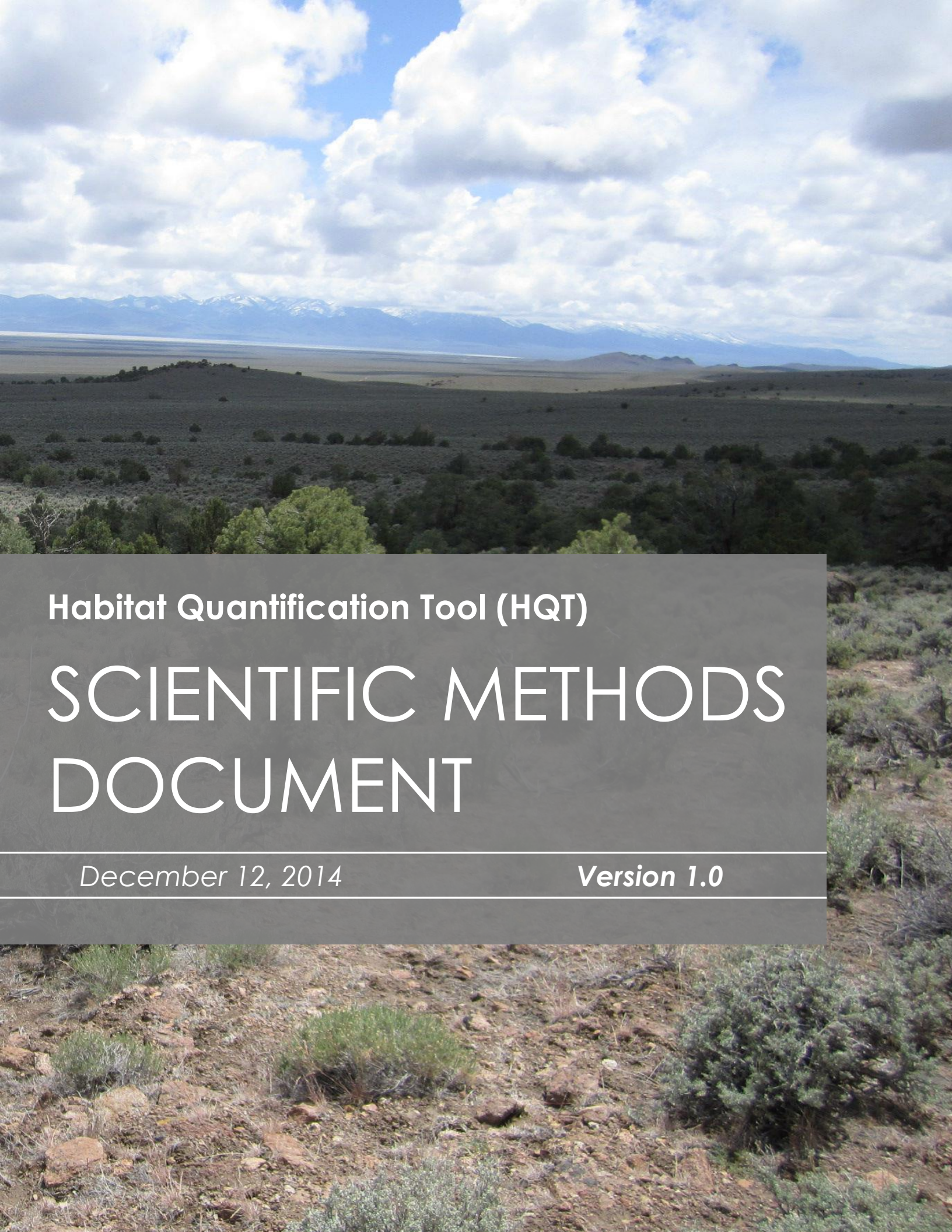

## Habitat Quantification Tool (HQT)

# SCIENTIFIC METHODS DOCUMENT

*December 12, 2014* ***Version 1.0***

# ACKNOWLEDGEMENTS

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The following individuals provided invaluable guidance and direction throughout development of this scientific methods document to ensure it accurately reflects the unique ecological systems and greater sage-grouse needs in the State of Nevada.

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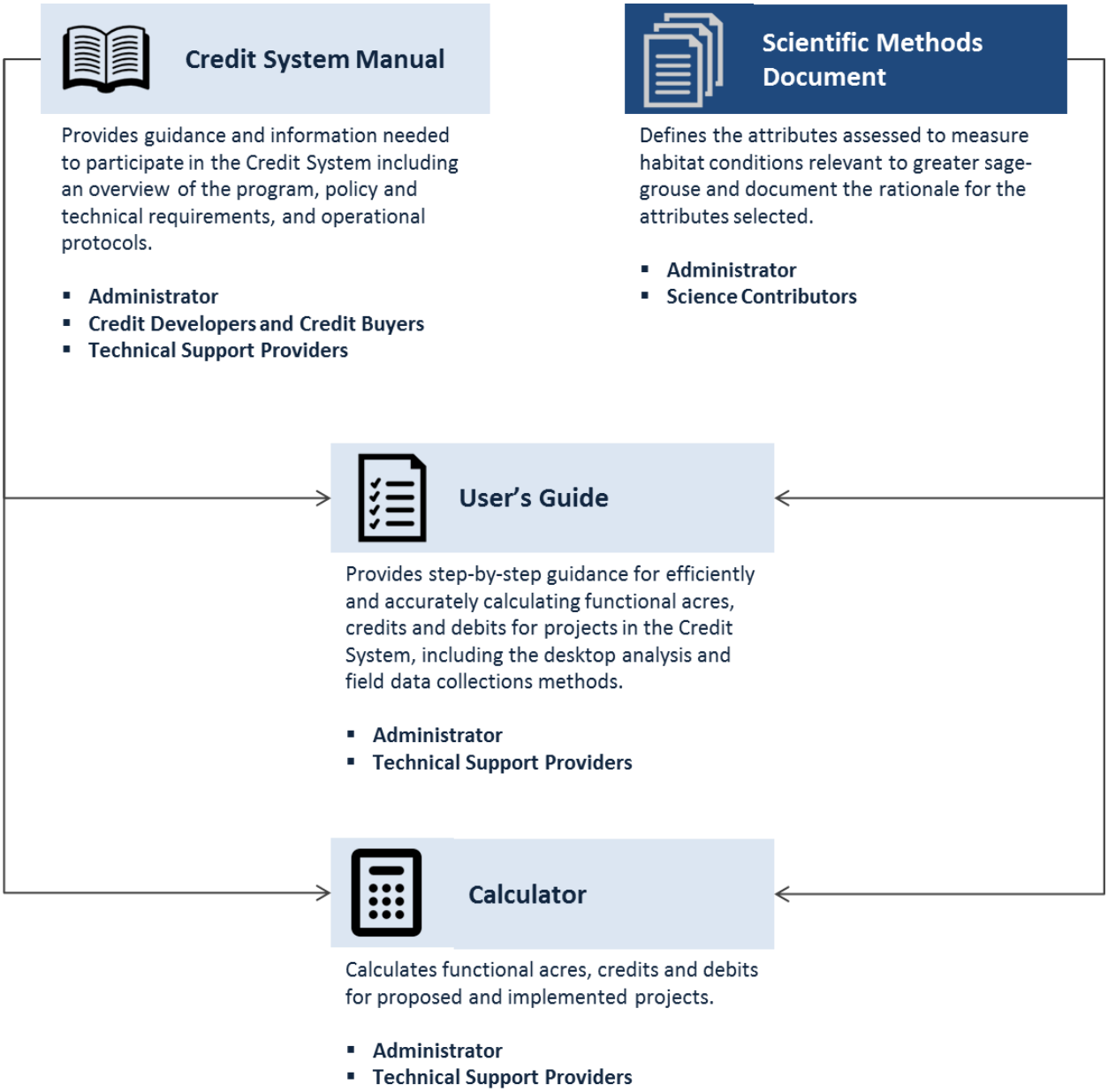
# CREDIT SYSTEM DOCUMENTS

The Nevada Conservation Credit System is described in multiple documents intended for different audiences. This is the Scientific Methods document. This document defines the attributes assessed to measure habitat function for greater sage-grouse and documents the rationale for the attributes selected. This document is intended for the Administrator and science contributors. If this does not describe you, please use the diagram below to identify the document most relevant to your needs.



# Table of Contents

**1.0 INTRODUCTION ..... 6**
**2.0 OVERVIEW OF THE HABITAT QUANTIFICATION TOOL ..... 7**
2.1 HABITAT QUALITY & SPECIES PERFORMANCE ..... 7
2.2 ANTHROPOGENIC DISTURBANCES ..... 7
2.3 FRAMEWORK FOR QUANTIFYING HABITAT FUNCTION ..... 7
2.4 FUNCTIONAL ACRE APPROACH ..... 8
2.4.1 Seasonal Habitat Types ..... 9
2.4.2 Benefits of the Functional Acre Approach ..... 9
**3.0 HABITAT QUANTIFICATION METHODS AND ATTRIBUTES ..... 12**
3.1 RANGE-WIDE SCALE (1ST ORDER) ..... 16
3.2 LANDSCAPE SCALE (2ND ORDER) ..... 18
3.2.1 Management Importance ..... 18
3.2.2 Limiting Seasonal Habitat ..... 19
3.3 LOCAL SCALE (3RD ORDER) ..... 22
3.3.1 Anthropogenic Disturbance ..... 22
3.3.2 Habitat Suitability Index ..... 25
3.3.3 Distance to Lek (Breeding) ..... 27
3.3.4 Distance to Late Brood-Rearing Habitat (Breeding) ..... 28
3.4 SITE SCALE (4TH ORDER) ..... 31
3.4.1 Triggers ..... 32
3.4.2 Scoring Curves ..... 32
3.4.3 Attribute Weighting ..... 33
3.4.4 Attributes Measured ..... 34
3.4.5 Modification of Site-Scale Habitat Function ..... 35
**4.0 PROJECT EXAMPLE ..... 39**
**5.0 LIMITATIONS OF THE HQT ..... 41**
**6.0 REFERENCES ..... 43**
**APPENDIX A: SCORING CURVES ..... 49**
**APPENDIX B. MONITORING AND ADAPTIVE MANAGEMENT ..... 67**
Tool Evaluation ..... 67
Credit System Management System ..... 67
**APPENDIX C. HQT DEVELOPMENT AND REVIEW ..... 69**
Internal Development and Review ..... 70
External Review ..... 70
**APPENDIX D. SAGE-GROUSE RESPONSE TO ANTHROPOGENIC DISTURBANCE LITERATURE REVIEW ..... 73**
Distance to Energy Development ..... 73
Density of Energy Development ..... 73

Mining ....74
Noise ....74
Roads ....74
Traffic ....75
Transmission and Power Lines ....75
Towers ....75
Urban Development ....76

# 1.0 INTRODUCTION

The Nevada Greater Sage-Grouse Habitat Quantification Tool (HQT) Scientific Methods Document (Scientific Methods Document) describes a scientific approach to quantify habitat function for greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) habitat in the State of Nevada. The HQT can be used quantify habitat function for a range of purposes including evaluating outcomes of conservation and development projects, and tracking anthropogenic and natural disturbances across the landscape. The Nevada Conservation Credit System (Credit System) uses the HQT to determine credits generated by conservation projects and debits generated by anthropogenic disturbances, target credit and debit projects to the most beneficial locations for the sage-grouse, and track the contribution of the Credit System to sage-grouse habitat and population goals over time.

This Scientific Methods Document includes a description of the attributes measured by the HQT, methods for measuring those attributes, and supporting rationale (e.g., peer-reviewed literature, gray literature, expert opinion) for why those specific attributes and methods were chosen. A scoring approach to generate a single habitat function score based on the measurements for a specific site is also described, and an example project is used to illustrate the application of the scoring approach.

### Users and Uses

The primary audiences of Scientific Methods Document are the Credit System Administrator (Administrator) and science contributors. The Administrator will use the methods document as the basis for adaptive management of the HQT and will update this Scientific Methods Document as the HQT is improved over time. Other stakeholders may use the Scientific Methods Document to understand the scientific basis for the HQT and scientists and other experts may be asked to review the Scientific Methods Document in order to provide recommended improvements to the HQT.

The HQT has been specifically designed for use in the Credit System. However, it could benefit other sage-grouse conservation programs in the State of Nevada. For example, the HQT could be used to target investment of public or non-governmental organization funding for sage-grouse conservation unrelated to the Credit System, and quantify the benefits of future conservation actions to sage-grouse.

### Development Process

The HQT is based on a well-established and academically-supported framework, derived from the Stiver et al. (2010) Habitat Assessment Framework and described within this document. The first release of the HQT was prepared by Environmental Incentives, Inc. and EcoMetrix Solutions Group in 2014. The Greater Sage-grouse Habitat Quantification Tool Scientific Methods Document developed for the Colorado Habitat Exchange provided the basis for this document. Environmental Incentives convened a group of local biologists and rangeland ecologists, the Technical Review Group (TRG), to revise the methods, attributes and scoring curves to reflect the best available scientific understanding of sage-grouse in Nevada.

# 2.0 OVERVIEW OF THE HABITAT QUANTIFICATION TOOL

The HQT is a scientific approach for assessing habitat function and conservation outcomes for greater sage-grouse. The purpose of the HQT is to quantify habitat function for a given location with respect to sage-grouse needs. The HQT uses a set of measurements and methods, applied at multiple spatial scales, to evaluate criteria related to sage-grouse habitat function.

## 2.1 HABITAT QUALITY & SPECIES PERFORMANCE

Habitat represents a particular combination of resources (e.g., food, shelter, and water) and environmental conditions that support survival and reproduction (Morrison et al. 2006). Habitat can vary in quality and therefore in its ability to support survival and reproduction over time (i.e., function). Inherent in the HQT approach is the assumption that there is a direct relationship between availability of high quality habitat and population resiliency. Conversely, poor quality habitat is assumed to result in low survival and reproduction (Van Horne 1983), leading to poor population resiliency. Marginal habitat may support some amount of occupancy by a species, but these marginal conditions may still result in low survival or reproduction and uncertain resiliency, which will likely lead to population declines.

As with many ecological processes, habitat selection occurs at multiple spatial scales, with individuals choosing to settle in a location by keying in to different features at different scales (Hilden 1965, Johnson 1980, Wiens et al. 1987, Wiens 1989, Orians and Wittenberger 1991, Fuhlendorf and Smeins 1996, Fuhlendorf et al. 2002, Morrison et al. 2006). This applies to vegetation in particular, as birds may first perceive vegetation structure over a relatively large, landscape scale, and then settle across the landscape according to more fine-scale vegetation composition and other factors (Wiens et al. 1987). Addressing the multiple spatial scales relevant to a species' habitat use and performance is essential for effective and efficient conservation and management (Johnson 1980).

## 2.2 ANTHROPOGENIC DISTURBANCES

In addition to vegetation structure and composition, research consistently indicates that greater sage-grouse select habitat based on the presence or absence of anthropogenic disturbances nearby (see Appendix D for a review of literature pertaining to the effects of anthropogenic disturbance on sage-grouse). The presence of anthropogenic disturbances surrounding a site can reduce the integrity of the site itself as habitat—even if the site has habitat characteristics beneficial to sage-grouse. This effect is known as an 'indirect effect'. Research suggests that the indirect effects on sage-grouse are based on the proximity to the anthropogenic disturbance; as the distance from the disturbance increases, the effect on sage-grouse decreases (Manier et al. 2013). Additionally, the indirect effects of disturbances with higher levels of human activity may be more significant than that of disturbances with lower levels of activity. The HQT accounts for the indirect effects associated with anthropogenic disturbance by applying scientifically-informed distance-decay curves to sage-grouse habitat near disturbance when quantifying habitat function.

## 2.3 FRAMEWORK FOR QUANTIFYING HABITAT FUNCTION

The HQT was developed to account for habitat characteristics or attributes, both natural and anthropogenic, which influence sage-grouse habitat selection across multiple scales. These habitat characteristics were based on different orders of selection (Johnson 1980, Stiver et al. 2010), which represent four spatial scales at which habitat attributes influence where sage-grouse reside and obtain

resources necessary for survival and reproduction[1]. Johnson (1980:69) describes this hierarchical nature of selection as: "a selection process will be of higher order than another if it is conditional upon the latter." For example, habitat conditions at the site may be conducive to successful breeding and early brood-rearing, but if suitable late brood-rearing habitat is not accessible within the landscape, the value of that habitat is diminished or negligible. The HQT assessed habitat quality at four orders.

- **Range-wide Scale (1st order):** 1st order selection is described by the geographic range of the sage-grouse population in Nevada. An important objective at this scale is to evaluate the contribution of changed habitat conditions resulting from site-level management actions to regional or statewide habitat and population conservation goals.
- **Landscape Scale (2nd order):** 2nd order selection determines the home range of a sage-grouse population or subpopulation. The purpose of measuring attributes at this scale is to provide a means of delineating the best areas for conservation and identifying where credit projects should be targeted and development should be avoided.
- **Local Scale (3rd order):** Within their home range, sage-grouse select seasonal habitats according to their life cycle needs. Factors that affect sage-grouse use of, and movement between, seasonal use areas determine habitat quality at this scale. Attributes are measured at the 3rd order to inform and incentivize management actions that meet the conservation goals prescribed at the 2nd order.
- **Site Scale (4th order):** At the 4th order, sage-grouse select for vegetation structure and composition that provide for their daily needs, including forage and cover. Measurements at this scale focus on vegetation attributes known to be meaningful to sage-grouse, and in part, are identified as components of structural habitat guidelines and are important in sage-grouse habitat selection (Connelly et al. 2000, Connelly et al. 2003, Hagen et al. 2007; BLM 2013).

The use of multiple spatial scales results in a more ecologically comprehensive approach to broad-scale siting of anthropogenic features and conservation decisions in conjunction with site-based assessments of local environmental suitability conditions. Information provided at the respective scales can be used through either a top-down or a bottom-up manner. For example, using it in a top-down manner provides for effective conservation planning and targeting; applying the information in a bottom-up manner provides an essential perspective for understanding overall benefits and detriments to landscape integrity over time (Figure 1).

## 2.4 FUNCTIONAL ACRE APPROACH

The HQT measures the quantity and quality of habitat at a site for sage-grouse in terms of functional acres. Habitat function refers to the quality of the habitat for meeting life history requirements (reproduction, recruitment and survival) for greater sage-grouse at multiple scales (site, local and landscape), and includes biotic and abiotic factors as well as the direct and indirect effects of anthropogenic disturbances on and surrounding the site.

Functional acres are a product of the site-scale habitat function, the local-scale habitat function, and the area assessed. Landscape-scale attributes are measured to provide information for targeting management

[1] While the term 'selection' may be interpreted as relating to individual bird behavior, in this context the term is applied broadly to describe the four geographic scales at which sage-grouse occur, are organized into populations and use habitat (per Johnson 1980, Connelly et al 2003, Stiver et al 2010). These four scales also correspond to scales at which sage-grouse policy and management are typically implemented (Stiver et al. 2010). Throughout this document, orders of selection will be identified by their descriptive terms (e.g., site scale, local scale, landscape scale).

actions on the landscape; they are not a component of the functional acre calculation for a site. They are incorporated into the quantification of credits and debits through the mitigation ratio defined in the *Credit System Manual*.

### 2.4.1 SEASONAL HABITAT TYPES

Different vegetation structure and composition is required for different seasonal periods of habitat use. Therefore, different criteria are measured for different seasonal habitat types essential to the sage-grouse lifecycle. The HQT focuses on three seasonal periods and their habitat associations: breeding, late brood-rearing, and winter habitat[2]. The HQT calculates a unique habitat function for each seasonal habitat type for every area of habitat assessed.

- **Breeding:** The breeding season includes habitats associated with the pre-nesting, nesting and very early brood-rearing season (approximately mid-March – June).
- **Late Brood-Rearing:** The late brood-rearing season includes habitats associated with mesic forb availability in late summer for brood-rearing females and broods, males, and unsuccessful females (approximately July – September).
- **Winter:** the winter season includes habitats that are almost exclusively sagebrush dominated (November – mid-March) (Connelly et al. 2011c).

### 2.4.2 BENEFITS OF THE FUNCTIONAL ACRE APPROACH

The functional acre approach has several advantages.

- **Establishes a common currency.** Functional acres serve as the basis of the currency of the Credit System: credits. Functional acres account for the quantity and quality of the habitat at multiple spatial scales. The integration of habitat quantity and quality allows for direct comparison of detriments and benefits, which provides a clearer understanding of whether or not conservation goals are being met (McKenney and Kiesecker 2010, Gardner et al. 2013). A common currency allows for standardization in the calculation of credits and debits, which affords the opportunity to conduct mitigation consistently across projects, land ownership and jurisdictional boundaries. It also provides a common language and metric for mitigation across agencies and industries, while striving to be responsive to new science as it emerges.
- **Provides full accounting of impacts.** Functional acres account for both direct and indirect effects of anthropogenic disturbance. Accounting for indirect effects provides a more accurate representation of the full biological impact of a disturbance on sage-grouse. It also provides a strong incentive for targeting debits and credits to the most appropriate places on the landscape, clustering development where it will have the least species impact and focusing conservation efforts where they will have the greatest benefit.
- **Focuses on outcomes.** Rather than rewarding the completion of management actions or practices that may or may not succeed, the Credit System focuses the activities of developers, ranchers and conservationists on what matters most to the sage-grouse – the resulting habitat outcomes of the practices. Paying for outcomes (i.e., effectiveness) rather than practices, (i.e., implementation) has been shown to achieve more conservation per dollar spent than paying for management practices (Just and Antle 1990, Antle et al. 2003). The outcomes-based functional acre approach of the HQT

[2] There are many citations outlining these seasons, summarized by Hagen et al. (2007) and Connelly et al. (2011c), and it is not the goal of this document to conduct an exhaustive review of the sage-grouse habitat use nomenclature. The HQT does not consider transitional periods where habitat selection is less uniform (Connelly et al. 2000).

enables the Credit System to provide strong incentives to achieve habitat benefits at the multiple scales relevant to sage-grouse.

- **Tracks the contribution of the Credit System to species habitat and population goals in Nevada over time.** The use of functional acres allows for a simple metric to measure the overall performance of the Credit System, which aims to provide net benefit of functional acres in Nevada to sage-grouse in response to anthropogenic disturbance.

# HABITAT QUANTIFICATION FRAMEWORK

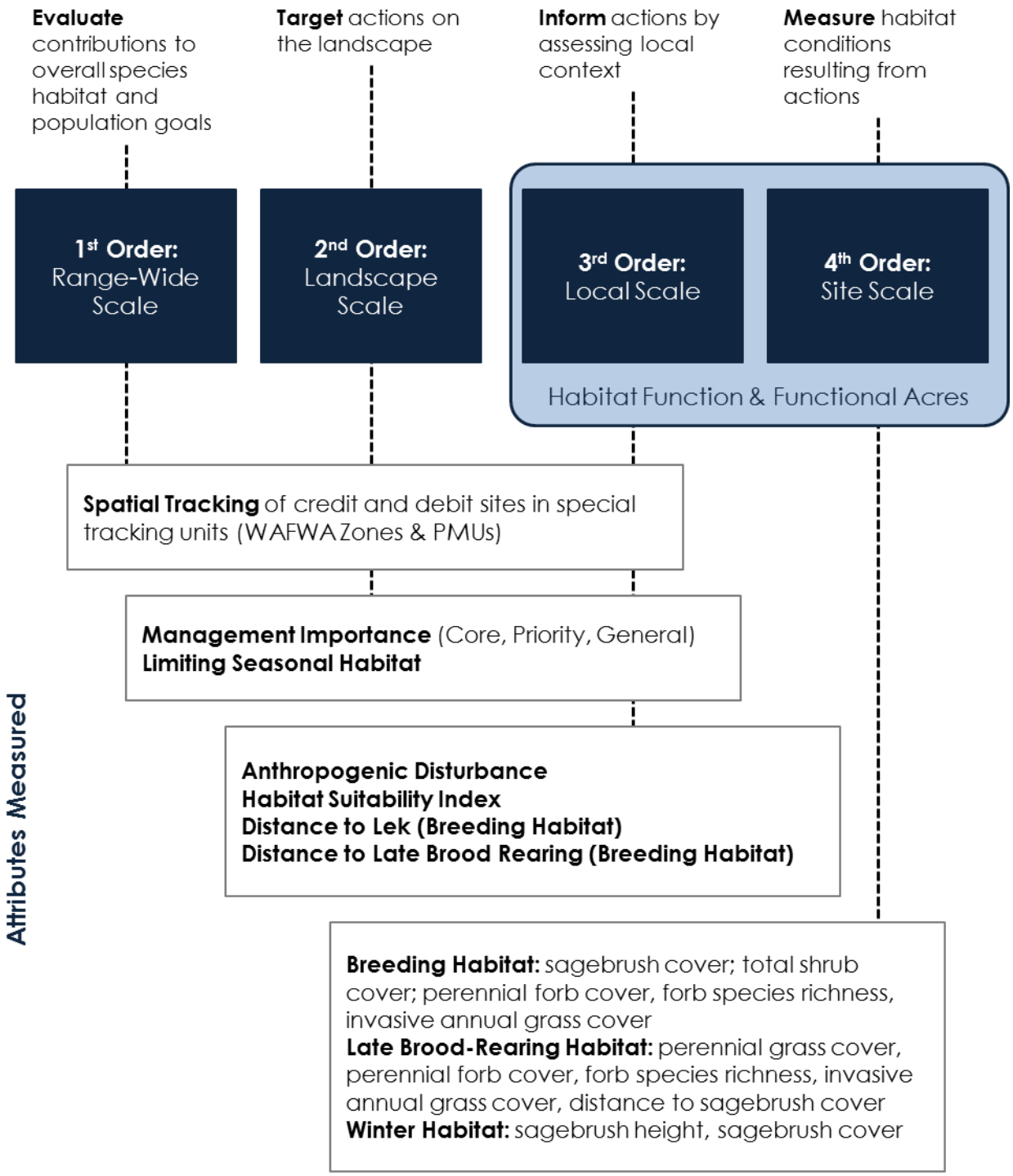



Figure 1. Use of multiple spatial scales for quantifying habitat function for greater sage-grouse

# 3.0 HABITAT QUANTIFICATION METHODS AND ATTRIBUTES

This section describes the attributes measured by the HQT at each of the four orders of selection (i.e., range-wide, landscape, local and site scales) to quantify habitat function and functional acres. Habitat function and functional acres can be quantified using the HQT for multiple purposes, including:

- **At a point in time** to understand the current condition of an area for greater sage-grouse.
- **At multiple points in time** for the same area to quantify changes in habitat function and functional acres to sage-grouse habitat.
- **To calculate credits and debits** associated with credit and debit projects in the Credit System. In order to calculate credits and debits, credit and debit baseline functional acres must be calculated as defined in the *Credit System Manual*. Credits and debits represent functional acre difference relative to baseline functional acres, multiplied by a mitigation ratio based in part on attributes measured by the HQT at the landscape scale.

### 3.0.1 Project Area & Map Units

Habitat function should be quantified over a discrete area when calculating functional acres. Thus, the project area must be clearly defined. When quantifying habitat function for a conservation project (e.g., a credit project), the project area should include all habitats within the exterior boundaries of the project. When quantifying the direct and indirect effects of anthropogenic disturbance on habitat function (e.g., a debit project), the project area must include all habitats directly or indirectly affected by the disturbance. Indirect effects associated with anthropogenic disturbance are discussed in *Section 3.3.1 Anthropogenic Disturbance*.

To facilitate the habitat assessment, the project area is divided into map units (Figure 2). Map units are sub-divisions of the project area based on unique vegetation communities and vegetation structure. Map units are delineated based on variation in habitat attributes assessed by the HQT, such as sagebrush canopy cover, forb abundance and distance to sagebrush cover. Guidance for delineating map units within a credit or debit site is provided in the *Credit System User's Guide*. All attributes are measured individually for each map unit and all map units are scored separately. Map Unit 1 of an example credit project shown below will be assessed throughout this section to illustrate the scoring approach.

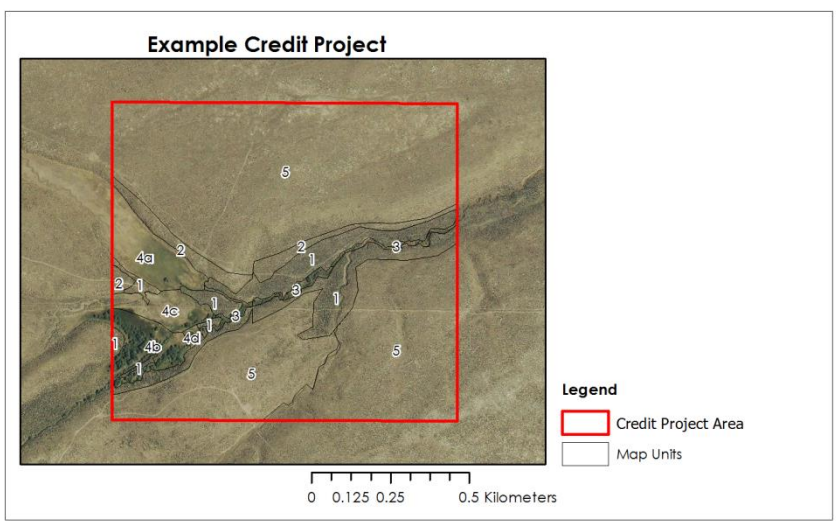



Figure 2. Map units delineated within the project area for an example credit project

### 3.0.2 Habitat Function & Functional Acres

The HQT generates local-scale habitat function and site-scale habitat function for each seasonal habitat type. The product of the local-scale habitat function and site-scale habitat function for each seasonal habitat type determines overall habitat function for each seasonal habitat type for a map unit. The overall habitat function for each seasonal habitat type is multiplied by the acreage of the map unit to produce a functional acre value for each seasonal habitat type. Table 1 provides an example calculation of functional acres for Map Unit 1 of the example credit project.

Table 1: Example calculation of functional acres for a single map unit

| SEASONAL HABITAT TYPE | LOCAL-SCALE HABITAT FUNCTION | SITE-SCALE HABITAT FUNCTION | OVERALL HABITAT FUNCTION | ACRES | FUNCTIONAL ACRES |
|---|---|---|---|---|---|
| **Breeding** | 56% | 61% | 34% | 17 | 5.9 |
| **Late Brood-Rearing** | 56% | 70% | 40% | 17 | 6.7 |
| **Winter** | 56% | 64% | 36% | 17 | 6.1 |

#### Seasonal Habitat Types

The HQT focuses on three seasonal habitat types: breeding, late-brood rearing, and winter habitat. The scoring process is repeated for each seasonal habitat type considered by the HQT. Attributes must be measured during the appropriate season to ensure that habitat function and functional acres associated with each seasonal habitat type are quantified correctly.

#### Landscape-Scale Attributes

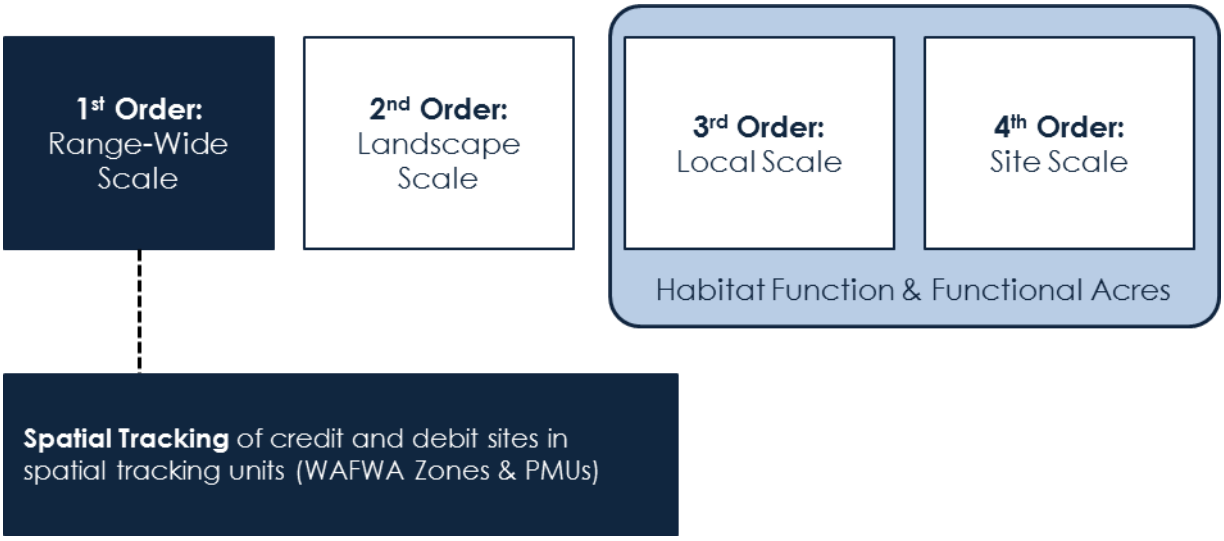
Landscape-scale attributes are measured to provide information for targeting management actions on the landscape; they are not a component of the functional acre calculation for a site. They are incorporated into the quantification of credits and debits through the mitigation ratio defined in the *Credit System Manual* (see *Section 2.2.3 Mitigation Ratio*).

### 3.0.3 Credits & Debits

To calculate credits or debits, credit or debit baseline functional acres are calculated as defined in the Credit System Manual (see *Section 2.3.4: Calculating Credit Baseline Habitat Function* and *Section 2.5.4: Calculating Debit Baseline Habitat Function* in the *Credit System Manual* for credit and debit projects respectively). Credits and debits are calculated from the difference between post-project functional acres (i.e., functional acres present after the debit or credit project is implemented) and the credit or debit baseline functional acres, respectively. A mitigation ratio is applied to the difference in functional acres for each map unit based in part on attributes measured at the landscape scale (see *Section 2.2.2: Mitigation and Proximity Ratios* in the *Credit System Manual*). See the *Credit System Manual* (*Section 2.2: Habitat Quantification and Credit and Debit Calculation*) for more information on calculating credits and debits.

The following sections describe the attributes measured at each scale, the rationale for the attributes selected, the methods for measuring each attribute, and the process for translating attribute measurements into scores that are used to calculate habitat function and functional acres. An example map unit will be used to illustrate the process. For a complete, step-by-step description of the scoring process used by the HQT, please see the *Credits System User's Guide*.

# 1ST ORDER: RANGE-WIDE SCALE



## 3.1 RANGE-WIDE SCALE (1ST ORDER)

### Geographic Scope

The Credit System's geographic scope is the 2014 Sage-Grouse Management Area, which was developed by the Sagebrush Ecosystem Program (Figure 3). Documented changes to the estimated range will be tracked and incorporated into the HQT over time through the Credit System Management System described in the *Credit System Manual*.

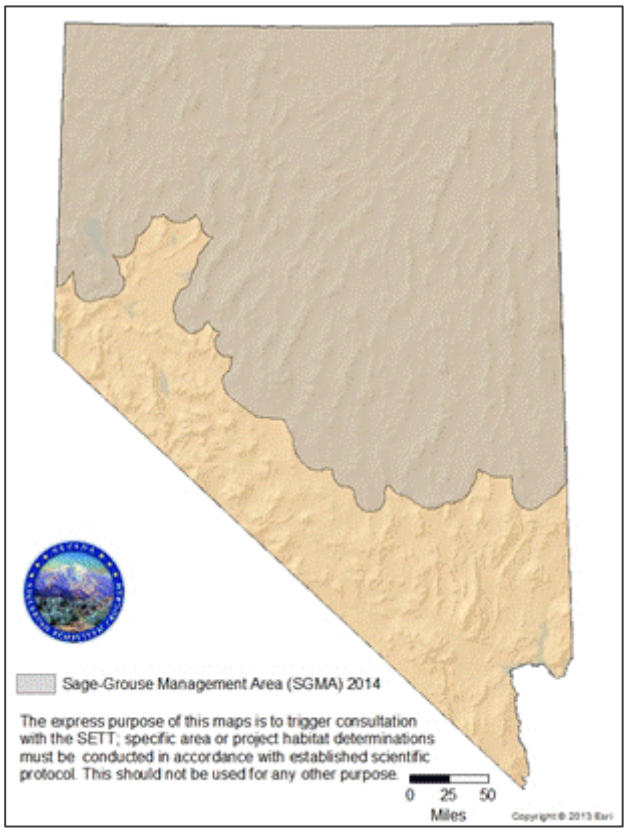



Figure 3. 2014 Sage-grouse Management Area map

### Spatial Tracking

The Credit System tracks the location of credit and debit sites in spatial tracking units. Spatial tracking units include Nevada Department of Wildlife Population Management Units (PMU) and Western Association of Fish and Wildlife Agencies Management Zones (WAFWA Zones). PMUs are used to understand the functional acre change to each population and WAFWA Zones are used to understand the functional acre change to populations connected through dispersal (Figure 4).

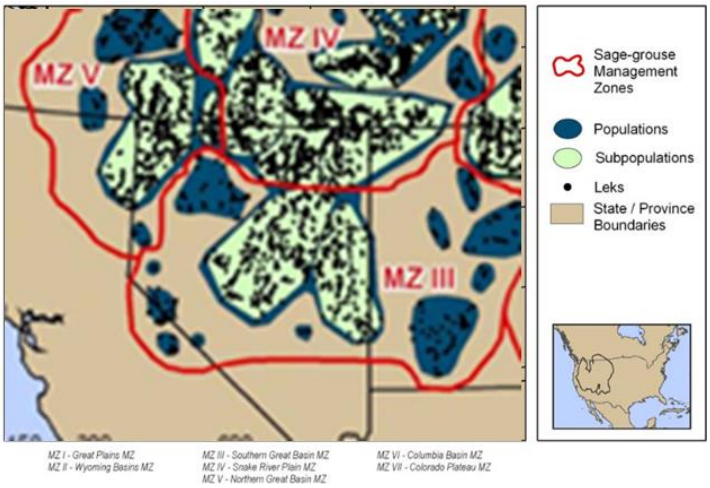
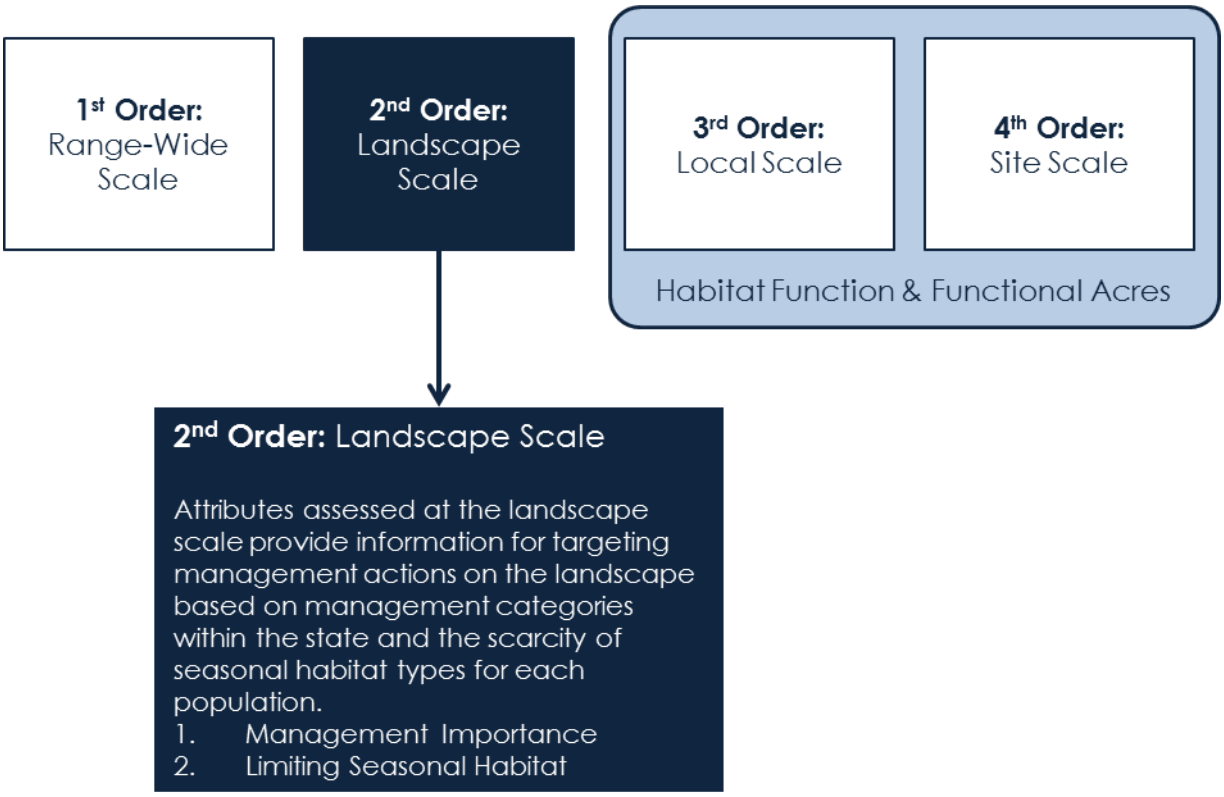



Figure 4. WAFWA Management Zones for Greater and Gunnison sage-grouse

# 2ND ORDER: LANDSCAPE SCALE



# 3.2 LANDSCAPE SCALE (2ND ORDER)

## 3.2.1 MANAGEMENT IMPORTANCE

The Sagebrush Ecosystem Program's Management Categories map is used to determine management importance (Figure 5). The map delineates four habitat management categories based on the intersection of modelled habitat suitability and sage-grouse space use: Core, Priority, General and non-habitat.

- **Core Management Area:** Areas of high estimated space use in suitable sage-grouse habitat in the State of Nevada. These areas represent the strongholds (or "the best of the best") for sage-grouse populations in the State and support the highest density of breeding populations[3].
- **Priority Management Area:** Areas that are determined to be highly suitable habitat for sage-grouse in areas of estimated low space use and areas of non-habitat which overlap with areas of estimated high space use.
- **General Management Area:** Areas determined to be moderately suitable habitat for sage-grouse in areas of estimated low space use.
- **Non-habitat Management Area:** Areas within the Sage-Grouse Management Area determined to be unsuitable for sage-grouse

Predictions of sage-grouse occurrence based on space use models and indices in combination with habitat suitability models and indices (e.g., Doherty et al., 2010a; Coates et al., 2013) provide valuable information regarding the relative importance of areas to sage-grouse (Coates et al. 2014). This information can be used to prioritize areas for different management scenarios and aid decision making processes across the landscape (Coates et al. 2014). This information is used by the Credit System to inform the Credit System mitigation ratio applied to each map unit, see the Credit System Manual for more information.

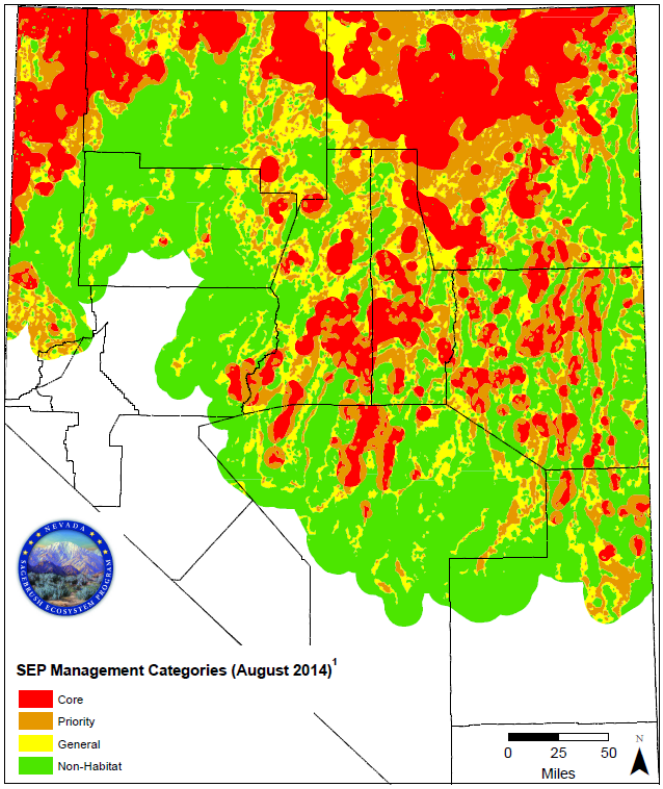



Figure 5. Sagebrush Ecosystem Program's Management Categories Map used to determine habitat importance at the landscape scale

[3] Habitat suitability and space use are determined by models developed by the USGS in partnership with the State of Nevada Sagebrush Ecosystem Technical Team (SETT), the Nevada Department of Wildlife (NDOW), the Bureau of Land Management, and the California Department of Fish and Wildlife (CDFW). See Coates et al. 2014, *Spatially explicit modeling of greater sage-grouse (*Centrocercus urophasianus*) habitat in Nevada and northeastern California—A decision-support tool for management: U.S. Geological Survey Open-File Report 2014-1163.*

### 3.2.2 LIMITING SEASONAL HABITAT

Research suggests that sage-grouse generally move between breeding, late brood-rearing and winter ranges as resource requirements differ during these seasons (Fedy et al. 2012). This means sage-grouse are typically found within a landscape context that includes all seasonal habitats within a distance that sage-grouse typically move. The interspersion, juxtaposition and availability of areas used by sage-grouse during an annual cycle influence the effectiveness of a given landscape to provide sage-grouse with useable and high quality habitat (Connelly et al. 2011c).

The availability of seasonal habitats within an area that is relevant to sage-grouse is measured for each map unit to identify whether a seasonal habitat type is limiting. A seasonal habitat type is considered limiting if the undisturbed quantity of that seasonal habitat type is found to be less than a scientifically-informed threshold (Table 2). Map units that provide functional habitat for a limiting seasonal habitat type should be prioritized for conservation efforts.

#### Calculation Method

1. Maps depicting seasonal habitat use areas for sage-grouse are used to evaluate the availability of seasonal habitats within 11.2 miles (18 kilometers) of a map unit ("analysis window"). 11.2 miles (18 kilometers) represents an approximation of the spatial scale used by an individual migratory sage-grouse on an annual basis (Davis et al. 2014; Connelly et al. 2000). Seasonal habitat maps will be developed for the range of sage-grouse in Nevada by the USGS in 2015. Until those maps are available, seasonal habitat use areas must be mapped within the analysis window based on a site survey.[4]
2. Areas that do not provide sage-grouse with functioning habitat due to high density of anthropogenic disturbance (e.g., urban developments, high-density energy developments) are eliminated from the seasonal habitat maps. Areas recently affected by wildfire are also eliminated from the seasonal habitat maps.
3. The total surface area of each seasonal habitat occurring within the analysis window is quantified and the total surface area values of each seasonal habitat are then converted to proportions of the total area within the analysis window. Breeding and winter seasonal habitats are considered limiting if they represent less than 40% (Connelly et al. 2000; Wisdom et al. 2011; Knick et al. 2013) of the analysis window. Late-brood rearing habitat is considered limiting if it represents less than 4% (TRG[5]) of the analysis window.

Table 2. Limiting seasonal habitat proportion of analysis window thresholds. Values below the thresholds will be considered limiting.

| BREEDING & WINTER* | LATE BROOD-REARING |
|---|---|
| Proportion of Analysis Window | Proportion of Analysis Window |
| 40% | 4% |

*Note that breeding and winter are evaluated independently. Breeding and winter must each be greater than 40% of the analysis window to not be considered limiting.

[4] Contact the Sagebrush Ecosystem Technical Team for guidance on conducting a survey and potentially available resources to assist with the survey.

[5] Based on analysis and best professional judgment provided by the Technical Review Group (TRG) on 10/29/14

## Box 1 | Example Map Unit Calculation (Landscape Scale)

Map Unit 1 is located within a Core Management Area as defined by the Sagebrush Ecosystem Program's Management Categories map. Seasonal habitat types within 11.2 miles (18 kilometers) of the map unit are measured and proportions of available habitat are depicted in the table. Late brood-rearing habitat is below the threshold of 4%, so it is considered limiting. See Figure 6 below for an illustration of the late brood-rearing limiting habitat assessment.

| | Management Category | Seasonal Habitat Proportion | Local-Scale Function | Site-Scale Function | **Overall Function** | Acres | **Functional Acres** |
|---|---|---|---|---|---|---|---|
| **Breeding** | Core | 55% | | | | 17 | |
| **LBR** | Core | 3% (Limiting) | | | | 17 | |
| **Winter** | Core | 50% | | | | 17 | |

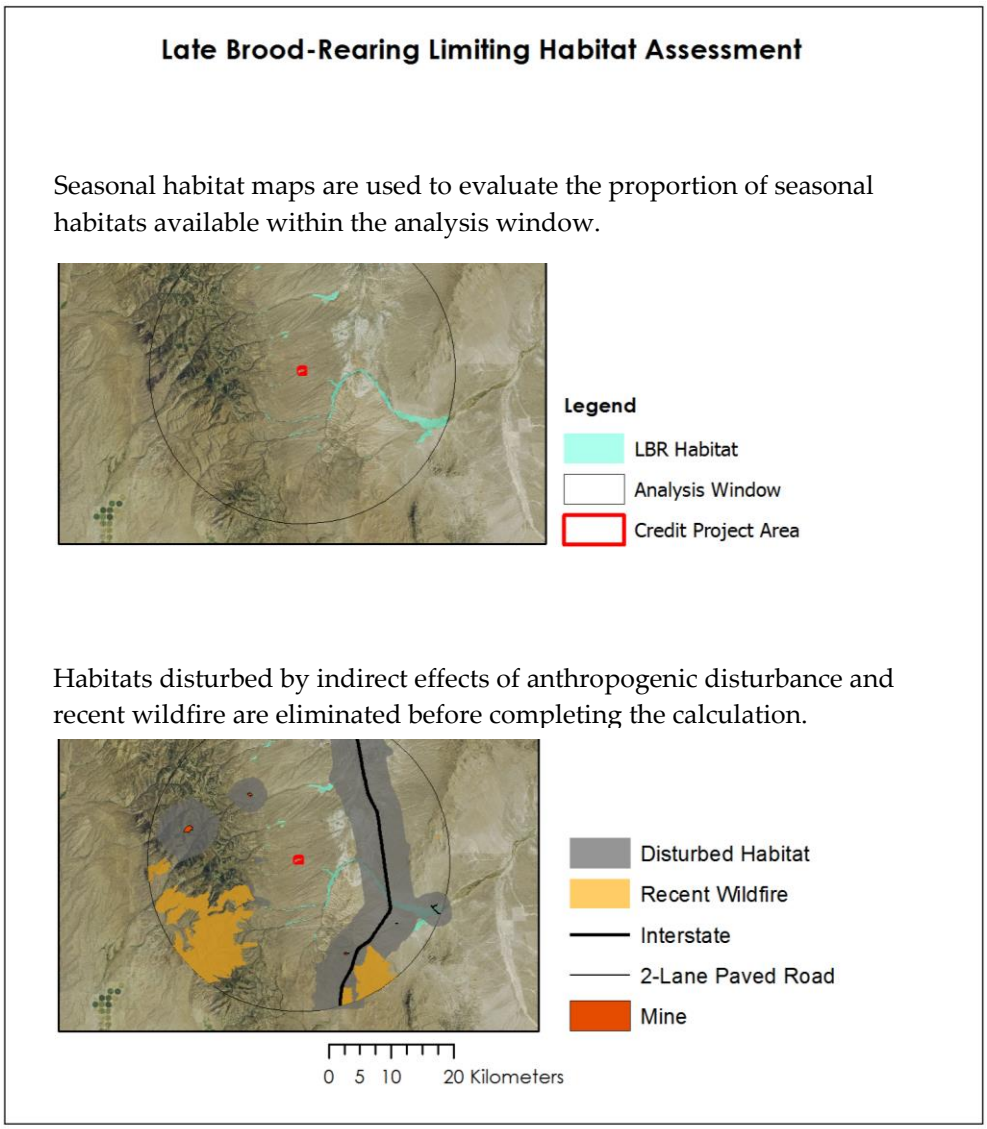
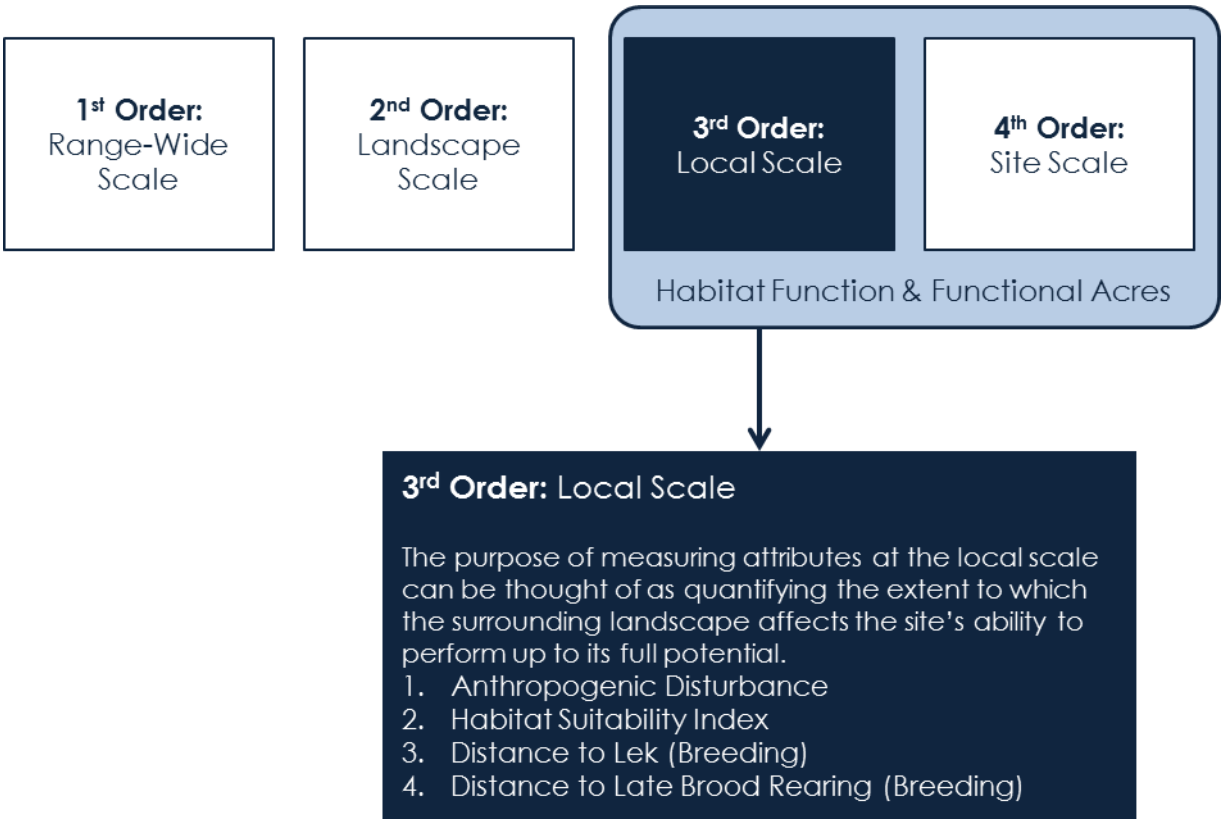



Figure 6. Illustration of the limiting seasonal habitat assessment method for late brood-rearing habitat

# 3RD ORDER: LOCAL SCALE



## 3.3 LOCAL SCALE (3RD ORDER)

The significance of the effect of local conditions on the quality of any given area is an important consideration (Stiver et al. 2010; Connelly et al. 2011c). Habitat conditions within and surrounding a project site may affect sage-grouse seasonal habitat use, dispersal, local persistence, and overall population trend (Connell et al. 2011a , Connelly et al. 2011c). The HQT assesses habitat function at the local scale related to anthropogenic disturbance, habitat suitability as identified by the Habitat Suitability Index (HSI) and, for breeding habitat function, distance to nearest active lek and distance to nearest late brood-rearing habitat.

### 3.3.1 ANTHROPOGENIC DISTURBANCE

Indirect effects of anthropogenic disturbance are measured by applying scientifically-informed distance-decay curves to habitat around anthropogenic features. The cumulative aspect of the distance-decay curves accounts for the density effects of anthropogenic disturbance on habitat function (e.g., Doherty et al. 2010b, Harju et al. 2010). For each anthropogenic disturbance considered, both a distance over which the effect of the disturbance extend and a relative weight are assigned. Effect distances are based on available literature and expert opinion (see Appendix D for a review of literature pertaining to the effects of anthropogenic disturbance on sage-grouse). Weights represent the relative degree of disturbance relative to the highest level of disturbance possible, and are based on expert opinion. The indirect effect relationship is established by a curve with the y-intercept the weight and the x-intercept the distance. Example distance-decay curves are provided in Figure 7.

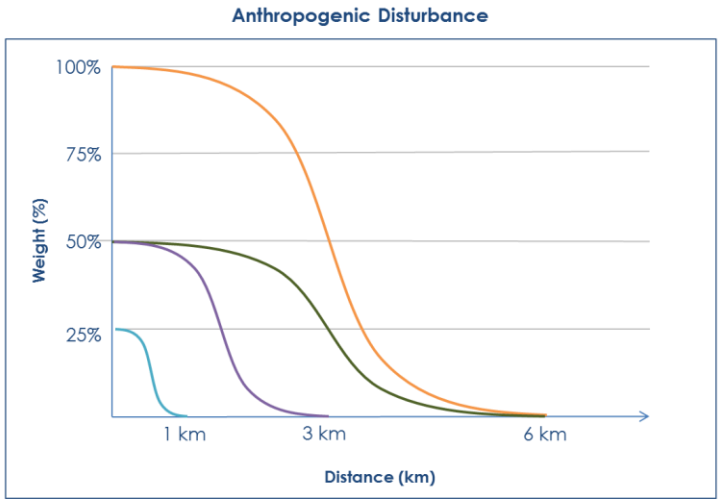



Figure 7. Example distance-decay curves with the y-intercept the weight and the x-intercept the distance associated with the anthropogenic disturbances.

While the distance effect of anthropogenic disturbance is well established, the literature is inconclusive on the magnitude of the effect at specific distances for specific anthropogenic disturbances. The main conclusion that can be drawn from the research is there is a significant effect near the source, and the effect fades as distance from the source increases. Given this uncertainty in the literature, conservative estimates for the rate of decrease of disturbance have been made initially. As new research is conducted, the magnitude of the effect at each distance may be reconsidered.

#### Site-Specific Consultation-Based Design Features

Site-specific consultation-based design features (design features) are used to minimize impacts to sage-grouse and its habitat from indirect effects of anthropogenic disturbance. When quantifying the indirect effect of anthropogenic disturbance on sage-grouse habitat function (e.g., for a debit project), the use of design features may minimize the indirect effects of certain anthropogenic disturbances or minimize the indirect effects during certain times of the year. Distance-decay curves applied to habitats around the anthropogenic disturbance may be modified to more accurately reflect minimization of disturbances. See

Appendix A in the 2014 Nevada Greater Sage-grouse Conservation Plan for more information on the use of design features for newly proposed projects and modifications to existing projects.

Anthropogenic features considered by the Credit System, and their assigned weights and distances, are described in Table 3.

Table 3. Anthropogenic features considered by the Credit System with assigned weights and distances

| DISTURBANCE TYPE | SUBTYPE* | WEIGHT (%) | DISTANCE (Miles (Kilometers)) |
|---|---|---|---|
| **Towers (cell, etc.)** | n/a | 25% | 3.73 miles (6 km) |
| **Power Lines** | n/a | 25% | 3.73 miles (6 km) |
| **Mines** | Active – Large (≥ 60 acres) | 100% | 3.73 miles (6km) |
| | Active - Med or small (< 60 acres) | 100% | 1.86 miles (3 km) |
| | Inactive – Large (≥ 60 acres) | 50% | 0.62 miles (1 km) |
| | Inactive - Med or small (< 60 acres) | 10% | 0.62 miles (1 km) |
| **Oil & Gas Wells** | Producing | 100% | 1.86 miles (3 km) |
| | Non-producing | 0% | 0 |
| **Urban, Suburban & Ex-urban Development** | Med-High | 100% | 3.73 miles (6 km) |
| | Low | 75% | 1.86 miles (3 km) |
| **Roads** | Interstate/4-lane | 100% | 3.73 miles (6 km) |
| | 2-lane Paved & High-use Improved Gravel | 100% | 1.86 miles (3 km) |
| | Low-use Improved Gravel | 25% | 0.62 miles (1 km) |
| | Dirt | 25% | 0.62 miles (1 km) |
| **Renewable** | Solar | 25% | 0.62 miles (1 km) |
| | Geothermal | 100% | 3.73 miles (6 km) |
| | Wind | 25% | 3.73 miles (6 km) |

*For precise definitions of each disturbance type and subtype, see the *Credit System User's Guide*

### Calculation Method

1. To calculate anthropogenic disturbance, anthropogenic features are digitized within a GIS.
2. Distance to the nearest anthropogenic feature for each disturbance subtype is calculated to create a continuous surface raster representing the distance from each cell to the nearest feature.
3. For each raster, distances are translated into functional scores using inverted distance-decay curves (i.e., 80% impact on the distance-decay curve represents a 20% function score).
4. Each raster is multiplied together to produce a final raster, where values range from 0 (full impact) to 1 (no impact). Figure 8 depicts the indirect effects of anthropogenic disturbance on sage-grouse habitat in the form of a continuous surface raster.

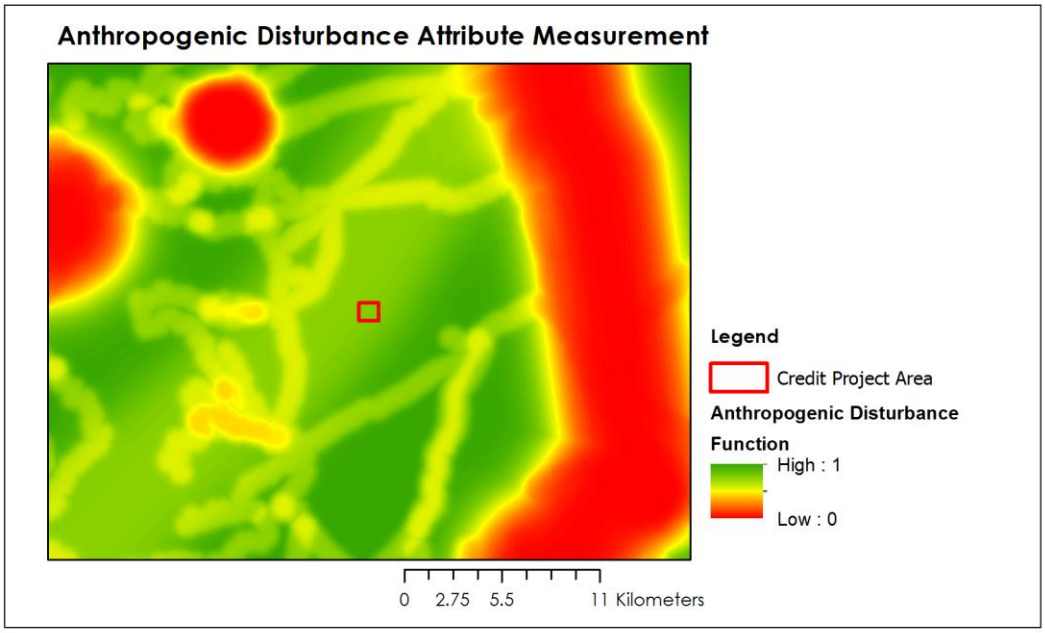



Figure 8. Indirect effects of anthropogenic disturbance on sage-grouse habitat as visualized in a continuous surface raster in the area surrounding an example credit project site

## 3.3.2 HABITAT SUITABILITY INDEX

The Habitat Suitability Index (HSI) is used as a local-scale modifier of habitat function. The HSI was generated based on model-averaged resource selection functions informed by more than 31,000 independent telemetry locations from more than 1,500 radio-marked sage-grouse across 12 project areas in Nevada and northeastern California collected during a 15-year period (1998–2013). Modeled habitat covariates included land cover composition, water resources, habitat configuration, elevation, and topography, each at multiple spatial scales that were relevant to empirically observed sage-grouse movement patterns (Coates et al. 2014). The HSI is also used in the Sagebrush Ecosystem Program's Management Categories map, which determines management importance (see Section 3.2.2 Management Importance). However, the management categories value space use (i.e., modelled probability of sage-grouse occupancy) more highly than habitat suitability, and classifies the HSI into broad categories (high, moderate, low and non-habitat), whereas the HSI is used at the local scale at far higher resolution to evaluate habitats based on local context.

HSI values are translated to function scores using the scoring curve and equation depicted in Figure 9. The scoring curve is generated based on the variance distribution of HSI values. Index values greater than 1.5 standard deviations above the mean (HSI value of 0.82) are considered fully-functioning and receive a

score of 1. Index values more than 1.5 standard deviations below the mean (HSI value of 0.64) are considered non-suitable habitat and receive a score of 0.25. A score of 0.25 for non-suitable habitat avoids eliminating habitats with low habitat suitability but high space use, especially those habitats in the 'priority' management category. A decline in value for intermediate values is represented by a sigmoidal curve with mid-point 0.5 standard deviations below the mean.

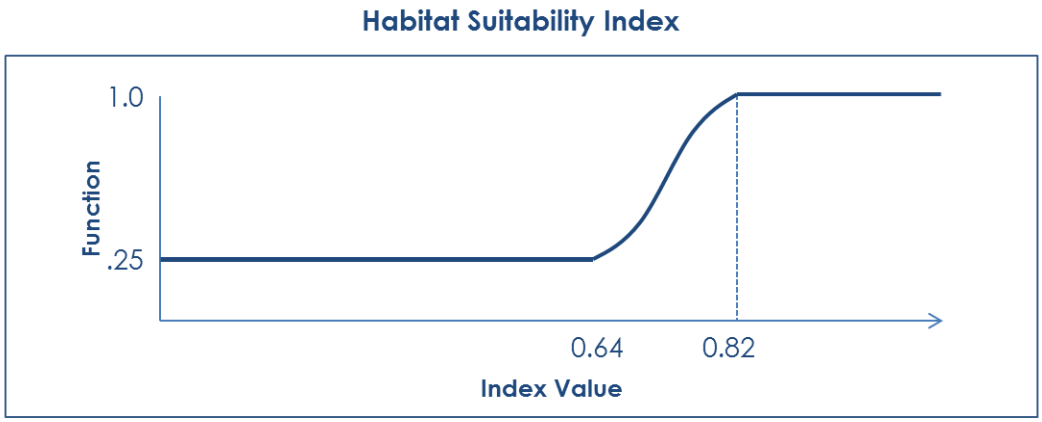



Figure 9. Scoring curve for the HSI attribute as a local-scale modifier of habitat function

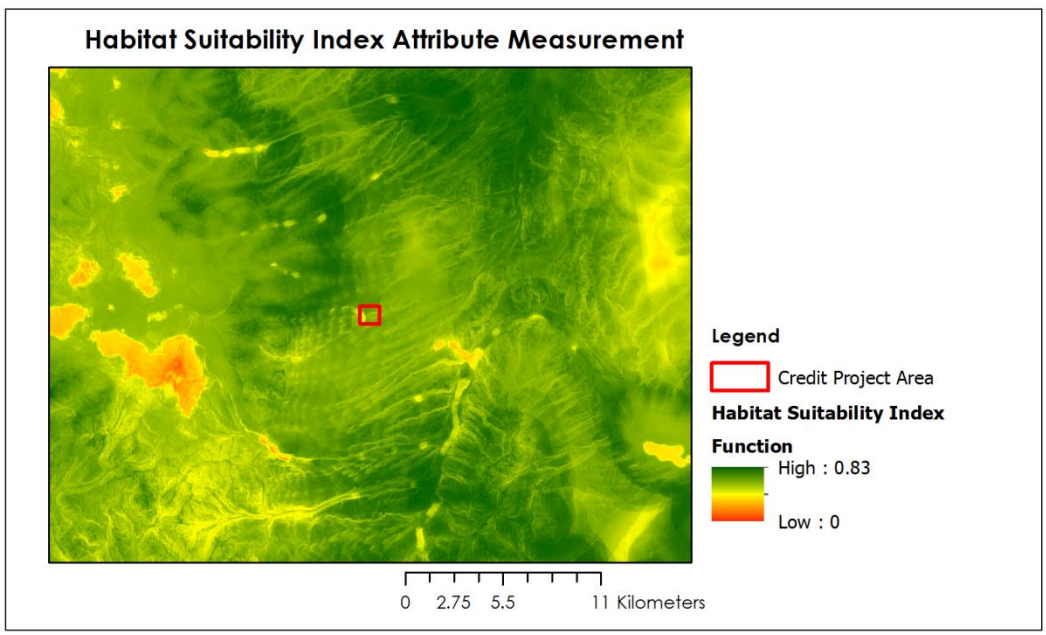


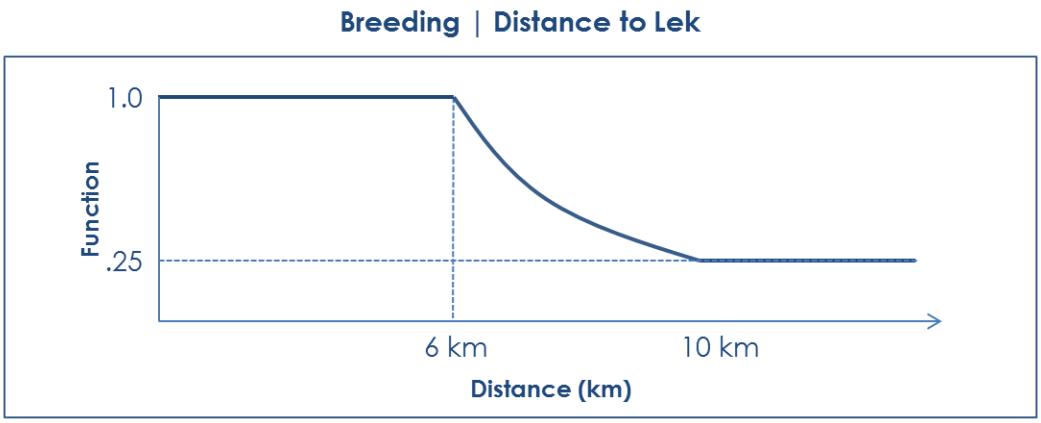

Figure 10. Habitat suitability related to the HSI in the area surrounding an example credit project site

## Habitat Suitability Index Modification

For sites where management actions will affect covariates measured by the HSI, especially for projects that propose to remove piñon-juniper cover or restore wet meadow systems, a modified HSI value will be required to quantify the change in functional acres related to the project. A method for estimating the effect of these management actions on the HSI will be developed in the future.

### 3.3.3 DISTANCE TO LEK (BREEDING)

Sage-grouse breeding habitat is spatially tied to lek locations; the majority of females breeding on a given lek nest within 3.73 miles (6 kilometers) of that lek (Colorado Greater Sage-grouse Steering Committee 2008). However, a portion of the female population will move farther than 3.73 miles (6 kilometers) from a lek to nest (Holloran and Anderson 2005, and see Doherty et al. 2011). The HQT therefore modifies breeding habitat function based on distance to closest known lek as follows: map units within 3.73 miles (6 kilometers) of a lek receive a score of 1.0 followed by a decline between 3.73 and 6.21 miles (6 and 10 kilometers) from a lek, map units farther than 6.21 miles (10 kilometers) from a known lek receive a score of 0.25 (Figure 11). The distance to lek score is multiplied by all other local-scale attribute scores to calculate overall local-scale habitat function for breeding habitat.




| Distance (km) | <6 | 6 – <7 | 7 – <8 | 8 – <9 | 9 – <10 | ≥10 |
|---|---|---|---|---|---|---|
| Score | 1.0 | 0.80 | 0.60 | 0.40 | 0.30 | 0.25 |

Figure 11. Scoring curve and table for distance to lek attribute as modifier to breeding habitat function

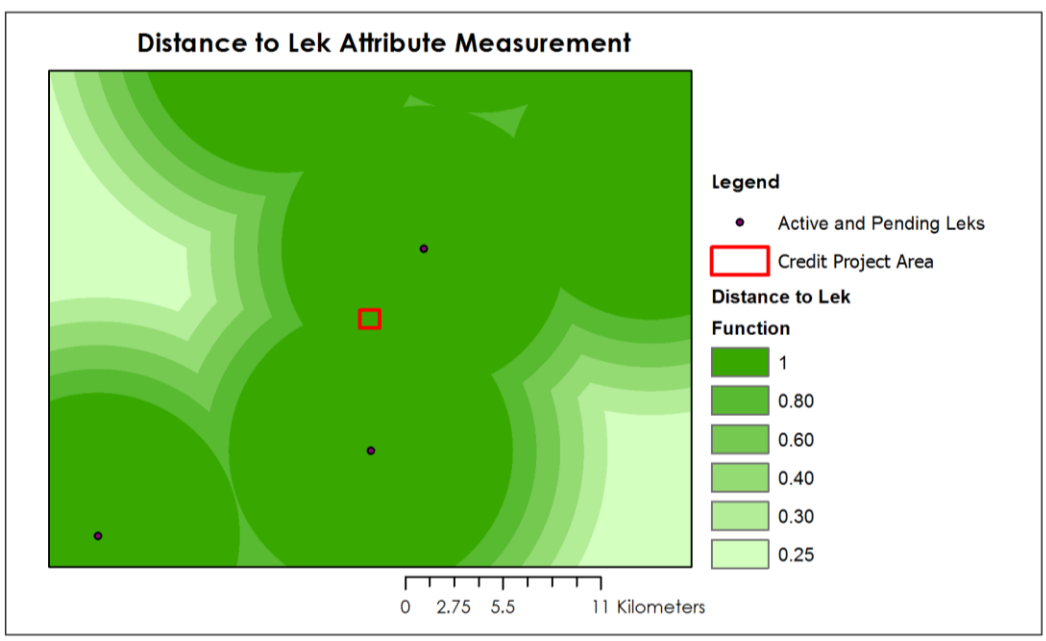
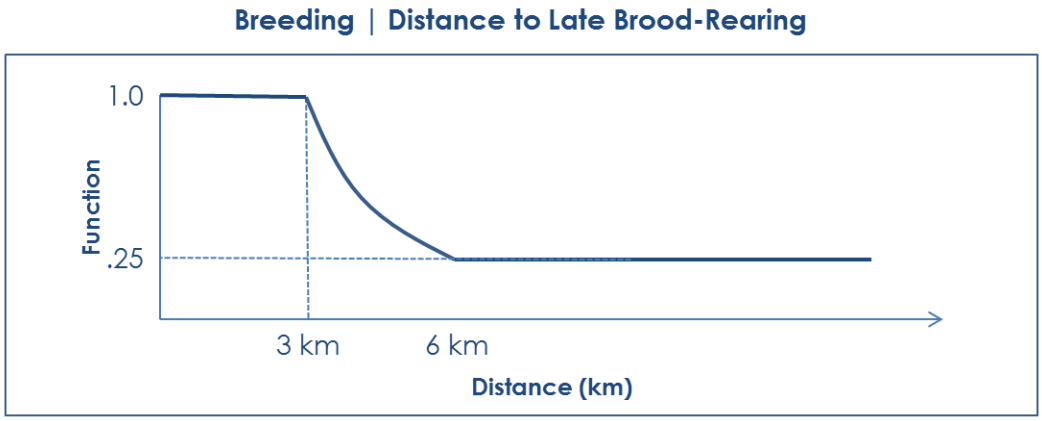



Figure 12. Effect of Distance to lek attribute on breeding habitat function for an example credit project

### 3.3.4 DISTANCE TO LATE BROOD-REARING HABITAT (BREEDING)

Research indicates chick survival drops significantly when broods are required to travel greater than 1.86 miles (3 kilometers) (Gibson et al. 2013). However, some broods successfully travel long distances to late brood-rearing habitat. Therefore, distance to late-brood rearing habitat is a modifier of breeding habitat function as follows: map units within 1.86 miles (3 kilometers) of late brood-rearing habitat receive a score of 1.0 followed by a decline between 1.86 and 3.73 miles (3 and 6 kilometers) from late brood-rearing habitat, map units farther than 3.73 miles (6 kilometers) from late brood-rearing habitat receive a score of 0.25 (Figure 13). The distance to late brood-rearing score is multiplied by all other local-scale attribute scores to calculate overall local-scale habitat function for breeding habitat.




| Distance (km) | <3 | 3 – <4 | 4 – <5 | 5 – <6 | ≥6 |
|---|---|---|---|---|---|
| Score | 1.0 | 0.8 | 0.6 | 0.40 | 0.25 |

Figure 13. Scoring curve and table for distance to late brood-rearing habitat attribute as modifier to breeding habitat function

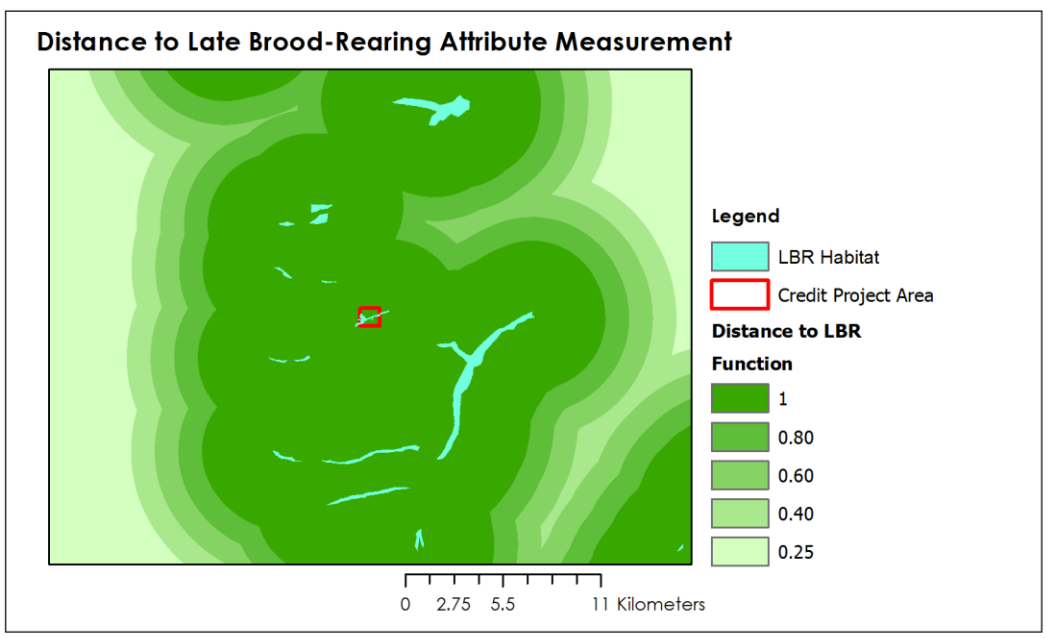



Figure 14. Effect of distance to late brood-rearing attribute on breeding habitat function for an example credit project

## Box 2 | Example Map Unit Calculation (Local Scale)

Each local-scale attribute is measured either through direct digitization of high resolution aerial imagery or with geospatial layers in a GIS. Local-scale habitat function is calculated separately for each seasonal habitat type: breeding, late brood-rearing, and winter (Figure 15). Local-scale habitat function is measured to be 65% for breeding, late brood-rearing and winter seasonal habitats for Map Unit 1.

| | Management Category | Habitat Proportion | 3rd Order Function | 4th Order Function | **Overall Function** | Acres | **Functional Acres** |
|---|---|---|---|---|---|---|---|
| **Breeding** | Core | 55% | 56% | | | 17 | |
| **LBR** | Core | 3% (Limiting) | 56% | | | 17 | |
| **Winter** | Core | 50% | 56% | | | 17 | |

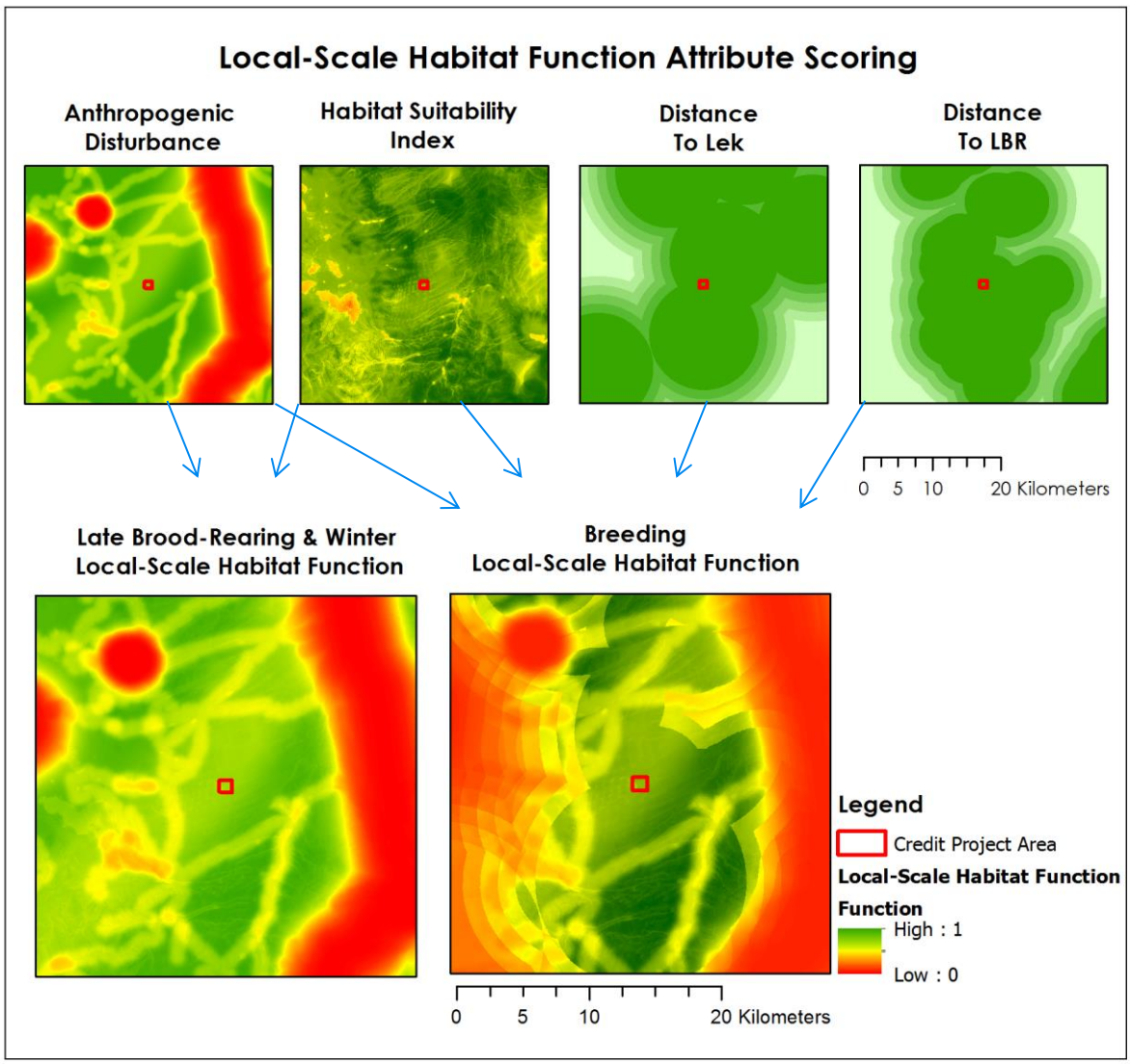
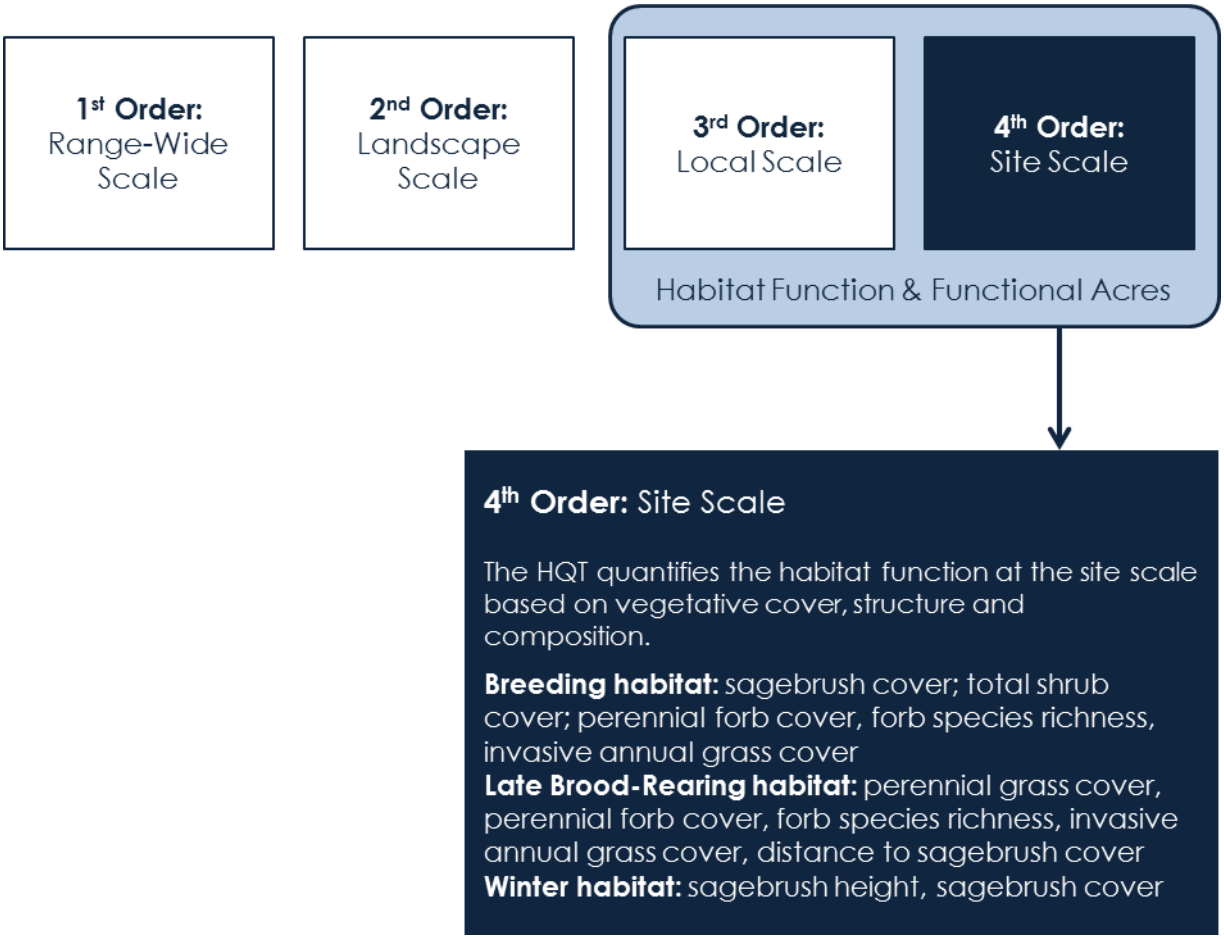



Figure 15. Local-scale attributes are measured in a GIS and combined to calculate local-scale habitat function for each seasonal habitat type.

# 4TH ORDER: SITE SCALE



## 3.4 SITE SCALE (4TH ORDER)

The HQT quantifies habitat function at the site scale based on vegetative cover, structure, and composition. Measurements include attributes that are indicative of habitat suitability and quality for sage-grouse, including conditions that support breeding, late brood-rearing, and winter habitats. Vegetation attributes are measured within each map unit and scored based on triggers, scoring curves and tables, and weighting. Modifiers of site-scale habitat function, including invasive annual grass and distance to sagebrush, are applied to habitat function for the appropriate seasonal habitat types.

The concept model below illustrates the conditions being measured at the site scale and the role they play in providing suitable breeding, late brood-rearing, and winter habitat (Figure 16).

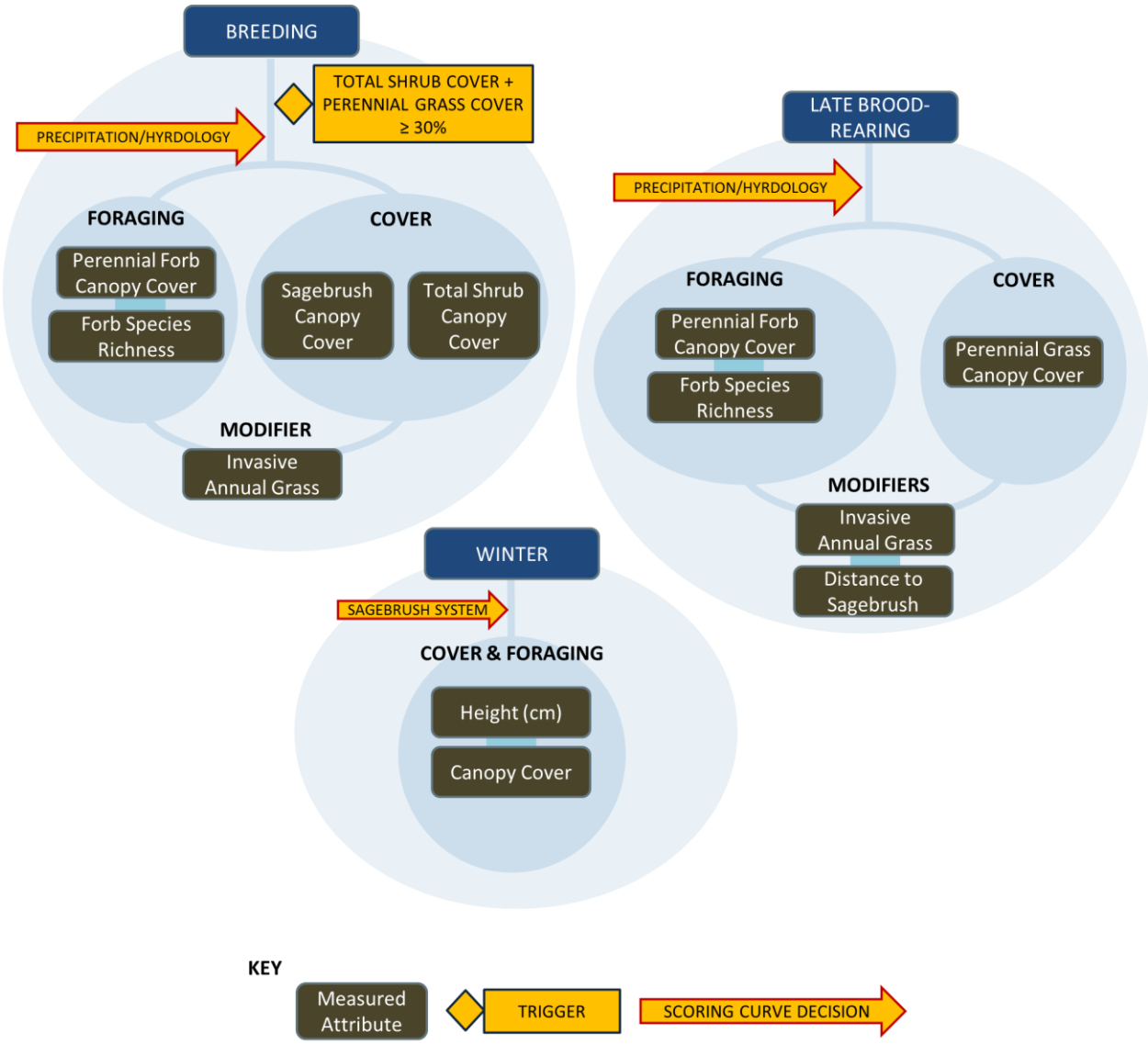



Figure 16. Conceptual model depicting sage-grouse life history requirements at the site scale (4th order)

### 3.4.1 TRIGGERS

For breeding habitat, when sagebrush cover is less than 25%, there should be at least 10% perennial grass cover (Coates et al. 2011; Coates and Delehanty 2010). However, the relationship is dynamic—as cover of sagebrush increases, perennial grass cover becomes less important. Further, any type of shrub can be used for cover. Therefore, a combined cover of 30% for total shrub cover and perennial grass cover is required for the map unit to be scored for breeding habitat function. Combined total shrub cover and perennial grass cover is a trigger to indicate that a map unit contains functional breeding habitat. If the trigger is met, the map unit is scored as usual for breeding habitat. If the trigger is not met, the map unit receives a breeding habitat score of zero. The map unit may still receive a score for other seasonal habitat types.

### 3.4.2 SCORING CURVES

A set of scoring curves has been developed with the TRG for each attribute measured to reflect an attribute's potential for supporting sage-grouse for a given measurement of that attribute, representing how a site's habitat function changes as the attribute measurements change. The scoring curves for all of the vegetation attributes measured are included in Appendix A. Scoring curves are used to score average measurements for each attribute within a map unit. Separate scoring curves are used for some attributes based on the map unit's mean annual precipitation, hydrologic system, and dominant sagebrush community.

#### Precipitation Regime & Hydrologic System

The wide geographic range of sage-grouse results in different vegetation potentials in different regions in Nevada. This may be due to variation in factors such as mean annual precipitation and the site's hydrology. Encouraging the identification of suitable and high quality habitat within each region of the state requires some flexibility in how attributes are scored. For example, vegetation height in lower precipitation areas may not attain the same levels as vegetation in wetter areas, even though the former area may otherwise be high quality habitat for sage-grouse.

The HQT addresses this potential for variability by using different scoring curves for sites in arid-shrub conditions, mesic-shrub conditions, and wet meadow systems.

- **Arid-shrub condition**: sites with mean annual precipitation of less than 10 inches (25.4 centimeters);
- **Mesic-shrub condition**: sites with mean annual precipitation of greater than or equal to 10 inches (25.4 centimeters);
- **Wet meadow systems**: sites where soils are saturated for part or all of the growing season. This can be determined based on presence of vegetation, soils or hydrologic conditions typical of wet meadows, and should be verified by in-the-field observations. Precipitation regime is disregarded for sites in a meadow system.

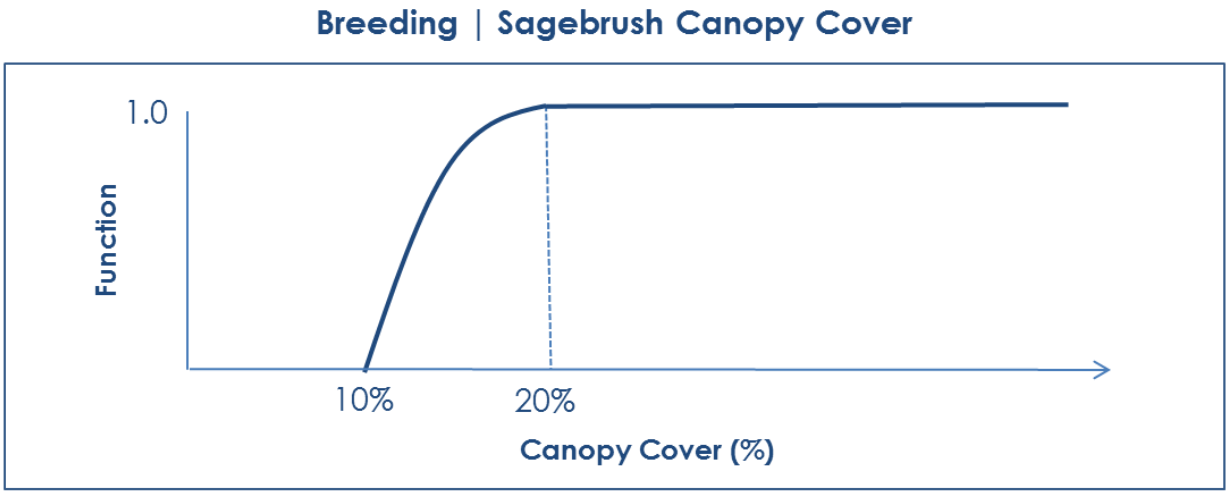
Note that annual precipitation changes (e.g., drought conditions) are different than mean annual precipitation as used by the HQT. Refer to PRISM Climate Group's "30-yr Normal Precipitation: Annual" for annual precipitation zones at http://prism.oregonstate.edu/normals/.

Dominant Sagebrush System

Different scoring curves for winter habitat function are used based on the dominant sagebrush community present. Sites dominated by Wyoming big sagebrush or mountain big sagebrush (*Artemisia tridentata* ssp.), which are typically taller and found where snow is deeper, are scored with different curves than sites dominated by low sagebrush (*Artemisia arbuscula* ssp.) or black sagebrush (*Artemisia nova*), which are typically shorter and found in areas where snow dissipates more quickly due to wind and solar radiation.

### Application of Scoring Curves

After establishing the specific seasonal habitats to be scored and which scoring curves to use, the average measurement for each vegetation attribute in the map unit is scored using the appropriate scoring curve. For example, Figure 17 is the scoring curve and associated table for sagebrush canopy cover for scoring breeding habitat function.




| Cover (%) | <10 | 10 – <12 | 12 – <14 | 14 – <16 | 16 – <18 | 18 – <20 | ≥20 |
|---|---|---|---|---|---|---|---|
| Score | 0 | 0.30 | 0.55 | .75 | .85 | .93 | 1.00 |

Figure 17. Scoring curve and table for sagebrush canopy cover in breeding habitat

The scoring curve above establishes the relationship between sagebrush canopy cover and breeding habitat function, the shape of which is established from literature and expert opinion. The scoring curve establishes the habitat function of each site relative to fully-functioning conditions—from 0 (non-functioning) to 1.0 (fully-functioning canopy cover).

## 3.4.3 ATTRIBUTE WEIGHTING

The score for each attribute is then weighted as established in Table 4. The weights are based on expert opinion, are on a relative scale and add to 100%. See also Connelly et al. 2011c for a review of habitat requirements for sage-grouse habitat, and aforementioned literature citations (and the citations within) that describe sage-grouse habitat. The scores are multiplied by the weight, and the weighted scores across all attributes for that season are then added to generate a score for a map unit.

### 3.4.4 ATTRIBUTES MEASURED

The following attributes of site vegetation are measured (the following tables are adapted from Table 4-1 in Appendix B "Development Process and Justification for Habitat Objectives for Greater Sage-grouse in Nevada" in the Nevada State Plan). Attributes must be measured for each seasonal habitat type during the appropriate time of year, except for winter habitat attributes which can be measured at any time.

Table 4. Description of vegetation attributes measured and attribute weighting

| BREEDING | | | |
|---|---|---|---|
| (SAMPLE APRIL THROUGH JUNE 15) | | | |
| Cover | Sagebrush canopy cover | This serves as nesting horizontal overstory substrate. The presence of sagebrush in nesting habitat is an active variable in all studies of sage-grouse. (Connelly et al. 2000; Blomberg et al. 2012; Kolada et al. 2009a; Kolada et al. 2009b). Qualifying sagebrush species are defined in the Credit System User's Guide. This is estimated with line intercept. | 20% Weight |
| | Total shrub canopy cover (includes sagebrush) | Shrub species such as rabbitbrush (*Chrysothamnus spp.*), antelope bitterbrush (*Purshia tridentata*), and horsebrush (*Tetradymia canescans*) are associated with higher nest success. Where sagebrush canopy cover is high, other brush species play a positive role. Total canopy cover of all species is a positive attribute for nest success (Coates and Delehanty 2010; Kolada et al. 2009b). This is estimated with line intercept. | 30% Weight |
| Foraging | Perennial forb canopy cover | Forbs are an important food resource and is a primary habitat component affecting brood persistence (Casazza et al 2011). This is estimated along line transects within Daubenmire frames. | 25% Weight |
| | Forb species richness | This is a measure of the number of forb species, both perennial and annual, available across the early brood-rearing period. Data indicate there is a direct correlation between the number of forb species present and sage-grouse persistence (Casazza et al. 2011). Species are tallied within Daubenmire frames along line-transects. | 25% Weight |
| Trigger | Perennial grass canopy cover | Combined perennial grass canopy cover and total shrub canopy cover must exceed 30% to be scored for breeding. | n/a |

| LATE BROOD-REARING | | | |
|---|---|---|---|
| (SAMPLE JULY THROUGH SEPTEMBER 15) | | | |
| Cover | Perennial grass canopy cover | Perennial grass cover is higher (17.4% versus 12%) in selected sites than non-selected sites (Kirol et al. 2012). This is estimated along line transects within Daubenmire frames. | 25% Weight |
| Foraging | Perennial forb canopy cover | Forbs are an important food resource and is a primary habitat component affecting brood persistence (Casazza et al 2011). This is estimated along line transects within Daubenmire frames. | 37.5% Weight |

| | | | |
|---|---|---|---|
| | Forb species richness | This is a measure of the number of forb species, both perennial and annual, available across the late brood-rearing period. Data indicate there is a direct correlation between the number of forb species present and sage-grouse persistence (Casazza et al. 2011). Species are tallied withing Daubenmire frames along line transects. | 37.5% Weight |

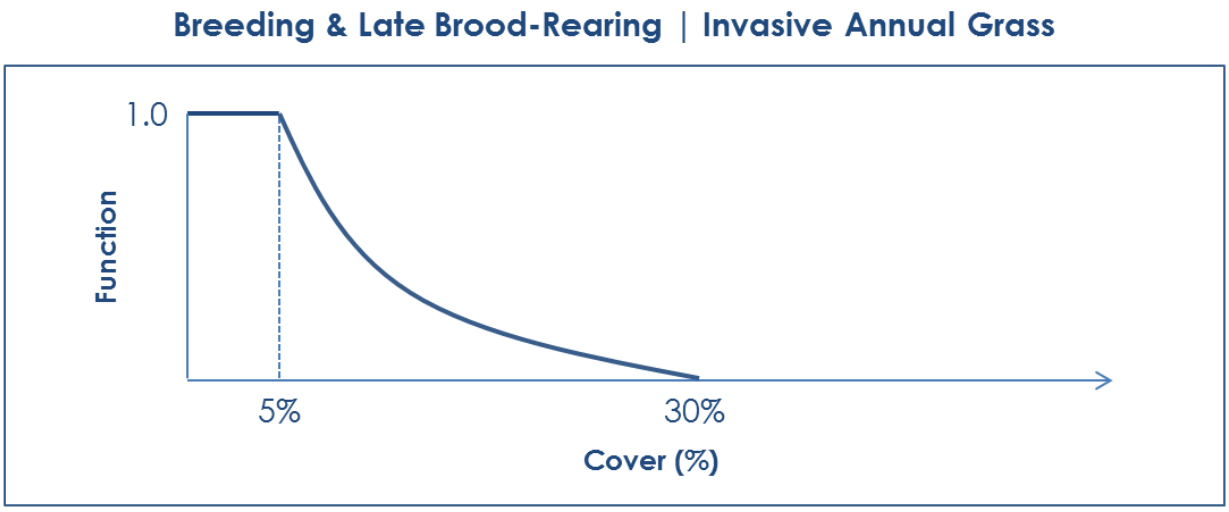
| WINTER | | | |
|---|---|---|---|
| (SAMPLE ANYTIME) | | | |
| Cover & Foraging | Sagebrush canopy cover | During winter, sagebrush canopy cover serves as both food and cover for sage-grouse (Connelly et al. 2000). This is estimated with line intercept. | 50% Weight |
| | Sagebrush height | Access to sagebrush during winter conditions is important (Connelly et al. 2000). This measures the average height of sagebrush. It is collected along line transects. | 50% Weight |

## 3.4.5 MODIFICATION OF SITE-SCALE HABITAT FUNCTION

Habitat function is modified at the site scale by invasive annual grass cover for breeding and late brood-rearing habitat function and distance to sagebrush cover for late brood-rearing habitat function. Scores associated with each modifier are multiplied by the pre-modified site-scale habitat function of the appropriate seasonal habitat types to calculate site-scale habitat function.

### 3.4.5.1 Invasive Annual Grass (Breeding & Late Brood-Rearing)

Invasive annual grass cover is a modifier for breeding and late brood-rearing habitat function, and is measured along line transects within Daubenmire frames (Figure 18).



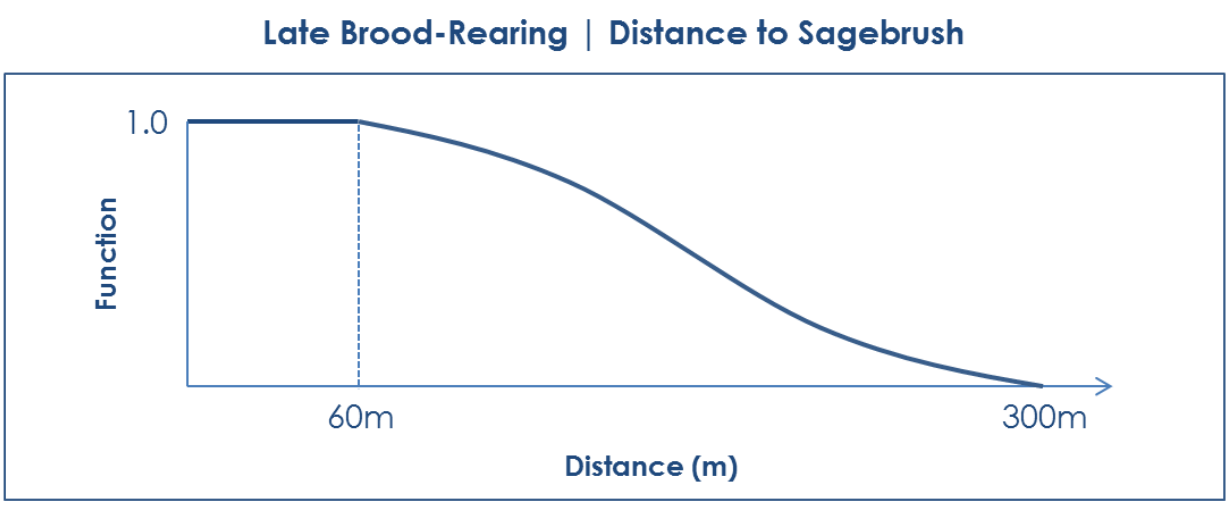

| Cover (%) | <5 | 5 – <10 | 10 – <15 | 15 – <20 | 20 – <25 | 25 – <30 | ≥30 |
|---|---|---|---|---|---|---|---|
| Score | 1.00 | 0.80 | 0.60 | 0.45 | 0.25 | 0.15 | 0 |

Figure 18. Scoring curve and table for invasive annual grass canopy cover as a modifier for breeding and late brood-rearing habitat

Big sagebrush ecosystems of the Intermountain West are especially vulnerable to invasions by annual exotic grasses such as cheatgrass, which can become dominant in the herbaceous understory community (Miller et al. 2011). Invasive plants, especially invasive annual grasses (e.g., cheatgrass) in sagebrush-steppe habitats, alter plant community structure, composition and productivity and may competitively exclude native plants important as cover and forage for sage-grouse (Vitousek 1990, Mooney and Cleland 2001, Rowland et al. 2010). The most pronounced negative consequence of invasive annual grass invasion into sagebrush habitats is the resulting change in fire frequency and intensity (Balch et al. 2013, Antonio et al 1992). Ultimately, invasive annual grasses promote fires and fires promote invasive annual grasses. Fire also facilitates the conversion of rangelands from perennial-dominated to annual-dominated systems by eliminating fire-intolerant species such as big sagebrush from these systems, rendering them permanently unsuitable to sage-grouse (Connelly et al. 2004, Epanchin-Niell et al. 2009, Davies et al. 2011). In central Nevada, recruitment of male sage-grouse to leks was consistently low in areas with high proportions of exotic grasslands interspersed in the landscape within 3.11 miles (5 kilometers) of a lek, even during years when climatic conditions resulted in substantial recruitment to leks in the region (Blomberg et al. 2012).

#### 3.4.5.2 Distance to Sagebrush Cover (Late Brood-Rearing)

Distance to sagebrush cover is a modifier of late brood-rearing habitat function as follows: map units within 196.9 feet (60 meter) of cover (defined as 10% cover and 11.8 inches (30 centimeters) height minimum over 98.4 feet (30 meter) x 98.4 feet (30 meter) area) of sagebrush or sagebrush mixed-shrub community (e.g., sagebrush, bitterbrush, rabbitbrush, serviceberry, broom snakeweed) receive a score of 1.0 followed by a decline between 196.8 feet (60 meter) and 984.3 feet (300 meter) to sagebrush or sagebrush mixed-shrub cover, map units farther than 984.3 feet (300 meter) from sagebrush or sagebrush mixed-shrub cover receive a score of 0 (Figure 19). Distance to sagebrush or sagebrush mixed-shrub cover is measured from the 98.4 feet (30 meter) mark of every transect.




| Distance (m) | <60 | 60 – <100 | 100 – <140 | 140 – <180 | 180 – <220 | 220 – <260 | 260 – <300 | ≥300 |
|---|---|---|---|---|---|---|---|---|
| Score | 1.00 | .90 | .75 | .55 | .35 | .20 | .10 | 0 |

Figure 19. Scoring curve and table for scoring late brood-rearing habitat based on distance to sagebrush cover

The interface between the sagebrush and meadow edge is the most highly forb-productive area for sage-grouse and provides immediate available escape cover (Connelly et al. 2000). Based on the expert opinion of the TRG, sage-grouse may use specific areas (e.g., wet meadows) during the late brood-rearing season

that do not have sagebrush within the perimeter of the meadow itself, as long as sagebrush is accessible to them. Meadows, riparian areas, other moist areas adjacent to sagebrush habitat and higher elevation sagebrush communities that maintain rich forb component later in summer can provide foraging areas during this season (Fischer et al. 1996a, Fischer et al. 1996b, Connelly et al. 2000, Connelly et al. 2011c).

## Box 3 | Example Map Unit Calculation (Site Scale)

The site-scale habitat function for each seasonal habitat type is multiplied by local-scale habitat function and the number of acres within the map unit to calculate functional acres.

| | Management Category | Habitat Proportion | 3rd Order Function | 4th Order Function | **Overall Function** | Acres | **Functional Acres** |
|---|---|---|---|---|---|---|---|
| **Breeding** | Core | 55% | 56% | 61% | **34%** | 17 | **5.9** |
| **LBR** | Core | 3% (Limiting) | 56% | 70% | **40%** | 17 | **6.7** |
| **Winter** | Core | 50% | 56% | 64% | **36%** | 17 | **6.1** |

Map Unit 1 is located in a mesic precipitation zone (i.e., more than 10 inches (25.4 centimeters) of precipitation per year) and contains dominantly mountain big sagebrush. The following measurements are obtained during the appropriate sampling period. Each measurement is scored using the appropriate scoring curves, the score is then weighted and the weighted scores are **summed** for each seasonal habitat type to calculate pre-modified site-scale habitat function.

The map unit is also assessed for invasive annual grass and distance to sagebrush. The map unit contains sagebrush within it, yielding a score of 100% for the distance to sagebrush modifier. Invasive annual grass cover is measured at 6% during the breeding assessment and 3% during the late brood-rearing assessment, yielding scores of 100% and 80%, respectively. Modifier scores are **multiplied** by the pre-modified site-scale habitat function for each seasonal habitat type in succession to calculate site-scale habitat function.

| **Breeding** | **Average Measurement** | **Score*** | **Weight** | **Weighted Score** |
|---|---|---|---|---|
| Sagebrush Canopy Cover | 17% | 85% | 20% | 17% |
| Total Shrub Canopy Cover | 24% | 75% | 30% | 23% |
| Perennial Forb Canopy Cover | 4% | 40% | 25% | 10% |
| Forb Species Richness | 3 species | 45% | 25% | 11% |
| | | **Pre-modified Site-Scale Breeding Function** | | **61%** |
| Invasive Annual Grass | 3% | 100% | n/a | 100% |
| | | **Site-Scale Breeding Function** | | **61%** |
| **Late Brood-Rearing** | | | | |
| Perennial Grass Canopy Cover | 7% | 64% | 25% | 16% |
| Perennial Forb Canopy Cover | 12% | 100% | 37.5% | 38% |
| For Species Richness | 4 species | 90% | 37.5% | 34% |
| | | **Pre-modified Site-Scale Late Brood-Rearing Function** | | **88%** |
| Invasive Annual Grass | 6% | 80% | n/a | 80% |
| Distance to Sagebrush | 0 m | 100% | n/a | 100% |
| | | **Site-Scale Late Brood-Rearing Function** | | **70%** |
| **Winter** | | | | |
| Sagebrush Canopy Cover | 17% | 88% | 50% | 44% |
| Sagebrush Height | 34 cm | 40% | 50% | 20% |
| | | **Site-Scale Winter Function** | | **64%** |

*See Appendix A for all scoring curves used to assess vegetation attributes at the site scale

# 4.0 PROJECT EXAMPLE

This section illustrates the completion of the scoring process for the remainder of the map units in the example credit project (Figure 20). The process used to evaluate Map Unit 1, described in the previous section, is repeated for each map unit.

The scoring process requires both a desktop analysis and a field analysis. The desktop analysis measures attributes at the landscape and local scale. The field analysis measures vegetation attributes relevant at the site scale. Overall habitat function is a product of local-scale habitat function and site-scale habitat function. Functional acres are a product of habitat function and the acres within the map unit. Each map unit is assessed for each seasonal habitat type: breeding, late brood-rearing and winter.

For a complete, step-by-step description of the scoring process used by the HQT, please see the *Credits System User's Guide*.

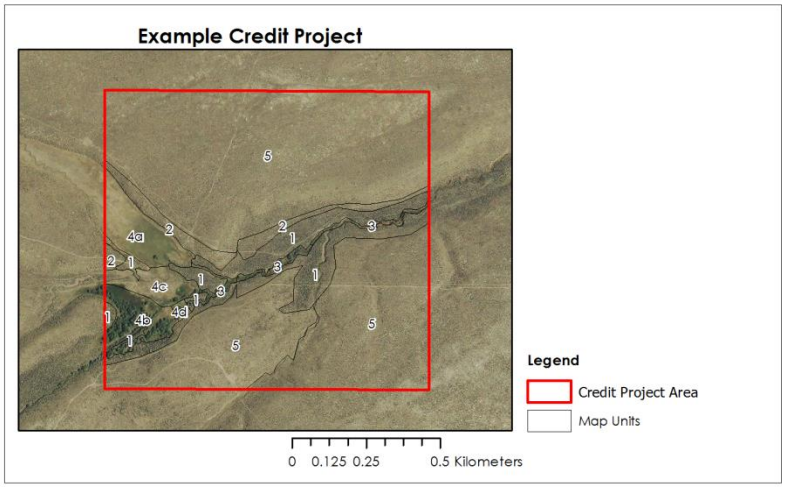



Figure 20. Example credit project and map units

Table 5. Attribute measurements, habitat function, and functional acre values for breeding habitat function

| BREEDING HABITAT FUNCTION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Map Unit | Acres | Precipitation Regime/ Hydrologic System | Dominant Shrub Community | Management Category | Limiting Seasonal Habitat (Proportion) | Local-Scale Habitat Function | Site-Scale Habitat Function | Habitat Function | Functional Acres |
| 1 | 17 | Mesic | Big Sagebrush | Core | 61% | 56% | 61% | 34% | 5.9 |
| 2 | 6 | Mesic | Big Sagebrush | Core | 61% | 55% | 46% | 26% | 1.5 |
| 3 | 2 | Wet Meadow | n/a | Core | 61% | 58% | 0% | 0% | 0.0 |
| 4a | 6 | Wet Meadow | n/a | Core | 61% | 53% | 0% | 0% | 0.0 |
| 4b | 5 | Wet Meadow | n/a | Core | 61% | 52% | 0% | 0% | 0.0 |
| 4c | 4 | Wet Meadow | n/a | Core | 61% | 52% | 0% | 0% | 0.0 |
| 4d | 0.5 | Wet Meadow | n/a | Core | 61% | 52% | 0% | 0% | 0.0 |
| 5 | 112 | Mesic | Big Sagebrush | Core | 61% | 58% | 58% | 34% | 37.6 |

Table 6. Attribute measurements, habitat function, and functional acre values for late brood-rearing habitat function

| LATE BROOD-REARING HABITAT FUNCTION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Map Unit | Acres | Precipitation Regime/ Hydrologic System | Dominant Shrub Community | Management Category | Limiting Seasonal Habitat (Proportion) | Local-Scale Habitat Function | Site-Scale Habitat Function | Habitat Function | Functional Acres |
| 1 | 17 | Mesic | Big Sagebrush | Core | 3% (Limiting) | 56% | 70% | 40% | 6.7 |
| 2 | 6 | Mesic | Big Sagebrush | Core | 3% (Limiting) | 55% | 64% | 35% | 2.1 |
| 3 | 2 | Wet Meadow | n/a | Core | 3% (Limiting) | 58% | 92% | 53% | 1.1 |
| 4a | 6 | Wet Meadow | n/a | Core | 3% (Limiting) | 53% | 29% | 15% | 0.9 |
| 4b | 5 | Wet Meadow | n/a | Core | 3% (Limiting) | 52% | 64% | 33% | 1.7 |
| 4c | 4 | Wet Meadow | n/a | Core | 3% (Limiting) | 52% | 24% | 12% | 0.5 |
| 4d | 0.5 | Wet Meadow | n/a | Core | 3% (Limiting) | 52% | 58% | 30% | 0.2 |
| 5 | 112 | Mesic | Big Sagebrush | Core | 3% (Limiting) | 58% | 11% | 6% | 7.1 |

Table 7. Attribute measurements, habitat function, and functional acre values for winter habitat function

| WINTER HABITAT FUNCTION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Map Unit | Acres | Precipitation Regime/ Hydrologic System | Dominant Shrub Community | Management Category | Limiting Seasonal Habitat (Proportion) | Local-Scale Habitat Function | Site-Scale Habitat Function | Habitat Function | Functional Acres |
| 1 | 17 | Mesic | Big Sagebrush | Core | 65% | 56% | 64% | 36% | 6.1 |
| 2 | 6 | Mesic | Big Sagebrush | Core | 65% | 55% | 53% | 29% | 1.8 |
| 3 | 2 | Wet Meadow | n/a | Core | 65% | 58% | 0% | 0% | 0.0 |
| 4a | 6 | Wet Meadow | n/a | Core | 65% | 53% | 0% | 0% | 0.0 |
| 4b | 5 | Wet Meadow | n/a | Core | 65% | 52% | 0% | 0% | 0.0 |
| 4c | 4 | Wet Meadow | n/a | Core | 65% | 52% | 0% | 0% | 0.0 |
| 4d | 0 | Wet Meadow | n/a | Core | 65% | 52% | 0% | 0% | 0.0 |
| 5 | 112 | Mesic | Big Sagebrush | Core | 65% | 58% | 71% | 41% | 46.0 |

# 5.0 LIMITATIONS OF THE HQT

The HQT is the scientific underpinning of the Credit System. The credibility of the Credit System and its effectiveness hinges upon the quality of the science upon which it is based and the integrity with which it is applied. The HQT is based on the best available science and best professional judgment. However, there are aspects of its content and potential uses that can be improved as it is adaptively managed over time. These limitations should be considered when applying the HQT.

### Linking to Population Outcomes

The ultimate objective of the Credit System is to contribute to conservation of the sage-grouse by providing net habitat benefits. However, these habitat benefits must ultimately lead to larger and more secure sage-grouse populations. Therefore, the Credit System must have a means of measuring aggregate cumulative habitat impacts and benefits, and relating the net contribution of habitat benefits achieved through the Credit System to populations.

To make this link, an estimate of population impacts from activities related to credit and debit projects is needed. Unfortunately it is not currently possible to make this link directly through published literature and thus site-level management actions cannot be quantified for the number of sage-grouse "produced" or "eliminated." However, additional research could contribute to a greater understanding of how cumulative habitat changes contribute to population viability. Furthermore, as long as debits are offset by credits, and as credits accumulate beyond debits, the Credit System will have contributed to increases in high quality habitat that can help to sustain resilient populations over time. The State of Nevada will continue to monitor sage-grouse populations across the state.

### Importance of Temporal Scale

Temporal scales must be taken into consideration when establishing a mitigation project, and as spatial scales of a project or evaluation area increase, so should temporal scales.

Temporal scales vary among ecological processes and may not be linear especially in varying environments (Wiens 1989). The time required for a vegetation community to respond to management practices or changes in habitat and its influence on sage-grouse vital rates varies by ecosystem, geography, climate, and land use. For sage-grouse, time lags of two to ten years have been observed for population response to infrastructure development (Holloran 2005; Harju et al. 2010; Walker et al. 2007) or even longer with changes in habitat structure (e.g., fire) (Connelly et al. 2011b). Temporal scale for sagebrush projects deserves especially close consideration given that recovery of sagebrush is an especially difficult and slow process due to abiotic variation, short-lived seedbanks, and long generation time of sagebrush; where soils and vegetation are highly disturbed, sagebrush restoration can be challenging if not impossible (Pyke et al. 2011, Monsen 2005).

The scoring approach used in the HQT does not include a short-term temporal aspect. Thus, it cannot detect short-term changes in impacts resulting from infrastructure. For example, a drilling rig may have more impact than a producing well. Due to this limitation, it scores the impact based on the primary level of activity the majority of the time the disturbance is present. In this example, it scores based on the impact of the active production phase, rather than the drilling rig phase, which may only last 60 days.

### Anthropogenic Impacts Literature

Most of the literature used to estimate the distance effects and relative weights associated with anthropogenic disturbance is derived from analyses of the response of sage-grouse on leks (i.e., number of males occupying leks) to that infrastructure (see Appendix D). Since the HQT seeks to quantify vegetation that supports seasonal needs of sage-grouse (i.e., breeding, summer and winter), and credits

and debits are based on these assessments of seasonal habitat value, anthropogenic weights and distances will be updated as more information pertaining to sage-grouse seasonal response to anthropogenic activity becomes available.

Additionally, most of this literature relates to oil and gas development. Although currently in Nevada there is little oil and gas development, other energy and mineral facilities are assumed to have similar effects as oil and gas-related infrastructure. Where literature is available specific to a type of anthropogenic disturbance, that literature is used to determine indirect effect distances and weights.

### Vegetation Sampling Protocol

The HQT currently relies on a standardized, site-specific vegetation sampling protocol to establish vegetation conditions. The methods established in the User's guide are based on the same methods that were used in the research the supports the scoring curves developed for this process. Standardizing vegetation sampling protocols over space and time has its challenges, which could be problematic in situations where quantifying vegetation change is the objective of monitoring (Seefeldt and Booth 2006). Aerial imagery and other remotely-sensed information offer the opportunity for more objective measurement of vegetation across space and time, but in most instances the products derived from these data are too coarse to effectively detect small-scale changes in the vegetation (Seefeldt and Booth 2006). As remote-sensing platforms and sensors mature, spatial and temporal resolution are expected to improve and costs decrease, making it easier to effectively quantify change in relevant vegetation attributes for attributes that can be assessed with these technologies. The Science Committee, a group of sage-grouse experts and scientists convened to inform monitoring efforts across the Credit System, will stay abreast of advances in remote-sensing and image analysis software so that GIS-based monitoring protocols can be incorporated into the HQT as suitable to address the HQT objectives.

### Seasonal Habitat Availability, Interspersion & Juxtaposition

The HQT uses the proportion of each seasonal range available to sage-grouse on the landscape within and surrounding a project site as a modifier of habitat quality. However, the interspersion, juxtaposition and availability of the differing cover types used by sage-grouse during an annual cycle influence the effectiveness of a given landscape to provide sage-grouse with useable and high quality habitat (Connelly et al. 2011c). Future iterations of the HQT could explore how to integrate interspersion and juxtaposition as modifiers of habitat function.

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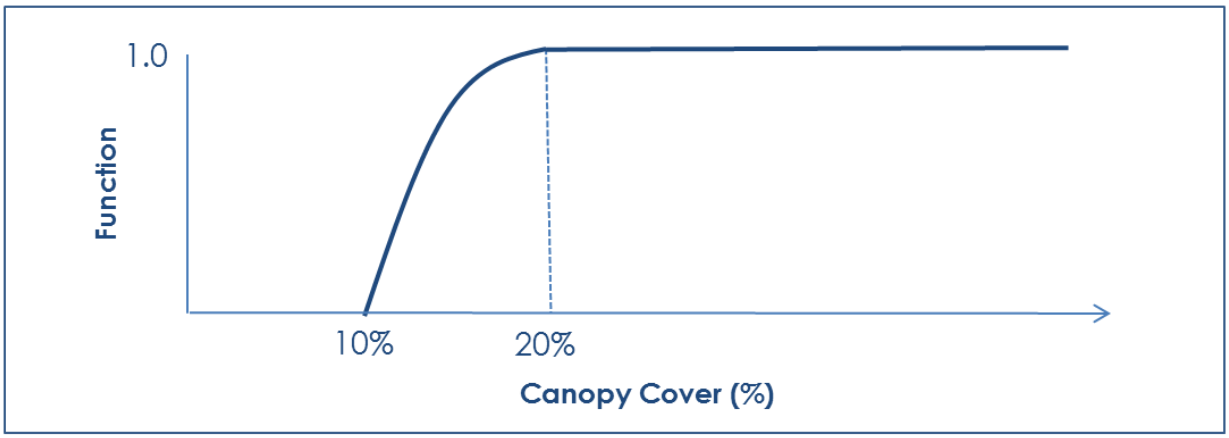
# APPENDIX A: SCORING CURVES

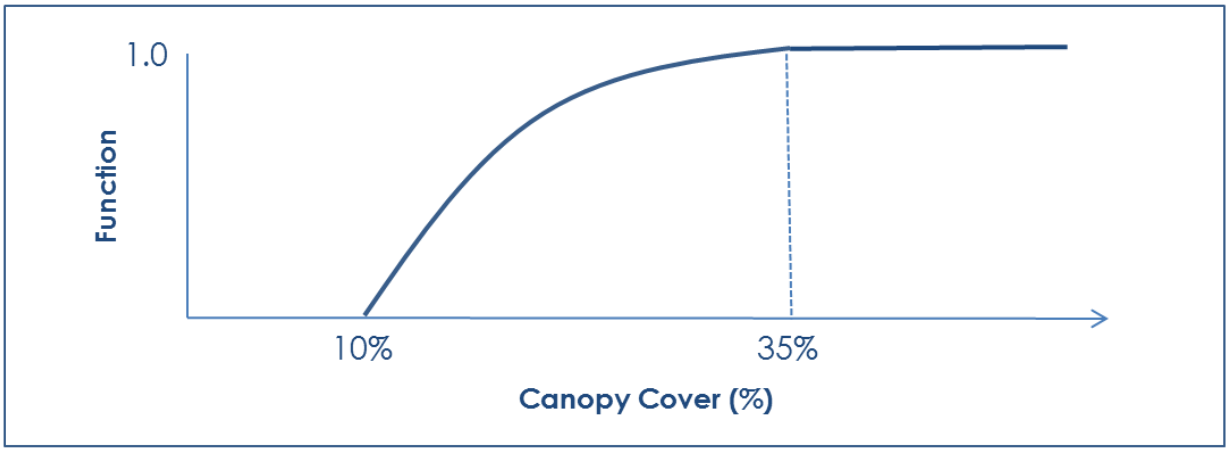
**Breeding | Sagebrush Canopy Cover**




| Cover (%) | <10 | 10 – <12 | 12 – <14 | 14 – <16 | 16 – <18 | 18 – <20 | ≥20 |
|---|---|---|---|---|---|---|---|
| Score | 0 | 0.30 | 0.55 | .75 | .85 | .93 | 1.00 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; Colorado Parks and Wildlife (CPW) unpublished data, and A.D. Apa personal communication which used 20% as the starting value and 30% as the minimum fully functional value. TRG input subtracted 10% from the starting point to reflect Table 2-6 (BLM 2013 and references therein) and Kolada et al. 2009a and Kolada et al. 2009b.

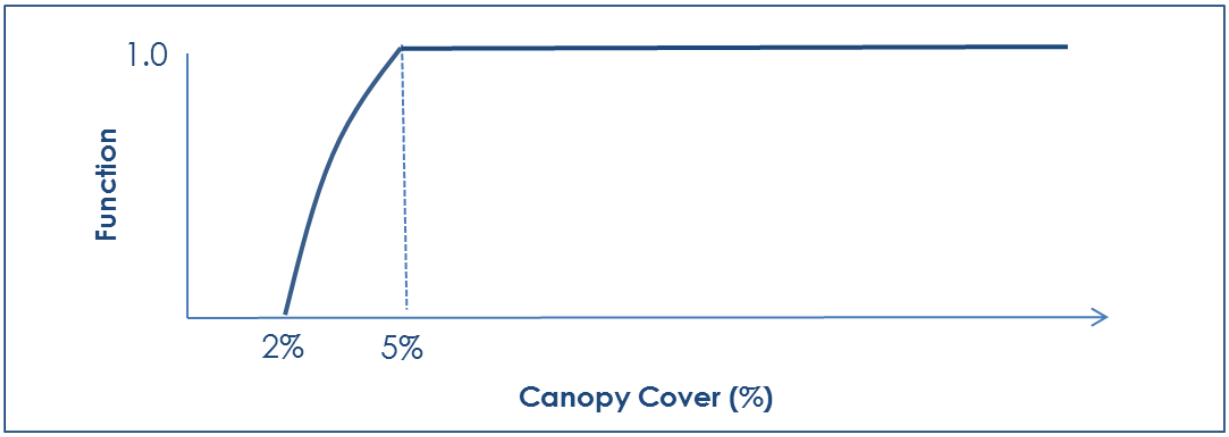
**Breeding | Total Shrub Canopy Cover**




| Cover (%) | <10 | 10 – <14 | 14 – <20 | 20 – <25 | 25 – <30 | 30 – <35 | ≥35 |
|---|---|---|---|---|---|---|---|
| Score | 0 | 0.3 | 0.55 | 0.75 | 0.85 | .93 | 1 |

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and developed curve setting the minimum fully functional value at 35% based on Kolada et al 2009a, Coates and Delehanty 2010, and Lockyer et al. In Press. Further modified by TRG to reflect data from Gibson et al. 2013.

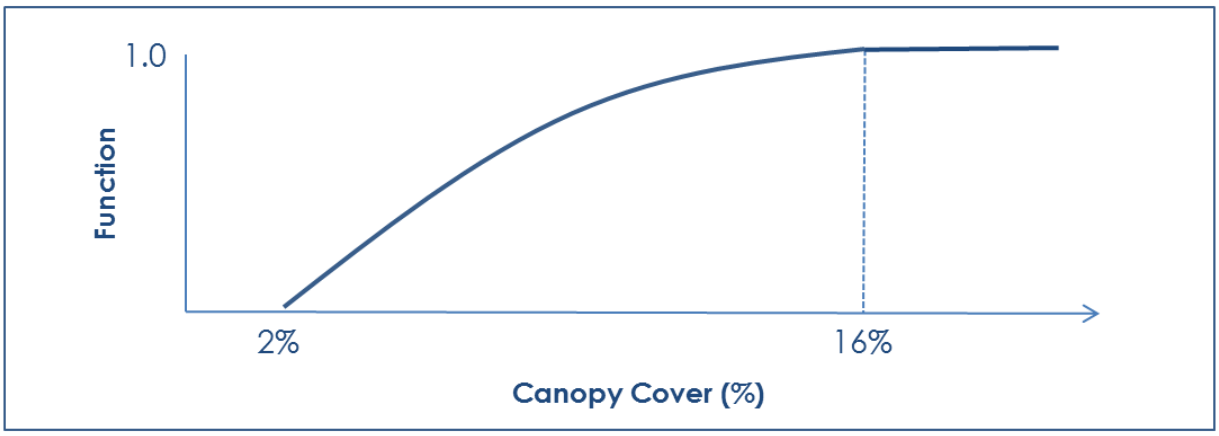
## Breeding | Perennial Forb Canopy Cover (Arid Conditions)




| Arid-Shrub Conditions | Cover (%) | <2 | 2 – <3 | 3 – <4 | 4 – <5 | ≥5 |
|---|---|---|---|---|---|---|
| | Score | 0 | 0.4 | 0.7 | 0.9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. In Press modified the minimum fully functional value set to 5%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

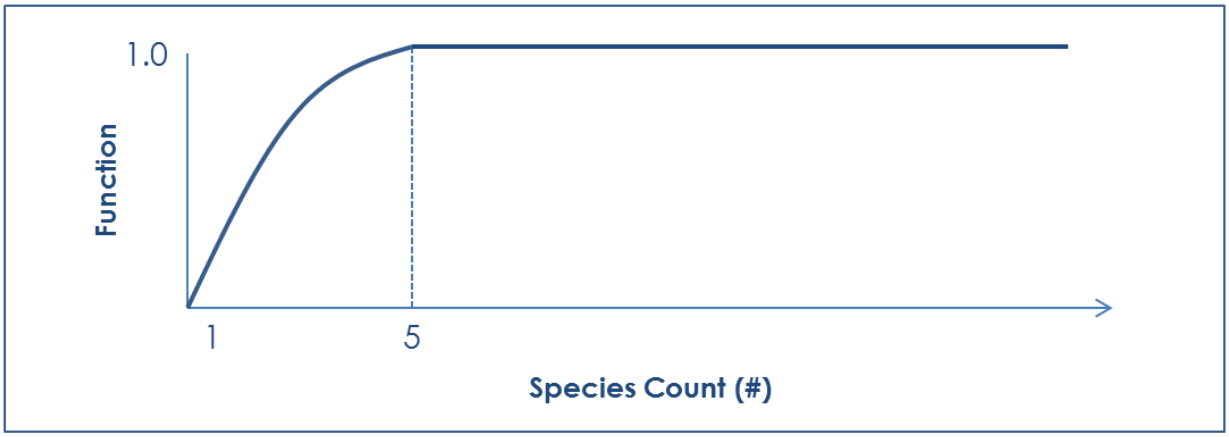
## Breeding | Perennial Forb Canopy Cover (Mesic-Shrub & Meadow Systems)




| Mesic-Shrub & Meadow Systems | Cover (%) | <2 | 2 – <4 | 4 – <6 | 6 – <8 | 8 – <10 | 10 – <12 | 12 – <14 | 14 – <16 | ≥16 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .2 | .4 | .55 | .7 | .79 | .86 | .93 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. In Press, and TRG input modified the minimum fully functional value set to 16%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

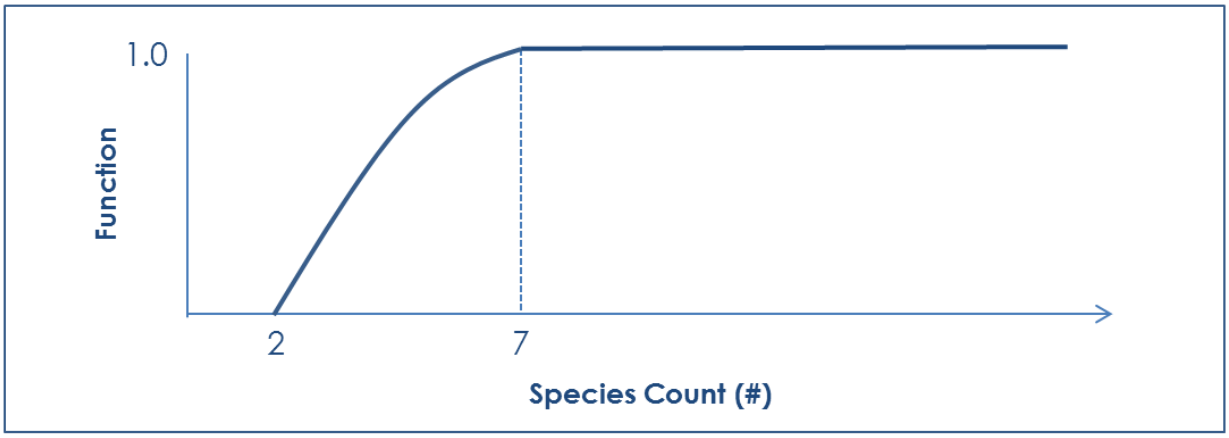
## Breeding | Forb Species Richness (Arid Conditions)




| Arid-Shrub Conditions | Species (#) | <1 | 1 – <2 | 2 – <3 | 3 – <4 | 4 – <5 | ≥5 |
|---|---|---|---|---|---|---|---|
| | Score | 0 | .3 | .6 | .75 | .9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set 8 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. In Press, and TRG input changing starting value to be 1 forb species as having no forbs has no value and reduced the minimum fully functional value to 5 species due to lower general forb abundance in Nevada.

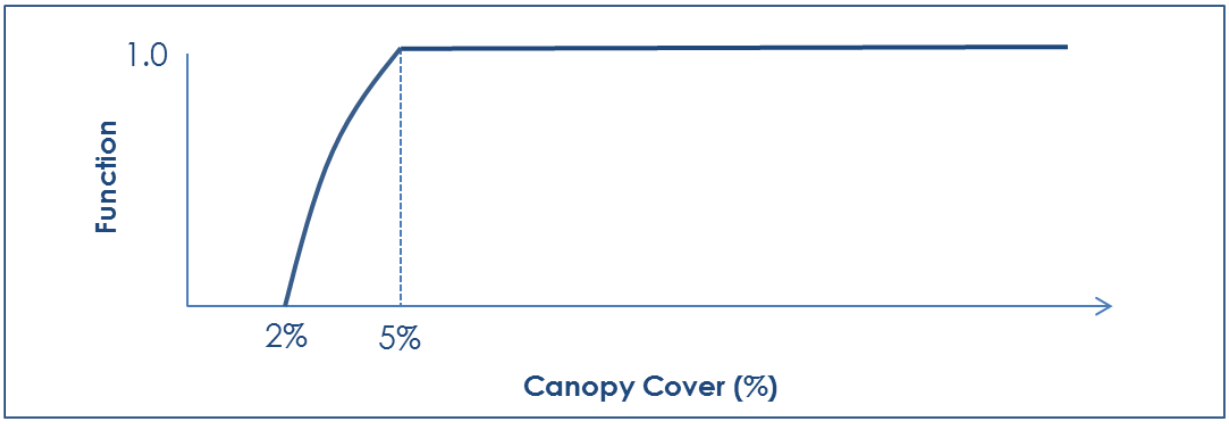
## Breeding | Forb Species Richness (Mesic-Shrub & Meadow Systems)




| Mesic-Shrub & Meadow Systems | Species # | <2 | 2 – <3 | 3 – <4 | 4 – <5 | 5 – <6 | 6 – <7 | ≥7 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .25 | .45 | .65 | .8 | .92 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set 12 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. In Press, and TRG input changing starting value to be 2 forb species as having no forbs has no value, but expectation that mesic sites should have more species than arid, and reduced minimum fully functional value to 7 due to lower general forb abundance in Nevada.

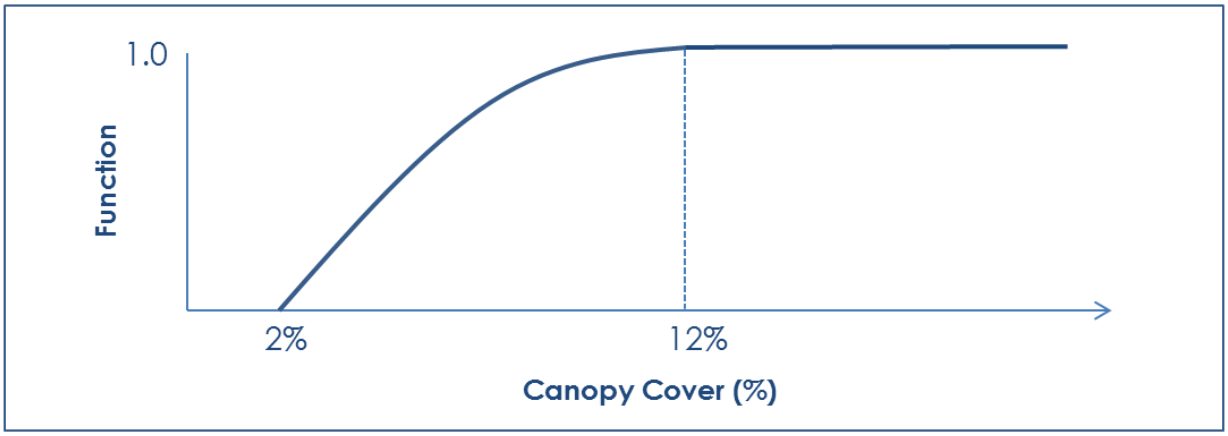
## Late Brood-Rearing | Perennial Forb Canopy Cover (Arid Conditions)




| Arid-Shrub Conditions | Cover (%) | <2 | 2 – <3 | 3 – <4 | 4 – <5 | ≥5 |
|---|---|---|---|---|---|---|
| | Score | 0 | 0.34 | 0.62 | 0.84 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. In Press modified the minimum fully functional value set to 5%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

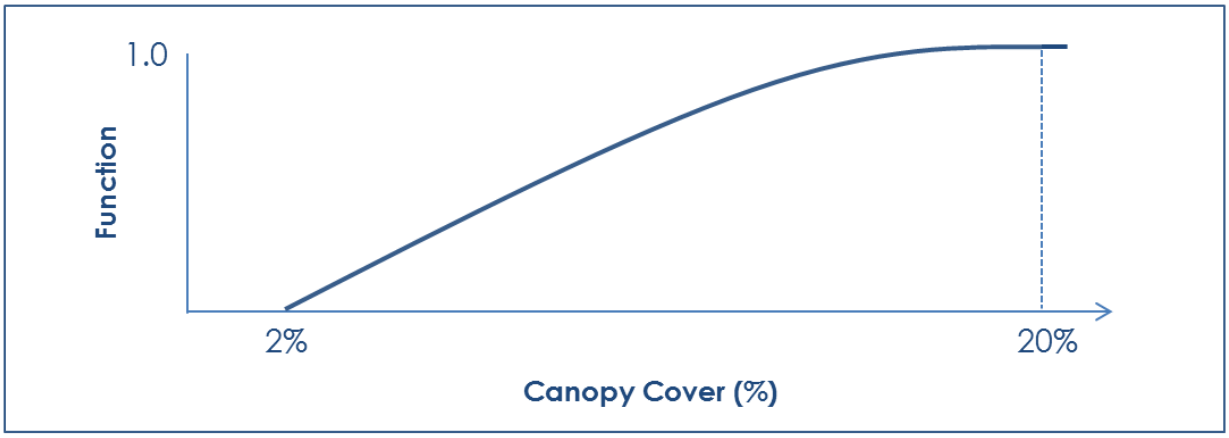
## Late Brood-Rearing | Perennial Forb Canopy Cover (Mesic-Shrub Systems)




| Mesic-Shrub Systems | Cover (%) | <2 | 2 – <4 | 4 – <6 | 6 – <8 | 8 – <10 | 10 – <12 | ≥12 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .25 | .45 | .64 | .78 | .9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. In Press, and TRG input modified the minimum fully functional value set to 12%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

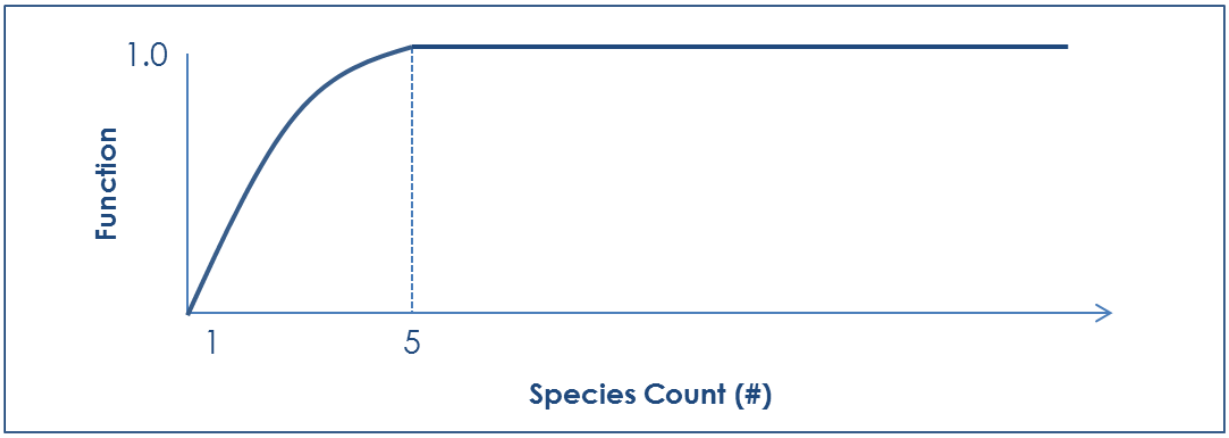
## Late Brood-Rearing | Perennial Forb Canopy Cover (Meadow Systems)




| Meadow Systems | Cover (%) | <5 | 5 – <8 | 8 – <10 | 10 – <14 | 14 – <16 | 16 – <20 | ≥20 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .25 | .45 | .64 | .78 | .9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on curves for Late Brood Rearing – Perennial Forb Canopy Cover (arid-shrub and mesic-shrub conditions) and increased productivity in meadow site, TRG modified the minimum fully functional value to 20%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

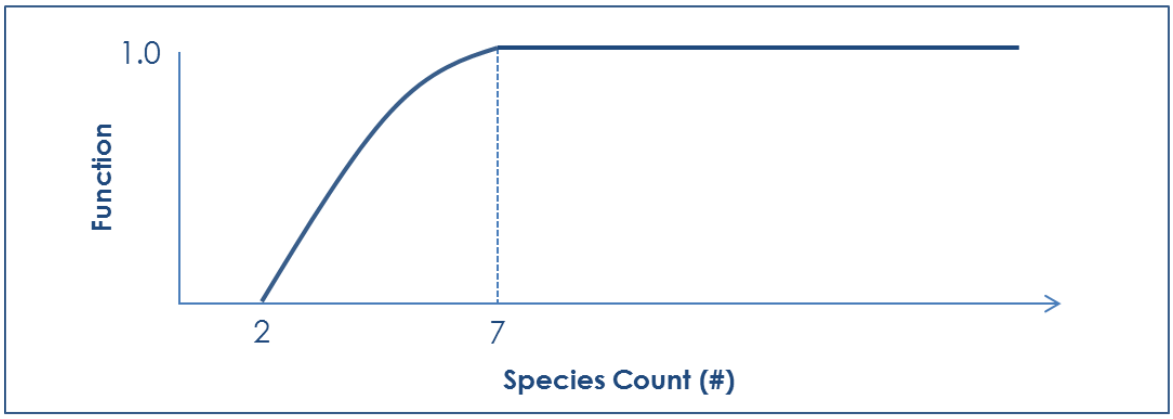
## Late Brood-Rearing | Forb Species Richness (Arid Conditions)




| Arid-Shrub Conditions | Species (#) | <1 | 1 – <2 | 2 – <3 | 3 – <4 | 4 – <5 | ≥5 |
|---|---|---|---|---|---|---|---|
| | Score | 0 | .3 | .6 | .75 | .9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set 8 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. In Press, and TRG input changing starting value to be 1 forb species as having no forbs has no value and reduced the minimum fully functional value to 5 species due to lower general forb abundance in Nevada.

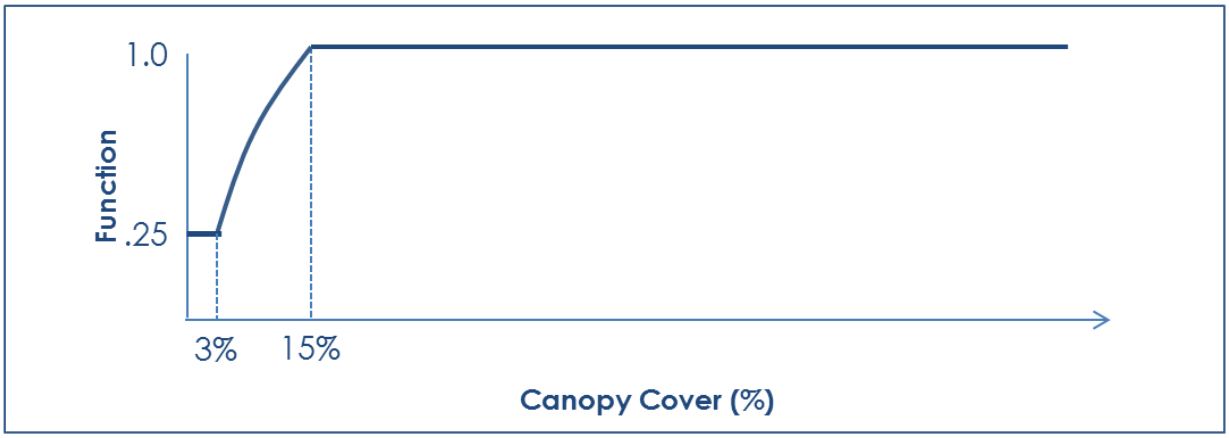
## Late Brood-Rearing | Forb Species Richness (Mesic-Shrub & Meadow Systems)




| Mesic-Shrub & Meadow Systems | Species # | <2 | 2 – <3 | 3 – <4 | 4 – <5 | 5 – <6 | 6 – <7 | ≥7 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .25 | .45 | .65 | .78 | .92 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set 12 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. In Press, and TRG input changing starting value to be 2 forb species as having no forbs has no value, but expectation that mesic sites should have more species than arid, and reduced minimum fully functional value to 7 due to lower general forb abundance in Nevada.

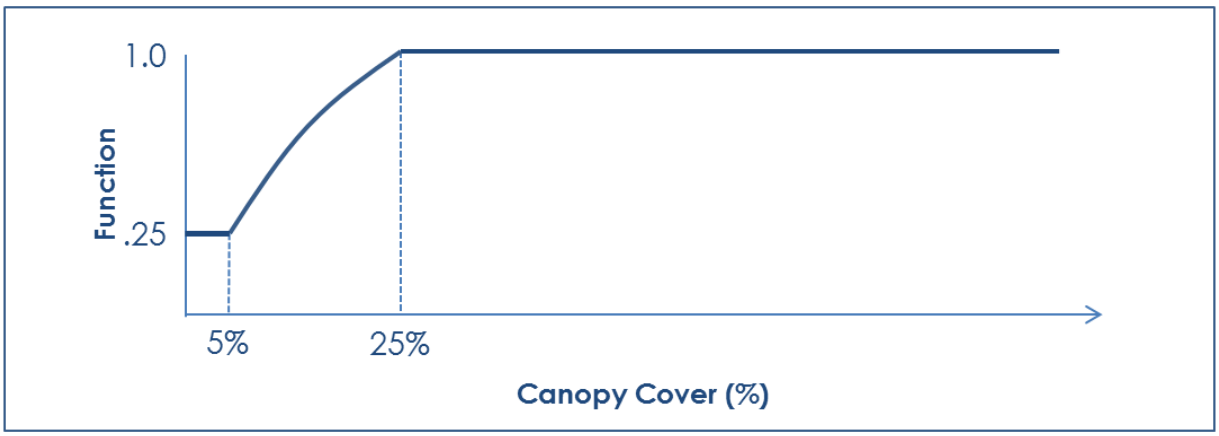
## Late Brood-Rearing | Perennial Grass Canopy Cover (Arid Conditions)




| Arid-Shrub Conditions | Cover (%) | <3 | 3 – <6 | 6 – <9 | 9 – <12 | 12 – <15 | ≥15 |
|---|---|---|---|---|---|---|---|
| | Score | .25 | .45 | .64 | .78 | .92 | 1 |

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value. The late brood-rearing perennial grass canopy cover curve was further informed by Kirol et al. 2012, which found perennial grass cover was 17.4% in selected sites, and 12% in non-selected sites.

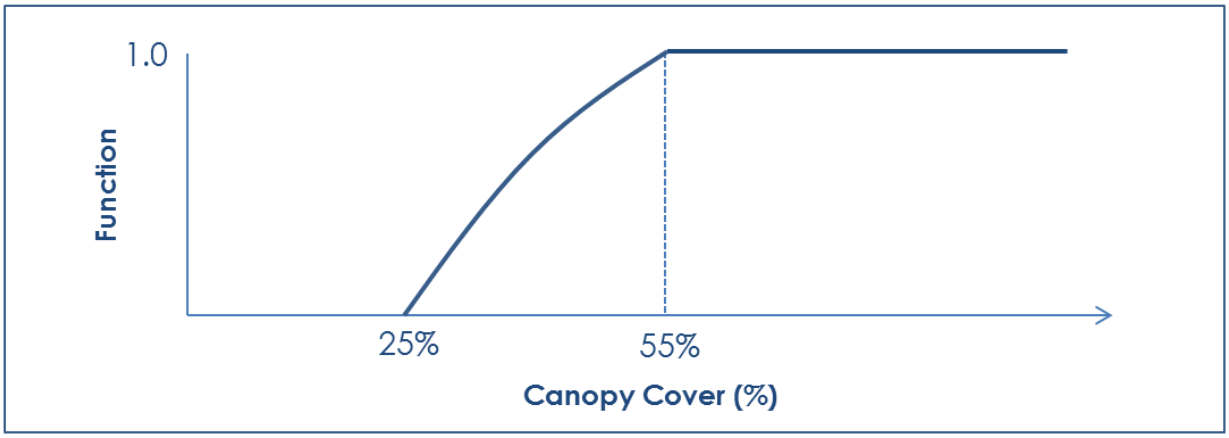
## Late Brood-Rearing | Perennial Grass Canopy Cover (Mesic-Shrub Systems)




| Mesic-Shrub Systems | Cover (%) | <5 | 5 – <10 | 10 – <15 | 15 – <20 | 20 – <25 | ≥25 |
|---|---|---|---|---|---|---|---|
| | Score | .25 | .45 | .64 | .78 | .92 | 1 |

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value for arid sites. TRG recommended different curves for arid-shrub conditions, mesic-shrub conditions and meadow systems. Starting and minimum fully functional values for mesic-shrub conditions were increased to 25% due to higher levels of productivity.

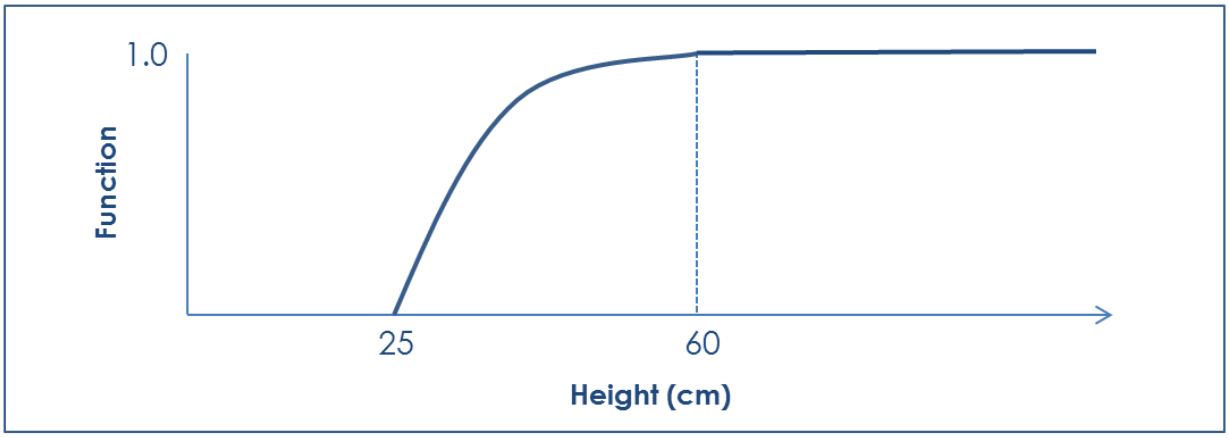
## Late Brood-Rearing | Perennial Grass Canopy Cover (Meadow Systems)




| Meadow Systems | Cover (%) | <25 | 25 – <30 | 30 – <35 | 35 – <40 | 40 – <45 | 45 – <50 | 50 – <55 | ≥55 |
|---|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .23 | .42 | .58 | .7 | .82 | .94 | 1 |

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value for arid sites. TRG recommended different curves for arid-shrub conditions, mesic-shrub conditions and meadow systems. Starting and minimum fully functional values for mesic-shrub conditions were increased to 55% due to higher levels of productivity.

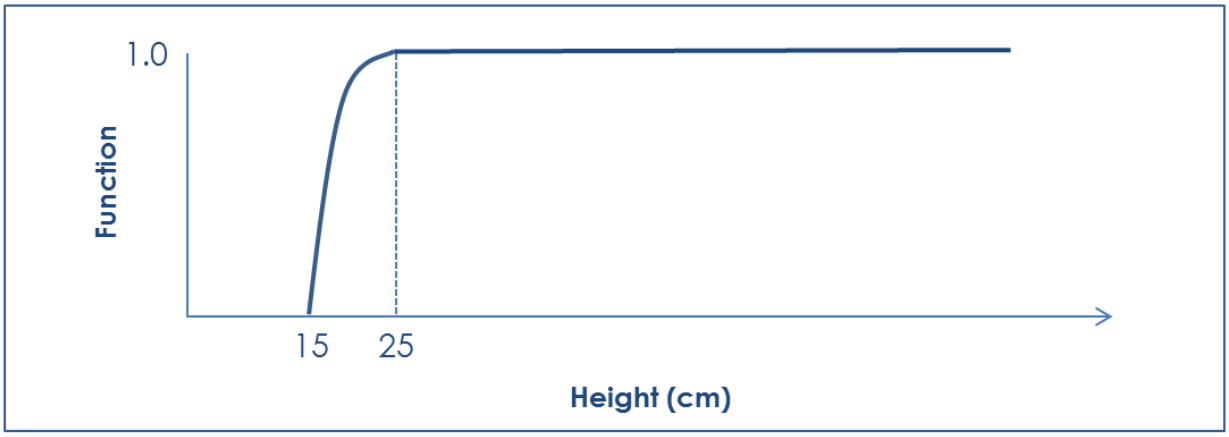
## Winter| Sagebrush Height (Dominantly Big Sagebrush)




| Dominantly Big Sagebrush | Height (cm) | <25 | 25 – <30 | 30 – <35 | 35 – <40 | 40 – <45 | 45 – <50 | 50 – <55 | 55 – <60 | ≥60 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .2 | .4 | .55 | .62 | 0.68 | .84 | .92 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set the minimum fully functional value at 15.7 inches (40 centimeters) and the starting point at 7.87 inches (20 centimeters) for slope < 5%, and 7.87 inches (20 centimeters as the minimum fully functional value and 3.94 inches (10 centimeters) as the starting point for slope > 5%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush heights snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. For big sagebrush species, TRG modified the minimum fully functional value to 23.6 inches (60 centimeters) to focus conservation of winter sites in areas that are key during heavy winters and that Connelly et al. 2000 recommendation of 9.84 inches (25 centimeters) *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow.

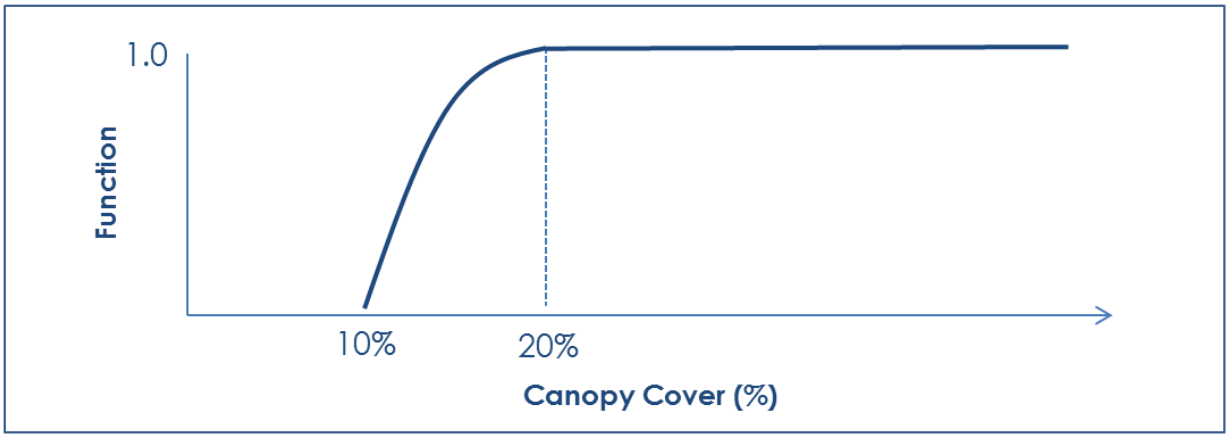
## Winter | Sagebrush Height (Dominantly Low or Black Sagebrush)




| Dominantly Low or Black Sagebrush | Height (cm) | <15 | 15 – <17 | 17 – <19 | 19 – <21 | 21 – <23 | 23 – <25 | ≥25 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .25 | .45 | .6 | .75 | .9 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set the minimum fully functional value at 15.7 inches (40 centimeters) and the starting point at 7.87 inches (20 centimeters) for slope < 5%, and 7.87 inches (20 centimeters) as the minimum fully functional value and 3.94 inches (10 centimeters) as the starting point for slope > 5%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush heights snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. This is lower than big sagebrush communities curve because of the inherently shorter stature of low/black sagebrush communities and that snow generally does not last as long (wind, solar radiation) in these communities as in big sagebrush communities.

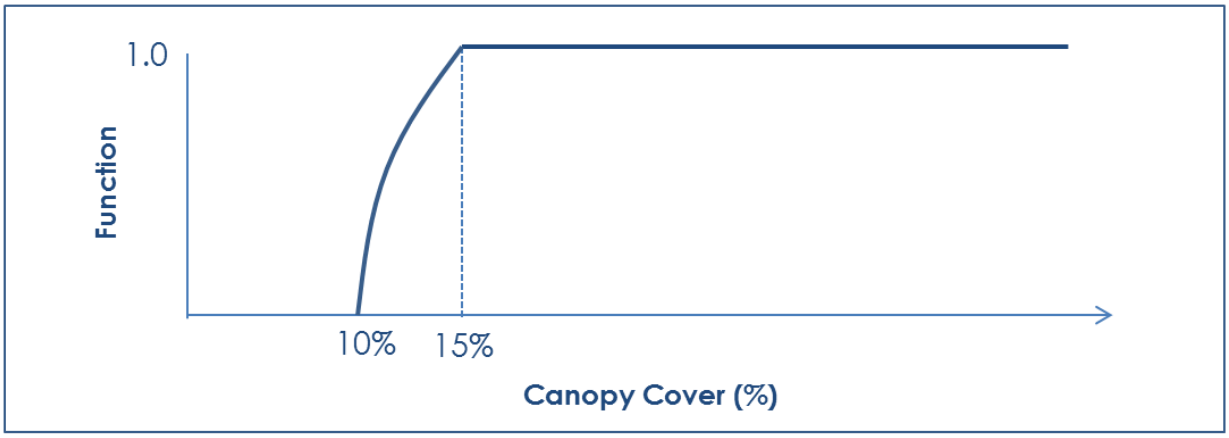
**Winter | Sagebrush Canopy Cover (Dominantly Big Sagebrush)**




| Dominantly Big Sagebrush | Cover (%) | <10 | 10 – <12 | 12 – <14 | 14 – <16 | 16 – <18 | 18 – <20 | ≥20 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .3 | .55 | .75 | .88 | .95 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set the minimum fully functional value at 30% and the starting value at 20%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush canopy cover above snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. For big sagebrush species, TRG input kept same value as Colorado Habitat Exchanged and justified that based on Connelly et al. 2000 recommendation of 10% *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow.

## Winter | Sagebrush Canopy Cover (Dominantly Low or Black Sagebrush)




| Dominantly Low or Black Sagebrush | Cover (%) | <10 | 10 – <11 | 11 – <12 | 12 – <13 | 13 – <14 | 14 – <15 | ≥15 |
|---|---|---|---|---|---|---|---|---|
| | Score | 0 | .3 | .55 | .75 | .88 | .95 | 1 |

Reference: Modified from a curve created for the Colorado Habitat Exchange based on the Greater Sage-Grouse Range-wide Steering Committee 2008; CPW unpublished data, and A.D. Apa personal communication which set the minimum fully functional value at 30% and the starting value at 20%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush canopy cover above snow levels given different inherent size of sage species and snow depths relative to sage species communities. For low/black sagebrush species, TRG input moved the minimum fully functional value to 15% based on Connelly et al. 2000 recommendation of 10% *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow. This is lower than big sagebrush communities curve because in low/black sagebrush communities snow generally does not last as long (wind, solar radiation) as in big sagebrush communities.

# APPENDIX B. MONITORING AND ADAPTIVE MANAGEMENT

This section is divided into two subsections: Tool Evaluation and Credit System Management System. The descriptions provided here represent only guidelines for monitoring and adaptive management and not a *plan* for carrying out these activities. Monitoring should be highly coordinated with federal land agency monitoring efforts.

## TOOL EVALUATION

Tool evaluation is defined as collection and analysis of data that pertains to the functionality and performance of the HQT. In particular, tool evaluation is concerned with: 1) Accuracy of the scores in measuring real and expected outcomes; 2) Utility (ease of use, efficiency, and cost) for a variety of users; 3) Repeatability of scores from one user to the next; and 4) Reliability of scores over time.

## CREDIT SYSTEM MANAGEMENT SYSTEM

The Credit System Management System s a formal, structured programmatic adaptive management approach to dealing with uncertainty in natural resources management, using the experience of management and the results of research as an ongoing feedback loop for continuous improvement. The Credit System Management System requires an ongoing flow of information from 1) research and monitoring activities conducted by scientists, 2) the practical experiences of Credit Developers and Buyers, and 3) changing context from stakeholders to inform Credit System improvements. A systematic and transparent decision making process ensures that improvements to the Credit System do not cause uncertainty for participants. Figure 20 provides an overview of the Credit System Management System steps[6].

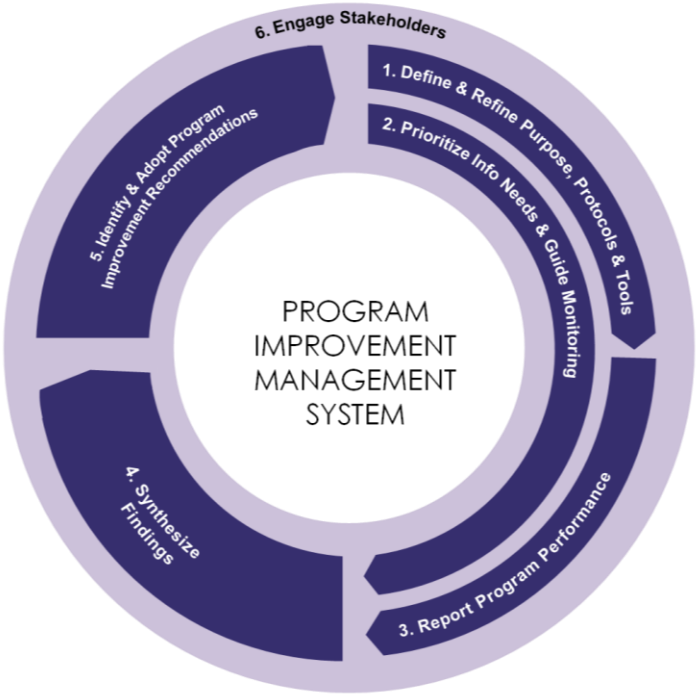



Figure 21. Steps in the Credit System Adaptive Management Process

Adaptive management is used in the Credit System Management System to refine and update the HQT over time. In other words, none of the content or components of the HQT are meant to be static in time, rather the HQT is intended to evolve over time as needed according to new science and monitoring. The

[6] This management process has been adapted from The Conservation Measures Partnership's Open Standards for the Practice of Conservation, which can be found at www.conservationmeasures.org. Significant changes were made to adapt the Open Standards to 1) a market context where individual projects are selected and implemented by individual market participants and 2) be a formally governed process that balances the needs for improvements with the needs to limit market uncertainty for all participants.

goal of adaptive management for the HQT is to make periodic changes that keep it up to date with the current state of ecological knowledge.

As specified in the Credit System Manual, the Credit System Administrator performs the day-to-day functions to manage the Credit System. The Administrator is accountable to the Oversight Committee (Sagebrush Ecosystem Council), which approves all changes to the Credit System Manual, HQT and other tools.

The Administrator convenes a Science Committee consisting of expert scientists to inform the development and revisions of technical decisions, products and tools, like the HQT. The Science Committee meets periodically to review and evaluate new information including new research on the species biology or ecology, new or changing threats to the species, recent substantial gains or losses of habitat for the species, and the establishment of new protected areas. The Science Committee then makes recommendations to the Credit System Administrator, based on the best-available science regarding the greater sage-grouse and sagebrush ecosystems. This review and evaluation process is also used to assess the overall status of the covered species, Credit System implementation and progress, and whether any adjustments are needed to the products and tools in order to further ensure conservation benefits to the species.

The Administrator decides whether any specific modifications are necessary according to Science Committee recommendations, and then the Administrator makes a recommendation regarding such modifications to the Oversight Committee. The Oversight Committee confers about the Science Committee's findings and Administrator's recommendations. Any modifications to the HQT are not applied retroactively.

# APPENDIX C. HQT DEVELOPMENT AND REVIEW

The HQT is the scientific underpinning of the Credit System. It is the approach to measure impacts and benefits, and is based on science. Science-related elements of the Credit System that are not entirely based on science (e.g. mitigation ratio factor related to the proximity of credits and debits) are defined in the Credit System Manual. The credibility of the Credit System and its effectiveness in generating net benefit for the species hinges upon the quality of the science upon which it is based and the integrity with which it is applied. It is therefore important to maintain the scientific integrity of the HQT over time as new science and implementation monitoring becomes available.

The HQT is not static. It is a working document that changes over time through the development and review processes outlined below as new scientific information becomes available. Transparent, fair, and consistent review processes are essential to ensure that the best and most recent scientific information is used incorporated over time.

Like any significant change to the Credit System, and changes to the HQT are under the control of the Oversight Committee, and the Administrator according to Credit System Management System . As such, the Administrator oversees the process of development and review, and the Oversight Committee approves all changes to the HQT.

This appendix outlines the processes, principles and schedule for internal and external development and review of the HQT. Outcomes of these processes inform the Credit System Management System defined in the Credit System Manual and summarize din Appendix E above. The table below summarizes the stages of development and review, including the participants and schedule.

| Development or Review Stage | Description | Who | Expected Completion Date |
|---|---|---|---|
| **Internal Development** | Development of initial components | Administrator in collaboration with consultants | December 2014 |
| **Internal Review** | Review early drafts, provide comments | Administrator and partner agency staff | December 2014 |
| **External Informal** | Meeting presentations, expert elicitation, etc. | Experts from partner agencies and universities | December 2014 |
| **Annual Improvement** | Review new published literature, and conduct research and monitoring | Administrator in collaboration with partner agencies and universities | Ongoing |
| **External Formal*** | Independently facilitated document review of later draft | Ten or fewer selected, independent published species and ecosystem experts from outside the Administrator and Science Committee | *TBD* |
| **External Independent Peer Reviewed Journal*** | Review of manuscript | Independent experts selected by Journal | *TBD* |

*Review stages are recommended but have not been formally defined and commissioned.

## INTERNAL DEVELOPMENT AND REVIEW

Internal development and review is conducted by the Administrator in collaboration with consultants. The internal review was facilitated during the internal development process to leverage input during development by experts on species biology and/or rangeland ecology.

### Internal Development

Internal development of the HQT is conducted by the Administrator in collaboration with consultants. Tasks associated with development include reviewing and compiling scientific information, developing concept models and scoring curves, and writing the HQT documents. While the HQT is in the development stage, decision-making and control over the content of the HQT is the responsibility of the Administrator. Members of the Administrator should declare any real or perceived conflict of interest with stakeholders, including offers or acceptance of funding.

### Internal Review

Internal review is conducted by official members of the Technical Review Group. During internal review, members of the Technical Review Group are given the first opportunity to provide comments on the HQT. Internal review comments from the Technical Review Group adhere to the following format and principles:

- Confidential – internal reviewers may not share the draft HQT with any non-official members of the group at this stage, unless those persons are experts or consultants within their own organizations.
- Constructive, practical, and cooperative – we expect comments to come from a positive spirit of cooperation, to improve the potential for the Credit System to meet its goals in a practical manner.
- Documented – all comments must be referenced and supported by scientific support (e.g. peer-reviewed research), independent analysis, expert opinion with a citation of "personal communication," and/or a thorough, clear rationale. Reviewers clearly state the source of documentation they are using. General preferences and opinions are useful and welcomed, but may not be sufficient for incorporation into the HQT. All committee participants are listed by name unless they request to remain anonymous, in which case they are acknowledged as an "anonymous reviewer."

### Annual Improvement

Annual improvement of the HQT is conducted by the Administrator in collaboration with Science Committee. Tasks associated with annual improvement include reviewing and compiling newly published scientific information, conducting research and monitoring, and revising HQT documents. While the HQT is in the annual improvement stage, decision-making and control over the content of the HQT is the responsibility of the Administrator. Members of the Administrator should declare any real or perceived conflict of interest with stakeholders, including offers or acceptance of funding.

## EXTERNAL REVIEW

External informal and formal review is coordinated by the Administrator with consultation of the Science Committee. External informal review is conducted by wide range of stakeholders, and external formal review is conducted by independently published species and ecosystem experts. Lastly, publishing the HQT in a peer-reviewed journal is desired and a responsibility of the Administrator.

### External Informal

External informal review consists of informal feedback from stakeholders that is solicited by the Administrator through presentations, meetings, conferences, etc.

Incorporating feedback provided through external, informal review is the responsibility of the Administrator, after consultation with the Science Committee, and then with the SEC. The Administrator informs the Science Committee of the comments and provides an opportunity for the Science Committee to comment. Then, the Administrator incorporates changes based on Science Committee responses and the Administrator's own best judgment. A best attempt is made to come to consensus. However, if there are disputes between the Administrator and the Science Committee, then the conflict resolution policy in the Administrator charter is enacted. Science Committee members are then provided an additional opportunity by the Administrator to comment on the changes made by Administrator and if any disputes arise over those changes, the conflict resolution policy is enacted.

### External Formal

External formal review begins after the Administrator provides verbal consent to the external reviewers. The Administrator identifies a referee for the peer review process in consultation with the Science Committee. The total number of outside reviewers is limited to 10 or fewer. The Administrator is responsible for observing the external formal review principles below, and evaluating and incorporating changes suggested by external formal reviewers using the same process described above for external informal reviewers.

External formal review consists of selected, independently published species and ecosystem experts from outside the Science Committee. External formal reviewers should be recommended and selected based on their expertise and independence, and must be subject matter experts. External formal reviewers are expected to adhere to principles of peer review below.

#### External Formal Review Principles

The Administrator observes and external formal reviewers adhere to the following principles:

*Expert Assessment*

- Only published subject matter experts that have not been involved with development or informal review are invited to participate in final round of independent, external peer review.

*Transparency*

- All developers of the documents are identified to reviewers
- The review process is tracked on a spreadsheet database throughout the process, including database manager & reviewer names, affiliations, contact information. All written reviews and relevant documentation are attached to the spreadsheet.
- With written consent, reviewers will be acknowledged by name in the acknowledgment section as having "reviewed an earlier version." Otherwise, the number of anonymous reviewers is accurately stated in the acknowledgments.

*Impartiality*

- Invited reviewers are asked to declare potential conflicting interests (e.g. political, professional, personal, financial) and a decision is made by the referee as to whether stated conflicts could potentially bias the review. If so, the request is withdrawn before releasing the document.
- External peer review is refereed by a third party that has not participated in development of the document and has no conflict of interest with the developers or process.

*Fairness*

- Reviewers are asked to decline the request if: they feel they are unable to provide a fair and unbiased review and/or have participated in preparation of the document.
- Reviewers are presented with a consistent set of questions and criteria by which to review the document.
- Reviewers are allowed a minimum of three (3) weeks to review and comment on the document. They are asked to notify the referee if they do not think they can complete a thorough review in that amount of time.

*Confidentiality*

- The manuscript and comments of reviewers are held in confidentiality by all parties until the time of release. Reviewers' identities are released by permission otherwise they are each listed as anonymous reviewers.

*Integrity*

- Reviewers should decline if: they have a conflict of interest, feel they cannot provide an unbiased or expert review, if they have issues with the peer review model, or if they have a very similar potentially competing document or framework in development.

*Timeliness*

- Reviewers are given a minimum of three (3) weeks for review and are asked to complete their review within that timeframe or notify the referees if they anticipate delays or are unable to thoroughly review the document within the allotted time.

## Peer-reviewed Journal

Publishing the HQT in a peer-reviewed journal would be extremely valuable to the overall credibility and acceptability of the tool to regulatory agencies and other stakeholders (e.g. potentially critical non-governmental organizations). The Administrator is expected to pursue this goal after external formal and informal review is complete and with the consent and cooperation of the Science Committee and Oversight Committee. The Administrator appoints a lead author and coordinates the manuscript submission process.

# APPENDIX D. SAGE-GROUSE RESPONSE TO ANTHROPOGENIC DISTURBANCE LITERATURE REVIEW

## DISTANCE TO ENERGY DEVELOPMENT

Researchers have reported indirect effects associated with the infrastructure of energy fields whereby sage-grouse on leks are negatively influenced to a greater extent if infrastructure is placed near the lek, with the response diminishing as distances from lek to infrastructure increase (Manier et al. 2013). Additionally, the distance-effect of infrastructure with higher levels of human activity may be larger than that of infrastructure with lower levels of activity. Harju et al. (2010) reported that impacts to lekking sage-grouse of well pads located at shorter distances to leks were more consistently observed across energy fields compared to well pads at longer distances. There was a consistent pattern whereby the presence of well pads within smaller radii buffers (< 0.99 – 1.24 miles (<1.6 - 2 kilometers)) around leks in extensively developed areas was associated with 35-76% fewer sage-grouse males on leks compared to leks with no well pads within these radii (Harju et al. 2010). Walker et al. (2007) found a strong negative effect of infrastructure within 0.50 and 1.99 miles (0.8 and 3.2 kilometers) of leks on lek persistence, with lesser impacts to lek persistence apparent at 3.98 miles (6.4 kilometers). Holloran (2005) reported that impacts of development to the number of males occupying leks were greatest when infrastructure was located near the lek, but that impacts were discernable to 1.86 miles (3 kilometers) for lower activity sites (producing well pads) and 3.73 miles (6 kilometers) for higher activity sites (drilling rigs). Johnson et al. (2011) reported negative lek trends for leks within approximately 2.49 miles (4 kilometers) of a producing well pad across the range of the species. Additionally, distance effects of infrastructure have been noted for other seasonal periods. Carpenter et al. (2010) found that sage-grouse avoided habitats within 1.18 miles (1.9 kilometers) of infrastructure during the winter. Holloran et al. (2010) reported that yearling females avoided nesting within 3,116.8 feet (950 meter) of well pads. Annual survival of sage-grouse chicks reared near gas field infrastructure was lower than those reared away from infrastructure, and the probability of male chicks reared near infrastructure establishing a breeding territory as a yearling was half that of male chicks reared away from infrastructure (Holloran et al. 2010). Dzialak et al. (2011) reported that the closer a nest was to a natural gas well (that existed or was installed in the previous year), the more likely it was to fail. LeBeau et al. (*In Press*) reported that the risk of a nest or a brood failing decreased by 7.1% and 38.1%, respectively, with every 0.62 mile (1 kilometer) increase in distance from the nearest wind turbine; however, no variation in female survival was detected relative to wind energy infrastructure.

## DENSITY OF ENERGY DEVELOPMENT

Substantial amounts of research suggest that increased infrastructure densities around leks will negatively influence sage-grouse. Harju et al. (2010) reported that well pad densities of 4 and 8 pads/section (square mile) within 5.28 miles (8.5 kilometers) of leks were associated with lek count declines ranging from 13-74% and 77-79%, respectively. Doherty et al. (2010a) reported that impacts to leks were indiscernible at well pad densities at or below 1 pad/section within 1.99 miles (3.2 kilometers) of leks, but that lek loss and declines in numbers of males on leks increased at greater pad densities. Holloran (2005) reported that well densities exceeding 1 well/section within 1.86 miles (3 kilometers) of leks negatively influenced male lek attendance. Hess and Beck (2012) reported 0% probability of lek occurrence in areas with well pad densities exceeding 6.5 pads/section within 0.62 miles (1 kilometer). Tack (2009) reported that larger leks (>25 males) did not occur in areas where well pad densities exceeded 2.5 pads/section within 7.64 miles (12.3 kilometers) of a lek. Johnson et al. (2011) found a generally negative trend in lek counts as numbers of producing wells increased within 3.11 and 11.18 miles (5 and

18 kilometers) of leks. Kirol (2012) reported that females avoided nesting and rearing broods in areas with increased numbers of visible wells within a 0.62 square mile (1 square kilometer) area. Aldridge and Boyce (2007) reported that chick survival decreased with increasing numbers of visible wells within 0.62 mile (1 kilometer) of brood-rearing locations. Doherty et al. (2008) found that sage-grouse were 1.3 times more likely to occupy suitable winter habitats with no gas field infrastructure within a 2.49 square mile (4 square kilometer) area compared to areas with 12.3 pads (8 pads/section).

## MINING

Coal mining has been a major activity within sage-grouse habitat (Braun 1998). Yet, the magnitude of the impacts of mining activities on sage-grouse and sagebrush habitats is largely un-quantified (Braun 1998). Development of surface mines and associated infrastructure (e.g., roads and power lines), noise and human activity negatively impact sage-grouse numbers in the short term (Braun 1998). The number of displaying sage-grouse on two leks within 1.24 miles (2 kilometers) of active coal mines in northern Colorado declined by approximately 94% over a 5-year period following an increase in mining activity (Remington and Braun 1991). However, Braun (1998) reports that studies in Montana, Wyoming and Colorado suggest that some recovery of populations occurred after initial development and subsequent reclamation of mine sites, although populations did not recover to pre-development sizes. Additionally, population re-establishment may take upwards of 30 years (Braun 1998).

## NOISE

Blickley et al. (2012) report that peak male attendance (i.e., abundance) at leks experimentally treated with noise recorded at roads in a natural gas field decreased 73% relative to paired controls. The authors reported that the intermittent nature of noise from roads impacted male sage-grouse to a greater degree than more constant noise as that from a drilling rig; peak male attendance at leks treated with noise from natural gas drilling rigs decreased 29% relative to paired controls (Blickley et al. 2012).

Noise is not directly addressed in the HQT. However, the potential differential effects of noise on sage-grouse relative to activity levels associated with infrastructure are accounted for in the indirect effects, and associated response curves, used to establish the anthropogenic disturbances distances and weights.

## ROADS

Sage-grouse avoidance of high-activity roads is well documented. Connelly et al. (2004) found that no leks occurred within 1.24 miles (2 kilometers) of interstate 80, there were fewer leks within 4.66 miles (7.5 kilometers) than within 9.32 miles (15 kilometers) of the interstate, and there were higher rates of decline in lek counts between 1970 and 2003 on leks located within 4.66 miles (7.5 kilometers) compared to beyond 4.66 miles (7.5 kilometers) of the interstate. Knick et al. (2013) reported that high habitat suitability was associated with <0.62 miles/square mile (<1.0 kilometers/square kilometer) of secondary roads, 0.03 miles/square mile (0.05 kilometers/square kilometer of highways, and 0.0062 miles/square mile (0.01 kilometers/square kilometer of interstate highways within 3.1 miles (5-kilometer) radius areas. LeBeau (2012) found that sage-grouse avoided nesting and summering near major roads (e.g., paved secondary highways). Tack (2009) found negative relationships with more roads around leks at all levels of lek attendance, but impacts were greatest for larger leks (>25 males); the probability of occurrence of a large lek was 50% with road densities of approximately 15.5 miles (25 kilometers) of road within 1.99 miles (3.2 kilometers) of a lek. Dzialak et al. (2012) documented sage-grouse during the winter avoiding haul roads associated with natural gas development. In contrast, Johnson et al. (2011) found negative trends in counts of males on leks throughout the range of the species with increasing distance to interstate highway—although few leks occurred near interstates; relatively consistent slight negative

trends in lek counts with distance to highways; and no relationship between distance to secondary roads and lek trends. Road densities within 3.1 miles (5 kilometers) radii of leks suggested similar relationships by road category (Johnson et al. 2011).

## TRAFFIC

Remington and Braun (1991) reported that the upgrade of a haul road accessing a coal mine was correlated with a 94% decline in the number of sage-grouse on leks <1.24 miles (<2 kilometers) from the road over a 5-year period; traffic speed was not measured but the potential for increased speed was inferred from upgraded road surface. Holloran (2005) reported that declines in lek counts on leks within 1.86 miles (3 kilometers) of roads were positively correlated with increased traffic volumes and that vehicle activity on roads within 1.86 miles (3 kilometers) of leks during the time of day sage-grouse were present on leks influenced the number of males on leks more negatively than leks where roads within 1.86 miles (3 kilometers) had no vehicle activity during the strutting period. Lyon and Anderson (2003) reported that traffic disturbance (1 to 12 vehicles/day) within 1.86 miles (3 kilometers) of leks during the breeding season reduced nest-initiation rates and increased distances moved from leks during nest site selection of female sage-grouse breeding on those leks. Blickley et al. (2012) report that peak male attendance (i.e., abundance) at leks experimentally treated with noise recorded at roads in a natural gas field decreased 73% relative to paired controls; the authors found that the intermittent nature of noise from roads impacted male sage-grouse to a greater degree than more constant noise, such as that from a drilling rig.

## TRANSMISSION AND POWER LINES

Research investigating the impacts of transmission and power lines on sage-grouse is not conclusive, but could be considered suggestive in that these structures may negatively influence sage-grouse habitat selection and survival. Knick et al. (2013) reported that leks were absent from 3.11 miles (5 kilometers) radius areas where transmission line and major power line densities exceeded 0.124 miles/square mile (0.20 kilometers/square kilometer). LeBeau (2012) reported that sage-grouse avoided habitats within 2.92 miles (4.7 kilometers) of transmission lines during brood-rearing, and that the probability of nest success and probability of female survival increased as distance to transmission line increased; but it is worth noting that the author found that brood-rearing and nesting sage-grouse selected habitats nearer transmission lines in the control study area. Walker et al. (2007) reported that the probability of lek persistence decreased with proximity to power lines and with increasing proportion of power lines within a 3.98 miles (6.4 kilometers) window around leks; but it is worth noting that distances to power line and power line densities as covariates were highly correlated with other gas development infrastructure covariates examined on the study site, and were not as good as predictors as gas wells. Other often cited studies that may provide evidence of impacts of tall structures on sage-grouse include the following: Braun (1998) reported that sage-grouse avoided habitats within 1,968.5 feet (600 meters) of transmission lines, but results were based on unpublished pellet survey data. Beck et al. (2006) reported that collisions with power lines accounted for 33% of juvenile sage-grouse winter mortality, but only 2 juvenile grouse were killed by running into power lines. Gibson et al. 2013 reported a negative effect of transmission line proximity on nest success for nests in high quality habitats and a negative effect of proximity to the line on female survival for females with generally lower survival. They did not find an avoidance of transmission lines by either males or females, but did find demographic effects.

## TOWERS

Despite low numbers of communication towers across the sagebrush biome, sage-grouse lek trends across the range of the species generally decreased with distance to nearest communication tower and

generally decreased with increasing numbers of towers within 3.11 miles (5 kilometers) and 11.18 miles (18 kilometers) of leks (Johnson et al. 2011). The authors surmised that the response of sage-grouse to communication towers may be correlative with human development in general as these types of towers tend to be concentrated along major roadways and near urban centers; however, with the increase in these types of structures throughout the sagebrush biome (e.g., meteorological towers at proposed wind developments), it is worth considering the documented effects.

## URBAN DEVELOPMENT

Urban areas by themselves remove habitat and present inhospitable environments for sage-grouse, but the physical boundaries of cities are small relative to the total sagebrush area. However, people in cities require resources from surrounding areas, and the connecting roads, railways, power lines and communications corridors exert a greater influence on sagebrush habitats (Connelly et al. 2004). Additionally, recreation, including hiking, hunting and fishing, and off-highway vehicle use in areas surrounding urban centers can negatively influence sage-grouse through habitat loss and fragmentation, facilitation of exotic plant spread, animal displacement or avoidance, establishment of population barriers, or increased human-wildlife encounters that increase wildlife mortality (Connelly et al. 2004). Across the sage-grouse range, lek count trends were lower when human-footprint scores exceeded 2 at leks, or when median scores exceeded 3 within either 3.11 miles (5 kilometers) or 11.2 miles (18 kilometers) of a lek (Johnson et al. 2011). The human-footprint index was a measure of the totality of direct anthropogenic features – including human habitation, highways and roads, railroads, power lines, agricultural lands, campgrounds, rest stops, landfills, oil and gas developments, and human-induced fires – on a landscape expressed on a 1 to 10 scale (Johnson et al. 2011). Wisdom et al. (2011) reported that human density was 26 times lower in occupied sage-grouse range compared to historically occupied but currently extirpated range. Aldridge and Boyce (2007) found that brood-rearing females avoided habitats associated with a high density of urban developments; it is worth noting that “urban” was defined as towns, farmsteads, and energy infrastructure in this study.