Great Northern Landscape Conservation Cooperative

Science Plan, 2014-2018

By: Sean Finn, Yvette Converse, Tom Olliff, Matt Heller, Rick Sojda, Erik Beever, Sergio Pierluissi, Jen Watkins, Nina Chambers, and Scott Bischke
Table of Contents

EXECUTIVE SUMMARY .................................................................................................................. 1
INTRODUCTION ........................................................................................................................................... 1

About the Great Northern Landscape Conservation Cooperative .......................................................... 1
The Purpose of this GNLCC Science Plan .............................................................................................. 1
Roles within the GNLCC Partnership ....................................................................................................... 2
GNLCC Conservation Vision, Goals & Targets ..................................................................................... 4
Conservation Paradigms .......................................................................................................................... 5
Conservation Vocabulary ....................................................................................................................... 5
Adaptive Management ........................................................................................................................... 5
Landscape Integrity ................................................................................................................................ 6

SECTION 1: Conservation Targets ....................................................................................................... 7

Stepwise Process .................................................................................................................................. 7
Step 1a: Strategic Conservation Framework ....................................................................................... 8
Step 1b: Refine Conservation Target Priorities .................................................................................... 8
Step 2a: Map Conservation Targets to Goals ..................................................................................... 9
Step 2b: Scope Conservation Threats and Actions .............................................................................. 10
Step 3: Conceptual Models ................................................................................................................... 15
Step 4: Set Quantifiable Objectives .................................................................................................... 17
Step 5: Identify Limiting Factors ........................................................................................................ 18
Step 6: Estimate Action Contributions ................................................................................................ 19
Step 7: Quantitative Modeling ............................................................................................................ 20
Step 8a: Identifying Needs and Uncertainty ....................................................................................... 21
Step 8b: Conduct Science .................................................................................................................... 21
Step 9: Determine Actions ...................................................................................................................... 22
Step 10a: Data Synthesis of Legacy Conservation Actions ................................................................. 22
Step 10b: Retrospective Analyses ....................................................................................................... 23
Step 11: Landscape Conservation Design ............................................................................................ 23
Step 12: Act, Evaluate, Monitor .......................................................................................................... 24
Step 13: Repeat ....................................................................................................................................... 25

SECTION 2: Landscape Goals ............................................................................................................. 26

Landscape Integrity Index ..................................................................................................................... 27
Defining Metrics and Geographies for Landscape Integrity .................................................................... 28
How these indicators work together to indicate Landscape Integrity for the GNLCC ..................................... 31
Immediate Science Needs for Landscape Integrity Estimation ............................................................... 31
How Collaborator Management Actions and Strategies Influence these Indicators ............................ 31
Partner Efforts to Measure or Monitor Landscape Integrity .............................................................. 32

SECTION 3: Integrating Filters ............................................................................................................. 33

Tracking Collective Progress toward Stated Goals .............................................................................. 33
Guiding Annual Workplans .................................................................................................................. 34

CITATIONS............................................................................................................................................... 36
APPENDIX A: Tools and Technological Resources Supporting the GNLCC Science Plan ................. 38
APPENDIX B: Elaboration on Wetlands Example .............................................................................. 41
APPENDIX C: Elaboration on Fire Regime Example .......................................................................... 49
APPENDIX D: Landscape Integrity Background .................................................................................. 51
EXECUTIVE SUMMARY

The Great Northern Landscape Conservation Cooperative (GNLCC) Science Plan builds off the Governance Charter and Strategic Conservation Framework (Chambers et al. 2013) showing how to apply the Conservation Framework to achieve landscape goals through an adaptive management approach. It describes:

- ecological relationships among conservation targets, threats, and actions as they relate to overall goals and vision
- a process for setting desired condition and quantifiable objectives for each fine filter conservation target which then serve as metrics to track progress toward coarse-filter conservation goals
- how to assess conservation actions for effectiveness towards goals
- where and how Cooperative partners contribute to and benefit from shared conservation delivery, and
- data and science gaps for understanding and achieving – via informing annual workplans – the above.

The Science Plan aligns GNLCC’s goals and vision with standard conservation approach and vocabularies and employs a fine filter/coarse filter approach to address those goals. The fine filters – the 29 Conservation Targets prioritized in the Conservation Framework – are linked to measures of ecological integrity through the development of a Landscape Integrity Index. The Plan also charts appropriate roles for each of the working groups (Steering Committee, Advisory Team, Science Community, Partner Forums, etc.) identified in the Governance Charter. In sum, The Plan draft a course for Partners to successfully inform, apply and track conservation across the landscape.

Section 1: Fine Filter Conservation Targets

The Science Plan describes a process by for GNLCC stakeholders to collaboratively act on specific priorities. A stepwise process (Fig. ES1) links a series of conservation paradigms and strategies, (e.g., SHC, vulnerability assessments, conservation triage) into a logical progression to deliver conservation. The process is intended as a heuristic, rather than a recipe, to guide partners toward achieving informed, effective action for focal targets.

Figure ES1. Stepwise process for directly addressing specific priority GNLCC Conservation Targets. This process includes assessing science needs, developing applications, and estimating conservation action effectiveness for each target while delivering data, models, and conservation planning to support toward attainment of collective landscape integrity objectives. Each step is addressed in detail below. The red flags represent steps where science needs are identified. In practice the specific needs will vary with the target being addressed.
Steps:

1a: **Strategic Conservation Framework** - The first iteration of the GNLCC’s Conservation Goals and priority Targets (see GNLCC Conservation Framework; Chambers et al. 2013).

1b: **Refine Conservation Target Priorities** - Within the 5 years of this Plan four states will deliver revised State Wildlife Action Plans, USFWS will implement a surrogate species approach, and multiple Forest (USFS) and Land Use (BLM) Plans will be approved; thus periodic review is an integral, iterative step.

2a: **Map Conservation Targets to Goals** - An explicit first step linking fine-filter targets to coarser landscape-scale goals. Partners and partnerships address targets from unique perspective; Step 2b works to resolve perspective and align programs.

2b: **Scope Conservation Threats and Actions** - Standardizes each conservation target to a lexicon as a means to consistently feed a Conceptual Model for each Conservation Target. We rely on the expertise exemplified by the Partner Forums to specify threats and actions in a structured discussion.

3: **Conceptual Models** - The next step is to develop common understanding of each focal Target’s ecological relationships by building conceptual models that may start off fairly simple but can get rather complex.

4: **Set Quantifiable Objectives** - A critical task for the GNLCC and partner-driven conservation in general. Many social, political, economic, and biological factors influence how objectives are set. The Steering Committee is critical to promote agreed-upon objectives.

5: **Identify Limiting Factors** - Tend to be lacking for species that have not been specifically targeted by recovery planning. Also, because we lack quantifiable objectives for many targets, critical limits to achieving those objectives are also not elucidated.

6: **Estimate Action Contributions** - Here the Plan invokes a conservation triage approach to estimate the relative costs and benefits of conservation actions identified in Step 2b and refined by setting objectives and identifying limiting factors.

7: **Quantitative Modeling** - We can now develop predictive models as a means to understand and quantify uncertainty, and prioritize and evaluate management actions in terms of their benefit to achieving objectives.

8a: **Identifying Needs and Uncertainty** - These outcomes encompass a large proportion of GNLCC science needs and serve as primary guidance for developing Annual Workplans.

8b: **Conduct Science** – The patient, stepwise and iterative process ensures our next steps are well informed – because they become more expensive and potentially difficult to reverse. They also ensure that our research investment is highly directed to ensure we pursue information that concisely informs management action.

9: **Determine Conservation Actions** - The second outcome of the modeling exercise is the suite of conservation actions – an improved Managers’ Toolbox – that are cost effective and predicted to be ecologically effective.

10a: **Data Synthesis of Legacy Conservation Actions** - To understand how much have we collectively changed the conservation estate and where those actions have occurred, we need to identify and compile data from multiple sources to document the cumulative status of past and current conservation actions.

10b: **Retrospective Analyses** - Data gathered and archived in Step 10a will be used to understand their contribution to GNLCC conservation targets.

11: **Landscape Conservation Design** - Both a process and a product, where the process is iterative and adaptive and the product results in a desired landscape condition as expressed through the integration of quantifiable biological, cultural, and physical resource objectives

12: **Act, Evaluate, Monitor** - This important step is largely outside the scope of the Science Plan except for two important concepts: the design of conservation actions using an experimental approach and considerations and integration of sound monitoring protocols

13: **Repeat** - Led by the GNLCC Steering Committee and Advisory Team, the process repeats in timeframes built around improved knowledge, technology, and conservation need.
Section 2: Coarse Filter Landscape Goals

Landscape conservation is a challenge of scales: spatial, temporal, ecological, jurisdictional, and socio-political. Preceding conservation paradigms (i.e., FWS 2008) have successfully defined useful frameworks within a specified spatial scale. However, an LCC’s challenge is to understand and address conservation objectives concurrently at many different scales. The Cooperative must roll up conservation actions aimed at specific targets to advance landscape-scale subgoals and roll those up to achieve our vision of landscapes with high ecological integrity. Thus, we need a cohesive means to describe and track landscape change and conservation outcome with a coarse filter.

The four GNLCC goals embody the definition, maintenance, and improvement of landscape integrity. We characterize landscape integrity as the inverse of human modification (i.e., the ‘H’ index of Theobald 2013) and as a subset of ecological integrity as defined by Noss (1990) and Parrish et al. (2003). Areas of high ecological integrity have unfragmented natural landscapes, highly functioning biotic and abiotic processes and native biotic components within a natural range of variability, and few impacts from invasive species.

The GNLCC will develop a Landscape Integrity Index (LII; Fig ES2) for the Great Northern region to serve as a 2014 baseline and provide the opportunity to monitor movement toward (or away from) desired condition from this baseline. The LII estimates landscape-scale threats to Conservation Targets as using standard threat classes (Salafsky et al. 2008) and spatial modeling techniques (Theobald 2013).
The LII approach promotes iteration in both spatial and temporal contexts and approximates a condition estimate that all GNLCC partners can identify with. This first iteration will allow the Cooperative to track changes by land use impact over time and identify important data gaps that are specifically identified at finer scales via the process described in Section 1. The LII map informs us where the more intense human impact is occurring, and where there is a high need to conserve native species, ecosystems, and processes. If LII is remaining relatively stable or decreasing (less human impact) we assume that ecosystem integrity at a coarse resolution in the GNLCC is maintained or improved.

The GNLCC-wide Landscape Integrity map will inform annual workplans in terms of prioritizing data acquisition and focus the partnership on particularly sensitive or threatened locales and conservation targets that are in need of attention and ripe for conservation action. Subsequent iterations, which will occur as a precedent to each 5 year Science Plan will use updated spatial data generated through GNLCC workplans and by partners developing CHAT, REA, SWAP and other spatial data improvements.

Section 3: Integrating Filters

The outstanding challenge to large landscape conservation is delivering cross-scale information to best inform conservation decision and action. The Science Plan guides the GNLCC partnership to integrate fine filter quantifiable objectives with landscape-scale desired outcomes by linking conservation target metrics to measures of landscape integrity (Fig. ES3).

![Figure ES3. Conceptual model for integrating coarse and fine filter conservation data to inform site managers and conservation partnerships on appropriate actions in the face of landscape-scale ecological stressors.](image)

An LCC will find success when it’s able to integrate multi-scale data to increase manager’s confidence that proposed actions will contribute to shared outcomes and coordinated evaluations that accurately measure trends (toward or away from) desired condition. This element of the GNLCC Science Plan remains a work in progress – a challenge we can only adequately address as a cooperative partnership.
INTRODUCTION

About the Great Northern Landscape Conservation Cooperative

The Great Northern Landscape Conservation Cooperative (GNLCC) is an applied conservation science partnership that convenes science expertise and provides technical support to inform resource management and landscape conservation in the face of landscape stressors. As a partnership of land managers, scientists and other conservation practitioners, the GNLCC provides the landscape context to support conservation planning, implementation, and evaluation towards a collective landscape vision through an adaptive management framework (Holling 1978).

The Purpose of this GNLCC Science Plan

The purpose of this document is to build upon the apply science standards and tools to support implementation of the GNLCC Strategic Conservation Framework (Conservation Framework; Chambers et al 2013) by GNLCC partners. Using an adaptive management approach, the Science Plan (Plan) attempts to give each partner a view of how they fit into the GNLCC partnership and what each individual and organization can contribute to a landscape that sustains its diverse natural systems to support healthy populations of fish, wildlife and plants; sustains traditional land uses and cultural history; and supports robust communities (Chambers et al. 2013).

The Science Plan explains and instructs how to apply the Conservation Framework to achieve landscape goals through an adaptive management approach by describing:

- ecological relationships among conservation targets, threats, and actions as they relate to overall goals and vision
- a process for setting desired condition and quantifiable objectives for each conservation target which then serve as metrics to track progress toward coarse-filter conservation goals
- how to assess conservation actions for effectiveness towards goals (conservation triage; Bottrill 2008
- where and how Cooperative partners contribute to and benefit from shared conservation delivery, and
- data and science gaps for understanding and achieving – via informing annual workplans – the above;

The Conservation Framework (Chambers et al. 2013) describes a collective landscape vision. It is composed of an over-arching landscape goal, four subgoals, and 29 conservation targets used to measure progress toward goal achievement. The Science Plan describes how GNLCC intends to synthesize ecological science and conservation practice across spatial and ecological scales – from fine grained, species-specific conservation targets through coarse quantifications of landscape integrity – to derive repeatable measures of conservation outcome effectiveness, thereby enabling the measurement toward goal attainment.

In Section 1, we use three conservation targets as example proofs-of-concept to illustrate a stepwise, iterative process for setting quantifiable objectives, evaluating and implementing conservation actions, and measuring progress toward goals. The examples describe ecological relationships and socio-economic factors influencing

---

1 We thank G. Chong, M. Cross, N. DeCrappeo, V. Kelly, M. Manning, C. McCreedy, J. Morisette, J. Pierce, and D. Theobold for providing valuable guidance and comments on this draft.
those targets and how they translate to the stated goals. Throughout the iterative process we highlight the science, data, and tools needed for effective planning, implementation, and monitoring of conservation actions by managers.

Section 2 addresses Landscape Integrity more directly. Although resource managers don’t generally implement conservation action at coarse scales, value results from tracking coarse grained changes resulting from consumptive land use, invasive species spread (Beever et al. 2014), climate impacts, and more. Section 2 describes a geospatial approach to tracking landscape change that informs LCC partners on trends in processes and conditions (e.g., connectivity and ecosystem health).

Finally, Section 3 describes how these multi-scale approaches will be used to (a) track our collective progress toward stated goals and desired conditions, and (b) identify critical gaps in scientific information to guide GNLCC annual work plans and funding.

This Science Plan guides GNLCC investments to best provide landscape scale context to the broader conservation community achieve their missions and mandates and enable partners to understand how they can affect and derive a landscape benefit through the GNLCC partnership.

Roles within the GNLCC Partnership

The roles of the various GNLCC partner groups are detailed below according to each step in the science process:

- **The Steering Committee** sets big-picture guidance for the GNLCC and approves science direction.
- **The Advisory Team** coordinates science needs, refines identified priorities, and leads the process of defining metrics for GNLCC success.
- **Partner Forums** consist of on-the-ground practitioners who have a major role in the GNLCC. Based on their local expertise, they identify fine-scale conservation priorities; link metrics describing conservation targets to the GNLCC landscapes; identify the extent and intensity of threats to those targets; ground-truth conceptual models; plan and deliver conservation actions; and share lessons learned.
- **The Science Community** shares knowledge, expertise, and tools for practitioners; helps advance conceptual models; and provides analysis and synthesis.
- **Management Agencies** are often part of partner forums, and are especially important for delivery of conservation and resource management on the ground. They help ground-truth conceptual models for application to management decisions, their decisions result in management actions, and they monitor and evaluate the success of their actions through adaptive management.
- **The Science Plan describes a role for inventory and monitoring partners** that includes improved planning, implementation, and data coordination by GNLCC partner organizations and/or inter-organizational work teams.

LCCs are complex partnerships that transcend geographical, jurisdictional and institutional boundaries. LCCs require consistent engagement from stakeholders who affect large landscape conservation by employing a range of roles unique to their missions and mandates. Because each partner’s capacity differs, the Science Plan provides a strategy on how these roles can best integrate across multiple resource management and jurisdictional levels (Figure 1). Key principles of the framework are:

- all partners can be engaged at some level throughout the cycle (as indicated by rings);
- the lead role changes throughout the cycle (as indicated by ring width); and
- science needs are identified throughout the cycle.
Figure 1: Linking GNLCC Partners and their contributions to adaptive management in the context of landscape conservation. The upper left circle depicts an adaptive management model (FWS 2008) describing iterative biological planning, conservation design and delivery, and monitoring informed by assumption-driven research. Sliding this model into the GNLCC partnership governance structure (lower right) helps visualize the relative timing of important contributions from each group contributing to landscape conservation in the Great Northern region.

Figure 2 represents the timing, level, and prominence of activity or engagement required by each functional group identified above through the adaptive management wheel as a rough progress bar. It is used in subsequent figures (i.e., Figs. 5, 6, and 9) to show shifting levels of role and responsibility. The timeline is relative and dependent on the specific conservation target(s) being addressed. Thicker bars indicate where each group takes a leading role. This representation of functional roles will continue through this Science Plan describing the ‘who’ where it accompanies subsequent figures describing the ‘what’ of each element of the Stepwise Process.

Figure 2: Example of a relative ‘progress bar’ graphic depicting GNLCC Partners and their contributions to landscape conservation (see Fig. 1). The timeline is relative, proceeds from left to right, and links to the specific conservation target(s) being addressed. See subsequent figures. Meaningful renditions of this example are paired with elements of the Stepwise Process (Section 1) in figures 5, 6, 9, 15 and 16. SC = Steering Committee; AT = Advisory Team; Sci = Science Community; PF = Partner Forums; Mgt = Management Agencies; M&E = Monitoring and Evaluation specialists.
**GNLCC Conservation Vision, Goals & Targets**

The GNLCC partnership envisions “a landscape that sustains its diverse natural systems to support healthy and connected populations of fish, wildlife, and plants; sustains traditional land uses and cultural history; and supports robust communities.” The GNLCC understands this vision is a stated desired future condition of high ecological integrity at a landscape scale for the Great Northern geography. GNLCC defines ecological integrity following Noss (1990): areas of high ecological integrity have unfragmented natural landscapes, highly functioning biotic and abiotic processes, native biotic components within a natural range of variability, and few impacts from invasive species. In other words, they have the composition, structure, and function of less-altered landscapes (Noss 1990). The concept is further described by four sub-goals (Chambers et al. 2013):

1. Maintain large, intact landscapes of naturally functioning terrestrial and aquatic community assemblages.
2. Conserve a permeable landscape with connectivity across aquatic and terrestrial ecosystems, including species movement, genetic connectivity, migration, dispersal, life history, and biophysical processes (recognizing this is species dependent, and recognizing in some circumstances connectivity is not desired).
3. Maintain hydrologic regimes that support native or desirable aquatic plant and animal communities in still and moving water systems.
4. Promote landscape-scale disturbance regimes that operate within a future range of variability and sustain ecological integrity.

The GNLCC addresses 29 taxa, habitats and ecosystems, and ecosystem processes as priority Conservation Targets (Table 1; Chambers et al. 2013). Targets were identified by a rigorous review of regional, national and international planning documents and vetted through the Steering Committee and Advisory Team.

Table 1: GNLCC Conservation Targets

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Ecosystems/Habitats</th>
<th>Ecosystem Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>whitebark pine</td>
<td>riparian corridors</td>
<td>aquatic connectivity</td>
</tr>
<tr>
<td>salmon</td>
<td>riverine</td>
<td>connectivity</td>
</tr>
<tr>
<td>steelhead trout</td>
<td>wetlands</td>
<td>natural fire regimes</td>
</tr>
<tr>
<td>bull trout</td>
<td>alpine lakes</td>
<td>insects and forest pathogens</td>
</tr>
<tr>
<td>cutthroat trout</td>
<td>watershed uplands</td>
<td></td>
</tr>
<tr>
<td>trumpeter swan</td>
<td>pothole lakes</td>
<td></td>
</tr>
<tr>
<td>greater sage-grouse</td>
<td>alpine</td>
<td></td>
</tr>
<tr>
<td>burrowing owl</td>
<td>sub-alpine</td>
<td></td>
</tr>
<tr>
<td>pygmy rabbit</td>
<td>woodland</td>
<td></td>
</tr>
<tr>
<td>pronghorn antelope</td>
<td>sage shrub/grasslands</td>
<td></td>
</tr>
<tr>
<td>mule deer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>grizzly bear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wolverine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada lynx</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conservation Paradigms

Conservation Vocabulary
To maintain consistency in process and outcome, this Plan adopts a standard conservation lexicon (Salafsky et al. 2008) which serves to structure and synthesize our cross-scale approach. The following definitions will be referenced throughout the Plan:

Conservation project – Any set of actions to achieve defined conservation goals and objectives; described as a chain linking targets, direct threats, contributing factors, and conservation actions. (Synonym in Chambers et al. 2013 – Goal).

Focal conservation target – Species, community, ecosystem, or process. (syn. in Chambers et al. 2013 – Conservation Target).

Stress – Attribute of a conservation target’s ecology; a degraded condition or “symptom.” (Synonym in Chambers et al. 2013 – none).

Direct Threat – The proximate human activity causing degradation of target. Threat may be historical, current, or likely to occur in future. (Synonym in Chambers et al. 2013 – none).

Contributing Factor – Ultimate factors (usually social, economic, political, cultural) that enable direct threat; may be negative effect (commodity demand) or opportunity (planning goal). (Synonym in Chambers et al. 2013 – Landscape Stressors and Impacts).

Conservation Action – Intervention designed to reach an objective or goal; can be applied to contributing factor, direct threat, or to conservation target. (Synonym in Chambers et al. 2013 – Conservation Actions)

Adaptive Management
The Plan employs Strategic Habitat Conservation (SHC; USFWS 2008, Figure 3) a species population based adaptive management framework used by the US Fish and Wildlife Service. SHC provides important structure to our Conservation Target approach. Building on SHC, we outline an iterative, adaptive process to achieve a resource outcome. That outcome can be used as a subset of resource targets to measure progress toward a stated desired condition or goal, in this case, the goal of maintaining or enhancing high ecological integrity at a landscape scale as achieved through the four subgoals.

![Figure 3. Strategic Habitat Conservation model (USFWS 2008).]
SHC guidance provides basic questions that must be addressed in a science-based strategy. We modify those questions to guide the Science Plan as follows:

1. What is the trend in long-term average populations (or resources) and what direct threats and contributing factors are driving those trends? (Fig. 5, Steps 2b, 5)
2. What do we want to achieve (i.e., the desired condition) and how can we achieve it? (Fig. 5, Steps 4-7)
   2.1. What are our collective objectives and desired conditions for focal Conservation Target? (Fig. 5, Step 4)
   2.2. What factors are acutely limiting our ability to achieve the desired condition? (Fig. 5, Step 5)
   2.3. What conservation actions are available to overcome these limiting factors? (Fig. 5, Steps 2b, 6)
3. Where should we apply these conservation actions to effect the greatest change at the lowest possible total monetary and non-monetary costs to management agencies and societies? (Fig. 5, Steps 6, 9-10b)
4. How much of a particular type of conservation actions will be necessary to reach our stated desired condition? (Fig. 5, Steps 9-11)
5. What are the key uncertainties in the answers to questions 1-4 and what assumptions were made in developing the strategy? These will guide our research and monitoring activities (Fig. 5, Steps 7-8b).

Landscape Integrity
We define landscape integrity as the ability of ecological systems to support and maintain communities of organisms that exhibit composition, structure, and function (after Noss 1990) comparable to those of natural habitats within an area (after Parrish et al. 2003). We define a Landscape Integrity Index (LII, described more completely in section 2) as the product of threat intensity and threat geographic footprint. Landscapes have high integrity where relatively intact natural core areas have low levels of human modification; there are linkages connecting those cores; and focal disturbance processes (e.g., wildland fire), focal ecosystems or habitats (e.g., wetlands), and focal taxa (e.g., greater sage-grouse) exist. Because no single metric accurately measures all of these ecological conditions, the GNLCC will employ multiple, combined approaches to: measure the status of conservation targets, understand and describe desired conditions, and design and evaluate our collective progress towards meeting stated goals (See Section 2). Using these combined approaches, we will develop indices that (a) measure impact and (b) measure conservation success. We will also link specific management strategies to conservation targets and threats to assess whether GNLCC goals are being achieved. In Section 1, we address fine filter taxa, ecosystems, habitats, and ecosystem processes and describe how they collectively inform goal advancement. In Section 2, we address generalized concepts of ecological integrity.
SECTION 1: Conservation Targets

Stepwise Process

To address fine filter Conservation Targets the Science Plan describes a logical progression by which the community of GNLCC stakeholders collaboratively act on specific priorities. The Plan calls for defined science needs, applications, and estimates of conservation action effectiveness toward attaining collective landscape integrity. The stepwise process links a series of conservation paradigms and strategies, (e.g., SHC, vulnerability assessments, conservation triage) into a logical progression toward delivering conservation for specific Conservation Targets. The process is intended as a heuristic, rather than a recipe, to guide partners toward achieving informed, effective action for specific targets; elements of the process may vary depending on the target and identified need. Elements of the process are already in place or underway for many targets. The Plan recognizes and embraces those efforts and seeks to ‘plug in’ existing plans and actions to develop holistic and consistent conservation delivery for all targets and employ the quantitative outcomes of that delivery as metrics to gauge progress toward shared landscape outcomes (see Section 2).

Figure 4: Stepwise process for directly addressing specific priority GNLCC Conservation Targets. This process includes assessing science needs, developing applications, and estimating conservation action effectiveness for each target while delivering data, models, and conservation planning to support toward attainment of collective landscape integrity objectives. Each step is addressed in detail below. The red flags represent steps where science needs are identified. In practice the specific needs will vary with the target being addressed.
We selected three GNLCC Conservation Targets – grizzly bear, wetlands, and fire regime – as proofs-of-concept to demonstrate the stepwise process. The targets selected represent the three target types: species, habitats and ecosystems, and ecosystem processes (Table 1). For grizzly bear, we elaborate on each step in Figure 4. In the other examples, we focus on application of a subset of the Plan’s process steps.

To date, GNLCC partners have made varying levels of progress working on each of the focal targets. Thus, some examples include more information than others as is typical across the suite of conservation targets. This disparity is one of the challenges of bringing these together under a single, large-landscape framework. It also allows us to use a few examples to evaluate progress while using others to consider how we approach targets through hypothetical application.

In the sections that follow, we break down each of the 13 Science Plan process steps shown in Figure 4.

**Step 1a: Strategic Conservation Framework**

The GNLCC Strategic Conservation Framework (Chambers et al. 2013) spells out the first iteration of the GNLCC’s Conservation Goals and priority Targets (see GNLCC Conservation Vision, Goals & Targets, above, and [http://greatnorthernlcc.org/sites/default/files/documents/gnlcc_framework_final_small.pdf](http://greatnorthernlcc.org/sites/default/files/documents/gnlcc_framework_final_small.pdf)). The Framework was completed by GNLCC staff, reviewed by the Advisory Team, and approved by the Steering Committee in 2013. The Framework is adaptive and iterative and includes scheduled revision cycles and opportunity for interim adjustments including incorporation of emerging concerns by partners and fine-scale adjustments through Partner Forum processes (Step 1b).

**Step 1b: Refine Conservation Target Priorities**

A more quantitative approach to linking Targets to priorities will lead to two immediate outcomes: 1) recognition of specific science needs to inform this early planning process and, 2) identification of important conservation targets that will help inform conservation goal achievement but are currently missing or mis-prioritized. This represents a first iterative assessment in the stepwise process. It is an
ideal role for Partner Forums as partners become familiar with the GNLCC process and call out oversights in the Conservation Framework. An example of this step is the GNLCC Science Webinar Series (https://my.usgs.gov/confluence/display/GNLCC/GNLCC+Science+Webinar+Series+2013), when a suite of partners reflected and commented on the GNLCC prioritization process. Within the 5 years of this Plan four states will deliver revised State Wildlife Action Plans (Wyoming revised its plan in 2013) and the USFWS will implement a surrogate species approach. GNLCC will recognize and integrate emerging prioritization approaches (i.e., Brock and Atkins 2013); thus periodic review is an integral, iterative step.

**Step 2a: Map Conservation Targets to Goals**

Because the ultimate objective is to measure the GNLCC partnership’s progress toward meeting our shared Conservation Goals, we need to identify appropriate metrics. Suitable metrics must be logically linked and evaluated. This task will be led by Advisory Team specialists but requires the substantial local knowledge and discipline-specific expertise from Partner Forums. It is an important, necessary step for several reasons. First, conducting the process is a way to engage Partner Forum members – the recognized local experts with specific knowledge about which metrics contribute to high ecosystem integrity. Engaging Partner Forums builds capacity, expands the Cooperative, and guides responsiveness to on-the-ground questions and needs. Second, identifying and prioritizing (in an ecological relationship sense) informs us of useful metrics for the high level Goals. Third, it is an explicit first step linking fine-filter targets to coarser landscape-scale goals. Partners and partnerships address targets from unique perspective; Step 2b works to resolve perspective and align programs. Outcomes from this step are important inputs for steps 5, 7, and 9.

The first sub-step is drafting qualitative links among Conservation Targets and Goals (Table 2 is an example). In practice the process is iterative and adaptive to ongoing planning and process. Individual implementations may modify how these objectives are approached (i.e., modify steps) provided necessary outcomes are well-documented.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Intact Blocks</td>
<td>Greater-sage grouse</td>
<td>Grizzly bear</td>
<td>Salmon</td>
<td>Wolverine</td>
</tr>
<tr>
<td></td>
<td>Pygmy rabbit</td>
<td>Wolverine</td>
<td>Rivers</td>
<td>Canada lynx</td>
</tr>
<tr>
<td></td>
<td>Sage shrub/grasslands</td>
<td>Canada lynx</td>
<td>Sage shrub/grasslands</td>
<td>Salmon</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Woodland</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sub alpine</td>
</tr>
<tr>
<td>Connectivity / Permeability</td>
<td>Pronghorn</td>
<td>Whitebark pine</td>
<td>Salmon</td>
<td>Whitebark pine</td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td>Bull trout</td>
<td>Steelhead</td>
<td>Salmon</td>
</tr>
<tr>
<td></td>
<td>Sage shrub/grasslands</td>
<td>Cutthroat trout</td>
<td>Mule deer</td>
<td>Steelhead</td>
</tr>
<tr>
<td></td>
<td>Riparian Connectivity</td>
<td>Trumpeter swan</td>
<td>Riparian</td>
<td>Mule deer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mule Deer</td>
<td>Riparian</td>
<td>Riparian</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grizzly bear</td>
<td>River</td>
<td>Alpine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wolverine</td>
<td>Aquatic connectivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Canada lynx</td>
<td>Connectivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. A first approximation linking Conservation Targets to Goals. The Science Plan calls for subject matter expertise to augment this matrix. Ecosystem process targets crosscut all ecotypes.

Step 2b: Scope Conservation Threats and Actions

At this step the focus shifts to specific Targets. Scoping conservation threats and conservation actions is a critical step as described by the Open Standards for the Practice of Conservation approach (http://www.conservationmeasures.org/; Salafsky et al. 2008). Because our traditional conservation practices have been multi-disciplinary, respective disciplines have developed their own terminology. A more integrative, inter-disciplinary approach calls for a standard lexicon (Salafsky et al. 2008) as a common language. The lexicon attempts to define the ‘universe’ of threats and conservation actions. Step 2b of the Science Plan standardizes each conservation target to the lexicon as a means to consistently feed a Conceptual Model (Step 3) for each Conservation Target. We rely on the expertise exemplified by the Partner Forums to specify threats and actions in a structured discussion framed by the Salafsky et al. (2008) lexicon.

Adopting the Salafsky et al. (2008) lexicon causes no loss of resolution from the Strategic Conservation Framework. For example, the Framework identifies 3 landscape stressors: Climate Change, Invasive Species, and Land Use Change (Chambers et al. 2013, page 7). These impact-scales are termed contributing factors (defined as: the ultimate factors, usually social, economic, political, institutional, or cultural, that enable or otherwise add to the occurrence or persistence of proximate direct threats) by Salafsky et al. (2008). To a degree, differences in terminology are semantic: GNLCC Steering Committee members agree these are the primary, high-level concerns in the geography. Discretely identifying them and other conservation threats and response actions serves to ensure the partnership is thinking and speaking in common terms.

Salafsky et al. (2008) describes a nested classification with 3 levels of threat. The highest (Table 3, left column) is coarse and describes general human activities; the second level (the body of Table 3) indicates finer – though still fairly general – activities that may impact a specific Conservation Target. Consider that not all threats impact all Conservation Targets (as indicated by blank cells in the Table 3) and this second level is worthy of additional discussion. However, the important determinations are ‘3rd level’ threats which identify specific threats or conditions that impact the Conservation Target. For example, Table 3 suggests (4) Transportation and Service Corridors – (4a) Roads and Railroads is a threat for grizzly bear through land use change. The specific, priority 3rd level threats might be collisions, increased human-bear interactions, and/or behavioral avoidance. Management responses to specific,
high priority threats may differ. Thus identification to this specificity informs conceptual modeling and subsequent steps leading to refining or initiating appropriate conservation action.

Through a structured discussion with Partner Forum members, the objectives are to: (1) identify those 3rd level threats that either occur at landscape scales or, by virtue of their pervasiveness, express across large geographies and (2) focus on the threats of highest priority. Using the grizzly bear example, partners recognize that residential and commercial development/housing and urban areas (1.1) are a potential threat to bear survival. Local managers and bear specialists likely agree the threat is specific to ex-urban development (i.e., 3rd level threat 1.1.1). Similarly, all-terrain vehicle use represents a specific threat of human intrusions and disturbance/recreational activities (6.1). Deliberations among Partner Forum participants can tease out these specifics to help the managers and scientists focus needed science and management action.

### Goal 1: Maintain Large Intact Blocks

<table>
<thead>
<tr>
<th>Conservation Targets</th>
<th>Grizzly Bear</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contributing Factor:</strong></td>
<td>Climate Change</td>
<td>Land Use Change</td>
</tr>
<tr>
<td><strong>THREATS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Residential and Commercial Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Housing and Urban Areas</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.2 Commercial and Industrial Areas</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1.3 Tourism and Recreation Areas</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>2. Agriculture and Aquiculture</td>
<td>2.1 Annual and perennial nontimber crops</td>
<td>X</td>
</tr>
<tr>
<td>2.3 Livestock farming and ranching</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Energy production and mining</td>
<td>3.1 Oil and gas drilling</td>
<td></td>
</tr>
<tr>
<td>3.3 Renewable energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Transportation and Service Corridors</td>
<td>4.1 Roads and railroads</td>
<td>X</td>
</tr>
<tr>
<td>4.2 Utility and service lines</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>5. Biological Resource Use</td>
<td>5.1 Hunting and Collecting Terrestrial Mammals</td>
<td></td>
</tr>
<tr>
<td>5.3 Logging and wood harvesting</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 3. Hypothetical example for identifying coarse- and mid-level Conservation Threats [as classified by Salafsky et al. (2008)] that impact grizzly bear and bear habitat in terms of maintaining large blocks of intact habitat. First and second level threats (Salafsky et al. 2008) listed in columns 1 & 2. GNLCC conservation targets subsetted by contributing factors (Stressors) listed in columns 3-7). ‘X’ indicates where a threat intersects a target/stressor. Only threats relevant to grizzly bear listed here.

Similarly, we identify conservation actions (Table 4). Again the Level 1 (left column) and Level 2 (Table 4, column 2) Actions are coarse and (probably) easily identified by GNLCC staff and the AT. It is the Level 3, fine resolution, actions that we strive to capture for Conservation Targets within and beyond the Great Northern. The grizzly bear example (Table 4) is well documented. The 3rd level following Action (3) Species Management – (3.2) Species Recovery entailed drafting a Recovery Plan (USFWS 2013a). Most GNLCC conservation targets have not reached this level of resolution. Similar to Threats, which we prioritize through input from Partner Forums, we strive to assemble a “Managers Toolbox” of ongoing actions and innovative approaches that are either currently being tested or in a conceptual stage. Thinking through and documenting actions will give us the management elements we need to build Conceptual Models.
Goal 1: Maintain Large Intact Blocks

<table>
<thead>
<tr>
<th>Conservation Targets</th>
<th>Grizzly Bear</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contributing Factor:</strong></td>
<td>Climate Change</td>
<td>Land Use Change</td>
</tr>
<tr>
<td><strong>ACTIONS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land/water protection</td>
<td>1.1 site/area protection</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>1.2 resource and habitat protection</td>
<td>X</td>
</tr>
<tr>
<td>2. Land/water management</td>
<td>2.1 site/area management</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>2.2 invasive/problem species control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3 habitat and natural process restoration</td>
<td>X</td>
</tr>
<tr>
<td>3. Species management</td>
<td>3.1 species management</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>3.2 species recovery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3 species reintroduction</td>
<td>X</td>
</tr>
<tr>
<td>4. Education and awareness</td>
<td>4.1 formal education</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>4.2 training</td>
<td>X</td>
</tr>
<tr>
<td>5. Law and policy</td>
<td>5.1 legislation</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>5.2 policies and regulations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.3 private sector standards and codes</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>5.4 compliance and enforcement</td>
<td>X</td>
</tr>
<tr>
<td>6. Livelihood, economic and other incentives</td>
<td>6.1 linked enterprises and livelihood alternatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.3 market forces</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 4. Hypothetical example for identifying coarse- and mid-level Conservation Actions [as classified by Salafsky et al. (2008)] for grizzly bear and bear habitat specifically for the Goal of maintaining large blocks of intact habitat. In practice, actions need to be directly linked to stressors/threats from Table 3 by experts best facilitated through a Partner Forum.

<table>
<thead>
<tr>
<th>6.4 conservation payments</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. External capacity building</td>
<td>7.1 institutional and civil society development</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7.2 alliance and partnership development</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7.3 conservation finance</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 6. Steps 3 - 6 of GNLCC Science Plan Stepwise Process. SC = Steering Committee; AT = Advisory Team; Sci = Science Community; PF = Partner Forums; Mgt = Management Agencies; M&E = Monitoring and Evaluation specialists. The red flags represent steps where science needs are identified. In practice the specific needs will vary with the target being addressed.
Step 3: Conceptual Models

Once partners align regarding concepts, terms, threats, and actions, we initiate adaptive management as applied to conservation delivery. The next step is to develop common understanding of each focal Target’s ecological relationships. We do this by building conceptual models (e.g., IAFWA 2011) that may start off fairly simple (Fig. 7) but can get rather complex (Fig. 8). The Science Plan calls for a basic conceptual model for each Conservation Target. Conceptual models inform subsequent steps of Setting Quantifiable Objectives (Step 4, Fig. 6), Identifying Limiting Factors (Step 5), and Calculating Action Contributions (Step 6) for each Conservation Target but also provide the synthetic benefit of understanding how and when Conservation Threats, Limiting Factors and Conservation Actions align among two or more Conservation Targets. This alignment informs Step 6 when we calculate the relative contribution of Conservation Actions (see below). Understanding the potential for multiple benefits of a given action adjusts the equation for that action and informs which actions may provide the greatest benefit. A conceptual model can also be a useful tool during collaborative planning, as it helps make participants’ assumptions about the system and key drivers transparent. Examples provided below give a sense of the conceptual modeling process. Some models (Fig. 8) are developed and can be resolved with the stepwise process. Newly developed models will integrate with the process.

![Example of Rocky Mountain Partner Forum Conservation Relationships](image)

**Figure 7.** Example conceptual model of conservation relationships for grizzly bear (Chambers et al. 2013). This example incorporates the suite of priority conservation targets identified by the GNLCC. It shows, through simple relationship arrows, an example of the complexity of the inter-relationships among scaled conservation targets.
Conceptual models can benefit from a suite of conservation-themed approaches and highly useful software. Examples include:

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Management for Conservation</td>
<td>Miradi</td>
</tr>
<tr>
<td>Vulnerability Assessments</td>
<td>CCVI</td>
</tr>
</tbody>
</table>
Step 4: Set Quantifiable Objectives

Here we begin transition from a conceptual to a quantitative approach by setting objectives and devising conservation strategies for focal Conservation Targets, which is a critical element of SHC (FWS 2008). Setting quantifiable objectives is a critical task for the GNLCC and partner-driven conservation in general. Many social, political, economic, and biological factors influence how objectives are set; therefore, the GNLCC Steering Committee is critical to promote agreed-upon objectives. Our primary focus here is the biological factors. Again, the first step is to identify if quantifiable objectives have been developed either through recovery planning (i.e., USFWS 2013a) or by existing, well-supported partnerships (i.e., Rich et al. 2004). For expediency, GNLCC will support such existing objectives recognizing that some may not have high rigor. Revisits might include adjustments. GNLCC-identified Targets include ecosystems/habitats and ecological processes in addition to taxa therefore we need to develop strategies for non-taxa targets.

Taxon-based objectives

Population (taxa) objectives are more useful if they are comprised of a desired abundance (i.e., population size) and a performance indicator (i.e., recruitment) since abundance objectives enable estimation of how much habitat to maintain and performance measures (typically a vital rate such as adult mortality or fecundity) describe the desired effect on the population (FWS 2008). In some cases these may not be practical from a management and monitoring standpoint. In that case, we may elect to use a coarser indicator (i.e., patch size, temporal trend, etc.). Moreover, the performance indicator objectives often relate back to response to habitat or population management strategies. Thus, they represent assumptions that can help us develop Steps 7a-c, (Figure 14).

Grizzly Bear Example

Two of the four extant populations of grizzly bear in the US portion of the GNLCC have established, agreed upon quantifiable objectives established for recovery planning (USFWS 2013a, 2013b). In line with SHC guidance and because grizzly bears are a difficult species to monitor, multiple criteria are identified to provide sufficient information upon which to base management decisions. In general, the conservation strategies set both demographic goals, which may be difficult to quantify, and demographic standards, which are objective and measurable criteria of population status and health (USFWS 2013b). The goal of the agencies implementing grizzly bear conservation strategies is to maintain genetically diverse bear populations (USFWS 2013a) with a focus on maintaining minimum thresholds (population size, mortality rates) in recognition of social and political tolerance and management of human interaction.

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Demographic Goals</th>
<th>Demographic Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># Individuals</td>
<td>Females with cubs</td>
</tr>
<tr>
<td>Northern</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Habitat and Ecosystem-based objectives (wetlands)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The conservation literature has extensive treatment on developing population (taxa)-based objectives but less emphasis on objective setting for coarser conservation targets. Indeed, SHC was designed with a taxon-centric approach. However, we recognize that SHC was developed by FWS and not all GNLCC partners have adopted it. The GNLCC has several non-taxa conservation targets that certainly merit inclusion in the list of targets, and the SHC philosophy can still apply to these targets. In this plan, we use wetlands as a demonstration of how we can apply SHC to a habitat.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Generally, SHC is thought of as a four-step process, where a species is the conservation target as well as the subject of the biological planning phase, and habitats are the subject of the conservation design phase. Once objectives are set for a species, then habitats can be designed to meet those objectives. Conservation delivery and monitoring follow. Here, wetlands (a habitat type) are targets in and of themselves, so the division between biological planning and conservation design is less clear. Most of the needs regarding landscape-level wetland conservation fit into this planning/design phase of SHC.

**Step 5: Identify Limiting Factors**

Factors that limit populations below objective levels are typically identified in National, State, and/or Provincial Recovery Plans for species listed as endangered or threatened. Limiting factors tend to be lacking for species that have not been specifically targets by such planning and, because we lack quantifiable objectives for many targets, critical limits to achieving those objectives are also lacking. Further, in most instances we have not defined potential future limiting factors with any rigor.

Using grizzly bear as the example Conservation Target, GNLCC staff and the AT translate the conservation threats developed for Conceptual Models and lead the Partner Forums through a process to elaborate on the threats. As we drill down we identify the highest threats (identified in Step 2b) that are limiting achievement of target objectives (i.e., population abundance and vital rate). This serves 3 purposes. First, it sets the parameter inputs for subsequent modeling (Step 7). Second it initiates our identification of uncertainty – this informs modeling and starts to populate Step 7a (Identify Uncertainties) as a key deliverable for the Science Plan. Third, it also begins the structured approach to Step 6 as we consider ongoing management actions to evaluate objective attainment. An important institutional element is continuing Partner Forums engagement. We call on the experts to help us drill down for each one of these Conservation Targets under the GNLCC Goal. In concept it opens the door to LCC participation and helps folks recognize their value beyond jurisdictional boundaries. If done correctly (i.e., using tools like Meeting Sphere) it could be dynamic, informative and draw the experts into a community that defines the Partner Forums.
Step 6: Estimate Action Contributions

Here the Plan invokes the conservation triage approach of Botrill et al. (2008) as a way to estimate the relative costs and benefits of conservation actions identified in Step 2b and refined by setting objectives (Step 4) and identifying limiting factors (Step 5). Botrill et al. (2008) presents a simple, scalable formula for comparing conservation actions (defined here as Relative Efficiency of management actions):

\[
\text{Relative Efficiency} = \frac{p[\text{success}] \times \text{value} \times \text{benefit}}{\text{cost}}
\]

where:
- \( p[\text{success}] \) = probability of success
- Value = distinctiveness of the conservation target
- Benefit = net increase toward quantifiable objective, and
- Cost = of the action in dollars

Much of our conservation action across the landscape is initiated with minimal understanding of the relative value of each action’s contribution to our shared objective. Part of this poor understanding is our lack of shared, quantified objectives. Thus, these 3 steps (setting objectives, identifying limiting factors, and estimating the effect of conservation action) are iterative with subsequent modeling exercises. Approaches to this step will likely be more qualitative than quantitative, at least initially, as GNLCC partners (via Forum collaboration) integrate conservation threats and actions (Step 2b), quantifiable objectives and actions (Step 4), and limiting factors (Step 5). Estimating the relative efficiencies of our collective current conservation actions is the final step of ‘what we know’. This conservation triage approach sets the stage for ‘what do we want to know’ (Step 7, Quantitative Modeling) and initiates and informs the ‘what should we do’ question (Steps 8 – 9) by attempting to quantify how current actions are affecting targets. Applying triage incorporates societal, ecological, and economic value and the predictive element of estimating how efficiently a given action, or suite of actions, will move us toward our objectives.
Figure 9. Steps 7 - 8 of GNLCC Science Plan Stepwise Process. SC = Steering Committee; AT = Advisory Team; Sci = Science Community; PF = Partner Forums; Mgt = Management Agencies; M&E = Monitoring and Evaluation specialists. The red flags represent steps where science needs are identified. In practice the specific needs will vary with the target being addressed.

Step 7: Quantitative Modeling

Elements are now in place to advance conservation in a defensible, transparent, analytical process. We can now develop predictive models as a means to understand and quantify uncertainty (for Step 8a) and prioritize and evaluate management actions in terms of their relative benefit to achieving objectives (Step 9). Step 7 directly engages the GNLCC Science Community, evoking a broad range of analytical capabilities in response to needs identified by prior steps. The diversity of potential modeling approaches are narrowed by the structured, stepwise process and supported by the GNLCC Strategic Science Program. Model predictions might stop at concluding an interim condition (i.e., min canopy cover or % edge for a single target) that inform that next step of designing a management strategy or may more broadly encompass multiple stressors and targets. The obvious overarching question is: how can we achieve objectives through cost-effective conservation actions (e.g., Step 6)?

Models are a means of organizing science to aid in understanding:

• the relationship between populations (Step 4) and limiting factors (Step 5)
• how a system functions by expressing real relationships in simplified terms

As a general guide, application of models to spatial data should target specific management treatments (Step 6) that can remediate limiting factor(s). Models should be stated in explicit and measurable terms and systematically applied so the products of applying them are useful for communicating the scientific foundation for actions, decisions, and recommendations, thereby yielding greater transparency and credibility. Model predictions must be expressed in the same terms as quantitative objectives to (1) estimate the amount of management necessary to attain those objectives; and (2) facilitate estimates of project, program, or agency accomplishments and progress toward achieving those objectives. The process of explicitly stating a model enables critical evaluation of uncertainties and assumptions, determines confidence in the predictions (leading to Step 9), and targets information needs (leading to Step 8a).

Modeling will also seeks to project future condition (population level, vital rate, extent or magnitude of disturbance, etc.) in response to changing land use patterns, climate, invasive species, or other Contributing factor (stressor). The step calls upon specialists in the Science Community (i.e., Climate Science Centers, agency and NGO research divisions, academia) to provide data, expertise, and novel approaches to inform management action under a range of future conditions.

Quality data and data management are hallmarks of useful model outputs. GNLCC designed the highly interoperable Landscape Conservation Management and Analysis Portal (LC MAP, Appendix 1) to facilitate data discovery, sharing and documentation. In addition to raw data, LC MAP delivers access to
a vast array of data analysis and modeling tools and documentation and hosts the forum to facilitate collaborative, partner-driven science.

**Step 8a: Identifying Needs and Uncertainty**

One outcome of the stepwise process (modeling exercise and prior steps) is a developing picture of key information gaps (identified by red flags) and uncertainty (outcome of modeling). These outcomes encompass a large proportion of GNLCC science needs (but see steps 10a-b) and serve as primary guidance for GNLCC’s Annual Workplan.

Steps 7, 8a, and 8b represent another potential iteration because objectives and outcomes of the steps are finely linked. Modeling outcomes identify uncertainty (reducible, irreducible, etc) and generate additional research questions, and newly collected field data augments analysis and modeling. Science needs prioritization necessitates an understanding of existing and ongoing science.

Step 8a prioritizes which of those science needs (for example, Table 7) are most critical and defines how to most efficiently acquire the information. It calls for regular committed efforts by the GNLCC Staff and Advisory Team, as exemplified by annual Funding Guidance (http://greatnorthernlcc.org/supported-science-projects) and science funding process. The Staff and Advisory Team apply input from their respective organizations and the Partner Forums to develop annual work plans and apply resources to drive priority science (see Section 3).

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>1b. Refine Conservation Target Priorities</td>
<td>Re-assess priorities based on partner input &amp; programs i.e., Surrogate Species, SWAP revisions, etc.</td>
</tr>
<tr>
<td>3. Conceptual Modeling</td>
<td>Conceptual models describing ecological roles, threats and action opportunities</td>
</tr>
<tr>
<td>4. Set Quantifiable Objectives</td>
<td>Standards and strategies for setting quantifiable objectives across range of Targets</td>
</tr>
<tr>
<td>5. Identify Limiting Factors</td>
<td>Better (more quantitative &amp; analytical) understanding of the factors limiting our objective achievement</td>
</tr>
<tr>
<td>7 Quantitative Modeling</td>
<td>Reliable models for many Targets and synthetic models informing on multiple targets</td>
</tr>
</tbody>
</table>

Table 7. Example summary of science needs expressed through the stepwise process.

**Step 8b: Conduct Science**

Nine (plus) iterative steps and we’ve only made it one-quarter the way around the SHC framework. But it takes this kind of patient, stepwise and iterative process to ensure our next steps are well informed – because they become more expensive and potentially difficult to reverse. They also ensure that our research investment is highly directed to ensure we pursue information to concisely inform management action. To this point, at least 6 of the 9 steps have specifically identified science needs.

Implied in Step 8b is effective delivery and dissemination of science products. The GNLCC Communication Plan (http://greatnorthernlcc.org/document/communications-and-outreach-strategy-2012-14-draft), Data Standard (http://greatnorthernlcc.org/sites/default/files/documents/gnlcc_datamgt_sharing_policy.pdf), and LC
MAP data portal (http://greatnorthernlcc.org/lcmap) ensure efficient, transparent delivery of priority science outcomes.

Figure 15. Steps 9 and 10 of GNLCC Science Plan Stepwise Process. SC = Steering Committee; AT = Advisory Team; Sci = Science Community; PF = Partner Forums; Mgt = Management Agencies; M&E = Monitoring and Evaluation specialists.

**Step 9: Determine Actions**

The second outcome of the modeling exercise is the suite of conservation actions that are cost effective and predicted to be ecologically effective. The result being an improved Manager’s Toolbox containing the vetted suite of actions we will use to advance conservation and attain objectives in the GNLCC landscape. Tools in the improved toolbox are critical components to design a strategy through Landscape Conservation Design (Step 11; citation). We then transition into the conservation design and delivery phase using the science to guide us on what we should do to achieve our Conservation Goals and quantifiable objectives.

**Step 10a: Data Synthesis of Legacy Conservation Actions**

Several prior steps (2b, 6) have addressed the legacy of management actions in terms of understanding what has been done to improve the trend of priority conservation targets. However, we’ve yet to address and compile the results of on-the-ground actions. How much have we collectively changed the conservation estate and where have those actions occurred? To understand this we need to identify and compile data from multiple sources to document the cumulative status of past and current conservation actions. Several such data integration efforts are underway (i.e., Protected Areas Database, National Conservation Easement Database, Land Treatment Digital Library) and interoperability tools (i.e., LC MAP (Appendix 1), Data Basin) are available to facilitate additional data discovery and synthesis. Data is expensive and getting more so. The Science Plan directs GNLCC
partners to maximize prior investments by ensuring legacy data is available to inform future Conservation Design.

Step 10b: Retrospective Analyses

Data gathered and archived in Step 10a will be used to understand their contribution to GNLCC conservation targets. Part of this challenge is technical and will require advanced information management practices to organize data in a way that gives a comprehensive view of the conservation estate and allows a retrospective approach to focusing our current conservation need.

Step 11: Landscape Conservation Design

Conservation design involves combining geospatial data with biological information and models to create tools such as maps that evaluate the potential of every acre of habitat to support a population, community, or ecosystem process. Using these tools, we can estimate the current habitat-acre capability — and what it needs to be — to achieve our quantifiable objectives (Step 4) or outcomes. The tool guides collaborative decisions about the kind, quantity, and configuration of habitat needed, what activities to undertake and where.

Figure 16. Steps 11 – 13 of GNLCC Science Plan Stepwise Process. SC = Steering Committee; AT = Advisory Team; Sci = Science Community; PF = Partner Forums; Mgt = Management Agencies; M&E = Monitoring and Evaluation specialists.
Landscape Conservation Design (LCD) is a partnership-driven, science-based, technologically-advanced, holistic method to assess current and anticipated future conditions (biological and socioeconomic), offers a spatially-explicit depiction of a desired future condition, and helps inform management prescriptions for achieving those conditions. LCD is both a process and a product where the process is iterative and adaptive and the product results in a desired landscape condition as expressed through the integration of quantifiable biological, cultural, and physical resource objectives, assesses the current and projected landscape condition, analyzes the landscape’s ability to achieve desired resource objectives under a variety of temporal and spatial scenarios, and identifies a variety of management strategies to achieve those objectives. LCD contains elements of both planning and design. (USFWS 2013c, ALI 2014, LCC Network, in prep).

In creating an LCD, each partner identifies the conservation features within their purview (such as the USFWS’ surrogate species and state SWAP priorities, e.g., Steps 1a & 1b). Features are used to define the geographic extent of the LCD, develop quantifiable objectives (Step 4) within that landscape, identify limiting factors (Step 5), conduct gap and population analyses, and model future resource relationships (Step 7). The partners then identify management, restoration, and protection strategies (Step 9) that can be implemented (Step 12) to address the identified resource concerns, attain desired future conditions, sustain ecosystem function, and achieve the missions, mandates, and goals of each partner organization. Upon completion of the LCD, partners implement the strategies applicable to their organization. Normally, this would require each individual partner to conduct more detailed, site-specific planning prior to implementation. Over time, partners monitor and evaluate the effectiveness (Step 12) of their individual and collective implementation and reconvene (Step 13) to assess and revise the LCD on a periodic basis.

**Step 12: Act, Evaluate, Monitor**

This Science Plan defines the process for partners to identify science needs for priority conservation targets and develop the roadmap to collaboratively design a landscape with high ecological integrity using the best available science. At best, the goal of this Plan moves the GNLCC to the midway point of an adaptive management cycle (Fig. 17). The next step (labeled Program Delivery in Fig. 17) is to apply conservation through a variety of on-the-ground actions, environmental education and awareness and, where necessary, regulation and enforcement. This important step is largely outside the scope of the Science Plan except for two important concepts: the design of conservation actions using an experimental approach and considerations and integration of sound monitoring protocols into conservation activities so actions themselves deliver reliable, measurable information to inform subsequent cycles.
Figure 17. The Strategic Habitat Conservation version of Adaptive Management. The GNLCC Science Plan focuses on Biological Planning, Conservation Design, Assumption-driven Research, and Outcome-based Monitoring – all primarily intended to provide high quality information to coordinate management action.

**Step 13: Repeat**

Led by the GNLCC Steering Committee and Advisory Team, the process repeats in timeframes built around improved knowledge, technology, and conservation need.
SECTION 2: Landscape Goals

Landscape conservation is a challenge that spans numerous scales and axes: spatial, temporal, ecological, jurisdictional, and socio-political. Preceding conservation paradigms (e.g., FWS 2008) have successfully defined useful frameworks within a specified spatial scale. However, an LCC’s challenge is to understand and address conservation objectives concurrently at many different scales. To measure progress toward shared, landscape-level goals, the Cooperative must accurately account for and quantify conservation actions aimed at specific targets and evaluate their contribution to advance landscape-scale subgoals and understand how subgoal objectives roll up to achieve our vision of landscapes with high ecological integrity.

Advancement toward goals requires agreement on desired conditions. For individual conservation targets, we look to quantifiable objectives. However, clearly articulated quantifiable objectives are not as easy to define at broad ecological scales. For example, Goal 1 (maintaining large intact landscapes of naturally functioning terrestrial and aquatic community assemblages) calls for desired condition of community elements (community assemblages) and geospatial considerations (large intact landscapes) of multiple processes (i.e., naturally functioning). Section 1 describes how to approach fine-scale objectives but setting objectives for landscape elements (i.e., how large? what defines “intact”? ) present different challenges. Landscape Conservation Design (Section 1, Step 11) helps us collectively address stated desired conditions by linking target-scale approaches to specific geographies. There may be some instances where subgoal desired conditions are directly quantifiable, but in other cases, the GNLCC will develop an iterative index, the Landscape Integrity Index (LII), using spatial modeling to track and refine existing condition relative to qualitative expression of desired condition.

GNLCC has identified climate change, land use change, and invasive species as priority landscape stressors (Chambers et al. 2013). Achieving our collective vision (through subgoals and conservation targets) requires understanding effects of stressor status and trend on conservation targets. Data describing stressors vary (e.g., in their resolution and extensiveness of information) but in general are more available for climate change and land use and largely lacking for invasive species. However, our immediate, proximate conservation actions typically focus on land-use change and invasive species. GNLCC will primarily focus a landscape approach on land use change, because it is where our knowledge (data) and opportunity (for conservation actions) converge.

The four GNLCC goals embody the definition, maintenance, and improvement of landscape integrity. We characterize landscape integrity as the inverse of human modification (i.e., the ‘H’ index of Theobald 2013) and as a subset of ecological integrity as defined by Noss (1990) and Parrish et al. (2003). Areas of high ecological integrity have unfragmented natural landscapes, highly functioning biotic and abiotic processes and native biotic components within a natural range of variability, and few impacts from invasive species. In other words, they have the composition, structure, and function of less-altered landscapes (Noss 1990). These areas are resilient to change, often contain large intact blocks of land, and sustain healthy and connected populations of fish, wildlife, and plants. Additional background and justification are in Appendix D.

Increasingly, natural resource agencies and organizations are monitoring and evaluating the status and condition of their lands and waters by measuring some element of ecological integrity of landscapes (e.g., Canada National Parks Act (2000), Lindenmayer et al. 2000, Fancy et al. 2007, Borja et al. 2008, US Forest Service Forest Planning Rule 2012, National Wildlife Refuge System Improvement Act of 1997).
For example, some measure of landscape integrity is typically used when assessing the current status and likely future condition of coarse-filter conservation elements that are central to the Bureau of Land Management’s (BLM) Rapid Ecoregional Assessments (REAs; http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html). Additional examples include the National Park Service’s Natural Resource Condition Assessments (http://www.nature.nps.gov/water/nrca/), the Western Governors’ Association (WGA) initiative on Wildlife Corridors and Crucial Habitat (www.westgov.org/initiatives/wildlife), and the US Department of the Interior’s Landscape Conservation Cooperatives (LCCs; www.lccnetwork.org).

**Landscape Integrity Index**

The GNLCC will develop a Landscape Integrity Index (LII, Fig. 18) for the Great Northern region to serve as a 2014 baseline and provide the opportunity to monitor movement toward (or away from) desired condition from this baseline. The LII estimates landscape-scale threats to Conservation Targets as described by Salafsky et al. (2008) and modeled by Theobald (2013). Briefly, the LII is used to characterize every pixel on the landscape in terms of its relative ecological integrity on a scale of 0 – 1. Evaluating collections of pixels within ecological (i.e., hydrologic units, vegetation communities), ecotypic (i.e., Partner Forums, ecoregions), or socio-political (i.e., states) units will provide characterizations of landscape integrity for those units. The LII approach promotes iteration in both spatial and temporal contexts and approximates a universally relevant condition estimate that all GNLCC partners can identify with. This first iteration will allow the Cooperative to track changes in extent and estimated intensity for each land use over time and identify important data gaps that are specifically identified at finer scales via the process described above (Section 1). The GNLCC-wide Landscape Integrity map will inform annual workplans in terms of prioritizing data acquisition and focus the partnership on particularly sensitive or threatened locales and conservation targets that are in need of attention and ripe for conservation action. Subsequent iterations, which will occur as supplement to each 5 year Science Plan will use updated spatial data generated through GNLCC workplans and by partners developing CHAT, REA, and other spatial data improvements. Additional data layers such as the Protected Areas Database (USGS, http://gapanalysis.usgs.gov/padus/; Cons. Bio. Inst., http://consbio.org/products/projects/pad-us-cbi-edition), Conservation Easements Database (http://conservationeasement.us/), Land Treatment Digital Library (USGS, https://ltdl.wr.usgs.gov/) and others will serve as initial representations of Conservation Actions (sensu Salafsky et al. 2008). These data will be overlaid with the LII to inform partners regarding historical and ongoing conservation activities. Appendix D and Theobald (2013) describe the technical approach to developing the LII; Fig. 18 describes the basic process of identifying landscape threats, overlaying source data, estimating relative univariate intensity, and synthesizing into a spatial LII.
Figure 18. The Landscape Integrity Index will identify priority conservation threats in GNLCC, refine spatial data describing those threats and apply target-specific weights to characterize the ecological integrity over broad extents. The process is collaborative, participatory and iterative. It requires contributions from all partners and delivers a consistent estimate of landscape condition.

Defining Metrics and Geographies for Landscape Integrity
Quantifying the impacts of land use, invasive species, and climate change and our collective conservation response to these stressors can be considered “Conservation Potential.” In addition, select focal ecological process, ecosystems or habitats, and taxa can be tracked to provide detail to Landscape Integrity measures and to determine how collective management actions are contributing to conserving specific resources. A concise understanding of partner interests describes how entities co-function.
<table>
<thead>
<tr>
<th>Type of CT</th>
<th>Conservation Target/Metric</th>
<th>Scale/Area</th>
<th>Objective set by:</th>
<th>Monitored by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stressor</td>
<td>Land Use/Invasives</td>
<td>GNLCC</td>
<td>Theobald (2013) Baseline</td>
<td>GNLCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land Use/Invasives</td>
<td>Sage Steppe Forum</td>
<td>Rocky Mountain Forum</td>
<td>Columbia Basin F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Columbia Platteu</td>
<td>High Divide</td>
<td>CoC</td>
</tr>
<tr>
<td>AIS</td>
<td></td>
<td></td>
<td></td>
<td>Potential GNLCC AT Project</td>
</tr>
<tr>
<td>Climate Change</td>
<td>Past and projected climate change described by area; impacts assessed per Conservation Target</td>
<td>Hostetler, CIG, etc</td>
<td>Climate Science Centers</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ecosystem Processes</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity</td>
<td>Baseline CHAT model</td>
<td>WGA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildland Fire</td>
<td>Baseline tracked by NIFC</td>
<td>NIFC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insect and Forest Pathogens</td>
<td>Baseline tracked by USFS</td>
<td>USFS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat or Ecosystem</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetlands</td>
<td>IMJV</td>
<td>GRYN NPS I&amp;M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverine</td>
<td>ALI/WA Conn</td>
<td>ALI/WA Conn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sage Steppe</td>
<td>WLCI/ALI/WA Conn</td>
<td>WLCI/ALI/WA Conn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whitebark Pine</td>
<td>Baseline tracked by NPS I&amp;M; USGS; USFS</td>
<td>Baseline tracked by NPS I&amp;M; USGS; USFS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grizzly Bear</td>
<td>IGBC</td>
<td>IGBC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sage-Grouse</td>
<td></td>
<td>???</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutthroat Trout</td>
<td></td>
<td>???</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mule Deer</td>
<td></td>
<td>???</td>
<td>WA Conn</td>
<td>WA Conn</td>
</tr>
<tr>
<td>Wolverine</td>
<td></td>
<td>???</td>
<td></td>
<td>USFS; WCS</td>
</tr>
<tr>
<td>Sockeye Salmon</td>
<td></td>
<td>???</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bull Trout</td>
<td></td>
<td></td>
<td>USFWS</td>
<td>USFWS</td>
</tr>
</tbody>
</table>

Table 8. Proposed matrix of Landscape Integrity Indicators. Colored cells indicate where the indicator would be tracked. Yellow is an ecosystem process; Green is a habitat or ecosystem; Red are taxa; Blue are stressors. For reporting, this type of table could serve as a template. Partners could insert numbers and/or arrows to indicate trend. WY B (Wyoming Basins); GYA (Greater Yellowstone Area); CoC (Crown of the Continent).
For example, the Washington Connected Landscapes Project, including Washington state and portions of Oregon, Idaho, and British Columbia, chose focal species to serve as “umbrellas” (*sensu* Launer and Murphy 1994; Sattler et al. 2014) that would encompass the diverse habitat needs of a broader array of species of conservation concern ([http://waconnected.org/wp-content/themes/whcwg/docs/statewide-connectivity/2010DEC%2017%20WHCWG%20Statewide%20Analysis%20FINAL.pdf](http://waconnected.org/wp-content/themes/whcwg/docs/statewide-connectivity/2010DEC%2017%20WHCWG%20Statewide%20Analysis%20FINAL.pdf), Chapter 2), and choose focal species to represent the connectivity needs of wildlife species for which coarse-scale planning is relevant. These species were selected based on their sensitivity to landscape features such as transportation infrastructure and urban development (WHCWG 2010). The team selected 11 focal species for the Columbia Plateau ecoregion, including Columbia sharp-tailed grouse, greater sage-grouse, black-tailed jackrabbit, white-tailed jackrabbit, Townsend’s ground squirrel, Washington ground squirrel, least chipmunk, mule deer, western rattlesnake, beaver, and tiger salamander (WHCWG 2012). Of these, greater sage-grouse and mule deer are GNLCC conservation targets.

The Crown Managers Partnership (CMP), covering the Crown of the Continent in portions of Montana, British Columbia, and Alberta, has adopted a Strategic Plan that strives for an ecologically healthy Crown achieved by management actions of multiple agencies each operating within their own jurisdiction with common goals in mind. The Managing for Ecological Health Project identifies six broad indicators to describe ecological health in the Crown: landscapes, water quantity and quality, biodiversity, invasive species, air quality, and climate. CMP partners are developing coordinated cross-jurisdictional management outcomes for a suite of trans-boundary focal species using occupancy and abundance models for grizzly bear, wolverine, cutthroat trout, and bull trout, all of which are GNLCC Conservation Targets.

Formed by practitioners in the Cascade Mountains of Washington and British Columbia during the summer of 2012, the Cascadia Partner Forum fosters a network of natural resource practitioners working with the Landscape Conservation Cooperatives to build the adaptive capacity of the landscape and species living within it. The forum hosted a series of workshops (2012-2013) to hear from a diverse array of partners on the ground in this transboundary landscape, and has hired three research fellows to organize and synthesize information to guide Pilot Council discussions. Four priority issues within Cascadia have been identified by the Pilot Council to focus on in 2013: 1) Habitat connectivity, 2) Water, 3) Iconic Species: Wolverine and Sockeye salmon, and 4) Access Management. The partner forum’s fellows are preparing a report that provides a synthesis of existing information on these priority issues, discusses case studies within the Cascadia region on each topic, highlights success stories in Cascadia, and identifies funding needs for further information and climate adaptation actions.

The Wyoming Landscape Conservation Initiative is a long-term, science-based program to assess and enhance aquatic and terrestrial habitats at the landscape scale in southern Wyoming, while facilitating responsible development through local collaboration and partnerships. The WLCI works to ensure that wildlife and habitat remain viable across the landscape, even with significant development pressure. The priority objectives addressed within the focus communities are: fragmented habitats, invasive species, and water quality and quantity. Greater sage-grouse has been a focal species of the WLCI since Wyoming harbors approximately 36-40% of the rangewide population of the species.

Each of these partnerships and the organizations that participate have preexisting missions and mandates. We cannot expect to measure any of these focal species across the whole GNLCC landscape. For example, we will likely facilitate monitor grizzly bears in the GYA and/or Crown relying on existing efforts. We can measure,
estimate, and characterize broad-scale metrics that help us understand status in terms of subgoals and interpret those results to estimate landscape integrity.

**How these indicators work together to indicate Landscape Integrity for the GNLCC**

The LII map informs us where the more extensive human modification is occurring, and where there is a high need to conserve native species, ecosystems, and processes. If LII is remaining relatively stable or decreasing (less human impact) we can generally assume that ecosystem integrity at a coarse resolution in the GNLCC is broadly maintained or improved. The next finer spatial and ecological resolution to address is exemplified by the four GNLCC Conservation Targets: large intact blocks, connectivity, aquatic integrity, and ecosystem resilience. Because these goals represent finer ecological targets we will address these at the ecotypic scales identified in the Conservation Framework – the Partner Forums.

For example, we have very good connectivity data for much of the Columbia Basin and the basic concepts on how to index relative patch quality stemming from work by Washington Department of Fish and Wildlife (J. Pierce, pers. comm.). However, it is very unlikely that we would be able to replicate these assessments across a broader landscape, at least immediately. Likewise, we have access to good measures of ecosystem resilience in sagebrush steppe systems (J. Chambers et al. 2013). We’ve seen from the Demonstration Project that legacy institutions are (understandably) hesitant to adopt landscape-scale, partner-driven approaches but we can explore and “drive” the collaboration in the Partner Forums. In the case of the Columbia Basin, GNLCC will (continue to) support the connectivity work and landscape conservation design approach. We will seek to integrate patch-scale characterizations of ecological integrity and through the LII, define how intact the Columbia Basin’s large block is and where resilience is high (and low). The assessment will identify specific needs that the Partner Forum will address. We know the Columbia Basin Partner Forum will include aquatic integrity folks. Scaling up, we also explore and identify how the Columbia Basin connects with neighboring blocks to address the four goals at scales approaching the GNLCC as a whole.

This multi-scale approach will help to estimate whether we are reaching our common vision of a landscape that sustains its diverse natural systems to support healthy and connected populations of fish, wildlife, and plants; sustains traditional land uses and cultural history; and supports robust communities.

**Immediate Science Needs for Landscape Integrity Estimation**

Currently, the impacts of climate change are not well reflected in Landscape Integrity Index. Also, as it stands, this index is a more robust tool within terrestrial systems than in aquatic systems. And, a database describing the distribution of terrestrial non-native and invasive plants database is incomplete; data for aquatic invasive species is missing entirely. Furthermore, whereas ecological integrity, which also reflects biodiversity, patterns of landscape heterogeneity, and an ecologically connected landscape, the LII seeks to quantitatively amalgamate/combine into one number [for each pixel of the landscape] estimates of the effect of numerous prominent land uses. Although the LII was ideologically ‘tuned’ for species particularly sensitive to land-use disturbance, the effect of a given landscape-level stressor will undoubtedly vary across species, geographies, and time (e.g., Beever et al. 2011), and thus need to be re-calibrated for greatest accuracy.

**How Collaborator Management Actions and Strategies Influence these Indicators**

Collaborators engage in management actions and strategies that, taken collectively, are intended to improve the condition of the landscape, including efforts to improve habitats, ecosystems, species, and ecosystem processes,
and reduce the impact from human modification. These actions include protection (land acquisition, conservation easements, etc), restoration (reclamation, rehabilitation, etc.), species and habitat management, (see Safalsky et al 2008). Some collaborators such as the Interagency Grizzly Bear Committee and the Intermountain West Joint Venture take direct action that seeks to benefit a priority species, habitat or process. Some ecosystems groups, such as Arid Lands Initiative, Crown Managers Partnership, Greater Yellowstone Coordinating Committee, Wyoming Landscape Conservation Initiative, are a collection of partners that take individual actions that roll up into action at the ecosystem level. Some groups, such as the Washington Connected Landscape Project, provide science that serve basis for management action. Some programs and organizations, such as the USGS and the agency Inventory & Monitoring programs, monitor these species, habitats, and processes to assess whether we are meeting objectives. Over time, the results of these actions will be reflected in the targets selected for the index and will thus contribute to the GNLCC collective vision of a landscape that sustains its diverse natural systems.

**Partner Efforts to Measure or Monitor Landscape Integrity**

<table>
<thead>
<tr>
<th>Effort</th>
<th>Extent</th>
<th>Metrics</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Governors Association CHAT</td>
<td>18 Western States, including 5 states in GNLCC</td>
<td>Landscape Condition; Large Natural Areas; Landscape Connectivity; Freshwater Integrity</td>
<td>Landscape Integrity dataset released December 2013; no specific plan to update at regular intervals</td>
</tr>
<tr>
<td>Washington Wildlife Habitat Connectivity Working Group</td>
<td>State of Washington; Columbia Basin;</td>
<td>Landscape Integrity; Connectivity; Resistance</td>
<td>Coarse Scale evaluation for entire state complete; finer-scale evaluation for Columbia Basin Complete; finer-scale evaluation for Okanogan-Kettle underway</td>
</tr>
<tr>
<td>Crown Managers Partnership Ecological Health Monitoring</td>
<td>Crown of the Continent</td>
<td>Human Modification Index</td>
<td>Underway</td>
</tr>
<tr>
<td>Montana Connectivity Map</td>
<td>State of Montana</td>
<td>Connectivity; Species Modeling</td>
<td>Complete</td>
</tr>
<tr>
<td>Wyoming Landscape Conservation Initiative</td>
<td>Southwest and central Wyoming</td>
<td>Integrated Assessment Index</td>
<td>Complete</td>
</tr>
<tr>
<td>BLM Wyoming Basins REA</td>
<td>Omenik’s Wyoming Basins (Level III Ecoregion)</td>
<td>Terrestrial Development Index; Aquatic Development Index</td>
<td>Scheduled to be completed 2014; no schedule for revision or update</td>
</tr>
<tr>
<td>BLM Middle Rockies REA</td>
<td>Omenik’s Wyoming Basins Level III Ecoregion</td>
<td></td>
<td>Scheduled to be completed 2014; no schedule for revision or update</td>
</tr>
</tbody>
</table>

Table 9. Partner Efforts to measure landscape integrity.
SECTION 3: Integrating Filters

Summarizing the GNLCC Science Plan includes describing (a) a way to track our collective progress toward stated goals and desired conditions, and (b) the process for identifying critical gaps in scientific information which then guide GNLCC annual work plans and funding strategies.

Tracking Collective Progress toward Stated Goals

The outstanding challenge to large landscape conservation is delivering cross-scale information to best inform conservation decision and action. The Science Plan guides the GNLCC partnership to integrate fine filter quantifiable objectives with landscape-scale desired outcomes by linking conservation target metrics to measures of landscape integrity. We acknowledge this element of the GNLCC Science Plan remains a work in progress – a challenge we can only adequately address as a cooperative partnership. Yet we recognize many elements are in place and should be leveraged to measure and evaluate progress in relation to goals. An LCC will find success when it’s able to integrate multi-scale data to increase manager’s confidence that proposed actions will contribute to shared outcomes and coordinated evaluations that accurately measure trends (toward or away from) desired condition. Conceptually, the integration is fairly straightforward (Fig. 19). In practice, GNLCC will rely on the coordinated interaction among management agencies, partnerships, and the Partner Forums.

Returning to the grizzly bear example: 2 of the 6 extant populations (recovery zones or ecosystems) in the U.S portion of GNLCC have well-defined population-based objectives (Northern Continental Divide (NCD), Greater Yellowstone, Table 6) and at least 2 ecosystems (NCD and Northern Cascades) have parallels to the Landscape

Figure 19. Conceptual model for integrating coarse and fine filter conservation data to inform site managers and conservation partnerships on appropriate actions in the face of landscape-scale ecological stressors.
Integrity Index (Table 9). Moreover, we have multi-level coordination ongoing within (site managers, partnerships; Fig. 19) and among the recovery zones (Interagency Grizzly Bear Committee; Partner Forums), and monitoring (http://www.igbconline.org/index.php/population-recovery/grizzly-bear-monitoring) is underway. However, some elements in the species-wide conservation effort remain unavailable and consistent models and indices informing among-population conservation planning and action are still needed. GNLCC, through the Steering Committee and Rocky Mountain and Cascadia Partner Forums will identify and prioritize those needs and incorporate into annual work plans. Further, GNLCC will support, through the Science Community in collaboration with partners, measurement and evaluation of response metrics (i.e., monitoring data, landscape integrity scores and trends) to estimate our collective effectiveness.

Most GNLCC Conservation Targets (Table 1) do not have the level of *in situ* conservation coordination and planning as grizzly bear. However, the standard model presented above is consistent. By understanding each target’s conservation ecology, establishing desired condition for target-specific metrics, and measuring specific and landscape metrics the GNLCC can collaboratively track progress and guide strategy adjustments. Target-specific monitoring is one critical element not directly addressed above. Although most agency partners have some monitoring in place (e.g., NPS Inventory and Monitoring program, Idaho Bird Inventory System) and coordination entities occur (e.g, Pacific Northwest Aquatic Monitoring Partnership, IGBC), GNLCC Staff, the Advisory Team, and partners will identify additional coordination opportunities, mechanisms for effective use of existing monitoring data, and gaps in our collective monitoring.

**Guiding Annual Workplans**

The Science Plan’s Fine Filter/Coarse Filter approach identifies numerous information and capacity gaps through the process of quantifying shared goals and objectives, characterizing desired condition, identifying limiting factors, recognizing important spatial data inadequacies, and disclosing needed analytical and decision-support tools. Since the first cycle in 2010, GNLCC Staff with support from the Science Team has interpreted these needs directly from the Governance Charter and Strategic Conservation Framework into annual Funding Guidance. The Science Plan and accompanying annual workplans will structure those interpretations supported by LC MAP, the GNLCC Project Tracking System, and the Communication Plan (Appendix A). In its simple concept, the annual workplan entails collecting the flags as described in Step 8a (page 21). However, pursuing 29 conservation targets, three landscape stressors, and characterizing multiple-scale status and trends will generate a broad spectrum of needs. Identified needs will be captured and summarized in annual reports but a prioritization process will guide work plans. Staff and the Advisory Team will lead the process and capture input from practitioners (via Partner Forums and partnerships), regional leadership (via Steering Committee) and through the iterative science process (Science Community). Staff and Advisory Team will identify and track parallel science delivery and on-going research to further refine gaps and cross-reference expressed needs among agency partners to identify a focal subset of high priority needs. These needs will be expressed as increasingly specific science calls that form a portion of the annual workplan and are appropriately interpreted in consequent funding guidance. Science solicitations may be direct requests from specific organizations with proprietary or jurisdictional rights or open for competition through a request for proposals.

A second element of the annual workplan is organizational objectives for GNLCC work teams. GNLCC Staff, through their parent agency, develop and achieve performance plans. These will be transferred to the GNLCC workplan. The Advisory Team will draft team-level objectives for the AT and Steering Committee which will approve both. Cursory evaluations of accomplishments at year end will inform subsequent annual workplans (Fig. 20).
Figure 20. Basic workflow describing Annual Workplan development and implementation.
CITATIONS

Arid Lands Initiative. 2014. Spatial Conservation Priorities in the Columbia Plateau Ecoregion: Methods and data used to identify collaborative conservation priority areas for the Arid Lands Initiative. Available at https://www.sciencebase.gov/catalog/folder/52050595e4b0403aa6262c64


APPENDIX A: Tools and Technological Resources Supporting the GNLCC Science Plan

Tools to Further Landscape Conservation Science
To facilitate the application of science and information exchange among those partners, the GNLCC has developed the following science communication tools:

A communication strategy
(http://greatnorthernlcc.org/sites/default/files/temp/comm_outreach_strategy_draft_29apr.pdf; Fig. 1) for the GNLCC clearly spells out strategies to keep key groups of partners engaged in and connected through the GNLCC. Clear communication and engagement among partners is critical for the GNLCC to function.

The GNLCC website (http://greatnorthernlcc.org) provides a location for sharing information. Specifically, for the partner forums to exchange information regarding mutual goals and shared projects, access to the results from research projects supported by the GNLCC, new tools for managers, and webinars on research and conservation initiatives happening throughout the region.

A project tracking tool (PTT) to house all science proposal, funded project and product information. The tool will serve as the point of reference for all projects GNLCC leads. The GNLCC website and other outreach sources will dynamically draw from the PTT fostering efficient, timely communication of GNLCC science and science support products. The PTT will also dynamically interact with data resources housed on LC MAP (see below). It will be integratable with National LCC Network and Climate Science Center project tracking resources (functional Dec. 2013).

LC MAP (or the Landscape Conservation Management and Analysis Portal; https://www.sciencebase.gov/catalog/?community=GNLCC) provides a collaborative virtual workspace for GNLCC partners to securely share, access, and analyze common datasets and information. It is a tool that facilitates data mining and discovery from the World Wide Web, uses mapping applications for data analysis, and advances collaborative research by providing a secure space for multiple partners to assess, edit, analyze, and model common data themes in near realtime - with advance data security and documentation functions.

Data standards ensure security and quality, and the ability to share and apply data throughout the region. See the document Data Management Standards for details.

These are a few of the tools developed to date to facilitate information exchange and science application among GNLCC partners. As this foundation is built, additional tools will be developed and the capacity for shared science will increase.
Figure A1.--Linking GNLCC Supported Science Product with GNLCC Science Plan components.

One function of the GNLCC project tracking system (PTS) is to serve as a data link between GNLCC science products and the GNLCC science plan and strategic framework components (conservation targets, strategic framework goals, and partner forum geographic areas). The linking provides the relationship for GNLCC audiences to navigate the science plan and GNLCC supported science products (data, tools, reports, etc.). The linkage includes products cataloged and archived on LC MAP, which has many robust features including a rich metadata repository. Various science plan meta-analysis reporting options can include GNLCC supported science trends, supported science gap analysis, breakdown of science products and related science plan components, spatial summarization of science plan components, etc.

- Supported Science Product Archiving and Cataloging
GNLCC supported science products come in many forms (vector/raster/tabular data, tools, reports, etc.) and proper cataloging and archiving ensure sustained use and discoverability. As the backbone of the science strategy’s supported science products, LC MAP is the GNLCC information system for cataloging and archiving. LC MAP has many functions including a cloud based data repository which includes robust data storage component. This repository is used as a cloud based archival repository for GNLCC deliverables. The primary repository for project information is in the project tracking system (PTS). The project and product cataloging and archiving is a two stage process starting at projects cataloged in the PTS. Projects may have one or many deliverables associated with it. At project initiation, the project background, science strategy components, and DMP are cataloged in the PTS and LC MAP. Next all supported science products are cataloged in the PTS and LC MAP and all digital data, files, and products is designed to be uploaded into LC MAP for archival. This process will be repeated if re-delivery of products is necessary or subsequent products are delivered. For more information on LC MAP visit greatnorthernlcc.org. For information on data management standards visit the Data Management Standards document.

- Product (data, tools, reports, etc.) Delivery (data, visualization, tools) and GNLCC Partner Information Integration

**Figure A2.--Product Archiving and Cataloging.**

**Figure A3.--Product Delivery and Information Integration.**
The overall methodology of GNLCC science product delivery is through cloud based architecture. The cloud based architecture allows other users or user applications (clients) to consume information and tools transferred over the internet. LC MAP is a cloud based system that can store and serve (distribute) data/metadata to others or can be a place to catalog locations on other partner cloud based systems. This framework allows for GNLCC web apps or partner web apps to utilize each other and work to entities strengths, reducing redundancy and confusion inherent with information technology duplication. Over time new hubs (cloud based web resources) will emerge and some will fade away. This design handles flexibility and scaling, minimizing disruption and promoting cooperation and growth.

Figure A4.—Technical design for Landscape Integrity Index development.

APPENDIX B: Elaboration on Wetlands Example

Wetlands in the GNLCC

Wetland conservation is critical to achieving all four goals outlined by the GNLCC Strategic Framework, and wetlands have rightfully been identified as one of the 29 conservation targets. They are valuable to wildlife, supporting a disproportionate number of species relative to the area they occupy on the landscape, and are equally valuable in maintaining aquatic systems by regulating surface water flow and filtering pollutants. Wetlands are also among the habitats most at risk due to climate change, putting at risk countless species that depend on them (IPCC). Furthermore, wetlands conservation is central to work that most of our partners do, making them an ideal ‘proof-of-concept’ as we begin to provide context and measure progress toward our conservation targets.
To achieve success in conserving wetlands, we need to identify those areas on the landscape where wetland conservation is the most critical, where and what types of wetlands are most vulnerable to change, what work has been done, what work can be expanded upon, and what knowledge gaps need to be filled.

**Wetland types and decline**

- Alpine meadows
- Emergent marsh
- Shrub scrub wetland
- Montane coniferous
- Riparian

This area has been understudied, and trends are not well understood.

**Interactions between wetlands and other GNLCC targets**

Wetlands can be tied to just about all of the GNLCC conservation targets either directly or indirectly. Following are the most direct links.

Of the wildlife target species in the Strategic Framework, **trumpeter swans** are most directly associated with wetlands. They require emergent palustrine wetlands (nontidal, dominated by herbaceous vegetation, freshwater) for all phases of their life cycle, including breeding, migration, and wintering. These wetlands support emergent herbaceous vegetation, and do not include other wetland types, such as wooded, shrub scrub, fens, and bogs. The Rocky Mountain population has increased from ~800 in 1975 to more than 5,000 in 2005 (Flyway Council). Most of the increase has been in Canada. They also rely on **connectivity** of wetlands on the landscape. Although swans rely on wetlands, they do not necessarily respond to increased wetland acreage (Shea et al. 2002), and much suitable habitat exists that remains unoccupied by trumpeter swans. Because of the lack of dispersal and irregular migratory patterns, and because they do not represent all wetland types, they may not be the best ‘surrogate’ species to track wetland conservation success.

Functioning wetlands rely on high-quality **watershed uplands**. Watersheds with intact vegetation and fewer impermeable surfaces maintain hydrology and water quality in connected wetlands. Land use change has had the biggest effect on uplands.

Wetlands enhance **riparian corridors** by regulating inputs into rivers, including water quality, timing of flow, and water quantity. **Cutthroat trout** and **bull trout** in turn rely on intact riparian corridors for channel stability and temperature regulation.

The contributing factors of **climate change** (Erwin 2009), **land use change**, and **invasive species** all degrade, or have the potential to degrade, wetland habitat and function in the GNLCC. Climate change is expected to have its most pronounced effect on hydrology in wetlands, causing altered hydroperiods and base flows. The expectation is a drying trend in the Great Northern landscape due to drier, hotter summers.
An SHC approach to wetlands conservation

Generally, SHC is thought of as a four-step process, where a species is the conservation target as well as the subject of the biological planning phase, and habitats are the subject of the conservation design phase. Once objectives are set for a species, then habitats can be designed to meet those objectives. Conservation delivery and monitoring follow. Here, wetlands (a habitat type) are targets in and of themselves, so the division between biological planning and conservation design is less clear. Most of the needs regarding landscape-level wetland conservation fit into this planning/design phase of SHC.

In the context of the Great Northern goals, wetlands are essential for intact large landscapes, connectivity, and functioning aquatic systems. How we prioritize wetland conservation on the landscape and how we monitor wetland change should be done to achieve progress toward those goals.

Overview of current efforts:

Wetland inventory. The most extensive inventory to date has been the National Wetland Inventory, which covers the entire U.S. portion of the Great Northern. It is a valuable tool that gives us a coarse overview of wetland concentration and wetland type (the Great Northern funded NWI in 2011, http://greatnorthernlcc.org/supported-science/122). However, much of the dataset is out of date and it does not document changes in wetland over time. Ducks Unlimited has partnered with Environment Canada to do a Canadian Wetlands Inventory, but most of the GN landscape has not been completed. To begin assessing where to concentrate and what habitats to concentrate on, we need a thorough wetland inventory.
Tracking wetland change. Another component to Biological Planning is understanding how wetlands are changing in response to landscape stressors such as climate change and land use change.

The Canadian Intermountain Joint Venture conducted a pilot project that was funded by the Great Northern LCC. They examined a landscape in the South Okanagan to determine if wetland occurrence has changed over the past 20 years. To determine wetland change, they tested SPOT imagery, which is available from the 1980s and is expected to continue. The remote sensing found a significant decrease in wetland occurrence in that time period.

Wetlands Adaptation Group – Wetland hydrologic projections in response to climate change. Examining how climate change will affect wetlands of different types by using temperature and water level data combined with climate models (North Cascades).

The Greater Yellowstone Wetland and Amphibian Monitoring program has been a successful, nine-year monitoring effort that has documented wetland amphibian change due to climate change and other factors in the Yellowstone and Grand Teton landscapes (Gould 2012). It has also expanded to include Glacier National Park, with the goal of documenting amphibian and wetland trends across the Rockies.
Describing wetland condition. Idaho Fish and Game recently completed a statewide wetland condition model that describes the physical condition of wetlands in terms of their proximity to detrimental land uses. Land uses included in the model as impairments to wetlands include agriculture, roads, residential development, other impervious surfaces, and clearcuts. The model can demonstrate condition in any geography of interest and can be scaled up, but it lacks data on invasive species, contamination, and wetland type.

This figure shows a sample of the model. Each wetland is pixelated, and each pixel is assigned a score based on its proximity to a land use disturbance. Higher scores are associated with more disturbance. Pixel scores can be averaged across any watershed size or any other area of interest.
Developing priority areas for wetland conservation. Concurrent with setting wetland objectives is determining where on the landscape wetland conservation is most critical. A common theme among conservation organizations is that the need for conservation far outweighs resources available for conservation, and the landscape of the Great Northern is no exception. Therefore, focusing efforts, and articulating rationale, is necessary with limited resources.

The Intermountain West Joint Venture has done extensive work setting wetland priorities. Based on bird concentrations, they have identified 20 priority areas for wetland conservation. The 20 priority areas include 50% of the wetland acreage in the IWJV boundary, but only 6% of the landscape, and are those areas that are critical to maintain populations of target bird species. Approximately nine of the priority areas are included in the GNLCC boundary. GNLCC must enhance collaboration with IWJV to define and prioritize wetlands. Their approach is a perfect example of large-scale prioritization of wetlands that the GNLCC can build from.
Figure 1. Location of the CIJV and IWJV in relation to the GNLCC and BCRs 9 and 10.
Landscape Conservation Design is a new concept being promoted by the U.S. Fish and Wildlife Service that incorporates landscape priorities of multiple partners to determine common objectives. A pilot project describing terrestrial priorities has been conducted for the Columbia Plateau, and although wetlands were not the main driver, they were one of the conservation targets and played a role in determining spatial priorities.

Finally, the National Audubon Society has been designating priority landscapes for birds as well, in a system of Important Bird Areas. Many, but not all, are water-based and are a source for delineating priority wetland areas.

**How to proceed**

For the Great Northern, all of the aforementioned tools can be used to further conservation of wetlands, and they are scalable and adaptable. However, applying them across the entire landscape is likely too time consuming and costly, and probably unnecessary. There are two approaches to applying them.

How and where they are applied can be driven by the goals of conserving large landscapes, ensuring connectivity, and maintaining aquatic integrity. For example, in any priority large landscape identified (goal 1), wetlands will be an integral component of that landscape, and we should develop wetland targets for those landscapes. Once those large landscapes are identified, then we can focus more thorough wetland inventory efforts there, examine wetland condition, and monitor closely how wetlands in that landscape have changed and are projected to change.

Some potential areas to begin are Yellowstone, Glacier, and the South Okanagan, because of existing efforts in those areas.

Conversely, the needs of a focal species, or group of species, may direct us to an area on the landscape and define a focal area. For example, our only wetland-dependent species, trumpeter swans, can be used to prioritize where we focus wetland conservation. One of their needs is an increased wintering range outside of the tri-state area, and wetland prioritization can be done with that goal in mind. Another example is prioritizing sandhill cranes like the Intermountain West Joint Venture has done, and using them as a surrogate for other wetland species and driving the landscapes we prioritize.

With either approach, these are the questions we need to answer:

Where do wetlands occur? Where are we interested in conserving wetlands?

What is wetland condition in those areas?

How vulnerable are those areas?

Where are they most important to maintain large, connected habitat?

Where are they most vulnerable to climate change?

Where are priority wetland conservation areas for wetland-dependent wildlife?

What watersheds are most vulnerable to change?

What land use changes are driving wetland gains and losses?

Do we need more data or use existing information?
How do we measure success? Surrogate species?

**APPENDIX C: Elaboration on Fire Regime Example**

The conservation target to manage for “Natural Fire Regimes” fulfills the Strategic Conservation Framework’s Goal #4 to “Promote landscape-scale disturbance regimes that operate within a future range of variability and sustain ecological integrity”. Due to the influence of this ecological process throughout the GNLCC landscape and its interactions with other ecological processes, patterns, and structure – it can be seen as a keystone process. A fire regime is a classification that describes the patterns of fire seasonality, frequency, size, spatial continuity, intensity, type, and severity of a spatial area.

Fire played a vital role in shaping the ecosystems across all of the GNLCC, but there is wide variation in the natural fire regimes that influence ecological patterns and processes. Fire suppression in the sagebrush steppe region has impacted the sagebrush communities by allowing fuels to build up over time, increasing fire severity when a fire does occur. Fire suppression has also allowed incursion of juniper woodlands into upper elevations of historic sage shrub habitat. Fires in sage shrub types reduce immediate cover and forage for greater sage-grouse. Though sage-grouse persist in sage shrub and grassland mosaics they rely on dense unburned stands of sagebrush especially during spring and winter. Landscape disturbances such as human development and transportation corridors can increase ignition risk, reduce fire management options in the case of natural fires, and increase need for fuels reduction in surrounding areas. In some portions of the GNLCC, the invasion of cheatgrass into native sage steppe communities has significantly reduced the fire return interval causing more frequent loss of important sagebrush cover for species such as sage-grouse. The accelerated fire return intervals associated with annual grass invasion and fire suppression leading to juniper invasion reduce sage shrub habitat and associated small mammal and insect populations potentially affecting burrowing owl populations. In addition to the terrestrial impacts of fire, they have the potential to positively and negatively impact aquatic systems. For example, increased size and severity of fires resulting from fire suppression and climate change will likely increase peak stream flows and flooding, reduce base flows and late-season water availability, increase size and frequency of landslides, reduce aquatic habitat quality due to increased stream temperatures and sedimentation, and increase failures of road crossing structures that result in barriers to aquatic organisms passage.
While establishing realistic goals, threats, and priority actions for this ecological process, there are key things to keep in mind. These include the need to establish reference conditions based on historical and future scenarios, classifications and metrics must be made at various spatial scales, the scale of a classification and measurement will influence the interpretation of that finding to management, the close relation of fire regimes to vegetation structure and patterns on the landscape, the land management objectives for a piece of land will influence the role and use of fire on that landscape, and the proximity of a landscape to human development and how that private land is managed (i.e. fire-safe communities).

**Conservation Actions Specifically designed to address particular threats**

All conservation actions for this target require an “all lands” approach since fire regimes inherently operate across watersheds, ownerships, and land allocations.

The National Fire Plan is a cooperative, long-term effort of the USDA Forest Service, Department of Interior, and the National Association of State Foresters to manage the impact of wildland fire, while individual land owners have fire plans or land management plans that integrate the management of fire including the restoration of fire regimes. Grand Teton National Park is currently revising its Fire Plan to provide direction and establish specific procedures for all fire program activities to manage fire on an ecosystem level. The Okanogan-Wenatchee National Forest Forest Restoration Strategy integrates restoration of fire regimes into an overall strategy including metrics for guiding management and measuring success. The Oregon Department of Fish and Wildlife lays out strategies to evaluate lands for appropriate use of prescribed fire for their “Strategy Habitat: Sagebrush Steppe and Shrublands” in their habitat assessments.

Due to the differences in the ability to manage fire on land ownerships and ecosystem types, while addressing social and ecological concerns unique to a landscape – conservation actions are best approached at the regional and partner level scale. At the regional level coordination of strategies, shared learning, and policy level discussions are appropriate. We will rely on Partner Forums to establish actions that specifically address each threat within their landscapes. We expect that these actions will include:

- Restoration of vegetation structure and pattern within plant communities (forested and sage steppe) to allow the reintroduction of fire and create more resilient stands.
- Use of prescribed fire to restore process, and utilization of wildfire where possible.
- Support FireWise communities and implementation of fuels reductions on private lands and around homes within the wildland urban interface.
- Invest in strategic conservation to reduce the development pressure in the wildland urban interface.
- Evaluation of parcels to guide restoration actions, and analysis to ensure conservation actions at the local scale done in a strategic way add up to landscape level patterns and impacts.

Notes on metrics and indicators. It is important to ensure that any measurement of departure is done at multiple spatial scales including regional landscapes to local landscapes to patch neighborhoods. For example, management and restoration actions often occur at the stand scale while indications of success will include not only metrics of change at that stand level but the interactions of those changes to effect a landscape scale pattern and change.

Metrics of associated conservation targets in species (i.e. lynx), processes (i.e. forest health and disease), and ecosystems (i.e. aquatic systems or shrubb-steppe) should be established.

Questions for partner forums:

- Can each partner forum link the conservation goals and management plans for natural fire regime within their landscape? Where are shortcomings in those plans that require further planning?
- Can each partner forum link natural fire regimes to specific conservation targets present on their landscape, and define shared metrics?
- What are the policy and social challenges associated with managing for natural fire regimes on the landscape of your partner forum, and are their any existing bodies working to address those as possible (i.e. existing Prescribed Fire Councils)?

**APPENDIX D: Landscape Integrity Background**

Noss (1990) developed the foundation for defining landscape integrity by defining three characteristics of biodiversity—composition, structure, and function—at four levels of ecological organization: landscape, ecosystem, species, and genetic. Building on this framework, Parrish et al. (2003) defined ecological integrity of a landscape. High integrity refers to a system with natural evolutionary and ecological processes, resilience to disturbance, and minimal or no influence from human activities (Angemeier and Karr 1994; Parrish et al. 2003). Species-specific approaches typically develop ecological indicators that attempt to measure attributes of a species or community, such as population size or species diversity. A complementary, and more general, approach is to develop indicators of the absence of human modification of habitat and alteration of ecological processes. An ecological indicator is a measurable attribute that provides insights into the state of the environment and provides information beyond its own measurement (Noon 2003). Indicators are usually surrogates for properties or system responses that are too difficult or costly to measure directly (Leibowitz et al. 1999).

**WHY THESE INDICATORS WERE SELECTED:**

**Stressors**
Land Use/Human Modification: Spatially explicit datasets measure intensity and footprint of threats classified by Salafsky et al (2008) including: urban areas, residential density, cropland, tree plantations, oil and gas wells, mining, wind turbines, road and road traffic effects (road type, traffic volume, distance to road), utility powerlines, cell towers, road effects, and terrestrial invasive species (Theobald 2013). Data layers can be calculated at different scales (GNLCC, Regional Forum, and Ecosystem), are in large part derived from publicly available databases, and can be scrutinized, quality-checked, edge matched and updated at regular time intervals using LC MAP and interoperable data management and analysis tools.

Collectively, these data quantify landscape integrity using a human modification metric (Theobald 2013). This human modification metric provides a good baseline, especially for impacts from land use and invasive species, for the GNLCC because it is (1) quantitative; (2) replicable over time (so we can determine trends); (3) scalable (it could be calculated at different resolutions for areas of interest within the GNLCC that differ in spatial extent, such as the Columbia Basin, Crown of the Continent, or the entire GNLCC); (4) standardized (in that it follows Salafsky et al’s (2008) conservation threat classification; (5) combines terrestrial and aquatic integrity; and (6) calculated using available datasets that are regularly updated. If we want to mention caveats … In contrast, the human-modification/landscape-integrity index does not take into account any patch dynamics (i.e., identity, distribution, richness, or proportion of habitat-patch types), fragmentation, perimeter-area ratio, grazing, fire, or contemporary climate change, each of which can be important for numerous ecosystem components and processes.

Climate Change

Climate change is an important stressor and pervades scales from the site to the continent. To date and in future projections, magnitude of temperature change throughout the year is highest in northern latitudes of the USA and North America. In response GNLCC and many partners, notably the Climate Science Centers, have funded several projects to project the impacts of climate change on taxa (e.g., greater sage-grouse, native trout, whitebark pine), ecosystems and habitats (e.g., greater sage-grouse habitat; aquatic systems), and ecological processes (e.g. wildland fire; outbreaks of mountain pine beetle in whitebark pine stands). Climate change projections are conducted by project area and for each conservation target.

Conservation Targets

Ecosystem Processes: Selected in specific ecosystems because (a) they were identified as priority conservation targets in the GNLCC Strategic Plan; (b) they have been identified important to monitor by a partner organization; (c) they are the subject of a GNLCC-sponsored science project that will identify their status and condition.

Habitats and Ecosystems: Selected in specific ecosystems because (a) they were selected as conservation targets in the GNLCC Strategic Plan; (b) they have been identified by partner organizations as important enough to (1) establish a conservation objective or (2) monitor to gauge whether conservation objectives have been established.

Focal Species

Selected in specific ecosystems for the reasons indicated in the Habitats and Ecosystems sections. In addition, the species are considered Tier 1 Species (umbrella species) [grizzly bear, sage grouse, wolverine]; Tier 2 Species (indicator species) [Cutthroat trout, Sockeye Salmon]; and Tier 3 Species (iconic or socially important) [mule deer, bull trout]. Finally, many GNLCC partners have suggested focal species, as follows:
Brock (2013) used a surrogate species approach to select conservation targets for portions of the Rocky Mountain Forum. Sanderson et al. (2002) refined criteria for selecting surrogate species, using a stepwise process based on the requirements of “landscape species,” including five criteria: area requirement, heterogeneity of habitat, vulnerability to environmental stressors, ecological function, and social and economic importance. Brock applied this approach to the Madison Valley, in western Montana, where he examined 410 native vertebrate species and refined that to a candidate pool of 63 species. Using this approach, Brock and his team selected grizzly bear, elk, western toad, bighorn sheep, northern goshawk, greater sage-grouse, pronghorn, westslope cutthroat trout, American beaver, and black-backed woodpecker as surrogate or landscape species. Grizzly bear, sage grouse, and westslope CT are GNLCC conservation targets.