Credit trading framework: conceptual basis for quantifying credits and debits in the sagebrush ecosystem

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The mission of the Cooperative Sagebrush Initiative (CSI), in part, is the recovery of the sagebrush (*Artemisia* spp.) ecosystem resulting in the recovery of populations of greater sage-grouse (*Centrocercus urophasianus*) and improvement in population status of other associated species of concern (http://sandcounty.net/programs/cbcn/sagewise/). This document describes the conceptual basis for credit trading programs that can help offset adverse impacts to environmental resources with commensurate (or greater) resource improvements, and offers a proposal for development and implementation of a potential credit trading program where the environmental resources of concern are sagebrush ecosystems and associated wildlife, especially greater sage-grouse. Whether the goal is simply balancing adverse impacts with commensurate resource improvements (i.e., fully mitigating adverse impacts) or achieving some net improvement in overall resource condition, the basic mechanics of how a credit trading program works are the same. It is important, however, that the goal of any credit trading program be clearly expressed, since that goal will influence the rules governing the trading of credits and debits. For simplicity we use the term ñmitigationò without regard to whether the goal is simply offsetting adverse impacts or achieving some additional change in resource condition.

The Conceptual Underpinnings

The fundamental concept underlying credit trading programs (indeed, underlying any mitigation effort) is that it is possible to compensate for lost ñservicesò (or ñvaluesò) at one site (the impact site) by replacing or increasing the same services at another site (the mitigation site) through purposeful management at the latter site. The challenge is to develop a consistent framework for quantifying the services lost or gained at each site, so that all parties can have confidence that the losses and gains are in fact commensurate. It is in the interest of those who are required to mitigate for the impacts of their activities, as well as those who are charged with conserving environmental resources, that a rational and consistent methodology be utilized for quantifying losses and gains so as to avoid the uncertainty associated with ad hoc bilateral bargaining over the scope and magnitude of mitigation.

It is not assumed that all impacts on all sites can be compensated for off-site. It must be acknowledged that impacts on some sites must be recognized as impacts that cannot be effectively mitigated. In addition, it must be recognized that some sites should be protected from development activities because of their high value to specific resources that cannot be effectively mitigated. The methodologies addressed here are directed at those sites where development has been approved as an appropriate activity and that seek to mitigate on-site impacts with off-site mitigation.

The basic framework for quantifying services lost at impact sites and gained at mitigation sites requires assessments of the following:

1. The *existing level* of services provided at the impact and mitigation sites prior to the initiation of development and mitigation activities, both at the site and the surrounding (cumulative) landscape;
2. The *resulting level* of services expected at the impact and mitigation sites after the impact development and mitigation activities are carried out, considering both site and landscape effects;
3. The *duration* of the change (or period of time over which a change in services occurs) at the impact and mitigation sites; and
4. The *length of time* before the mitigation is expected to be fully successful at the mitigation site.

Additional factors that should be addressed are:

1. the *risk* that the mitigation project may not succeed, and
2. assuring that sufficiently similar ecological conditions are present at the impact and mitigation sites.

There are a number of ways of potentially implementing approaches to offsite mitigation as well as a number of tools to facilitate this task including modeling, habitat suitability indices, and expert judgment. Accounting of mitigation efforts has been applied to other natural resource management situations (e.g., Weems and Canter 1995). Thus, if one can assess the above factors, it should be possible to design a trading system that allows consistent quantification of mitigation required to offset expected impacts from a broad range of development activities. Unlike traditional ad hoc determinations of mitigation requirements on a project-by-project basis, a credit trading program enables mitigation activities to be carried out in advance of development activities such that ñcreditsò can be ñbankedò for future use to offset the impacts of later development activities.

The basic units proposed to quantify benefits associated with conservation activities or detriments associated with development activities are simply called ñcredit unitsò and ñdebit unitsò respectively in this discussion (again keeping in mind that the ñunitsò are really streams of ecosystem services lost or gained over time) (see also Appendix A). They are calculated in the same manner, so that a ñcredit unitò has an equal, but opposite, value as a ñdebit unit.ò Thus, the beneficial impact of a credit unit is intended to fully (and exactly) offset the detrimental impact of a debit unit. As noted above, one could design a trading program intended to produce a net positive impact by requiring that each debit unit be offset by more than one credit unit. Other than to acknowledge that one could design trading rules to achieve any of several possible objectives, this discussion is not primarily concerned with trading rules. Rather, its primary purpose is to propose how credit units and debit units may be quantified using a set of metrics.

Considerations Associated with a Credit-trading Program for the Sagebrush Ecosystem

In the case of the sagebrush ecosystem, the number of credit units or debit units associated with any activity should be a function of the following factors:

1. The area affected by the activity;
2. The existing conditions within the area (essentially a measure of quality evaluated relative to a baseline);
3. The extent of change (positive or negative) caused by the activity relative to the existing conditions;

4. The spatial or landscape context in which the area is located (related primarily to habitat quality); and
5. The timing and duration of the expected change.

The discussion that follows elaborates on each of these factors. What is presented here is a general framework of factors that should be included in the determination of credits and debits. How various components of the factors are to be specifically calculated will require additional development.

Area Affected. The quantification of credit units (or debit units) begins with a determination of the size and characteristics of the area affected by any action. Development activities will often affect both the specific area directly impacted by the development (the physical ñfootprintò of the activity), and additional area where the activity is expected to exert a negative influence (e.g., effects of noise or visual features, habitat fragmentation, other impacts that discourage use of nearby areas by sagebrush-associated wildlife). Rules will be needed to set minimum size of areas on which conservation activities will generate credits. Rules might also recognize some further distinction between very large projects and smaller projects. That is, if the area affected exceeds one or more size thresholds, each acre might be given an extra weight. For example, if the affected area exceeds 1,000 acres, each acre might be treated as 1.1 acres; if the affected area exceeds 10,000 acres, each acre might be treated as 1.5 acres. The purposes of such adjustments are to encourage larger scale conservation actions and to encourage efforts to reduce the area affected by development actions. Note, however, that if such weighting factors are used, it may be necessary to have some mechanism to address the cumulative impact of many smaller individual actions, beneficial or detrimental.

Existing Conditions. The areas affected must also be characterized in terms of their existing and inherent (potential) conditions. Natural Resources Conservation Service (NRCS) ecological sites (www.nrcs.gov/technical/efotog/) is a classification system that can facilitate identification of biotic and underlying abiotic drivers of ecosystem diversity that could provide consistency for measuring ecosystem services and thus mitigation benefits. Ecological sites classify areas that have similar soils and other abiotic and biotic conditions within defined precipitation zones within a Major Land Resource Area. Major Land Resource Areas (MLRA) are geo-climatically defined areas delineated by NRCS that have been mapped for the entire U.S. Ecological site classifications have been developed for most MLRAôs, with ecological site descriptions developed for each specific ecological site. These sites are linked to soils, and are therefore mapped wherever NRCS soils mapping has occurred. For each ecological site, various vegetation communities, described as specific ñstatesò as influenced by natural or anthropogenic disturbances have been described. Changes among states are defined as ñtransitions,ò with some changes crossing ñthresholdsò that may make transition back to a prior state difficult (Friedel 1991, Laycock 1991). Various states that might occur on each ecological site have been described in ecological site descriptions (ESDs) for most MLRAs in the Rocky Mountain West (www.nrcs.gov/technical/efotog/), with work proceeding on those areas not yet completed. Descriptions of states for a specific ecological site typically includes both states that occurred historically, under historical disturbance regimes, as well as other states produced by anthropogenic influences including introduction of exotic species.

Use of ecological sites assures that ecosystem services within a similar ecological context are being tracked or measured from development sites to mitigation sites. Other ecological classification systems are not available within the sagebrush ecosystem with the same level of development, mapping, and acceptance by potential users as this system. Ecological sites provide mapping units and area descriptions that provide for consistency. In areas where soils have been mapped, the specific ecological sites occurring on an impact or mitigation area will have been mapped and descriptions typically available. In areas where soils have not been mapped, on-site sampling will be needed to map the specific ecological sites based on the soils present in the area.

In addition to the ecological site, the current vegetation communities (states) occurring on the site will need to be described through field sampling. The composition of the community as well as other potential measures such as its structure should be characterized. Measures that are important for assessing the value of the area for species of concern should also be included in this sampling. The existing condition can then be rated as to its ecological integrity in comparison to a reference condition. Ecological integrity refers to an ecosystemôs completeness, including the presence of all appropriate components (e.g., species), structures (e.g., heights of vegetation) and processes (e.g., nutrient cycling) (Karr 2004). Complete ecosystems possess ecological integrity because they support a biota that is the product of evolutionary and biogeographic processes with little or no influence from human impacts (Karr 2004). Ecological integrity has been a policy objective in several national and bi-national laws and agreements, including the

U.S. Water Quality Amendments of 1972 (Clean Water Act), the Great Lakes Water Quality Agreement between the United States and Canada, the Canadian National Parks Act, and the National Wildlife Refuge System Improvement Act of 1997 (Noss 2004).

Planned development activities may be evaluated as to the reduction of ecosystem services associated with the loss of ecological integrity to the site, potentially going to zero, while conservation activities on mitigation sites may be designed to maintain or increase the ecological integrity of the site and thus its ecosystem services. Two data sets (ecological site information and the existing characteristics of vegetation communities on a site) are required to complete this evaluation. On each site, the amounts of each vegetation community and its underlying ecological site provide the basis for the determination of ecological integrity. The existing community characteristics are evaluated relative to a reference condition generated from the ecological site information to produce a value for ecological integrity, which is then further evaluated relative to landscape context (described below).

Ecological sites allow for the description of not only existing vegetation communities, but also historically occurring vegetation communities. Historical vegetation communities occurred as a result of disturbance regimes that influenced the composition, structure, and processes of each vegetation community. Various historical states typically occurred on any given ecological site. Many additional vegetation communities or states that did not occur historically may now occur as a result of human activities over the past 100+ years. Descriptions of the historical states that occurred for each ecological site can be used to provide a baseline reference for comparison. Ecological integrity at a site must be evaluated and quantified relative to an identified reference or baseline to allow an interpretation of its existing and potential future quality for ecosystem services.

As discussed, areas being impacted in development zones can be characterized as to their ecological sites and existing vegetation communities. Off-site mitigation areas that have equivalent ecological sites could be improved by restoring these areas to conditions that more closely resemble one of the historical states or other desired vegetation communities based on reference information. The more dissimilar the off-site mitigation area is to the desired vegetation communities (i.e., high levels of exotic species, low diversity of native species), the greater the potential gain in mitigation value through restoration. Numerous ecosystem services could be increased, including better soil stabilization, improved water quality, increases in grazing land health, and increased quality of fish and wildlife habitat.

Extent of Change. A metric for credit banking could measure the change in conditions of vegetation communities indexed in relation to historical or other desired vegetation communities. The baseline reference provides a description of the conditions that could be considered optimum in value for a given site, with a possible score of 1 on a 0.1 ï 1.0 scale. The existing conditions are then evaluated in relation to this reference condition. If historical states are being used as a baseline reference, various historical states typically occurred for any ecological site. In this case, the specific historical reference community used for measuring impacts (debits) or mitigation gains (credits) would need to be identified.

The metric for a site would evaluate the quality of the existing vegetation communities at the site in comparison to a reference, and then quantify gains or losses to this quality from impacts or mitigation. For example, a completely degraded site, perhaps dominated by invasive species might score a 0.1 in reference to an identified baseline vegetation community for a specific ecological site. Improving the degraded site to more closely resemble a specified historical vegetation community or other reference community might get partway towards this goal in 3 years, resulting in a 0.6 score. Each acre improved by this amount would then receive a benefit of the acre times the increase in value, so that in this example, 10 acres increased from 0.1 to 0.6 on a certain ecological site would result in 5 units of improvement for each year that condition was maintained. These might offset impacts to other areas of the same ecological site disturbed by energy production or other impacts. In another example, if an existing site had a value of 0.9, and was maintained in that condition when it might have decreased to a 0.6 without specific mitigation efforts, then a gain of 0.3 times the area might be identified for each year that the site is maintained in the better condition.

Landscape Context. Impact sites may have differences in their intrinsic values due to their location within a landscape and the use of that landscape by various sagebrush-associated species. For example, mule deer (*Odocoileus hemionus*) winter range areas could contain similar ecological sites (and even existing vegetation communities) as another area without wintering mule deer, but might be of greater importance because of their use by this species. These locations, influenced by elevation, slope, aspect, and other factors, may best be identified by known distributions of selected species of interest. They may receive special emphasis in the determination of appropriate impact or mitigation areas. High quality areas may be placed off-limits to impacts, but could generate mitigation credits through improvements. Such areas should be designated in the assessment phase of development planning prior to application of this credit and debit system.

An important need in determining mitigation metrics is to determine how landscape features influence ecosystem services at a site. The same ecological site and vegetation community occurring in an impact site or mitigation site may not have the same value or produce the same wildlife benefits through mitigation due to these landscape effects. Therefore, an additional level of analysis must be considered that would evaluate the landscape context for wildlife benefits at a site. Models of habitat quality that include landscape components for selected species of concern could be used to evaluate declines in habitat quality in the development area compared to potential gains in habitat quality for these same species in the mitigation area. Using derivations of habitat suitability index (HSI) models (US Fish and Wildlife Service 1981) that operate at landscape scales, the influence of amounts of specific habitat conditions and their impacts from various developments can be modeled. Appendix B lists a number of landscape models and associated variables that have been identified for use in landscape evaluations for species of concern in sagebrush ecosystems. These or similar models can be used to further modify benefits or impacts quantified from the metrics described above. In this way, spatial influences can be used as modifiers of the impacts or mitigation calculated for a specific site.

Several considerations must be addressed relative to landscape context including how habitat requirements of selected species should be incorporated. Is the metric of interest the overall change in quality of habitat for a species (maintaining or increasing the limiting factor(s) of a species in a particular landscape), or should potential metrics address the same specific seasonal requirements across both impact and mitigation landscapes? For example, if winter habitat is a primary limiting factor in one landscape, and is being potentially impacted by a proposed development, and breeding habitat is limiting in another landscape, can improvement in the breeding habitat in the second landscape off-set the reduction in wintering habitat in the first landscape? A second question is which species and how many species of concern should be used as indicators of landscape effects? If an off-site mitigation is shown to improve conditions for one species but to decrease conditions for another species, how should these be evaluated in the landscape context? Should the net gains and losses of all species be averaged, or are some species more important and therefore receive a higher weighting in the analysis of landscape context?

Timing and Duration of Change. Key determinants of the amount of credits or debits attributed to an activity include expected annual changes, and the total amount of cumulative change (positive or negative) anticipated from the action over some period of time (e.g., 20 years), compared to the conditions that would be expected over the same period without the action. Note that under this approach, ñpreservationò of existing habitat does not gain any credits unless it eliminates some expected deterioration in condition. ñChangeò here is intended to refer to changes in the ecosystem services or values provided by the affected areas. As a practical matter, such changes are likely to be inferred from changes in the vegetative characteristics of the affected areas. Some changes, however, may be independent of vegetative characteristics, such as changes in the use of the area by sagebrush-associated wildlife as a result of increases or decreases in noise or visual features. These changes need to be evaluated in the context of the extent to which they may impact the flow of services over time relative to the reference condition. In measuring ñchangeò in vegetative characteristics, one could attempt to quantify precisely the amount of change (e.g., an acre that is currently judged to be at 30% of its ñinherent capacityò ï however measured ï will be improved to 80% of its inherent capacity over some specified period of time). Alternatively, change could be measured more qualitatively (e.g., change might be recognized only when land condition changes among such categories as good, fair, or poor, provided these categorizations can be defined and agreed upon, be relatively easily determined in the field, and provided that the time dimension associated with transitioning from category to category can be agreed upon). It is recommended that credits accrue only when beneficial change is actually documented, rather than when a commitment to undertake conservation action is made. This recommendation addressed the risk component discussed above. More risky mitigation measures can be encouraged, but would not generate credits until they are shown to produce desired conditions.

In the sagebrush ecosystem, the impacts of development activities on ecosystem services and species of concern will often be immediate, but they may not always be permanent (e.g., well pads and associated roads can be removed after they are no longer in use). Conversely, the impacts of conservation activities on ecosystem services or species of concern will often be neither immediate (e.g., restoring sagebrush at dry sites will take many years), nor permanent. Thus, the timing and duration of impacts and conservation activities need to be taken into account when quantifying credits or debits.

A goal of the credit trading program is to ensure that sagebrush-associated species do not become more likely to need the protection of listing under the Endangered Species Act. Achieving that goal might, for example, require that permanent detrimental impacts be offset only by permanent conservation benefits, or more generally that the expected duration of conservation benefits be more or less the same as the expected duration of the negative impacts of the development actions they are intended to offset. Consideration of these types of trading rules could be addressed once the basic framework for the ñcurrencyò has been established. Developing a catalog of the most likely types of development projects (including scale, magnitude, time frames of their impacts) and the most likely types of mitigation projects (also with scale, duration) would facilitate this discussion.

Sagebrush Ecosystem Credit Metric Framework

Development and implementation of a credit trading program will be based on the best available, peer-reviewed science whenever possible and the best professional judgment of experts whenever peer-reviewed documentation is not available. Essential components of the credit trading program are the development of specific crediting metrics to quantify the ecosystem services that are created or degraded, policy decisions defining the Trading Rules for the exchange of credit and debit units, development and implementation of a monitoring program to verify actual debits and credits, and an Adaptive Management process that will be used to evaluate, and modify the credit trading process (Holling 1978, Williams et al. 2007). Demonstration projects sponsored by CSI are anticipated to provide an opportunity for testing and evaluating the credit metric.

Credit Metric Framework. This Credit Metric Framework (CMF) provides a general example of application of the concepts described above. This credit metric would need further development to determine how various components such as the landscape context and ecological integrity would be quantified and in actual on-the-ground testing. This Framework utilizes USDA-NRCS Ecological Site Descriptions, on-site vegetation surveys, and landscape assessments for selected species of concern. The assignment of the number of credit and debit units is determined through a multi-phase process.

Site evaluation and quantification of ecological integrity. One level of assessment included in the CMF is at the ecological site. The CMF identifies *ecological integrity* of a site as an important aspect related to the provision of ecosystem services. As discussed previously, Karr (2004) identified the relationship of ecological integrity to those species and species assemblages adapted to a particular site. Stated differently, ecological integrity can be linked to the maintenance or restoration of native sagebrush ecosystems because it is recognized that native ecosystems contain the appropriate plant species that are adapted to that specific location and that wildlife species assemblages have developed in response to these adaptations. Definition of a native ecosystem requires reference to what occurred in the area historically, which is typically considered those conditions that occurred prior to major perturbations brought about following European settlement. Ecological site descriptions (ESD) (NRCS 2003; www.nrcs.gov/technical/efotog/) use state and transition models to define vegetation states that can occur across sites both historically and under current conditions. For each site, one historical state has been selected by the developers of the ESD, termed the historical climax plant community (HCPC), and described in more detail relative to its composition and productivity of native species. However, there are often multiple historical states that may occur at a site depending on disturbance history. Additional historical states may be included in the state and transition model for each ESD, and their historical compositions, structures, and productivity deduced from the information provided. In this way, each historical state for an ecological site can be described in terms of the composition, structure, and processes for that historical vegetation community. For example, a post-fire state dominated by grasses and forbs, and further influenced by either light or heavy grazing (two different states) might have occurred on a certain ecological site. Over time, sagebrush might reestablish on the site, resulting in a state with moderate amounts of sagebrush intermixed with grasses and forbs, which is often selected as the HCPC for the ESD. Eventually, sagebrush cover may dominate the site, reducing the amounts of grasses and forbs. A reference condition for each of these four historical states can be described and used as a basis for comparison to any existing community through use of evaluation tools such as similarity indices. Similar methods using similarity indices have been described by Kimberling et al. (2001) and Coppedge et al. (2006).

The proposed metric that addresses *ecological integrity* in credit banking is a measure that compares conditions of current vegetation communities at a site compared to historical vegetation communities and subsequent changes to the current vegetation communities in response to development or mitigation. Because various historical vegetation communities may have occurred on an ecological site selected for specific mitigation activities, a specific historical vegetation community would need to be selected as the baseline reference.

The historical state to be used as a baseline reference in the index of *ecological integrity* may be selected in several possible ways:

1. Evaluate which historical states currently have the lowest representation in the surrounding landscape relative to the amounts estimated to have occurred historically, and emphasize restoration of one of those vegetation communities. These under-represented communities provide conditions that are most likely to be limiting to sagebrush-associated species in the landscape because these communities are in the smallest amounts relative to their past availability. An analogy to forest ecosystems is to emphasize restoration of late-successional forest conditions in an area that has been heavily logged, as these are the forest conditions that are likely the most limiting to forest-dependent species in the area.
2. Alternatively, a Panel of Experts could determine which historical community described for a site is the most important to be emphasized based on their assessment of the most desired vegetation conditions in the landscape either for anticipated ecosystem services or for the importance of that community to the habitat needs of one or more species of concern.

The information for the current vegetation community that is necessary to determine differences in *ecological integrity* between it and baseline conditions will be directly measured in the field (e.g., vegetation composition, structure, and/or ecosystem processes). Baseline conditions of historical states will be evaluated and defined from detailed ESDs by a Panel of Experts. Comparisons will be made with the use of a similarity index. An index may then be calculated for a site that represents the ecological integrity of the ecosystem for that site:

I_{EISE} = (Ecological Integrity of existing vegetation community)

Process

1. A site is selected for improvement and accrual of credits, or scheduled for development and creation of debits.
2. A field survey is conducted at the site to provide data to identify the existing vegetation community and the current condition of the community.
3. One of several historical states, as defined in a state and transition model, will be selected as a reference baseline condition to compare the site to and that could serve as a target to work towards for desired changes.
4. Similarity indices will be used to compare the condition of the current vegetation community to the selected historical reference state of the baseline community to determine *ecological integrity*.
5. As management progresses on the site, *ecological integrity* may be reassessed to monitor progress toward the selected reference community, and credits granted at the end of the management program based on a final assessment of changes in *ecological integrity* when compared to the reference historical community.

At this point, the ecological integrity values are entered into the larger CMF, and further modified by other factors such as landscape context.

Impacts or mitigation would produce changes to the ecological integrity and would be reflected in the index. For example, a given site consisted of vegetation communities A and B; the existing *ecological integrity* was determined from field surveys to be 0.8 for A and 0.3 for B, compared to the baseline *ecological integrity* described for either an historical state, reference to average conditions, or other baseline reference. Through mitigation, the *ecological integrity* of community A might be increased to 0.9 by actions that might increase the composition of desired native plant species or by decreasing the occurrence of exotic species, while conditions in community B might be increased to 0.6 through similar treatments. The change in *ecological integrity* due to mitigation treatments would therefore be 0.1 for community A and 0.3 for community B. The resulting *ecological integrity* of these vegetation communities (I_{EISR}) would be 0.9 for A and 0.6 for B. The resulting credits would equal the acres of both vegetation community A and B times 0.1 for community A and 0.3 for community B as an improved condition. A further modification, discussed below, is the length of time that these changes either take to produce, or are maintained.

Required data:

1) Ecological site descriptions (ESD) are available at (www.nrcs.gov/technical/efotog/).
2) Defining the existing conditions in terms of ecological integrity of the site.
3) Quantifying the change in ecological integrity for each defined vegetation community for each ecological site requires the selection of a baseline standard, description of the existing conditions of the vegetation community at the impact or mitigation site, and an assessment of the change in the vegetation community as a result of either the impact or mitigation activities. Existing vegetation community conditions would be determined by direct measurement in the field, and then monitored for changes produced by mitigation or through impacts.

4) A measure of comparison (e.g., similarity index; www.nrcs.gov/technical/efotog/) would be needed to quantify the composition and condition of the existing vegetation community compared to the baseline reference community. Variables that could be used in the comparison might include:

   a. total native taxa richness or abundance;
   b. total alien or nonindigenous taxa richness or abundance; and
   c. other measures of community condition.

For example, while some occurrence of exotic species is expected in virtually every existing vegetation community, existing conditions might be evaluated as progressively poorer as percentages of the exotics increase in the composition. Values between 0 and 1 could be defined for any vegetation community based on its characteristics determined through field measurement and compared to the baseline or reference condition(s) for each ecological site. Changes in *ecological integrity* produced by either impacts (debits) or mitigation (credits) would then be quantified based on resulting increases or reductions in exotic species, increases or reductions in desired native species, changes in structure of the vegetation such as residual heights of herbaceous vegetation, or other such changes relating to ecological integrity.

Outputs from the Site-level Model:

An index of ecological integrity of the sagebrush ecosystem (I_{EISE}) is estimated for specific locations for existing conditions and resulting conditions (I_{EISR}).

Area weighting. A weighting factor (W_{AJ}) may be developed and applied that weights credit or debit units higher for larger projects or for aggregates of projects in an area. However, the various factors that might influence the results of this, discussed previously, need to be evaluated.

Landscape Context. A fundamental premise of the CMF is to develop a process that promotes the recovery of greater sage-grouse and other species of concern in the sagebrush ecosystem. The CMF assumes that the likelihood of recovery of sagebrush-associated species will be the highest where the landscape is most favorable for those species. The condition of the landscape for the *i*th species of concern [I_{iLC}] is a function of the habitat value of the landscape and a measure of the cumulative impacts present within the landscape. See Appendix B for examples of models available to estimate landscape condition.

The *Index of Landscape Condition* (I_{LC}) is an average of the species-specific indices of landscape condition for greater sage-grouse and other species of concern (I_{iLC}) as estimated by landscape models, each of which may be weighted depending on the species importance to the over-all conservation goal.

I_{iLC} = [(Landscape Value for species *i*) ï (Cumulative Impacts on species *i*)] * [Weighting Factor]

$$I_{LC} = \frac{(I_{1LC}) + (I_{2LC}) + (I_{3LC}) + (I_{4LC}) + (I_{5LC}) + \text{é} + (I_{nLC})}{\text{Number of species of concern (n)}}$$

As the cumulative impacts increase, I_{LC} decreases.

Required resources:

1) Landscape models for all the species of concern considered in the analysis (e.g., Appendix B).

2) Spatial data necessary to apply the landscape models.

Outputs from Landscape Model:

1) The I_{LC} for a specific location in ideal condition will have a value of 1. It will have a value of 0 when the landscape does not have value for any of the species evaluated.

Issues associated with Landscape Models:

The issues associated with the selection and use of species to evaluate landscape context, discussed above, need to be addressed before applying this metric. In addition, landscape models for many species need careful evaluation to ensure that they can adequately operate in the landscape of interest.

Applying the CMF. The components of the CMF include the site level measure of existing ecological integrity, area weighting (if used), the landscape context based on species models, the resulting changes to existing ecological integrity from either impacts or mitigation, and the timing and duration of these changes. These are combined in a metric for calculating overall credits or debits.

Definitions

I_{LC} = Index of the condition of the landscape surrounding a site.

I_{EISE} = Existing ecological integrity of the sagebrush ecosystem for a site.

I_{EISR} = Resulting ecological integrity of the sagebrush ecosystem for a site.

t = Time step.

tc = Length of time defined in a contract.

W_{AJ} = Index to the size of the impact area or the mitigation area.

Process

1. the *existing* level of services is measured as $I_{EISE}(t=0)$ for the site condition and $I_{LC}(t=0)$ for the landscape condition;
2. the *resulting* level of services is measured as $I_{EISR}(t=tc)$ for the site condition where tc is duration of time defined in a contract;
3. the *duration* of time is tc;
4. the *length of time* before the mitigation is fully successful is not represented in this Metric model but could be incorporated with a multiple phase analysis; and
5. differences among impact and mitigation sites are reflected in differences in the site conditions (I_{EISE}) and (I_{EISR}) and landscape conditions (I_{LC}).

The number of credit (C) or debit (D) units can be calculated for each Ecological Site as:

C or D = (Change in Site Condition) x (Landscape Condition) x (Area) x (Duration)

$$= [I_{EISR}(t=tc)\ \text{ï}\ I_{EISE}(t=0)]\ \text{x}\ [I_{LC}(t=tc)-I_{LC}(t=0)]\ \text{x}\ [W_{AJ}\ \text{x}\ (\text{Area in acres})]\ \text{x}\ (\text{tc in years})$$

If the values for Change in Site Condition and Landscape Condition are both negative, the value resulting from (Change in Site Condition) x (Landscape Condition) is assigned a negative sign.

Credit and debit units are measured as changes in the site condition (I_{EISE}) - (I_{EISR}). Credit units are earned when I_{EISR} increases, and debit units are accrued when I_{EISR} decreases. If the site condition does not change, credit or debit units are not created.

The Landscape Condition (I_{LC}) scales the change in the site condition to reflect the overall quality or priority of a given landscape. If a landscape has a low value to the species of concern (I_{LC} <0.5), changes in the site condition will not result in the creation of large numbers of credit units or the accrual of debit units. Likewise, if a landscape has the maximum value (I_{LC} = 1), changes in the site condition result in the greatest number of credit or debit units. Mitigation should change the quality of the landscape to selected species, resulting in increases to the landscape context over time.

Trading Rules

An operational CMF needs policy decisions that define trading rules for Service Areas, Mitigation Ratios, Release of Credits, Compensation Ratios, and the role of public versus private lands. Whenever possible, the CMF will follow the óGuidance for the Establishment, Use, and Operation of Conservation Banksô issued by the U. S. Fish and Wildlife Service (2 May 2003).

The CMF provides an index of ecosystem services provided per acre that can be used to determine the number of credit and debit units. The credits or debits are based on the ecological site classification system of NRCS. This classification system, describes ESDs that occur within Precipitation Zones and Precipitation Zones overlap with MLRAs. Credit and debit units are therefore defined as Ecological Sites within a Precipitation Zone and MLRA. This combination of areas then defines the minimum Service Area for operation of the credit trading system. Other Service Areas could be defined, such as Greater Sage-grouse Management Zones or Bird Conservation Regions (BCRôs), but the similarity of ecological sites in the CMF will be lost if the primary Service Area is set larger than the Precipitation Zone and MLRA combinations. Note, however, that credits and debits tracked by Precipitation Zone and MLRA could be aggregated and reported relative to larger management areas such as Greater Sage-grouse Management Zones or BCRôs, while still maintaining their specific values. Use of ESDs within the Precipitation Zones and MLRA combination as the basis for defining metrics at a specific impact or mitigation site assures that similar ecosystem services are being traded. A policy is needed to clearly define the Service Area in which credit and debit units will be exchanged.

A second policy decision relates to the value of specific units to be traded. To reduce potential degradation of the sagebrush ecosystem and habitat for associated species, a ñlike-for-likeò mitigation rule might be specified that goes beyond the specification of the Service Area. For example, if an acre of a vegetation community (A) with an ecological integrity value of I_{EISE} is impacted, a credit must be available from the management of an acre with a vegetation community that has an ecological integrity equal to or higher than I_{EISE}. It is unclear if an equitable exchange would be 100 acres of 0.1 quality improvement for 10 acres of reduction of 1.0 quality area to a 0 value (both would generate 10 credits or debits, but the influence of these debits or credits might be quite different on resulting ecosystem services). Policies relative to such trade-offs need to be considered and set.

A policy decision must also be made concerning the timing of the Release of Credits. To ensure that a temporary shortage of ecosystem services (i.e., habitat) is not created, credit units should not be released and exchanged for debit units before the actual improvements in the ecological integrity have occurred elsewhere on the landscape. However, land managers often need capital to initiate the creation of credits. A policy decision must be made as to what percentage could be released early to generate capital to support additional land management activities and what degree of improvement must be made for additional release of credits.

A policy decision must be made concerning Compensation Ratios. If a goal of the Crediting Program is the recovery of the sagebrush ecosystem and enhancement of greater sage-grouse populations, then a policy decision could be made to require two or more credit units to be created for every debit unit generated from development. This Compensation Ratio could also reflect, in part, the risk associated with an early release of credit units. This risk results when credits are released but the actual improvement in ecological integrity have not occurred.

An additional policy question is to decide to what extent are credits available for beneficial actions that may be undertaken on public lands as compared to private lands? This question does not affect how credits are quantified, but it does have an important bearing on how any credit trading system would actually work. Addressing this question could be an important policy consideration for this metric system.

Monitoring

The scope of monitoring instituted in association with credit trading should be commensurate with the scope of the development and conservation actions. The ecological goals associated with the proposed mitigation provide a framework for developing a monitoring program that measures progress toward meeting those goals. The level and kind of monitoring may vary by individual project; an effective monitoring program should be sufficiently flexible to allow modifications, if necessary, to obtain the appropriate information. Monitoring designed to measure and assess habitat protection, restoration, or creation under the credit trading program should include components to:

1. evaluate compliance with authorized debits and credits;
2. determine if biological goals and objectives are being met; and
3. provide feedback information for subsequent management changes and adaptations (i.e., adaptive management).

Standard survey procedures or other previously established monitoring protocols based on sound science should be used. Though the specific monitoring for each project may differ, some factors that may be important to monitor include vegetative response to management, the presence of invasive species, water quality, and presence of species of concern.

Adaptive Management

Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (Williams et al. 2007). Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies as part of an iterative learning process. The outcomes of interest here are the restoration of the sagebrush ecosystem and recovery of populations of greater sage-grouse and other sagebrush-associated species. The management actions are the various techniques used to create and accrue credits. The policies are the rules and metrics used by the crediting program.

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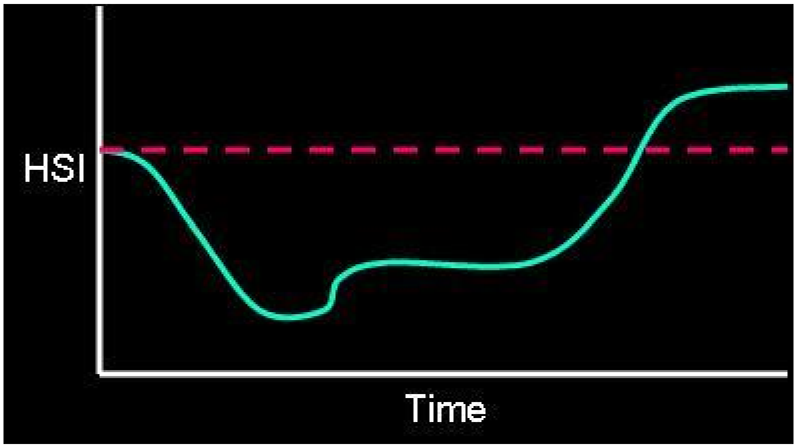
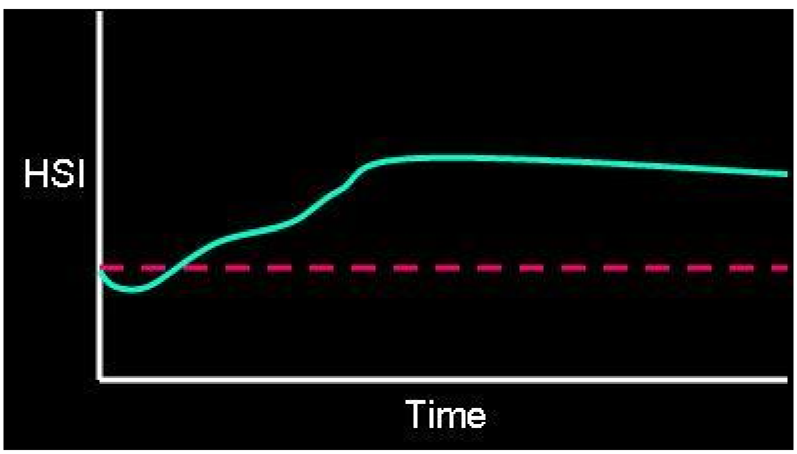
Appendix A



Debit Scenario:

Operator proposes to develop lease over 160 acres ï well pad, compressor, roads, pipeline, electric transmission. Habitat quality is projected to diminish over majority of time period, with increase post reclamation. Project period of 40 years. Modeled results suggest net HSI loss of 0.4/160 acres/40 years, resulting in a Habitat unit (year/acre) equivalent (HUE) debit of -2560.



Credit Scenario:

Private landowner proposes to enhance habitat over 200 acres via mechanical manipulation of decadent sagebrush overstory, reduction of grazing pressure, and planting of native forbs. Project commitment to maintain for 20 years. Modeled results suggest net HSI increase of 0.3/200acres/20 years, resulting in a habitat unit (year/acre) equivalent (HUE) credit of +1200

Appendix B

Wildlife species with landscape models available for use in evaluating values for mitigation credit and loss.

		Variables																																									
Species	Source of model	Elevation	Aspect	Slope	Topographic complexity	Solar radiation	Livestock grazing	Campground - distance	Communications towers - distance	Fence density	Human impact zone	Interstate highway - distance	Irrigation canal - distance	Landfill ï distance	Oil/gas well - active only - distance	Oil/gas well ï all - distance	Oil-Gas development density by type	Pipelines	Railroad - distance	Road density	Secondary road - density	Secondary road - distance	State/federal highway - distance	Transmission line - distance	Urban/human populated areas - distance	NDVI[a] - Value	Agriculture land - distance	Agriculture/other habitat density	Land cover	Forage	Cover	Juniper Forest - Interior vs. non juniper	Juniper forest ï other habitat ecotone - distance	Sagebrush fragmentation 18km	Sagebrush fragmentation 5km	Sagebrush patch size/sagebrush habitat	Sagebrush percent within a 18km radius	Sagebrush percent within a 3km radius	Sagebrush percent within a 50km radius	Sagebrush percent within a 5km radius	Water - distance	Soil % Clay	Soil depth
Greater sage-grouse	1							x	x			x	x	x	x	x			x			x	x	x	x				x									x					
Pygmy rabbit	1			x								x	x		x	x			x			x		x	x		x		x							x						x	x
American pronghorn	1	x		x						x		x					x				x		x		x				x												x		
Sagebrush lizard	1					x		x			x	x	x	x		x						x	x		x	x	x		x														
Short-horned lizard	1					x		x			x	x	x	x		x						x	x		x	x	x		x														

Wildlife species with landscape models available for use in evaluating values for mitigation credit and loss.

Species	Source of model	Variables: Elevation	Aspect	Slope	Topographic complexity	Solar radiation	Livestock grazing	Campground - distance	Communications towers - distance	Fence density	Human impact zone	Interstate highway - distance	Irrigation canal - distance	Landfill ï distance	Oil/gas well - active only - distance	Oil/gas well ï all - distance	Oil-Gas development density by type	Pipelines	Railroad - distance	Road density	Secondary road - density	Secondary road - distance	State/federal highway - distance	Transmission line - distance	Urban/human populated areas - distance	NDVI[a] - Value	Agriculture land - distance	Agriculture/other habitat density	Land cover	Forage	Cover	Juniper Forest - Interior vs. non juniper	Juniper forest ï other habitat ecotone - distance	Sagebrush fragmentation 18km	Sagebrush fragmentation 5km	Sagebrush patch size/sagebrush habitat	Sagebrush percent within a 18km radius	Sagebrush percent within a 3km radius	Sagebrush percent within a 50km radius	Sagebrush percent within a 5km radius	Water - distance	Soil % Clay	Soil depth
Brewer's sparrow	1											x									x		x											x	x		x		x	x			
Sage sparrow	1											x									x		x			x								x	x		x		x	x			
Sage thrasher	1											x									x		x			x								x	x		x		x	x			
Loggerhead shrike	1											x									x		x			x								x	x		x		x	x			
Ferruginous hawk	1	x		x				x						x			x			x				x	x	x		x				x	x										
Mule deer	2				x		x													x									x	x	x												

Wildlife species with landscape models available for use in evaluating values for mitigation credit and loss.

		Variables																																									
Species	Source of model	Elevation	Aspect	Slope	Topographic complexity	Solar radiation	Livestock grazing	Campground - distance	Communications towers - distance	Fence density	Human impact zone	Interstate highway - distance	Irrigation canal - distance	Landfill ï distance	Oil/gas well - active only - distance	Oil/gas well ï all - distance	Oil-Gas development density by type	Pipelines	Railroad - distance	Road density	Secondary road - density	Secondary road - distance	State/federal highway - distance	Transmission line - distance	Urban/human populated areas - distance	NDVI[a] - Value	Agriculture land - distance	Agriculture/other habitat density	Land cover	Forage	Cover	Juniper Forest - Interior vs. non juniper	Juniper forest ï other habitat ecotone - distance	Sagebrush fragmentation 18km	Sagebrush fragmentation 5km	Sagebrush patch size/sagebrush habitat	Sagebrush percent within a 18km radius	Sagebrush percent within a 3km radius	Sagebrush percent within a 50km radius	Sagebrush percent within a 5km radius	Water - distance	Soil % Clay	Soil depth
Mule deer	3	x	x													x				x																							
Data sources		4	4	4	4	4	?	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	1 5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	8	8

[a] NDVI is a greenness index, derived from combinations of the spectral bands in satellite imagery, that correlates highly with ñaboveground biomassò (Boelman et al. 2003) or annual aboveground primary production (Paruelo et al. 1997).

1 ï Rowland et al. 2006.

2 ï Lehmkuhl et al. 2001.

3 ï Sawyer et al. 2006.
4 ï Digital elevation model
5 ï Connelly et al. 2004.
6 ï Normalized Difference Vegetation Index (NDVI)
7 ï Zho et al. 2006 (LANDFIRE).
8 ï USDA NRCS Soil Survey Staff 2006 (STATSGO).