomas et al. 2004, Laidre et al. 2008, and Rowland et al. 2011). Trait-based approaches examine projected climate change where the species occurs, aspects of the genetic variation, natural history, physiology, and landscape context to assess sensitivity and adaptive capacity (Foden 2009, Young et al. 2010). Assessments of **landscapes** often center on producing spatially explicit results at regional scales. Evaluation of exposure may result in maps showing where climate stress is projected to be greatest, whereas examination of the potential climate-change effects on disturbance regimes or invasive species, can address sensitivity (Enquist and Gori 2008, Swantson et al. 2010, Rustad et al. 2011). Adaptive capacity can be measured through examination of the heterogeneity of topography, moisture gradients, or microclimates under the assumption that more diverse landscapes provide more opportunities for organisms to find climate refugia than homogeneous ones.

A vulnerability assessment of a **community type** requires understanding of the ecological processes such as fire regime, hydrological regime, or food web dynamics that define the community at relatively local scales. As for species, exposure estimates relate to the magnitude of projected changes in temperature and precipitation over the area where the community occurs. Sensitivity estimates can include how the defining ecological processes are affected by changing climates, and synergies between climate and non-climate stressors of the community. Adaptive capacity estimates of a community can include the roles of component guilds of organisms, the vulnerability of important component species, and the natural biophysical variability across the range of the community. Assessing the vulnerability of communities can provide a useful compliment to both landscape and species assessments. Where landscape assessments indicate a high potential for climate-change impacts in certain subregional areas, analysis of component communities could be the next logical step to identify practical adaptation strategies. Assessment of communities also presents the opportunity to avoid time-consuming analyses of long lists of sympatric species, or when the community itself is an effective focus for conservation.

4.2 Overview of Methodology for Vulnerability Assessment

The methods developed for this Habitat Climate Change Vulnerability Index (HCCVI) will be applicable to any given ecosystem or community type that the user might select. For this assessment, we used units within the National Vegetation Classification that are abundant within the Snake River Plain and at Camas National Wildlife Refuge. The advantage of using this classification system is that it represents an established standard nationwide classification of several hundred upland and wetland types (FGDC 2008), and was used to map the vegetation at Camas NWR (Miewald et al. 2012). However, the HCCVI methods are consciously designed to support other ecosystem or community concepts as well; for example, habitats described for individual bird or ungulate species of conservation concern. The four selected types for this assessment are listed in **Table 4**.

Table 4. Focal Natural Communities for HCCVI Assessment.

National Vegetation Classification Group Name	Mapped Acres at Camas	USFWS Habitat
Vancouverian & Rocky Mountain Montane Wet Meadow Group (G521)	1,958	Wet Meadow
Intermountain Dry Tall Sagebrush Shrubland & Steppe Group (G303)	1,942	Sagebrush Steppe
Western North American Temperate Interior Freshwater Marsh Group (G518)	794	Marsh
Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland Group (G526)	277	Riparian Shrubland, Riparian Scrub-Shrub

4.2.1 *Index Framework*

An index approach to documenting climate change vulnerability aims to organize a series of sub-analyses in a coherent structure that will shed light on distinct components of vulnerability, so that each can be evaluated individually, or in combination. This approach follows a number of related indexing approaches to documenting at-risk status of biodiversity (Faber-Langendoen et al. 2007), or climate change vulnerability for species (Young et al. 2010). The structure implemented here organizes the components of climate change vulnerability in to three main categories: Direct Effects, Indirect Effects, and Adaptive Capacity (Figure 28). These are defined as follows:

Direct Effects encompass the current and forecasted exposure to climate change and their likely effects on ecosystem-specific processes. Analyses of direct effects consider climate forecasts themselves, and their likely implications for increasing ecosystem stress, changing dynamic processes such as wildfire or hydrological regime; and for changing species composition.

Indirect Effects encompass predisposing conditions affecting ecological resilience, with ecological resilience as initially defined by Holling (1973) and Gunderson (2000), and later Walker et al. (2004). Walker et al. (2004) defined it as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.” Analyses of indirect effects consider human alterations to characteristic pattern and process, such as landscape fragmentation, effects of invasive species, or human alterations to dynamic processes. Here, these human alterations are considered independent of climate change, but once identified, have some potential interactions with forecasted climate change. These analyses also include a temporal dimension, considering both legacies of past land use along with current conditions.

Adaptive Capacity encompasses natural characteristics that affect the potential for ecological resilience in light of climate change. Analyses of adaptive capacity for climate change consider the inherent variability in climate regime or geophysical features that characterize the distribution of a given ecosystem or community. They also consider aspects of natural species composition, such as the relative diversity within groups of species that provide functional roles, or the relative vulnerabilities of individual species that provide “keystone” functions.

Authors of this index drew inspiration from Magnuss et al. (2011) and others in structuring analyses with a logic model to combine information in two stages, with the first analyses gauging relative ecological resilience by matching results from indirect effects against adaptive capacity. The direct effects of climate exposure and sensitivity are then considered to arrive at an overall gauge of climate change vulnerability (**Figure 28**).

4.2.1.1 Numerical and Categorical Summaries of Vulnerability

The index aims to use component analyses to consistently arrive at a 3-level series of scores; i.e., High, Medium, and Low (**Figure 28**). Where quantitative data are available, numerical scores should aim to be normalized to a 0.0 to 1.0 scale. Numerical results for component analyses are then averaged. However, where quantitative models are unavailable for a given analysis, expert categorization for each score is sufficient (with documented justification). The H/M/L result for resilience is the average of scores for indirect effects and for adaptive capacity. The H/M/L result for sensitivity is the average of scores for direct effects. From this point, a simple logic model combines categorical results for resilience and sensitivity to arrive at an overall categorization of climate change vulnerability.

Very High climate change vulnerability results from combining high sensitivity with low resilience. These are circumstances where climate change stress and its effects are expected to be most severe, and relative resilience is lowest. Ecosystem transformation is most likely to occur in upcoming decades.

High climate change vulnerability results from combining either high or moderate sensitivity with low or medium resilience. Under either combination, climate change stress would be anticipated to have considerable impact.

Moderate climate change vulnerability results from a variety of combinations for sensitivity and resilience; initially with circumstances where both are scored as moderate. However, this also results where resilience is scored high, if combined with either high or medium sensitivity. Where both resilience and sensitivity are low, some degree of climate change vulnerability remains.

Low climate change vulnerability results from combining low sensitivity with high resilience. These are circumstances where climate change stress and its effects are expected to be least severe or absent, and relative resilience is highest.

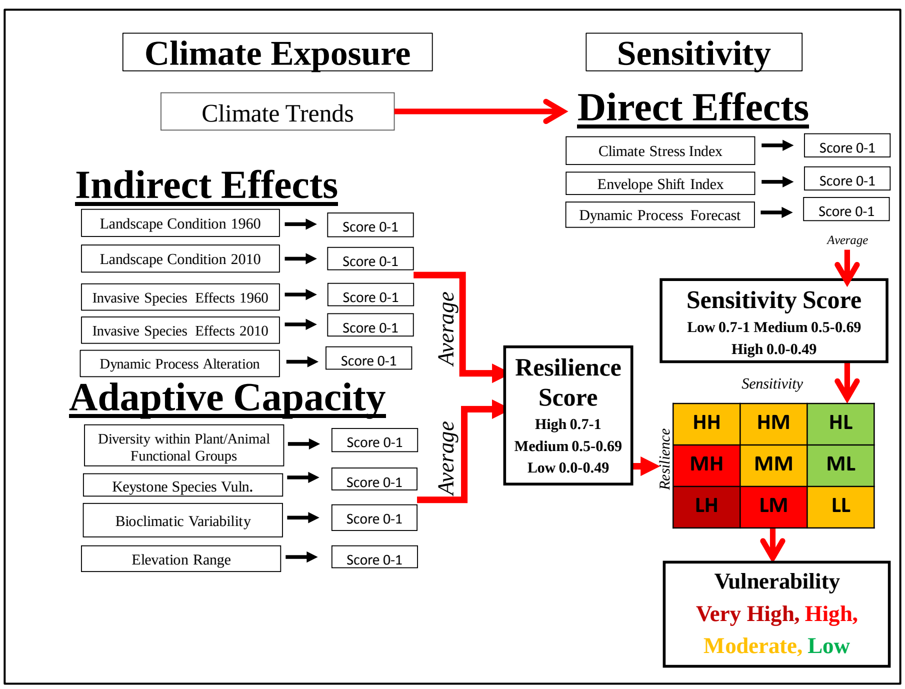


Figure 28. Flow Chart for Habitat Climate Change Vulnerability Index (HCCVI).

4.2.1.2 Spatial and Temporal Dimensions for Documenting Vulnerability

Climate change vulnerability for ecosystems and habitats was placed here within an explicit spatial and temporal framework. Spatially, a vulnerability assessment initially applies to the distribution of the type within an EPA Level III ecoregion[3]. Across North America, these equate with Level III ecoregions from the Commission for Environmental Cooperation (CEC). Scores for each type are summarized for each applicable ecoregion of their natural distribution. For this project, we focused on the distribution of each target community type within the Snake River Plain ecoregion (**Figure 29**).

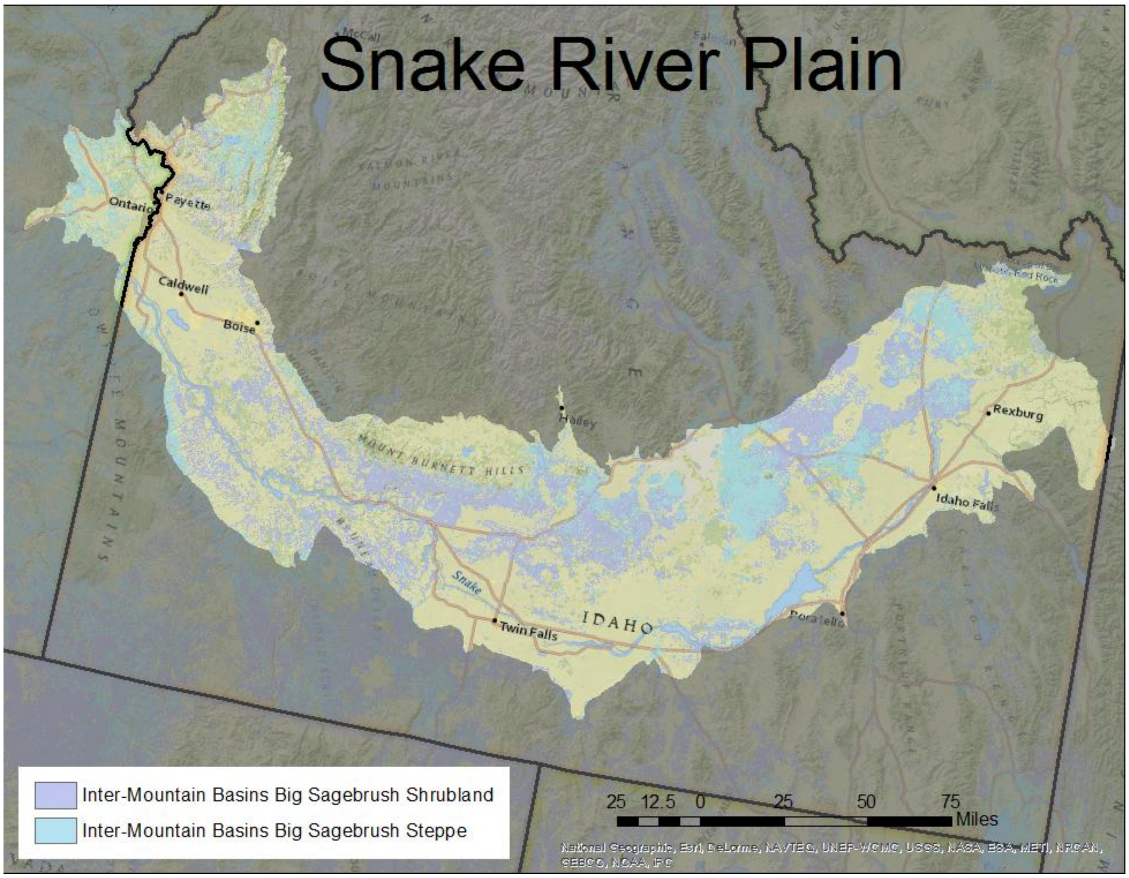


Figure 29. Level III ecoregion and Sagebrush Steppe & Sagebrush Shrubland focal community distribution for HCCVI assessment.

One might apply the same analyses and gauge vulnerability for narrower or broader distributions of a given community type, but this level of ecoregionalization was selected because it likely reflects regional pattern of climate-change exposure and effects. It therefore should provide a practical starting point for efforts to systematically document climate change vulnerability at national or regional scales.

Similarly, one must explicitly consider the temporal dimension of climate change vulnerability, as the magnitude of climate exposure varies over the upcoming decades. By utilizing forecasts of climate

[3] http://www.eoearth.org/article/Ecoregions_of_the_United_States-Level_III_%28EPA%29

exposure and sensitivity over a 50-year timeframe (e.g., between 2010 and 2060) provides a practical time period where realistic climate trends can emerge within acceptable bounds of uncertainty.

4.2.2 *Climate Exposure in the Snake River Plain Ecoregion*

Where available, historical climate data can and should be used to characterize a given community types 'climate baseline' over the 20th century. This enables meaningful comparisons of climate trends from subsequent time periods to clarify the significance of measurable change. Climate Wizard is an on-line tool (www.climatewizard.org, Girvetz et al. 2009) that uses Global climate model output from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al. 2007), downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al. 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003). We used this tool to compare the projected decadal mean for 2050-2060 (the "2060 scenario") against the mean from a 30 yr. period "current conditions" (1971 to 2000), and the historic baseline 70 yrs. record (1901 -1971) on a 4 km grid for the Snake River Ecoregion. The future scenario is based on the A2 (continued population growth, provides the "worst case" scenario) for 50 years into the future. The 50 percentile for all GMCs "ensemble" means were used for analyses.

An analysis of monthly variables for the 1901-1971 intervals can then characterize the "expected" variability of historical conditions. That time period is useful because a) it includes the oldest available climate records suitable for developing a climate baseline, and b) about the end of this time frame was the point at which a human influence on climate change was detectable (Lee et al. 2006, Solomon et al. 2007). One can then compare with this baseline summaries of the same climate variables since 1980, and/or climate forecasts, to identify the likely location and magnitude of climate-induced stress across the areas that define the range of the community type. Statistically, a >2 stdv departure indicates that forecasted climate variables fall outside of 95% of the 20^{th} century baseline values.

The trend in sobering, and shows an overall annual average warming of 4.7-5.4° F (Figure 30). This amount of warming outside 95% of the historic annual means for 1901-1971. The greatest warming occurs during the summer and fall months. The months of July, Aug and Sept 2060 projections show an increase of 5-8° F over the current period (1971-2000) which is also significantly warmer (>2 standard deviations) than the historic period (Figure 31). Winter and spring months are also projected to see 3-5° F increases in mean monthly temperatures, but these were < 2 standard deviations from the historic period. Precipitation is projected to increase annually by 2.5 inches, but this is not a significant increase over the historic record.

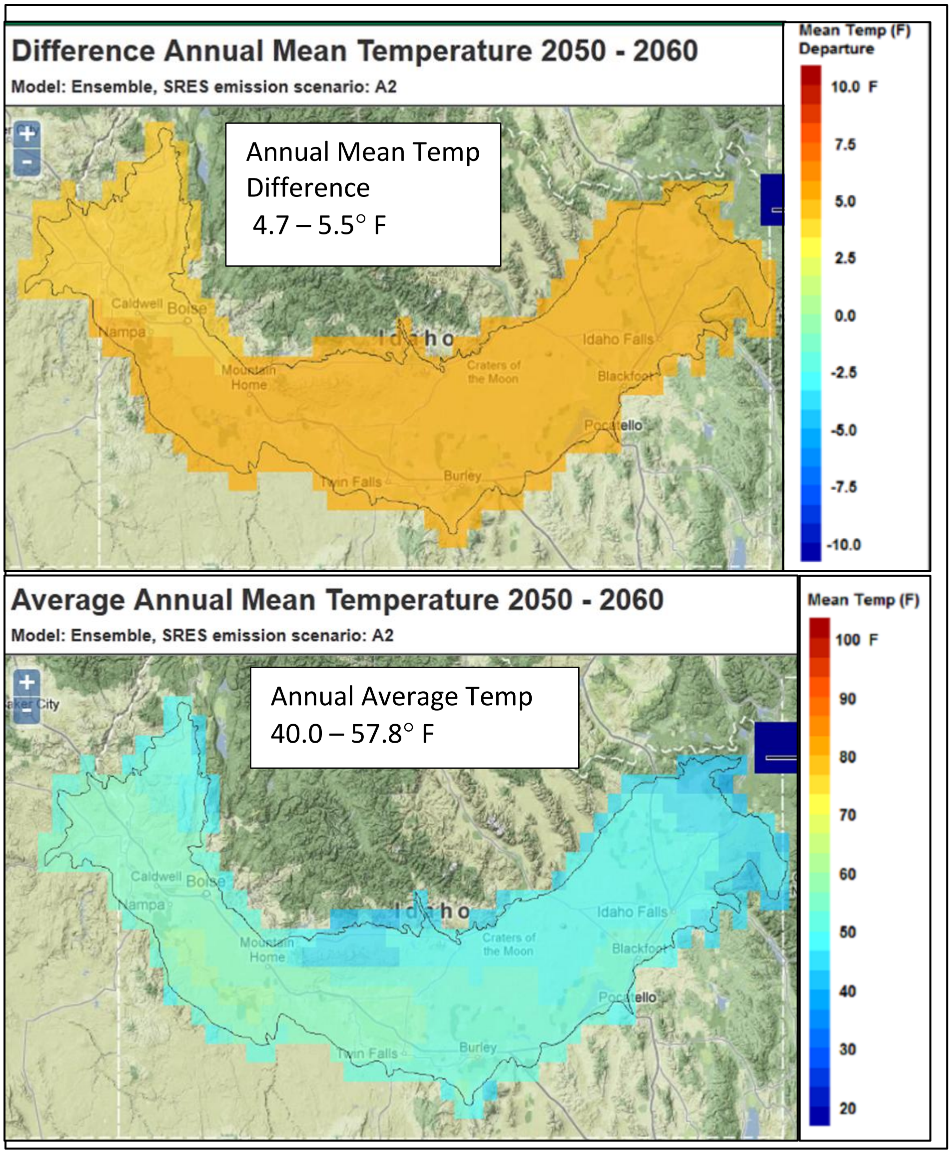


Figure 30. Annual Average Temperature Departure projected for 2060 by the Climate Wizard Tool (www.climatewizard.org, Girvetz et al. 2009). Top is degree change from "current" 1971-2000 period. Bottom is Annual Average Temperature for 2050-2060 decadal mean.

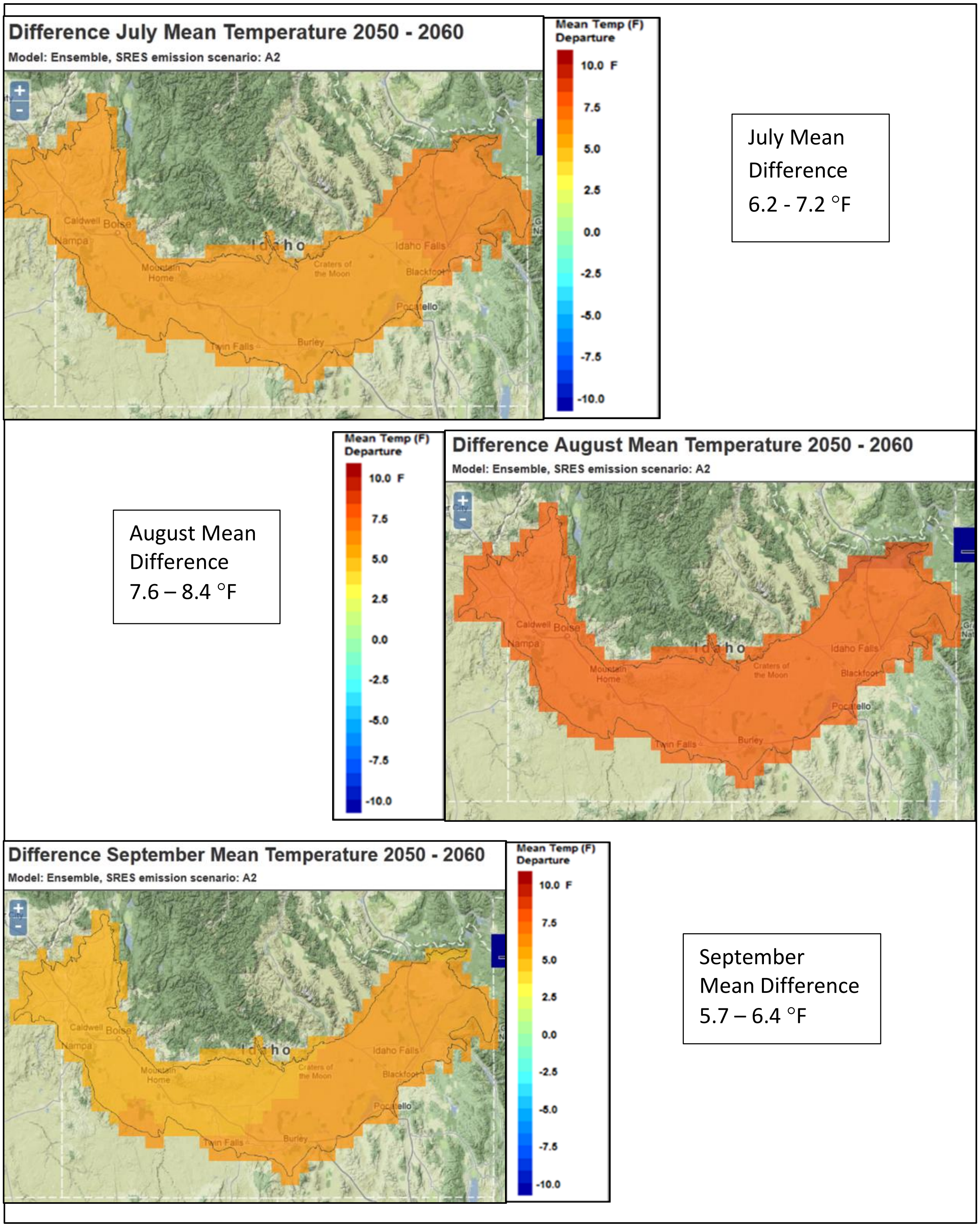


Figure 31. Model ensemble 50th percentile projected temperature increases for July, Aug and Sept. Values are difference of decadal mean 2050-2060 from “current period” 1971-2000, and are significant (>2 std dev) from the historic period (1901-1071).

Average precipitation forecast from all models shows little change because models do not have consistent trends. Projected range is from negative 0.2 to positive 9.8 inch increase for some pixels. The middle shows the average of all models with an increase of just 0.7 – 2.3 inches. All of these values are within 2 std dev of the historic record (Figure 32). Seasonally, winter, spring and fall have 0 to 4 inch increase while the summer months have the greatest decrease with -1 to -2.5 inches less than historic to up to about +1 to +1.5 inches increase over historic. The greatest change of climate change appears to manifest itself in the growing season months (June, July and August) with the highest temperature increases and the least precipitation gains and greatest predicted losses. Thus in the summer/growing season may be much warmer and drier. Any predicted increases in precipitation may not be enough to offset warmer temperatures.

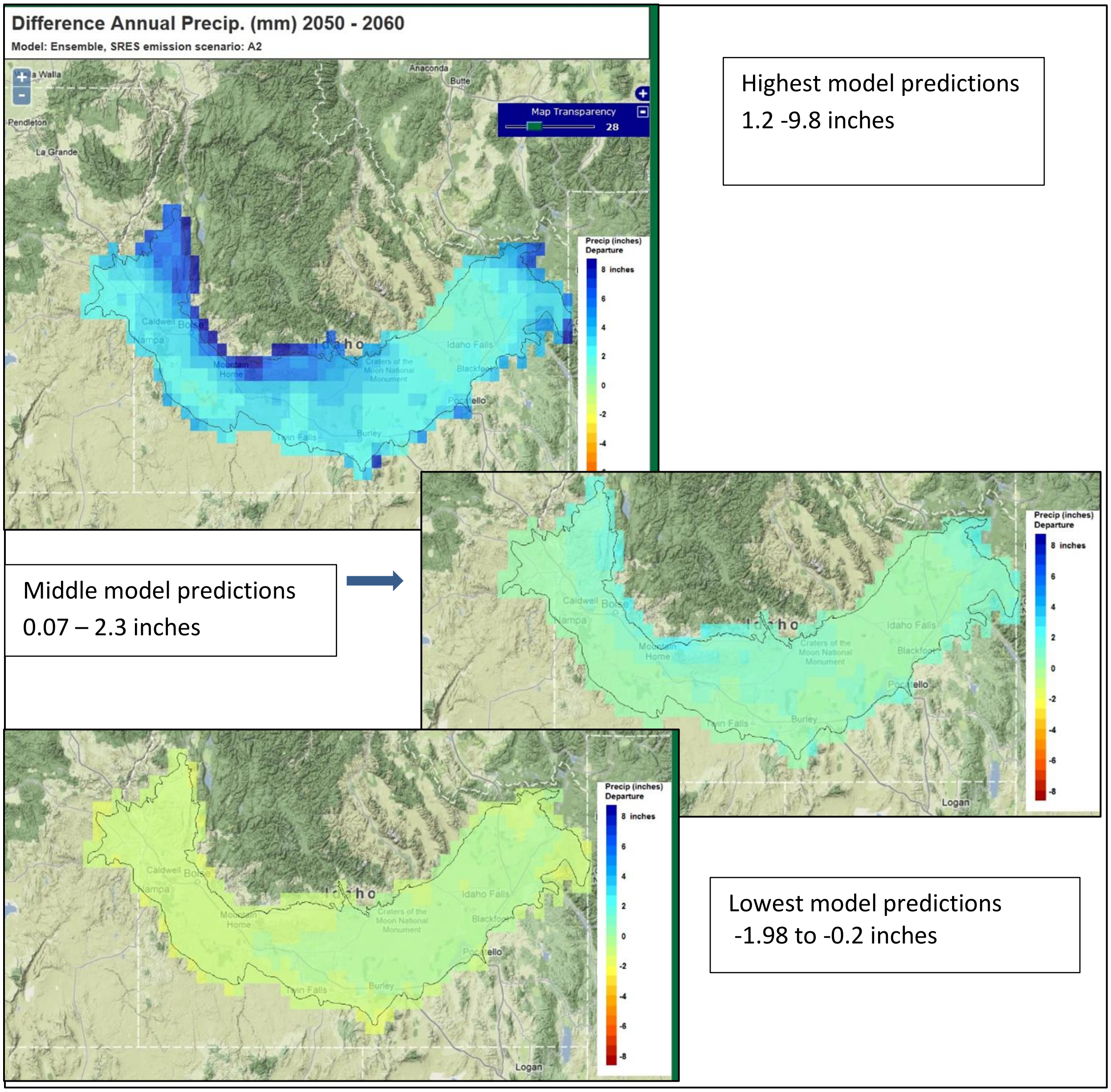


Figure 32. Projected change in precipitation annual average for the decadal average, 2060. Top: maximum model results, center: middle model results and bottom: lowest predicted amount.

4.2.2.1 Describing Climate Stress and its Direct Effects

The first three climate-change analyses for the HCCVI aim to measure the overall magnitude of climate-induced stress and its likely effect on the type across the ecoregion. Each analysis produces an index value either in qualitative categories of High, Medium, or Low Sensitivity, or a numerical 0.0-1.0 result, with scores approaching 0.0 indicating higher climate change sensitivity; i.e., with trends in climate forecasted out for 50 years suggest higher ecological impact. Summarized below, these measures of climate-change direct effects include a climate stress index and a dynamic process forecast.

4.2.2.2 Climate Stress Index

This can be measured using the proportion of the community distribution where the climate is forecasted to depart significantly from 20th century conditions (Figure 31). Projected 2060 mean temperatures are compared to historic record (1901-1971) and those values >2 standard deviations are deem a significant departure. The greater the number of variables that are outside 95% of the historic means, the greater the climate stress on that community. The extreme events of the past become the norm events in the future.

4.2.2.3 Dynamic Process Forecasts

Localized hydrologic or fire regime models for aquatic and upland ecosystems, where available, can help account for past alterations, and then provide insight for projected future climate regimes, applying those estimates as a third measure of direct effects or climate-change sensitivity.

Potential effects of climate change on the hydrologic regime were based on 1) ecological literature identifying the key surface water, groundwater, and hydrogeomorphic dynamics that affect the aquatic/wetland/riparian systems of interest; 2) hydrologic and meteorological literature identifying the key climate variables that have the greatest effect on the ecologically important surface water, groundwater, and hydrogeomorphic dynamics, including studies of prehistoric and historic conditions; and 3) hydrologic and geologic literature identifying the specific ways in which changes in these climate variables would affect the surface water, groundwater, and hydrogeomorphic dynamics of concern, including studies of prehistoric and historic conditions. Given limitations on the availability of quantitative hydrologic models of use for our purposes in the Snake River Plain, estimates of climate sensitivity were qualitative, scaled between 0.0 and 1.0 for each community type.

Fire regimes are characterized quantitatively using state-and-transitions models that describe various successional stages and the transitions between them (FRCC 2010). Using estimates of fire frequency and successional rates, fire regime models predict the relative proportion of natural successional stages one might expect to encounter for a community type across a given landscape. For example, sagebrush shrublands are modeled with 5 successional stages and different types of fire and fire frequencies (Figure 33). Comparison of the observed vs. predicted aerial extent of successional stages is then used to gauge relative departure from expected proportions (measured in % departure). Models for each upland vegetation type characterizing its expected or “natural” range of variation were compared against current conditions to describe current fire regime departure. Current conditions include new uncharacteristic states such as invasive species in the understory or invasive juniper in the overstory. Future models are more complex to account for the natural and uncharacteristic successional stages and their influence on fire type and frequencies (Figure 33, Figure 34). Forecasted departure scores for each upland vegetation type were normalized to a 0.0-1.0 relative score.

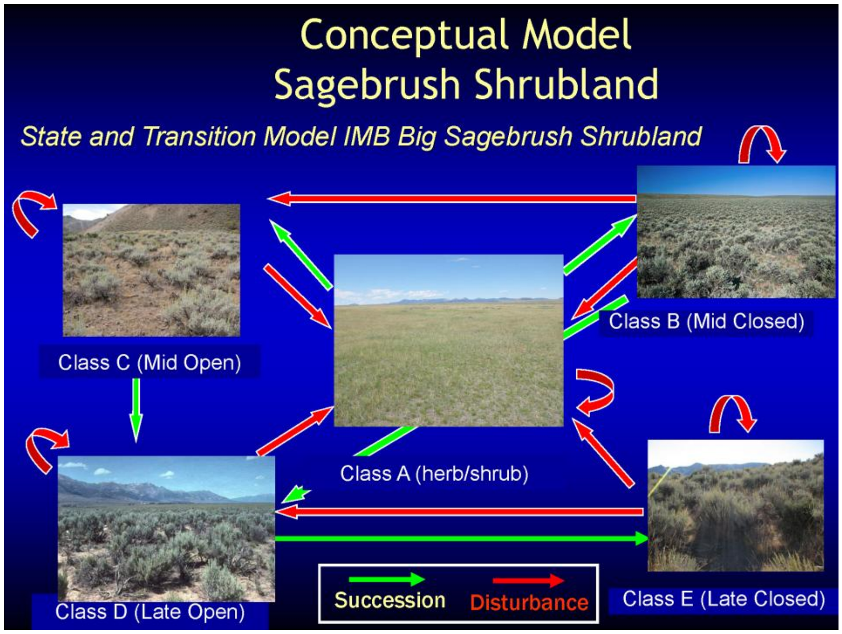


Figure 33. State and Transition model for Sagebrush.

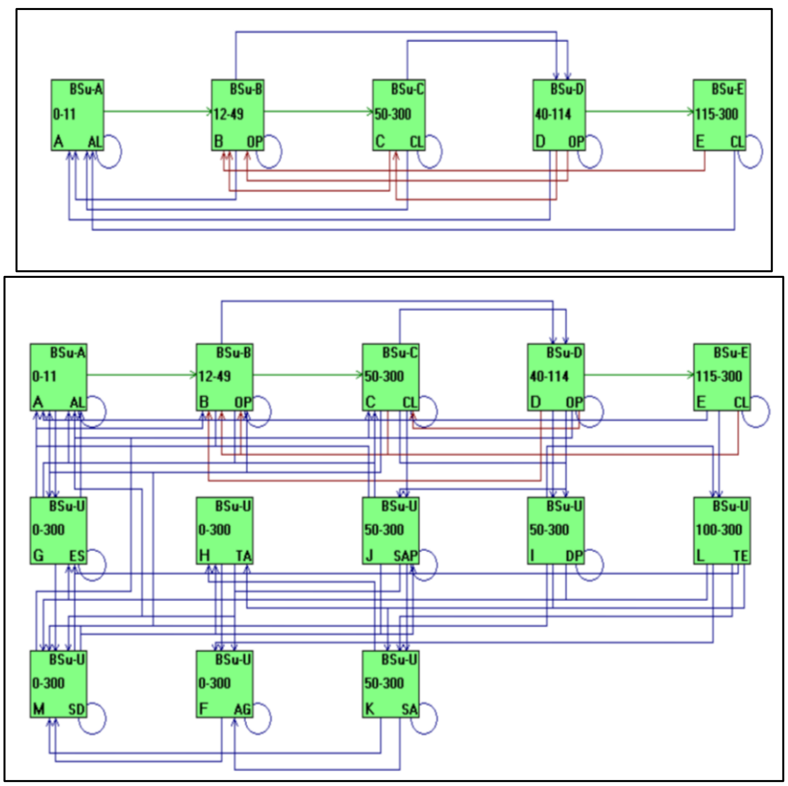


Figure 34. Historic (simple) state and transition model (upper) and current status (more complex) model with additional "uncharacteristic states" (lower) (FRCC 2010).

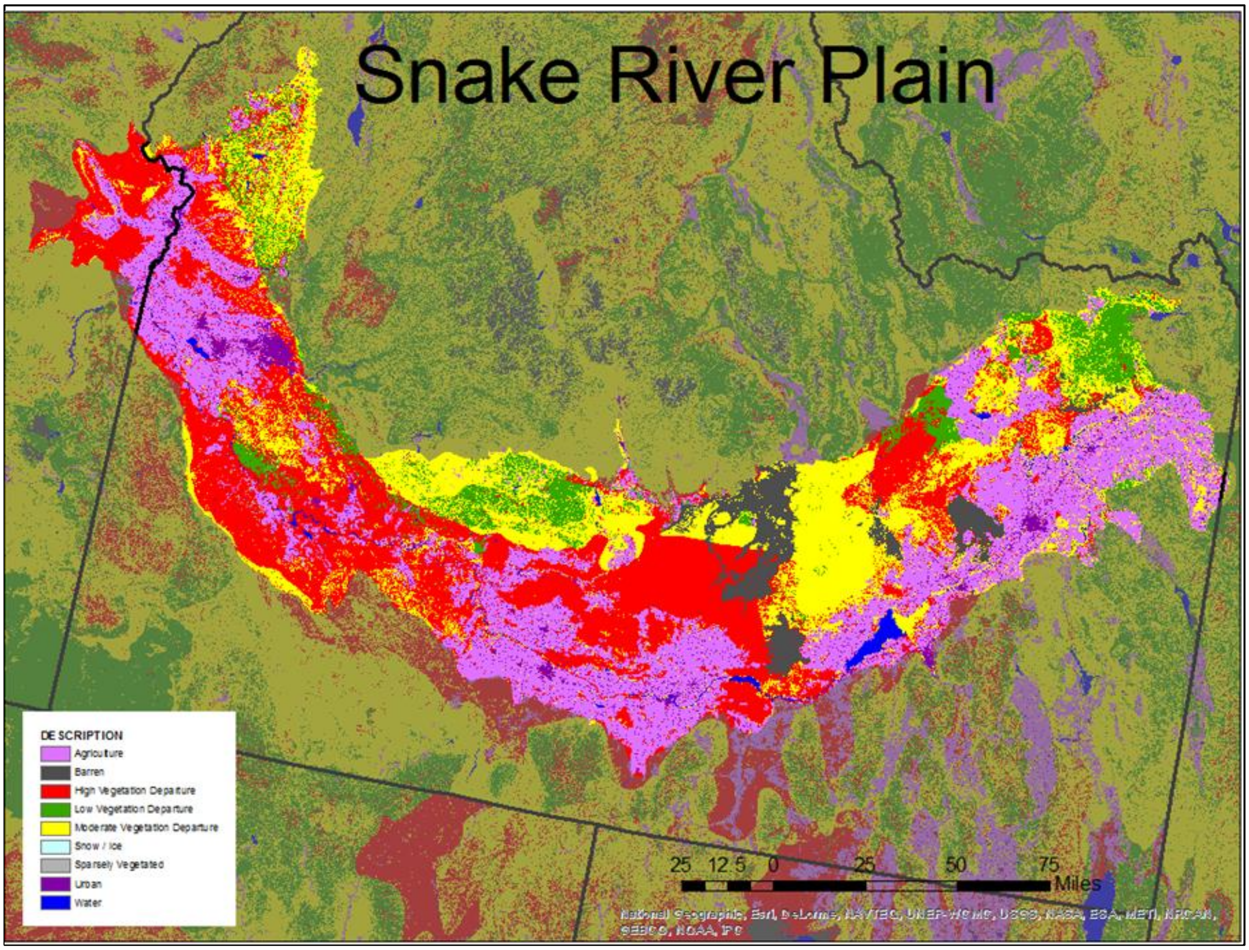


Figure 35. Current (2010) Fire Regime Departure based on current vegetation structure, including invasive grasses (FRCC 2010). Red and yellows indicate high and moderate departure from historic natural range of variation.

4.2.3 *Accounting for the Indirect Effects of Climate Stress*

Indirect effects address the potential interacting effects of climate-induced stress on the landscape conditions within and surrounding the habitat across its distribution. For example, if the analysis of direct effects indicates the strong need for component species to migrate towards higher elevations or latitudes, and the landscape is fragmented, the relative vulnerability of a community type could increase. In many instances, communities occur in landscapes that were already highly fragmented by the mid-20th century, and are therefore the associated land use legacies make them all the more vulnerable to current and future stressors. Similarly, the introduction of non-native species may also alter natural food-webs or compromise key dynamic processes, such as wildfire regimes, and have high potential for interactions with likely climate stress.

Literature review, and where available, regional maps of landscape condition, land use, invasive species, and fire regime departure, where possible reflecting 1960 and 2010, can provide measures for these effects (Figure 35, Figure 38).

4.2.3.1 Landscape Condition

Ecological condition commonly refers to the state of the physical, chemical, and biological characteristics of natural ecosystems, and their interacting processes. Many human land uses affect ecological condition, (e.g., through vegetation removal or alteration, stream diversion or altered natural hydrology, introduction of non-native and invasive species, etc.). Landscape condition assessments apply principles of landscape ecology with mapped information to characterize ecological condition for a given area (e.g., USEPA 2001, Sanderson et al. 2002). Since human land uses - such as built infrastructure for transportation or urban/industry, and land cover such as for agriculture or other vegetation alteration – are increasingly available in mapped form, they can be used to spatially model inferences about ecological stress and ecological condition.

The spatial models of landscape condition used in this project built on a growing body of published methods and software tools for ecological effects assessment and spatial modeling; all aiming to characterize relative ecological condition of landscapes (e.g., Knick and Rotenberry 1995, Forman and Alexander 1998, Trombulak and Frissel 1999, Theobald 2001, Seiler 2001, Sanderson et al. 2002, Riitters and Wickham 2003, Brown and Vivas 2005, Hansen et al. 2005, Leu et al. 2008, Comer and Hak 2009, Theobald 2010, Rocchio and Crawford 2011). The intent of these models is to use regionally available spatial data to transparently express user knowledge regarding the relative effects of land uses on natural ecosystems and communities. This current model has been developed and evaluated for the entire western United States. Western regional model development and evaluation was completed in cooperation with the Western Governors Association landscape connectivity working group.

Each input data layer is summarized to a 90m grid and, *where the land use occurs*, given a **site impact score** from 0.05 to 0.9 reflecting presumed ecological stress or impact. Values close to 1.0 imply relatively little ecological impact from the land use. For example, a given patch of ‘ruderal’ vegetation – historically cleared for farming, but recovering towards natural vegetation over recent decades, is given a Very Low (0.9) score for site impact as compared with irrigated agriculture (High Impact 0.3) or high-density urban/industrial development (Very High Impact 0.05). Certainly, there are some ecological values supported in these intensively used lands, but their relative condition is quite limited when compared with areas dominated by natural vegetation.

A second model parameter – *for each input data layer* - represents a **distance decay** function, expressing a decreasing ecological impact with distance away from the mapped location of each feature with Euclidian Distance. Mathematically, this applies a formula that characteristically describes a “bell curve” shape that falls towards plus/minus infinity (Appendix D). Those features given a high decay score (approaching 1.0) result in a map surface where the impact value dissipates within a relatively short distance. Those features given a low decay score (approaching 0.0) create a map surface where the per-pixel impact value dissipates more gradually with distance away from the impacting feature.

The result is a map surface indicating relative scores per pixel between 0.0 and 1.0 (**Figure 36**). This provides one composite view of the relative impacts of land uses across the entire ecoregion. Darker green areas indicate apparently least impacted areas and orange to red areas most impacted.

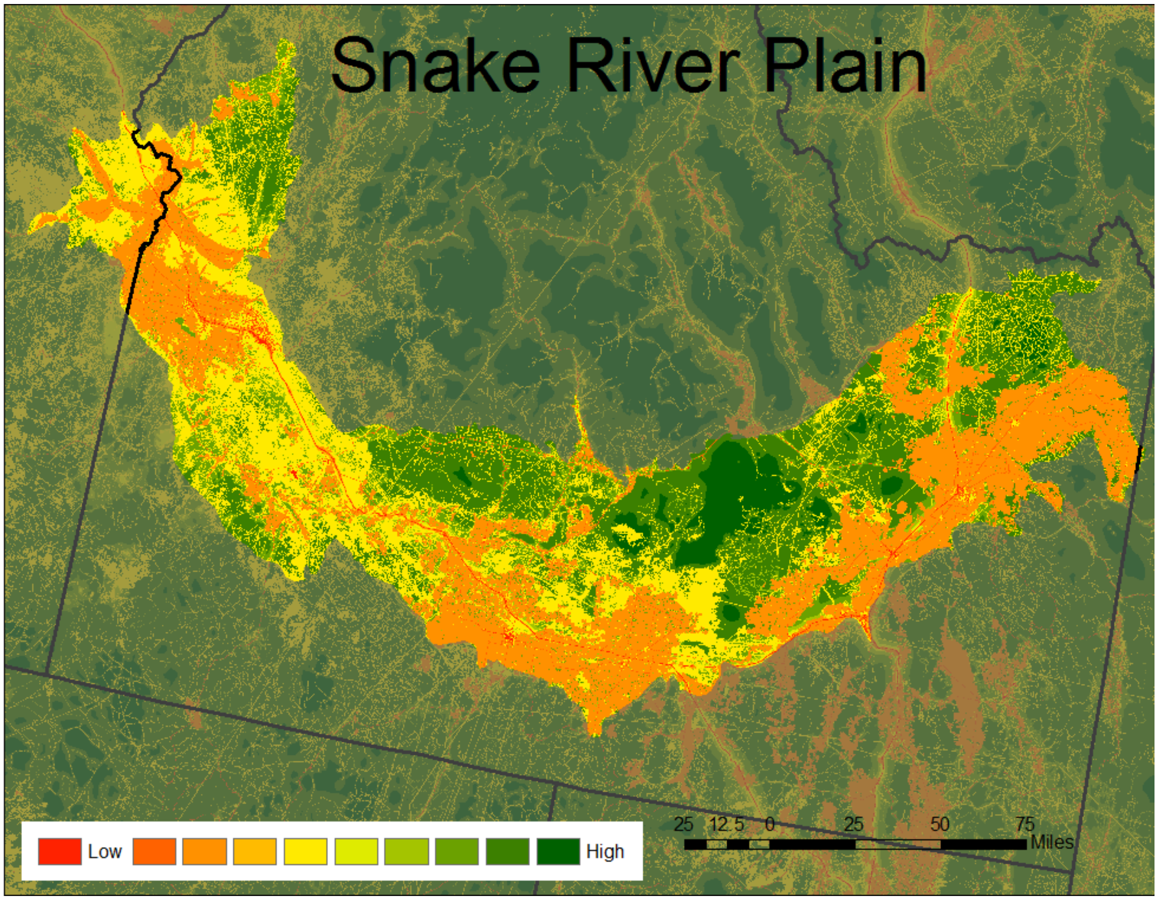


Figure 36. Landscape Condition model (90 m) for the Snake River Plain. . Darker green areas indicate apparently least impacted areas and orange to red areas most impacted.

Current Landscape Condition (2010): Current Landscape Condition of each community distribution was assessed using the NatureServe (LCM).This indicator is measured by intersecting the community distribution map with the LCM layer and reporting the average per-pixel LCM index value within each ecoregion. The average per-pixel score provides a relative index for landscape condition resulting with a score from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition (**Figure 36**).

Past landscape condition (1960): Historical data were lacking for spatial analysis using a LCM so landscape conditions for 1960 were researched and summarized (0.0-1.0 scale) based on estimated extent of roads and other development and various anthropogenic disturbances. Examples of disturbance include agriculture in the western half of the Snake River valley (since mid-1800's), and livestock grazing primarily in the eastern half, which has significantly affected most ecosystems, as well as the development of transportation system of highways and roads have fragmented many areas. Additionally, surface water diversions and some ground water pumping has affected springs (increases in the west) and changes to surface flows in riparian ecosystems, and local disturbance from agriculture, urbanization and mining have converted many sites (Figure 37).

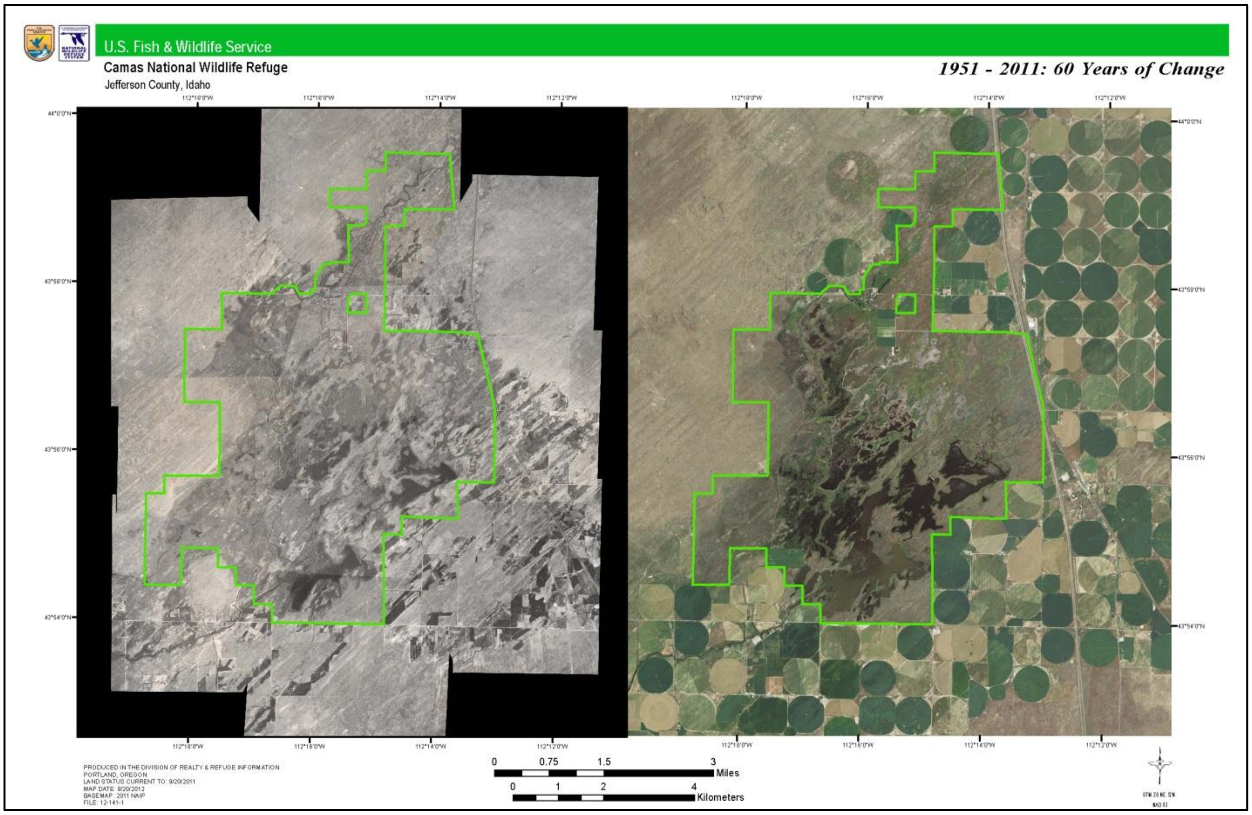


Figure 37. Historic (1951) and modern (2011) comparison of surrounding land use at Camas NWR.

Invasive Species Effects (2010): Like the landscape condition model, potential invasives effect is measured by intersecting the community distribution map with the invasives model output and reporting the average per-pixel invasives index value. The invasives index is a scaled from 0 to 1 with 0 representing high potential of lands in the pixel to experience annual grass encroachment and 1 representing no encroachment. Models of risk of conversion (probability of conversion within 30 years) of native vegetation to annual grass such as cheat grass have been developed (BLM 2010). Vegetation types included in the model were sagebrush steppe, salt desert scrub and juniper woodlands. Across upland types, model scores of invasive species risk ranged from High (high probability of displacement; exotic species currently dominant the understory), Moderate (probability moderate and lower than high risk areas; either native or exotic species dominate understory currently) and Low (minimal probability of conversion, native species dominant the understory currently) (Figure 38) (BLM 2010).

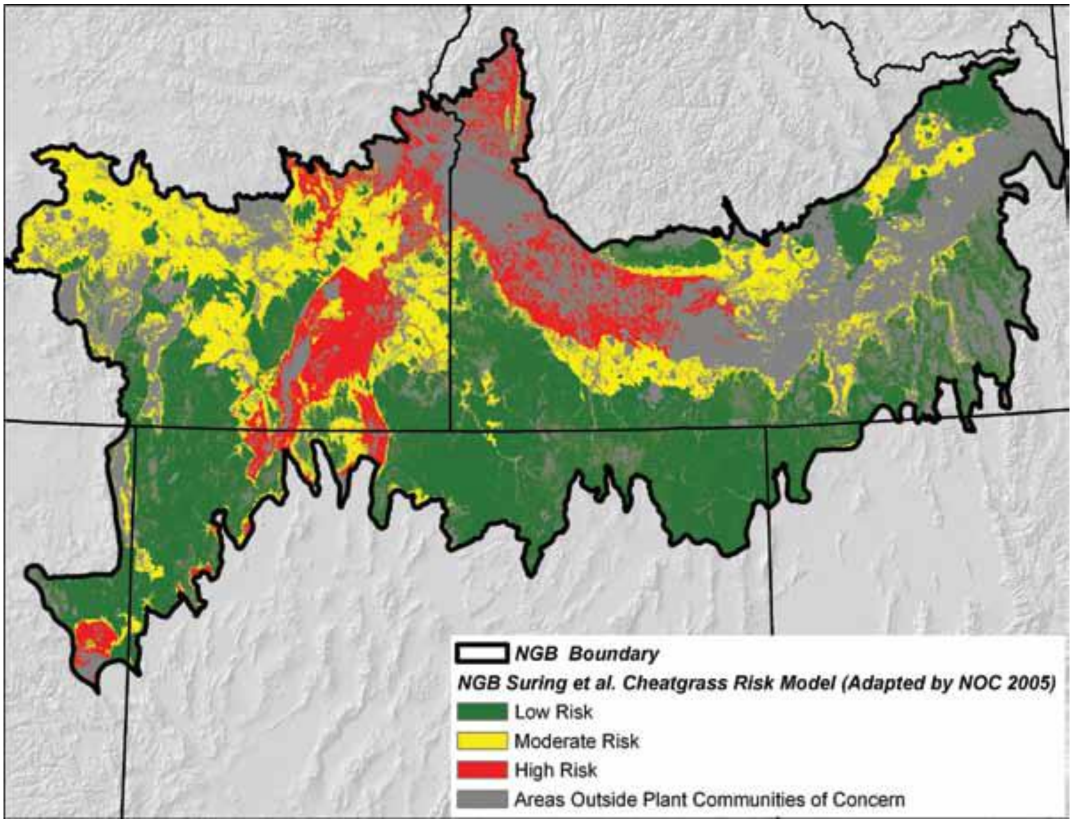


Figure 38. Invasive species model showing high (red) and moderate (yellow) risk of significant exotic cover for much of the Snake River Plain ecoregion (figure from BLM 2010)

Past Invasive Species Effects (1960): Given a lack of historical mapped information on invasive species, an expert estimate built upon a review of available literature and evaluation of the 2010 results.

4.2.3.2 Dynamic Process Alterations

As noted previously under Dynamic Process Forecasts, localized hydrologic or fire regime models for aquatic and upland ecosystems can provide insight for projected future climate regimes. They apply equally for characterizing current conditions. Given limitations on the availability of quantitative hydrologic models of use for our purposes in the Snake River Plain, estimates of 2010 hydrologic regime alterations were qualitative for each community type, scaled between 0.0 and 1.0 for each community type. For fire regime models mentioned previously, the same model for each upland type, updated to describe current conditions (e.g., with introduced invasive species included) were used to describe current departure relative to the 'expected' proportions of successional stages (FRCC 2010). Departure scores were normalized to a 0.0-1.0 relative score.

4.2.4 *Adaptive Capacity for Responding to Climate Stress*

As described previously, adaptive capacity is the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (IPCC 2007). As climate changes, community types with the capacity to support more gradual ecological transformation will have a higher likelihood of maintaining essential ecological relationships than those where transformations are more abrupt. Natural characteristics of ecosystems and communities therefore can make them more or less vulnerable to abrupt transformation brought on by rapid climate change. This inherent adaptive capacity may be initially measured in terms of natural composition and environmental variability characterizing the given community type across its distribution. Below are described four measures of adaptive capacity.

4.2.4.1 Diversity within characteristic functional groups

Natural communities may include a number of functional groups, or groups of organisms that pollinate, graze, disperse seeds, fix nitrogen, decompose organic matter, depredate smaller organisms, or perform other functions (Rosenfeld 2002, Folke et al. 2004). Experimental evidence gathered over the last two decades supports the theoretical prediction that communities with functional groups made up of increasingly diverse members tend to be more resilient to perturbations (Walker et al. 2004, Folke et al. 2004). Since individual species respond differently to disturbances, where there is high species diversity within a given group, as individual species are lost over time, it is more likely that the community will retain key functions and therefore have greater resilience to stressors. The more diverse the group, the greater the likelihood that at least one species will have characteristics that allow it to continue to perform its function in the community even if, say, precipitation patterns or the fire regime changes (Diaz and Cabido 2001) . For example, a study of semi-arid grasslands showed where sites with a diversity of grass species, including some seemingly “redundant” ones, was more resilient to changing states because different grass species dominated under different grazing and precipitation conditions (Walker et al. 1999). Thus a factor contributing to the adaptive capacity of a community is the diversity within its component functional groups.

However, the challenge remains to reliably describe functional groups of species for a given community type. Common approaches center on analysis of plant growth forms or specific traits in response to environmental constraints (Lavorel et al. 1997; Diaz and Cabido 2001). In this assessment, plant functional groups were initially identified by evaluating characteristic growth forms among plant species, and specific groups related to plant responses to drought. Pollinator diversity was also identified as an important functional species group to evaluate; although information on within-group diversity was limited. In each instance, expert knowledge was brought to bear in order to document each group, and score them along a 0.0 to 1.0 scale; with 1.0 indicating high species diversity within a functional group. Results from multiple functional groups were averaged together for an overall estimate.

4.2.4.2 Characteristic Elevation Range

Following a similar logic to measuring isobioclimates, elevation range can serve as an additional and distinct measure of biophysical variability that characterizes the distribution of a give community type. Elevation belts of 500 foot (152 meters) intervals were used for this measurement. Elevation belts of this interval may help to indicate local-scale microclimatic variation not well expressed by isobioclimates. Again, with an overlay of several hundred terrestrial ecological system types for the western United States, a maximum score of 12 elevation belts (i.e., 6,000 ft./ 1829 m) was established for comparison with the elevation range measured for each community type.

4.2.4.3 Dealing with Uncertainty

It is important to keep in mind that the future scenario presented here (A2, model ensemble 50th percentile) is but one of the many possible ways climate change may manifest itself. It conveys an important message that the system is indeed sensitive to change. However uncertainty lies in the climate models themselves and in the downscaling process, as there are many assumptions, such that the regional climate models will continue to function with future climate inputs as they have in the past. And we must recognize that a focus on one set of projections constrains the outlook on possible futures because they do not represent the full domain of possible future climates (Kittel et al. 2011). For these reasons, it is inappropriate to make management decisions based on one grid cell results vs. another. It is just a likely that results may be spatially reversed at that fine scale. Managers can use this information to understand the magnitude and type of spatial variation that may come about, but must not be locked in to any one scenario or particular spatial result. These results are based on the best science available, and climate change is already being observed (warmest records keep being broken). There is no uncertainty that change is happening and more change is to come (Lee et al. 2006, Solomon et al. 2007).

Another source of uncertainty is how species and ecosystems will respond to these changes. Again we have sophisticated models based on years of observations and expert input, but ecosystem response and species biology is vastly complex, with layers of positive and negative feedback loops (Kittel 2013).

Rather than relying on our limited knowledge to predict the future, and plan only for that future, we can view climate change as threat like other stressors. We can use our expert knowledge to assess vulnerabilities and recommend strategies to enhance their resistance and resilience (Groves 2003, Comer et al. 2012, Kittel et al. 2012). This is the approach we applied for this project.

Vulnerability-based adaptive capacity strategies are a “no-regrets” approach to management decisions. These are short term and long term goals designed to reduce stressors and enhance ecosystem and species resistance (avoidance) and resilience (buffering capacity) to other threats. Adaptive management protocols are: (1) reassessing species and system status through monitoring, (2) evaluating current and alternative innovative strategies through research and expert elicitation, and (3) adapting management plans in light of these new insights (Kittel 2013). We propose a suite of adaptive strategies based on each community’s level of vulnerability.

4.3 Results

A high-level summary of analysis scores and overall results for each community type as they occur within the Snake River Plain are provided in Table 5. A complete set of scores for each community type along with a description and characterization follows these summary results.

Climate Sensitivity scores were high for all types and ranged from 0.18 for sagebrush steppe to 0.3 for the wetland communities. The combination of high climate change exposure with an expected change in the already altered dynamic processes of hydrology and fire regimes, leads to these low scores and high vulnerability.

Indirect Effects scores show stress from past and current land use and range from 0.38 to 0.51 (low to moderate). Riparian areas have had the most change in their hydrologic regimes from diversion and storage of water for agriculture. Considerable agricultural development has occurred within this ecoregion prior to 1950, and again post 1950 with growth from the development of ground water well pumping technology. A century of fire suppression followed by massive influx of invasive species have significantly altered the fire regime of sagebrush steppe, and consequently also affecting surrounding habitats including wetlands. Invasive species (tamarisk, annual grasses) also change community structure by changing seasonality of growth, food source quality, food chain webs and competition. Hydrologic alterations for agricultural use have stressed surface water dependent wetlands (riparian, marsh, wet meadow) and ground water dependent wetlands (wet meadows, springs and seeps).

Adaptive Capacity scores range from 0.73 – 0.80, and indicate these communities are not limited by specific elevations or bioclimates within the Snake River Plain ecoregion, but most are relatively simple structure in their functional groups (marshes being the least diverse, and sagebrush steppe and riparian shrublands the most diverse).

Resilience scores (average of indirect effects and adaptive capacity) range from 0.59 to 0.62, and tells us that while inherently highly resilient, these communities are currently in stressed states. When combined with high climate sensitivity scores, all four communities will be highly vulnerable to climate change.

	Climate Sensitivity				Indirect Effects						Adaptive Capacity						
NVC Group Name	CC Stress	Dynamics Forecast	Sensitivity Score		LC 1960	LC 2010	IS 1960	IS 2010	Dynamics Current	Avg.	Functional Group Diversity	Bio-clim	Elev.	Avg.	Resilience Score		CC Vulnerability
Vancouverian & Rocky Mountain Montane Wet Meadow	*0.3*	*0.3*	***0.3***	H	*0.5*	*0.35*	*0.45*	*0.25*	*0.5*	**0.41**	*0.5*	*0.9*	*1.0*	**0.80**	***0.61***	M	**High (.45)**
Intermountain Dry Tall Sagebrush Shrubland & Steppe	*0.3*	*0.05*	***0.18***	H	*0.59*	*0.35*	*0.40*	*0.5*	*0.10*	**0.39**	*0.50*	*0.85*	*1.0*	**0.78**	***0.59***	M	**High (.38)**
Western North American Temperate Interior Freshwater Marsh	*0.3*	*0.3*	***0.3***	H	*0.5*	*0.35*	*0.7*	*0.5*	*0.5*	**0.51**	*0.35*	*0.85*	*1.0*	**0.73**	***0.62***	M	**High (.46)**
Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland	*0.3*	*0.3*	***0.3***	H	*0.45*	*0.35*	*0.5*	*0.25*	*0.35*	**0.38**	*0.5*	*0.9*	*1.0*	**0.80**	***0.59***	M	**High (.45)**

Table 5. HCCVI scores of four NVC Groups within the Snake River Plain Ecoregion.

Scoring—***Sensitivity: Low .7-1.0, Medium .5-.69, High 0.0-.49; Resilience: Low 0.0-.49, Moderate .5-.69, High 0.7-1.0; CC Vulnerability: Low .7-1.0, Moderate .5-0.69, High 0.0-.49***

4.3.1 *Habitat Vulnerability Climate Change Index for NVC Group G521 Vancouverian & Rocky Mountain Montane Wet Meadow Group aka "Wet Meadow Habitat" within the Snake River Plain Ecoregion*

CONCEPT


Wheat Sedge (*Carex atherodes*) meadow (left), and Baltic Rush (*Juncus balticus*) meadow (right, with Tom Meiwald, USFWS Geographer) at Camas NWR.

USFWS Habitat Wet Meadow = NVC Group G521 Vancouverian & Rocky Mountain Montane Wet Meadow Group

Camas NWR Local Description—Wet meadows cover about 1,958 acres (18%) at Camas NWR and are dominated by native Baltic rush (*Juncus balticus*) or native sedges such as wheat sedge *(Carex atherodes),* northwest-territory sedge *(Carex utriculata),* or clustered field sedge (*Carex praegracilis).* Many areas are invaded by quack grass *(Agropyron repens),* a non-native planted for seed production for waterfowl, and other non-native weed species such as Canadian thistle (*Cirsium arvense*), prickly lettuce (*Lactuca serriola*) and field pennycress (*Thlaspi arvense*). These are meadows that are sheet flooded most years from rising lake levels or Camas Creek overflow (in very wet years) and are primarily kept moist throughout the growing season by a shallow water table from artesian springs.

Range-wide Description This group contains the wet meadows found in montane and subalpine elevations, occasionally reaching into the lower edges of the alpine elevations, about 3300 – 11,800 feet (1000-3600 m) from California's Transverse and Peninsular ranges north to British Columbia's coastal mountains and from throughout the Rocky Mountains of Canada and the U.S. (including the Black Hills of South Dakota) and mountain ranges of the intermountain interior west, including the high desert regions of the Great Basin, Snake River Plain and Columbia Plateau. Wet meadows occur in open wet depressions, basins and flats with low-velocity surface and subsurface flows. They can be large meadows or occur as narrow strips bordering ponds, lakes and streams, and along toe slope seeps. They are typically found on flat areas or gentle slopes up to 10%. In alpine regions, sites typically are small depressions located below late-melting snow patches. Most locations are seasonally wet, often drying by late summer, and many occur in a tension zone between perennial wetlands and uplands, where water tables fluctuate in response to long-term climatic cycles. They may have surface water for part of the year, but depths rarely exceed a few centimeters. Wet meadows can be tightly associated with snowmelt and typically are not subjected to high velocity disturbance, but can be flooded by slow-moving waters. Soils are mostly mineral and show typical hydric soil characteristics such as low chroma and redoximorphic features; some areas may have high organic content as inclusions or pockets. Vegetation of this group can manifest as a mosaic of several plant associations, or be a monotypic stand of a single association which is dominated by graminoids or forbs. Varying dominant herbaceous species include native graminoids bluejoint and mountian reedgrass (*Calamagrostis canadensis, Calamagrostis stricta*),sedges (*Carex atherodes, Carex bolanderi, Carex exsiccata, Carex illota, Carex microptera, Carex praegracilis, Carex scopulorum, Carex utriculata, Carex vernacular),* hairgrass *(Deschampsia caespitosa),* fewflowered spike rush (*Eleocharis quinqueflora),* mannagrass (*Glyceria striata = Glyceria elata),* rushes *(Juncus balticus, Juncus drummondii, Juncus nevadensis)*. Forb species include small camas (*Camassia quamash*)*,* heartleaf bittercress (*Cardamine cordifolia*)*,* shooting star (*Dodecatheon jeffreyi*)*,* icegrass (*Phippsia algida*)*,* alpine yellowcress (*Rorippa alpine*)*,* arrowleaf ragwort (*Senecio triangularis*)*,* Parry's clover (*Trifolium parryi*), and California false helbore (*Veratrum californicum*). Common but sparse shrubs may include willows (*Salix* spp.), bog blueberry (*Vaccinium uliginosum*)*,* Aiton cranberry (*Vaccinium macrocarpon*), and big birch *(Betula glandulosa*).

Overall Climate Change Vulnerability Score **0.45 Highly Vulnerable**

DIRECT EFFECTS

Forecasted Climate Stress Index: Results **(0.3) High Sensitivity**

Based on an ensemble of down-scaled Global Circulation Models proved by Climate Wizard Tool (Girvetz et al. 2009), A2 scenarios (continuation of current emission rates and government policies) for climate forecast for 2060 (50 years into the future) the Snake River Plain may warm, on an annual average, by 4.7-5.5 degrees F (Figure 30). Summer and fall months of July, August and September are projected to experience the greatest day time maximum temperatures increase (5.7-8.4 degrees F, Figure 31). Precipitation forecast shows little change because models do not have consistent trends. Overall annual precipitation is predicted to change from -1 to + 8 inches with a mean of about 1-2" increase. Seasonally, winter, spring and fall have 0 to 4 inch increase while the summer months have the greatest decrease with -1 to -2.5 inches less than historic to up to about +1 to +1.5 inches increase over historic (Figure 32). The greatest change of climate change appears to manifest itself in the summer or growing season months (June- July and August) with the highest temperature increases and the least precipitation gains and greatest predicted losses. Thus in the summer/growing season may be much warmer and drier. Predicted increases in precipitation may not be enough to offset warmer temperatures. Given the higher probability of warming, the climate stress on component species is high for a drought and heat intolerant species, as many intermountain marsh plant species are. With the higher uncertainty on how precipitation may change, it is difficult to rate the hydrologic stress this may have on this ecosystem. The direct effect on the hydrologic regime is considered separately.

Dynamic Process Forecast

Hydrologic and Fire Regime Change 2060 – Result **(0.3) High Sensitivity**

→ Current and forecasted trends—The Snake River Plain has a potential for moderate increases (+1-2 inches) in precipitation in winter months; and declines in the summer months (-1-2 inches) or increases of the same magnitude. It doesn't appear any increase in summer precipitation would be enough to offset the increase in temperatures. Forecasted changes in temperature and precipitation patterns would be expected to result in several effects on aquatic CEs in the ecoregion, as discussed by Melack et al. 1997, Mote 2006, Chambers and Pellant 2008, Brown and Mote 2009, Covich 2009, Das et al. 2009, McCabe and Wolock 2009, Isaak et al. 2010, USBOR 2011: These changes could result in:

- **higher evapo-transpiration rates** leading to an earlier, more rapid seasonal drying-down of wet meadow communities;
- **increased water stress** in wet meadow communities
- **shrinkage of areas wet meadows**, coupled with higher water temperatures at locations/times when water temperatures are not controlled by groundwater discharges or snowmelt;
- **persistence of these hydrologic conditions later** into the fall or early winter; and
- **reduced groundwater recharge** in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface.

Based on the ways in which these hydrologic factors affect ecological dynamics in the aquatic CEs, persistence of these hydro-meteorological impacts over multiple decades could result in several long-term impacts at both high and low elevations, as discussed by many of the authors cited above, and also by Harper and Peckarsky 2006, Hultine et al. 2007, Martin 2007, Jackson et al. 2009, and Seavy et al. 2009:

- **Loss of wet meadow vegetation** at lower elevations where the frequency and spatial extent of seasonal flows into meadows (overland flow and groundwater seepage) determines the spatial limits of this vegetation;
- **Reduced discharge** to springs and seeps as a result of reduced aquifer recharge;
- **A continuation of normal "warm-season" aquatic ecological dynamics later into the fall** as a result of seasonally normal (baseline) overnight near-freezing temperatures becoming less common in many areas until later in the fall; and
- **A possible de-coupling** of the places and timing of emergence of insects, the plants on which they depend, and the animals that feed on the insects, as individual species respond to different cues from air and water temperatures, water availability, and flow conditions.

→ Where <u>increases</u> in precipitation, especially in July and Aug, might occur this may result in:

- Increased soil erosion from increased surface flows, which may negatively impact water quality
- Increased stream flow magnitude in summer time, more frequent precipitation events on wet meadows

Increased fire frequency and intensity in the watersheds (Figure 35) of these systems will have enormous post-fire effects on marshes:

- *Increased* winter precipitation causes increased fire in low/mid elevation shrublands and in wet meadows (due to increase spring fuel loading), which causes decreased short-term evapotranspiration (from fuel reduction by fire). This leads to increased groundwater recharge, which increases post-fire runoff, increasing runoff and sediment deposition in wet meadows.
- Long-term *decreased* precipitation (e.g., drought) causes increased fire in woodlands and forests, which causes decreased evapotranspiration. This leads to increased groundwater recharge, which increases post-fire runoff, changing groundwater levels, sediment runoff levels and water chemistry. Drier months may increase the probability of fire in wet meadows.
- Fires also have direct effects on these systems, changing fuel loads, increasing invasive species spread, and increasing inflammability.

INDIRECT EFFECTS

Landscape Condition circa 1960 **Result (0.5) Moderate Resilience**

→ Ranching and farming have been primarily diverting surface water from the relevant streams and rivers since the late 1800s. Extensive water development with dams and canal systems diverted surface water and changed stream flow regimes. Irrigated agriculture grew from few hundred thousand acres to millions of acres (Figure 37). Irrigation increased groundwater recharge rates in some areas, especially the central portion of the ecoregion (De Grey and Link nd, Geller 2006, Slaughter 2004). Groundwater extraction was just beginning to grow between 1950 and 1960.

Landscape Condition Current 2010 **Result (0.35) Low Resilience**

→ Urban and agricultural areas have continued to grow exponentially with an increase in center pivot groundwater fed irrigation for agricultural. Nearly all arable land on the Snake River plain is in production. There are cumulative effects of groundwater withdrawals, lowering water table in local areas, affecting spring recharge. Intensive farming along the riparian corridors impact and fragment floodplains and remove riparian and adjacent wet meadow habitats. Greater number of acres have been converted to intensive agriculture. Urban and rural growth has increase the foot print and impact of roads surrounding towns and cities (**Figure 36**).

Invasive Species Impact 1960 **Result (0.45) Low Resilience**

→ Cheatgrass was introduced in the 1880's and rapidly spread over lands degraded by severe overgrazing by cattle and sheep (BLM 2010). Wetlands and riparian areas were particularly hard hit by concentrations of livestock and the introduction of additional invasive species of tamarisk and Russian olive. In addition, wet meadows were seeded with non-native species such as quackgrass (*Agropyron repens*) and smooth brome (*Bromus inermis*).

Invasive Species Impact Current 2010 Result **(0.25) Low Resistance**

→ Current footprint of the extent of exotic species is incompletely mapped, however models of areas likely to contain significant amounts of tamarisk, Russian olive, and annual grasses indicate >50% of the riparian and low wetland areas are affected (Morisette et al. 2006, Kerns et al. 2009, BLM 2010)(Figure 38).

Dynamic Process Current

Hydro Regime Change 2010- Current **Results (0.50) Moderate Resilience**

Surface water diversions and dams on main stem of the Snake and Boise Rivers have significantly changed the hydrologic regime of these rivers. High spring flows have been reduces and low fall flows have been increased. Flood control structures have provided protection from flooding for towns, and have disconnected the floodplain from the stream channel, changing the timing and frequency of flooding, a significant source of moisture for floodplain wet meadows. Agricultural and residential/urban use has dropped groundwater levels significantly, already reducing or eliminating many gaining reaches. Groundwater irrigation rose from 100,000 acres in 1950 to 700,000 acres in 1965 and 1.1 million acres by 1980 (Slaughter 2004).

ADAPTIVE CAPACITY

Bioclimate Variability– Result **(0.9) High Resilience**

→ This NVC Group could occur throughout all local climate regimes that characterize the Snake River Plain ecoregion.

Elevation range – Result **(1.0) High Resilience**

→ This NVC Group is not limited by available elevations within the Snake River Plain Ecoregion.

Diversity with Plant/Animal Functional Groups – Result **(0.49) Low Resilience**

→ This NVC Group has is limited to freshwater graminoid and forb plant species. Functional groups include rhizomatous and bunch graminoids, and mostly perennial forb species.

Potential Climate Change Adaptation Strategies

Generalized strategies and notes:

-Protect and enhance wet meadow areas and the listed species that depend on them

-Preservation of remnant wet meadow areas to support migratory birds

-Protect upper watershed

-Reduce invasives

-Maintain biodiversity and processes (such as flooding)

-Preserve scenery, water-based natural and cultural resources for public enjoyment

-Identify information needs of land managers, conduct research, and provide information

“No-regrets” actions to take within the next 5 years:

- Restore shallow groundwater,
- retire surface diversion and groundwater pumping permits, where these can be identified as affecting the stream and/or alluvial aquifer(s) of concern – sometimes well upstream of the occurrence(s) of concern. Transferring upstream diversion rights to downstream rights will also allow more water to be kept in-channel for longer reaches, but will still allow the water to be withdrawn elsewhere (downstream).
- Aggressively control invasive species.
- Protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff

Actions to anticipate over the coming 5-15 years:

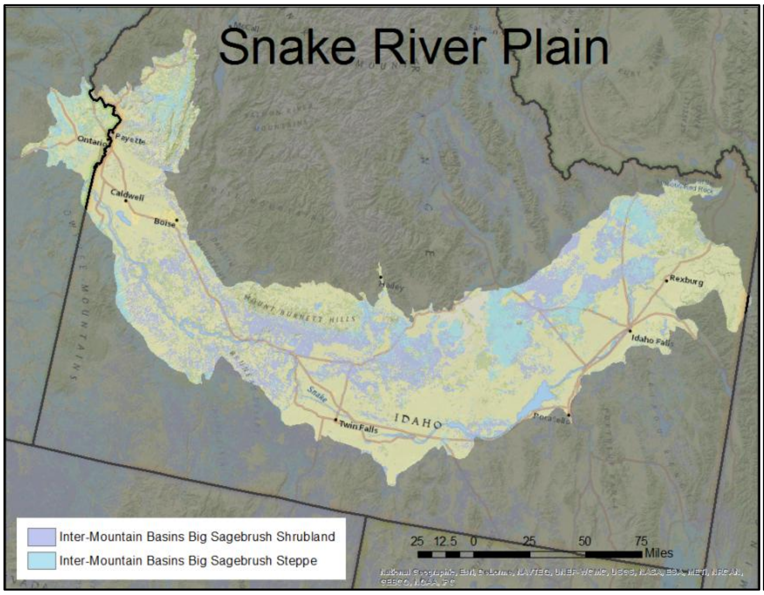
- Increase capacity of culverts in anticipation of more frequent and more severe precipitation events.
- Protect recharge areas and their surface catchments to provide long-term insurance for continued recharge (effects may take decades to realize).

“Watch and Wait” Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Shift in species composition may be expected (more southern species appearing). ***Monitor for change in species composition.***
- Novel invasive species may appear in coming decades, even in currently high-integrity sites.

4.3.2 *Habitat Vulnerability Climate Change Index for NVC Group G303 Intermountain Dry Tall Sagebrush Shrubland & Steppe Group aka “Sagebrush Steppe Habitat” within the Snake River Plain Ecoregion*

CONCEPT



Sagebrush Steppe Habitat = NVC Group (G303) Intermountain Dry Tall Sagebrush Shrubland & Steppe Group

Camas NWR Local description— The 2012 vegetation map shows just under 2000 acres of sagebrush steppe, covering about 18% of the refuge. Open to dense stands of basin big sagebrush (*Artemisia tridentata ssp. tridentata*) or wyoming sagebrush (*Artemisia tridentata ssp. Wyomingensis*) with small amounts of rubber and green rabbit brush (*Chrysothamnus nauseosus, Chrysothamnus viscidiflorus*) and with native grasses such as Indian ricegrass (*Achnatherum hymenoides), needle and thread grass (Hesperostipa comata = Stipa comata),* purple three-awn (*Aristida purpurea*),and mat muhly (*Muhlenbergia richardsonis*). Native Forbs include prickly pear cactus (*Opuntia polyacantha*) and Bruneau mariposa lily (*Calochortus bruneaunis*). Non-native grasses are also present such as cheatgrass (*Bromus tectorum*) and crested wheatgrass (*Agropyron cristatum*).

Range-Wide description This shrubland and shrub herbaceous group is widely distributed from the Great Basin, Columbia River Basin, Columbia Plateau, Snake River Plain, Colorado Plateau, northern Rocky Mountains, northeastern Great Plains and as far east as the Dakotas at elevations as low as 500 m in the northwestern Great Plains to 2500 m in the Rocky Mountains and Colorado Plateau. This group occurs on flat to steeply sloping upland slopes on alluvial fans and terraces, toeslopes, lower and middle slopes, draws, badlands, and foothills. Sites with little slope tend to have deep soils, while those with steeper slopes have shallow to moderately deep soils. Climate ranges from arid in the western Great Basin to subhumid in the northern plains and Rocky Mountains with much of the precipitation falling primarily as snow. The amount and reliability of growing-season moisture increase eastward and with increasing elevation. Stands are dominated by Wyoming big sagebrush (*Artemisia tridentata ssp. Wyomingensis*) and basin big sagebrush (*Artemisia tridentata ssp. tridentata*) and, in some cases, codominated by service berry (*Amelanchier utahensis), fourwing saltbush (Atriplex canescens), morman tea (Ephedra nevadensis, Ephedra viridis) rabbitbrush (Ericameria nauseosa)*, or greasewood (*Sarcobatus vermiculatus)*. Other common shrubs include prairie sagewort (*Artemisia frigida), other saltbush species (Atriplex confertifolia, Atriplex gardneri), other rabbitbrush species (Chrysothamnus* spp., *Ericameria* spp.), spiny hopsage (*Grayia spinosa),* winterfat *(Krascheninnikovia lanata),* wild crab apple *(Peraphyllum ramosissimum),* choke cherry *(Prunus virginiana),* bitter brush *(Purshia tridentata),* snowberry *(Symphoricarpos longiflorus)*, and horsebrush (*Tetradymia* spp.) The herbaceous layer may be sparse to strongly dominated by graminoids including Indian ricegrass (*Achnatherum hymenoides), Letterman's needle and thread grass (Achnatherum lettermanii = Stipa lettermanii), pine needlegrass (Achnatherum pinetorum),* Thurber's needlegrass (*Achnatherum thurberianum),* blue grama *(Bouteloua gracilis),* the invasive non-native cheatgrass *(Bromus tectorum), threadleaf sedge (Carex filifolia), wildrye species (Elymus albicans, Elymus elymoides, Elymus lanceolatus, Leymus ambiguus),*Idaho fescue*(Festuca idahoensis), needle and thread grass (Hesperostipa comata = Stipa comata), James' galleta (Pleuraphis jamesii),* bluegrass *(Poa fendleriana, Poa secunda),*western wheatgrass (*Pseudoroegneria spicata),* and dropseed (*Sporobolus airoides*, *Sporobolus cryptandrus)*. A sparse layer of cold-deciduous needle-leaved or scale-leaved evergreen trees may occasionally be emergent over the shrubs.

Overall Climate Change Vulnerability Score **0.38 Highly Vulnerable**

DIRECT EFFECTS

Forecasted Climate Stress Index: Results **(0.3) High Sensitivity**

Based on an ensemble of down-scaled Global Circulation Models proved by Climate Wizard Tool (Girvetz et al. 2009), A2 scenarios (continuation of current emission rates and government policies) for climate forecast for 2060 (50 years into the future) the Snake River Plain may warm, on an annual average, by 4.7-5.5 degrees F (Figure 30). Summer and fall months of July, August and September are projected to experience the greatest day time maximum temperatures increase (5.7-8.4 degrees F, Figure 31). Precipitation forecast shows little change because models do not have consistent trends. Overall annual precipitation is predicted to change from -1 to + 8 inches with a mean of about 1-2" increase (Figure 32). Seasonally, winter, spring and fall have 0 to 4 inch increase while the summer months have the greatest decrease with -1 to -2.5 inches less than historic to up to about +1 to +1.5 inches increase over historic. The greatest change of climate change appears to manifest itself in the summer or growing season months (June- July and August) with the highest temperature increases and the least precipitation gains and greatest predicted losses. Thus in the summer/growing season may be much warmer and drier. Predicted increases in precipitation may not be enough to offset warmer temperatures. Given the higher probability of warming, the climate stress on component species is high for a drought and heat intolerant species; however sagebrush and native grasses are very drought and heat tolerant.

Dynamic Process Forecast **Result (0.05) High Sensitivity**

Fires also have direct effects on these systems, increasing invasive species spread, and increasing inflammability. Predictions by some regional models indicate a high potential for sagebrush to convert to cheatgrass cover (BLM 2010). Projecting from the current state of high fire departure (Figure 35, FRCC 2010), by 2060 the fire regime may well be still highly different from the historic pattern as more and more areas convert to non-native grasses. However predictions are difficult with the complex interaction between climate, timing of precipitation events, fuel loads, fire intensity and frequency.

Primary concerns include:

- **Increased flammability** due to exotic annual grass causes increased fire frequency and fuel continuity, which results in changes in species composition and structure.
- Compounding effects of in situ climate change on **post-fire regeneration of dominant species** (e.g. inability for big sagebrush to resprout after fire, seedlings must compete with non-native annual grass species).

INDIRECT EFFECTS

Landscape Condition circa 1960 **Result (0.59) Moderate Resilience**

→ Cattle and sheep ranching were the primary use of sagebrush habitat between 1880 and 1950. Towns of Boise and Twin Falls (and many others) developed and grew into surrounding areas, fragmenting the landscape with highways, smaller roads and transmission lines. After about 1950 improvements of groundwater well technology made deep wells feasible, and many areas of sagebrush habitat were converted to center pivot irrigated agriculture between 1950 and 1960 (Figure 37).

Landscape Condition Current 2010 Result **(0.35) Low Resilience**

→ Urban and agricultural areas have grown exponentially. Nearly all arable land on the Snake River plain is in production. Urban areas have grown and some areas or rural or exurban have increased the density of housing in the wildland interface, predominantly within the sagebrush dominated areas. Cities, agriculture, roads and utility lines now fragment much of the Snake River Plain ecoregion. The development of center it irrigation has made the conversion of uplands of sagebrush possible and considerable acres of sagebrush habitat has been converted to irrigated crops. Irrigated agriculture is 3 million acres, some of which was sagebrush habitat (**Figure 36**).

Invasive Species Impact 1960 Result (0.40) **Low Resilience**

→ Cattle and sheep ranching were the primary use of sagebrush habitat between 1880 and 1950. Widespread overgrazing throughout sagebrush habitats severely disrupted soil crusts, increased soil erosion and facilitated the spread of exotic annual grass such as cheatgrass) (BLM 2010).

Invasive Species Impact Current 2010 Result **(0.35) Low Resilience**

→ Levels of livestock have been reduced significantly however the legacy of soil disturbance and exotic species remains. Increase recreational use by humans is a new disturbance pressure within sagebrush habitats. The current footprint of the extent of exotic species is incompletely mapped, and models of potential continued spread of invasive species indicate significant amounts of annual grasses especially for the lowest elevations within the Snake River Plain ecoregion (Figure 38) (BLM 2010).

Dynamic Process Current

Fire Regime Departure 2010—Current **Result (0.10) High Sensitivity**

→ Current Fire Regime Departure—as measured by the Fire Regime Condition Class (FRCC 2010) shows for sagebrush steppe and sagebrush shrubland Group distribution within the Snake River Plain ecoregion that >90% is in high or medium fire departure (Figure 35)—meaning that the rather than the a natural suite of successional classes, there are more areas with exotic grasses (an "uncharacteristic state"), more areas old growth from decades of fire suppression, more areas where juniper has invaded sagebrush (another "uncharacteristic state") than what is expected from historic natural variation.

ADAPTIVE CAPACITY

Bioclimate Viability– **Result (.85) High Resilience**

→ Much of the landscape of the Snake River Plain has Bioclimate that supports sagebrush habitats.

Elevation range – Result **(1.0) High Resilience**

→ This NVC Group is not limited by available elevations within the Snake River Plain Ecoregion.

Diversity with Plant/Animal Functional Groups – Result **(0.50) Moderate Resilience**

→ This NVC Group has is limited to evergreen drought tolerant shrubs that includes both fire re-seeders and fire-resprouting species. The herbaceous understory is primarily characterized by a suite of bunch grasses, although a few rhizomatous species as well as both cold and warm season grasses do occur within this Group.

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species
- Aggressive management of wildland fire

Anticipated actions over the coming 5-15 years:

- Develop monitoring program for sage grouse to detect changes in populations and work towards protecting habitats
- Implement a phenology monitoring protocol to document changes in timing of blooming for rare plants and effects on pollinators
- Hold workshops that bring together all managers that focus on an important species, and use workshop to share information (e.g., phenology, abundance), develop hypotheses of change (e.g., sage grouse)
- Evaluate, share, analyze existing weather station information across managed areas, states; and develop strategy to prioritize locations for new stations.

Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

Research and Monitoring Priorities

- What is the capacity for invasive grasses to expand and therefore shift fire regime?
- Within the Snake River Plain, what are the indicator and keystone species and what is the impact of their loss?
- How do you characterize adaptive capacity for sparsely vegetated systems (e.g. lava barrens)?
- What are the displacement effects of invasive species in sagebrush systems?
- Are soil crusts susceptible to climate change and to what degree?
- What is the potential of strategy to inoculate soils for soil crusts?
- Need guidance and best practices on efficient monitoring protocols to track and detect plant community change associated with climate change.
- What is the relationship of precipitation regime (e.g. seasonal precipitation patterns) with plant recruitment?
- Need a study that identifies pollinators that serve a keystone role in Snake River Plain ecological systems.

4.3.3 *Habitat Vulnerability Climate Change Index for NVC Group G518 Western North American Temperate Interior Freshwater Marsh Group aka "Marsh Habitat" within the Snake River Plain Ecoregion*

CONCEPT

USFWS Habitat Marsh = NVC Group G518 Western North American Temperate Interior Freshwater Marsh Group

Camas NWR Local Description— Freshwater Marshes (not including open water) cover about 794 acres (7%) at Camas. These are semi-permanently flooded emergent marshes dominated by bulrush (*Scirpus acutus*), cattails (*Typha* spp.) or spikerush (*Eleocharis palustris*). Few other species occur in often near mono-typic stands of one of these three species although there are areas where bulrush and cattail are mixed together. Aquatic plants include southern waternymph *(Najas guadalupensis),* common duckweed *(Lemna minor)* and coon's tail *(Ceratophyllum demersum*). Water depths are generally shallow, 1-3 feet, and pond level nearly completely dry down in the winter.

Range-wide Description Freshwater marshes are found at all elevations below timberline throughout the temperate Pacific Coast, temperate western interior and coastal mountains of western North America. This group includes shallow freshwater water bodies found in small depressions gouged into basalt by Pleistocene floods, channeled scablands of the Columbia Plateau and within dune fields in the intermountain western U.S. These wetlands are mostly small-patch, confined to limited areas in suitable floodplain or basin topography. They are mostly semi-permanently flooded, but some marshes have seasonal hydrologic flooding. Water is at or above the surface for most of the growing season. A consistent source of freshwater is essential to the function of these systems. Soils are muck or mineral or muck over a mineral soil, and water is high-nutrient. Occurrences of this group typically are found in a mosaic with other wetland systems. It is often found along the borders of ponds, lakes or reservoirs that have more open basins and a permanent water source throughout all or most of the year. Some of the specific communities will also be found in floodplain systems where more extensive bottomlands remain. They may occur at the bottom of a basalt cliff in a lined circular or linear depression, or occur as small (usually less than 0.1 ha) interdunal wetlands in wind deflation areas, where sands are scoured down to the water table.

By definition, freshwater marshes are dominated by emergent herbaceous species, mostly graminoids, bulrush (*Scirpus* and/or *Schoenoplectus*), spike rush (*Eleocharis),* rushes (*Juncus),* cattails (*Typha*) and sedges (*Carex*) but also some forbs. Common emergent and floating forb species include bur-reed (*Sparganium*)*,* arrowhead (*Sagittaria*)*,* beggarticks (*Bidens),* water hemlock (*Cicuta*)*,* cress (*Rorippa*)*,* monkey flower (*Mimulus*), and canary grass (*Phalaris*). In relatively deep water, there may be floating-leaved genera such as duckweed (*Lemna*)*,* pondweed *(Potamogeton),* smartweed *(Polygonum),* pond lily (*Nuphar),* marshpennywort (*Hydrocotyle*), and watershield (*Brasenia)*. Water tolerant woody plants, including cottonwood (*Populus), willows (Salix), Hawthorne (Crataegus)*, or wildrose (*Rosa woodsii)*, may present.

Overall Climate Change Vulnerability Score **0.46 Highly Vulnerable**

DIRECT EFFECTS

Forecasted Climate Stress Index: Results **(0.3) High Sensitivity**

Based on an ensemble of down-scaled Global Circulation Models proved by Climate Wizard Tool (Girvetz et al. 2009), A2 scenarios (continuation of current emission rates and government policies) for climate forecast for 2060 (50 years into the future) the Snake River Plain may warm, on an annual average, by 4.7-5.5 degrees F (Figure 30). Summer and fall months of July, August and September are projected to experience the greatest day time maximum temperatures increase (5.7-8.4 degrees F, Figure 31). Precipitation forecast shows little change because models do not have consistent trends. Overall annual precipitation is predicted to change from -1 to + 8 inches with a mean of about 1-2” increase (Figure 32). Seasonally, winter, spring and fall have 0 to 4 inch increase while the summer months have the greatest decrease with -1 to -2.5 inches less than historic to up to about +1 to +1.5 inches increase over historic. The greatest change of climate change appears to manifest itself in the summer or growing season months (June- July and August) with the highest temperature increases and the least precipitation gains and greatest predicted losses. Thus in the summer/growing season may be much warmer and drier. Predicted increases in precipitation may not be enough to offset warmer temperatures. Given the higher probability of warming, the climate stress on component species is high for a drought and heat intolerant species, as many intermountain marsh plant species are. With the higher uncertainty on how precipitation may change, it is difficult to rate the hydrologic stress this may have on this ecosystem. The direct effect on the hydrologic regime is considered separately.

Dynamic Process Forecast

Hydrologic and Fire Regime Change 2060 – Result **(0.3) High Sensitivity**

→ Current and forecasted trends—The Snake River Plain has a potential for moderate increases (+1-2 inches) in precipitation in winter months; and declines in the summer months (-1-2 inches) or increases of the same magnitude. It doesn't appear any increase in summer precipitation would be enough to offset the increase in temperatures. Forecasted changes in temperature and precipitation patterns would be expected to result in several effects on aquatic CEs in the ecoregion, as discussed by Melack et al. 1997, Mote 2006, Chambers and Pellant 2008, Brown and Mote 2009, Covich 2009, Das et al. 2009, McCabe and Wolock 2009, Isaak et al. 2010, USBOR 2011: These changes could result in:

- **higher evapo-transpiration rates** leading to an earlier, more rapid seasonal drying-down of pond levels and marsh communities;
- **increased water stress** in in shallow marsh communities
- **shrinkage of areas of ponds and emergent marshes**, coupled with higher water temperatures at locations/times when water temperatures are not controlled by groundwater discharges or snowmelt;
- **persistence of these hydrologic conditions later** into the fall or early winter; and
- **reduced groundwater recharge** in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface.

Based on the ways in which these hydrologic factors affect ecological dynamics in the aquatic CEs, persistence of these hydro-meteorological impacts over multiple decades could result in several long-term impacts at both high and low elevations, as discussed by many of the authors cited above, and also by Harper and Peckarsky 2006, Hultine et al. 2007, Martin 2007, Jackson et al. 2009, and Seavy et al. 2009:

- **Loss of wetland vegetation** at lower elevations where the frequency and spatial extent of seasonal flows into ponds and marshes determines the spatial limits of this vegetation;
- **Reduced discharge** to springs and seeps as a result of reduced aquifer recharge;
- **A continuation of normal "warm-season" aquatic ecological dynamics later into the fall** as a result of seasonally normal (baseline) overnight near-freezing temperatures becoming less common in many areas until later in the fall; and
- **A possible de-coupling** of the places and timing of emergence of insects, the plants on which they depend, and the animals that feed on the insects, as individual species respond to different cues from air and water temperatures, water availability, and flow conditions.

→ Where <u>increases</u> in precipitation, especially in July and Aug, might occur this may result in:

- Increased soil erosion from increased surface flows, which may negatively impact water quality

- Increased stream flow magnitude in summer time, higher pond levels

Increased fire frequency and intensity in the watersheds (Figure 35) of these systems will have enormous post-fire effects on marshes:

- *Increased* winter precipitation causes increased fire in low/mid elevation shrublands (due to increase spring fuel loading), which causes decreased short-term evapotranspiration (from fuel reduction by fire). This leads to increased groundwater recharge, which increases post-fire runoff, changing pond sediment levels and water chemistry.
- Long-term *decreased* precipitation (e.g., drought) causes increased fire in woodlands and forests, which causes decreased evapotranspiration. This leads to increased groundwater recharge, which increases post-fire runoff, changing pond water and sediment levels and water chemistry.
- Fires also have direct effects on these systems, changing water chemistry, increasing aquatic invasive spp. spread, and increasing inflammability.

INDIRECT EFFECTS

Landscape Condition circa 1960 **Result (0.5) Moderate Resilience**

→ Ranching and farming have been primarily diverting surface water from the relevant streams and rivers since the late 1800s. Extensive water development with dams and canal systems diverted surface water and changed stream flow regimes. Irrigated agriculture grew from few hundred thousand acres to millions of acres. Irrigation increased groundwater recharge rates in some areas, especially the central portion of the ecoregion (De Grey and Link nd, Geller 2006, Slaughter 2004). Groundwater extraction was just beginning to grow between 1950 and 1960 (Figure 37)

Landscape Condition Current 2010 **Result (0.35) Low Resilience**

→ Urban and agricultural areas have continued to grow exponentially with an increase in center pivot groundwater fed irrigation for agricultural. Nearly all arable land on the Snake River plain is in production. There are cumulative effects of groundwater withdrawals, lowering water table in local areas, affecting spring recharge. Intensive farming along the riparian corridors impact and fragment floodplains and remove riparian and adjacent wet meadow habitats. Increases in ponds and reservoirs have increased the amount of emergent marsh habitat, although these tend to be small and can have water quality issues. Urban and rural growth has increase the foot print and impact of roads surrounding towns and cities (**Figure 36**).

Invasive Species Impact 1960 **Result (0.7) High Resilience**

→ Historic cattle grazing introduced invasive plant spp. Late-19^{th} -early 20^{th} century. Deliberate introductions of tamarisk, Russian olive and annual grasses in residential areas and grazing lands brought these species into the area. Marshes are less prone to these terrestrial plant invasions, but are susceptible to nuisance aquatic animal and plant species, few of which were known prior to 1960's.

Invasive Species Impact Current 2010 **Result (0.5) Moderate Resilience**

→ Current footprint of the extent of exotic species is incompletely mapped, however models of areas within the Unites States likely to contain significant amounts of tamarisk, Russian olive, and annual grasses indicate >50% of low wetland areas are affected (Morisette et al. 2006, Kerns et al. 2009) (Figure 38). In addition, there are aquatic invasive species such as mollusks and non-native fish, which could completely change the aquatic food chain dynamics and eliminate native aquatic species. Current records of aquatic invasive species indicate it is only a matter of time before all bodies of water including freshwater marshes to have more than one aquatic invasive species (Comer et al. 2012a).

Dynamic Process Current

Hydro Regime Change 2010- Current **Results (0.50) Moderate Resilience**

Agricultural and residential/urban use has dropped groundwater levels significantly, already reducing or eliminating many gaining reaches. Groundwater irrigation rose from 100,000 acres in 1950 to 700,000 acres in 1965 and 1.1 million acres by 1980 (Slaughter 2004). Ponds that were fed by streams and springs naturally historically first increased in size due to greater recharge (1880 – 1950s) are now shrinking due to drops in groundwater table and less surface runoff (1960-2010)(Idaho State University 2011).

ADAPTIVE CAPACITY

Bioclimate Variability– **Result (0.8) High Resilience**

→ This NVC Group could occur throughout all local climate regimes that characterize the Snake River Plain ecoregion.

Elevation range – **Result (1.0) High Resilience**

→ This NVC Group is not limited by available elevations within the Snake River Plain Ecoregion.

Diversity with Plant/Animal Functional Groups – **Result (0.35) Low Resilience**

→ This NVC Group has is limited to freshwater graminoid and forb plant species, and often has low functional diversity (often a monoculture of graminoids with low species richness).Functional groups include rhizomatous and bunch graminoids, and mostly perennial forb species.

Potential Climate Change Adaptation Strategies

Generalized strategies:

-Protect and enhance marsh areas and the listed species that depend on them

-Preservation of remnant marsh areas to support migratory birds

-Protect upper watershed

-Reduce invasives, especially aquatic species

-Maintain biodiversity and processes (such as flooding)

-Preserve scenery, water-based natural and cultural resources for public enjoyment

-Identify information needs of land managers, conduct research, and provide information

"No-regrets" actions to take within the next 5 years:

- Restore shallow groundwater,
- Retire surface diversion and groundwater pumping permits, where these can be identified as affecting the stream and/or alluvial aquifer(s) of concern – sometimes well upstream of the occurrence(s) of concern. Transferring upstream diversion rights to downstream rights will also allow more water to be kept in-channel for longer reaches, but will still allow the water to be withdrawn elsewhere (downstream).
- Aggressively control invasive species.
- Protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff

Actions to anticipate over the coming 5-15 years:

- Increase capacity of culverts in anticipation of more frequent and more severe precipitation events.
- Protect recharge areas and their surface catchments to provide long-term insurance for continued recharge (effects may take decades to realize).

"Watch and Wait" Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Shift in species composition may be expected (more southern species appearing). ***Monitor for change in species composition.***
- Novel invasive species may appear in coming decades, even in currently high-integrity sites.

4.3.4 *Habitat Vulnerability Climate Change Index for NVC Group G526 Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland Group aka "Riparian Shrubland Habitat" within the Snake River Plain Ecoregion*

CONCEPT

USFWS Habitat Woody Riparian and Riparian Scrub-Shrub = NVC Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland Group (G526)

Camas NWR Local Description—The riparian shrubland footprint at Camas covers a narrow discontinuous band of about 277 acres or 3% of the refuge. The dominant shrub is coyote willow (*Salix exigua*) often with a native understory of yellow cress (*Rorippa palustris* ssp. *hispida*) or spike rush (*Eleocharis palustris*), or non-native weeds such as Canadian thistle (*Cirsium arvense*), prickly lettuce (*Lactuca serriola*) and field pennycress (*Thlaspi arvense*).

Range-Wide description This group occurs in on the lower foothills and valley floors within the mountain ranges of the Rocky Mountains, the Great Basin, on the Columbia Plateau, the Snake River Plain, as well as along the eastern slope of the Sierra Nevada within a broad elevation range from about 1220 m (4000 feet) to over 2135 m (7000 feet). A mosaic of multiple vegetation communities occur within this group that are shrub -dominated. Shrubs species include silver sage, red osier dogwood, and several types of willows such as coyote, yellow and strapleaf. Some shrublands have very dense shrub cover with low herbaceous component, other are communities of widely spaced shrubs with very abundant herbaceous layer. The herbaceous species include several species of sedge (*Carex*), grasses such as blue stem (*Calamagrostis*), and a wide variety of forb species such as big leaf evens, willow herb, columbine, cress and monkshood (*Geum, Epilobium, Aquiligia*, *Rorippa* and *Actonium*).

Overall Climate Change Vulnerability Score **0.45 Highly Vulnerable**

DIRECT EFFECTS

Forecasted Climate Stress: Results **(0.3) High Sensitivity**

Based on an ensemble of down-scaled Global Circulation Models proved by Climate Wizard Tool (Girvetz et al. 2009), A2 scenarios (continuation of current emission rates and government policies) for climate forecast for 2060 (50 years into the future) the Snake River Plain may warm, on an annual average, by

4.7-5.5 degrees F (Figure 30). Summer and fall months of July, August and September are projected to experience the greatest day time maximum temperatures increase (5.7-8.4 degrees F, Figure 31). Precipitation forecast shows little change because models do not have consistent trends. Overall annual precipitation is predicted to change from -1 to + 8 inches with a mean of about 1-2" increase (Figure 32). Seasonally, winter, spring and fall have 0 to 4 inch increase while the summer months have the greatest decrease with -1 to -2.5 inches less than historic to up to about +1 to +1.5 inches increase over historic. The greatest change of climate change appears to manifest itself in the summer or growing season months (June- July and August) with the highest temperature increases and the least precipitation gains and greatest predicted losses. Thus in the summer/growing season may be much warmer and drier. Predicted increases in precipitation may not be enough to offset warmer temperatures. Given the higher probability of warming, the climate stress on component species is high for a drought and heat intolerant species, as many intermountain marsh plant species are. With the higher uncertainty on how precipitation may change, it is difficult to rate the hydrologic stress this may have on this ecosystem. The direct effect on the hydrologic regime is considered separately.

Dynamic Process Forecast

Hydrologic and Fire Regime Change 2060 – Result **(0.3) High Sensitivity**

→ Current and forecasted trends—The Snake River Plain has a potential for moderate increases (+1-2 inches) in precipitation in winter months; and declines in the summer months (-1-2 inches) or increases of the same magnitude. It doesn't appear any increase in summer precipitation would be enough to offset the increase in temperatures. Forecasted changes in temperature and precipitation patterns would be expected to result in several effects on aquatic CEs in the ecoregion, as discussed by Melack et al. 1997, Mote 2006, Chambers and Pellant 2008, Brown and Mote 2009, Covich 2009, Das et al. 2009, McCabe and Wolock 2009, Isaak et al. 2010, USBOR 2011: These changes could result in:

- **higher evapo-transpiration rates** leading to an earlier, more rapid seasonal drying-down of stream/riparian communities;
- **increased water stress** in nearby basin-floor phreatophyte communities (e.g., cottonwood and willows), and later, less frequent, briefer wetting of ephemeral reaches;
- **shrinkage of areas of perennial flow/open water**, coupled with higher water temperatures at locations/times when water temperatures are not controlled by groundwater discharges or snowmelt;
- **persistence of these hydrologic conditions later** into the fall or early winter; and
- **reduced groundwater recharge** in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface.

Based on the ways in which these hydrologic factors affect ecological dynamics in the aquatic CEs, persistence of these hydro-meteorological impacts over multiple decades could result in several long-term impacts at both high and low elevations, as discussed by many of the authors cited above, and also by Harper and Peckarsky 2006, Hultine et al. 2007, Martin 2007, Jackson et al. 2009, and Seavy et al. 2009:

- **Loss of riparian vegetation** at lower elevations where the frequency and spatial extent of seasonal flows determines the spatial limits of this vegetation;
- **Loss of basin-floor phreatophyte** (deep-rooted plants that obtain water from ground water sources) communities as a result of lower near-surface ground elevations;

- **declines in the spatial extent** and biodiversity of perennial streams and open waters as a result of shrinkage and warmer temperatures;
- **Reduced discharge** to springs and seeps as a result of reduced aquifer recharge;
- **A continuation of normal "warm-season" aquatic ecological dynamics later into the fall** as a result of seasonally normal (baseline) overnight near-freezing temperatures becoming less common in many areas until later in the fall; and
- **A possible de-coupling** of the places and timing of emergence of insects, the plants on which they depend, and the animals that feed on the insects, as individual species respond to different cues from air and water temperatures, water availability, and flow conditions.

→ Where <u>increases</u> in precipitation, especially in July and Aug, might occur this may result in:

- Increased soil erosion from increased surface flows, which may negatively impact water quality
- Increased stream flow magnitude in summer time

Increased fire frequency and intensity in the watersheds of these systems will have enormous post-fire effects on riparian systems.

- *Increased* winter precipitation causes increased fire in low/mid elevation shrublands (due to increase spring fuel loading), which causes decreased short-term evapotranspiration (from fuel reduction by fire). This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.
- Long-term *decreased* precipitation (e.g., drought) causes increased fire in woodlands and forests, which causes decreased evapotranspiration. This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.

Fires also have direct effects on these systems, changing water chemistry, increasing invasive spp. spread, and increasing inflammability.

Primary concerns include:

- **Increased flammability** due to tamarisk and exotic annual grass causes increased fire frequency and fuel continuity, which results in changes in species composition and structure.
- Many of the hydrological regime changes could be exacerbated by fire.
- Compounding effects of in situ climate change on **post-fire regeneration of dominant species** (e.g., cottonwood regeneration by seed germination, resprouting by willows).

<u>INDIRECT EFFECTS</u>

Landscape Condition 1960 **Result (0.45) Low Resilience**

→ Ranching and farming have been primarily diverting surface water from the relevant streams and rivers since the late 1800s. Extensive water development with dams and canal systems diverted surface water and changed stream flow regimes. Irrigated agriculture grew from few hundred thousand acres to millions of acres. The main channel of the Snake River was channelized as well as tributaries. Floodplain development grew significantly as well as flood control structures. Irrigation increased groundwater recharge rates in some areas, especially the central portion of the ecoregion (De Grey and Link nd, Geller 2006, Slaughter 2004). Groundwater extraction was just beginning to grow between 1950 and 1960 (Figure 37).

Landscape Condition Current 2010 Result **(0.35) Low Resilience**

→ Urban and agricultural areas have grown exponentially and center pit groundwater fed irrigation is now primary agricultural water use. Nearly all arable land on the Snake River plain is in production (**Figure 36**). There are also cumulative effects of groundwater withdrawals from ranches and numerous small towns. Intensive farming along the riparian corridors impact and fragment floodplains and remove riparian habitats. Riparian corridor areas are impacted by domestic livestock grazing that reduces bank stability and causes high soil erosion, channel widening and increased in-channel water temperatures. In addition there are watershed-scale impacts of domestic livestock grazing, including soil compaction and removal of runoff-retaining vegetation.

Invasive Species Impact 1960 **Result (0.5) Moderate Resilience**

→ Historic cattle grazing introduced invasive plant spp. Late-19th -early 20th century. Deliberate introductions of tamarisk, Russian olive, and annual grasses in residential areas and grazing lands brought these species into riparian corridors.

Invasive Species Impact Current 2010 Result **(0.25) Low Resilience**

→ Current footprint of the extent of exotic species is incompletely mapped, however models of areas within the Unites States likely to contain significant amounts of tamarisk, Russian olive, and annual grasses indicate >50% of the riparian areas are affected (Morisette et al. 2006, Kerns et al. 2009) (Figure 38). In addition, there are aquatic invasive species such as mollusks and non-native fish, which could completely change the aquatic food chain dynamics and eliminate native aquatic species. Current records of aquatic invasive species indicate it is only a matter of time before all bodies of water including streams and rivers to have more than one aquatic invasive species (BLM 2010).

Dynamic Process Current

Hydro Regime Change 2010- Current Conditions **Results (0.35) Low Resilience**

Surface water diversions and dams on main stem of the Snake and Boise Rivers have significantly changed the hydrologic regime of these rivers. High spring flows have been reduces and low fall flows have been increased. Flood control structures have provided protection from flooding for towns, and have disconnected the floodplain from the stream channel, changing the timing and frequency of flooding. Agricultural and residential/urban use has dropped groundwater levels significantly, already reducing or eliminating many gaining reaches. Groundwater irrigation rose from 100,000 acres in 1950 to 700,000 acres in 1965 and 1.1 million acres by 1980 (Slaughter 2004).

ADAPTIVE CAPACITY

Bioclimate Variability– Result **(0.9) High Resilience**

→ This NVC Group could occur throughout all local climate regimes that characterize the Snake River Plain ecoregion.

Elevation range – Result **(1.0) High Resilience**

→ This NVC Group is not limited by elevations available within the Snake River Plain.

Diversity with Plant/Animal Functional Groups – Result **(0.49) Low Resilience**

→ This NVC Group has a limited number of functional plant groups. It is predominately characterized by phreatophytic and shallow rooted woody shrub species.

Potential Climate Change Adaptation Strategies

Generalized strategies and notes:

-Protect and enhance riparian areas and the listed species that depend on them

-Preservation of remnant riparian areas to support migratory birds

-Protect upper watershed

-Reduce invasives

-Maintain biodiversity and processes (such as flooding)

-Maintain and enhance connectivity for fish

-Preserve scenery, water-based natural and cultural resources for public enjoyment

-Identify information needs of land managers, conduct research, and provide information

“No-regrets” actions to take within the next 5 years:

- Restore in-channel waters,
- reduce domestic livestock grazing pressure,
- retire surface diversion and groundwater pumping permits, where these can be identified as affecting the stream and/or alluvial aquifer(s) of concern – sometimes well upstream of the occurrence(s) of concern. Transferring upstream diversion rights to downstream rights will also allow more water to be kept in-channel for longer reaches, but will still allow the water to be withdrawn elsewhere (downstream).
- Aggressively control invasive species.

- Protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff

Actions to anticipate over the coming 5-15 years:

- Increase capacity of culverts in anticipation of more frequent and more severe precipitation events, replace culverts and bridges that "pinch" the stream widths.
- Increase channel grade stabilization to prevent downcutting, if increased monsoonal runoff proves to be an accurate forecast.
- Protect recharge areas and their surface catchments to provide long-term insurance for continued recharge (effects may take decades to realize).

"Watch and Wait" Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Shift in species composition may be expected (more southern species appearing). ***Monitor for change in species composition.***
- Novel invasive species may appear in coming decades, even in currently high-integrity sites.

4.4 Discussion

Growing season temperatures increases are forecasted to be the highest amount of warming in the Snake River Plain by 2060, so scores for climate stress were high (0.3). Past landscape condition with the significant agricultural conversion of the ecoregion along with hydrological alteration to support that agriculture resulted in low scores for indirect effects for all communities past and present (0.5 -0.35). The Snake River Plain has not escaped the onslaught of invasive species, which has altered fire regimes and community structure for three of the 4 communities assessed, for both current status and the projected continued change with time and warming, the marshes being the least effected (0.7-0.25). These communities are not limited to substrate or elevation within the ecoregion so these scores were in the high range (0.73-0.8). Indirect effect scores combined with adaptive capacity scores gave moderate resilience scores. When combined with the climate sensitivity scores the result is high vulnerability overall score for each of the for community types (Table 5).

Resulting Habitat Climate Change Vulnerability scores were Highly Vulnerable for all types and ranged from 0.38 for sagebrush steppe to 0.46 for the wetland communities. The combination of high climate change exposure with an expected change in the already altered dynamic processes of hydrology and fire regimes, leads to these low scores.

The geographic location of Camas NWR may prove to will play an important role in the resilience of these communities within the Snake River Plain. Camas is located in some of the least altered part of the ecoregion. While much agriculture occurs close by, models show that this part of the ecoregion has the lowest risk for invasive species to completely alter ecosystems and fire regime departure. While invasive species are already present at Camas, there are areas on the refuge and on neighboring lands that have not been completely altered and transformed by invasive species. The effort to eradicate and control the spread of invasive species at Camas becomes an important management tool for increasing the resilience of native ecosystems. Additional “no-regrets” management recommendations designed to increase the resilience of Camas ecosystems are: restore shallow groundwater, retire surface diversion and groundwater pumping permits, aggressively control invasive species and protect a buffer zone for natural watershed vegetation, to minimize effects of storm runoff.

5 Conclusions

The current Ecological Integrity Assessments (EIA) of Camas habitats indicate they are compromised by numerous invasive species (cheatgrass, Canadian thistle), planted non-native species (quack grass and western wheat grass) and by a receding ground water table. However the EIA also found areas that represent high ecological integrity that can be used as reference sites for both wetland and upland habitats. Restoration efforts need not look far for seed sources, soil information and land history patterns to inform effective and efficient restoration actions.

Watershed Analysis illustrates the important strategic geographic location of Camas NWR for representing low elevation wetlands within the Beaver-Camas watershed and within the larger Upper Snake River watershed. Continued groundwater pumping by the USFWS means supporting some of the last intact low elevation wetlands within the Upper Snake River watershed, wildlife movement corridors and important stop-over sites within the North Pacific Flyway.

Habitat Climate Change Vulnerability Index of four communities that occur throughout the Snake River Plain Ecoregion and are well represented at Camas NWR show that the stressors of agricultural conversion, hydrologic manipulations, including a receding groundwater table in the upper sections of the ecoregion, along with high potential for invasive weeds to transform entire ecosystems and high fire regime departures lowers the ecological resiliency to cope with changing climates. Climate change exposure is likely to be high, as models indicate summer and fall warmer temperatures will be significantly different from historic means. What was once considered extremes in climate may become the new “norm” within 50 years.

Camas NWR is strategically located in one of the least altered parts of the Snake River Plain ecoregion. Efforts to improve upland and wetland ecosystem resilience by eradicating and controlling invasive species will help these ecosystem cope with climate change. Restoration efforts to convert lands back to native ecosystems will increase the size and diversity of native habitats at Camas, which further increases their resiliency. Equally important will be restoring the shallow groundwater by retiring surface and groundwater pumping permits in the surrounding landscape. Regardless of how climate change manifests itself within the Snake River Plain ecoregion, these are no-regret management goals that can only increase ecosystem integrity by reducing current stressors, which in turn will support the resiliency of ecosystems and wildlife species within the ecoregion.

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7 Appendix A. Crosswalk of NVC, NatureServe Ecological Systems and USFWS Habitat Types.

NVC Group Code	NVC Group Name	NVC Group Colloquial Name	NS System Code	NatureServe Ecological System Name	USFWS Habitat Name
G303	**Intermountain Dry Tall Sagebrush Shrubland & Steppe Group**	Sagebrush Steppe and Sagebrush Shrubland	CES304.778 & CES304.777	Inter-Mountain Basins Big Sagebrush Steppe & Inter-Mountain Basins Big Sagebrush Shrubland	Sagebrush Steppe, Sagebrush/Shrub-Steppe, Big Sagebrush, Sagebrush Lowland, Low Sagebrush Shrublands and Steppes
G310	**Intermountain Semi-Desert Shrubland Group**	Rabbitbrush Shrubland	CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe	Shrub-Steppe
G311	**Intermountain Semi-Desert Grassland & Steppe Group**	Desert Grassland	CES304.787	Inter-Mountain Basins Semi-Desert Grassland	Sagebrush Steppe, Sagebrush/Shrub-Steppe, Big Sagebrush, Sagebrush Lowland, Low Sagebrush Shrublands and Steppes, Native Perennial Grassland, Native Short Grassland
G518	**Western North American Temperate Interior Freshwater Marsh Group**	Marsh	CES200.877	Temperate Pacific Freshwater Emergent Marsh	Hemi-Marsh, Open Water – Submerged Aquatic, Permanent Wetlands – Open Water With Aquatic Beds, Emergent Marsh, Deep Marsh, Semi-Permanent Wetlands – Persistent Emergent Vegetation, Shallow Marsh, Shallow Emergent Marsh, Shallow Ephemeral Marsh, Seasonal Wetlands, Seasonally-Flooded Marsh
G521	**Vancouverian & Rocky Mountain Montane Wet Meadow Group**	Wet Meadow	CES200.998	Temperate Pacific Subalpine-Montane Wet Meadow	Wet Meadow, Temporarily-Flooded Wet Meadow, Wet Prairie, Moist Meadow
G524	**Western North American Ruderal Wet Meadow & Marsh Group**	Non-Native Mesic-Wet Meadow	n/a	None	See Wet Meadow
G525	**Temperate Pacific Freshwater Wet Mudflat Group**	Mudflat	CES200.878	Temperate Pacific Freshwater Mudflat	Often In Juxtaposition With Wet Meadows Or Marshes
G526	**Rocky Mountain & Great Basin Lowland & Foothill Riparian & Seep Shrubland Group**	Woody Riparian	CES304.045	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	Riparian, Alluvial Riparian Woodland, Riparian Scrub-Shrub, Woody Riparian, Riverine Wetlands, Willow Woodland, Aspen/Deciduous Shrub Riparian Forests, Shrub-Dominated Riparian
G538	**Intermountain Basins Alkaline-Saline Herb Wet Flat Group**	Alkaline-Saline Wet Meadow	CES304.998	Inter-Mountain Basins Alkaline Closed Depression	Seasonal Alkali Wetlands
G600	**Great Basin & Intermountain Ruderal Dry Shrubland & Grassland Group**	Non-Native Dry-Mesic Meadow	n/a	None	See Desert Grassland

8 Appendix B. Ecological Integrity Assessment Metric Definitions and Criteria

[Separate document]

9 Appendix C. Example EIA Field Forms

[Separate document]

10 Appendix D. Landscape Condition Model

[Separate document]