Yukon River Lowlands – Kuskokwim Mountains – Lime Hills

BLM

Rapid Ecoregional Assessment

FINAL REPORT

Alaska

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1 INTRODUCTION

The Bureau of Land Management (BLM) recently developed a landscape approach to enhance management of public lands (BLM 2014). As part of this landscape approach, the BLM and collaborators are conducting Rapid Ecoregional Assessments (REAs) in the western United States. REAs are designed to transcend management boundaries and synthesize existing data at the ecoregion level, while addressing current problems and projected future conditions. The synthesis and analysis of available data benefits the BLM, other federal and state agencies, and public stakeholders in the development and management of shared resources (Bryce 2012).

REAs evaluate questions of regional importance identified by land managers, and assess the status of regionally significant ecological resources, as well as agents of change that are perceived to impact those ecological resources. The resulting synthesis of regional information is intended to assist management and environmental planning efforts at multiple scales. REAs have two primary purposes:

- To provide landscape-level information needed in developing habitat conservation strategies for regionally significant native plants, wildlife, and fish and other aquatic species; and

- To inform subsequent land use planning, trade-off evaluation, environmental analysis, and decision-making for other interconnected public land uses and values, including development, recreation, and conservation.

Once completed, this information provides land managers with an understanding of current resource status and the potential for future change in resource status for the near term (year 2025) and long term (year 2060).

Much of the analysis relies on computer modeling to generate predicted distributions of species and explore future climate and development scenarios that are inherently uncertain. Therefore the primary utility of REAs lies in the generalized patterns observed and predicted. Second, the development of new information by synthesizing existing data offers tangible products to aid in the management of natural resources. Third, REAs are a useful tool for identifying critical yet unavailable information and generating questions for further analysis.

A number of other REAs are underway or have recently been completed in Alaska. These include the Seward Peninsula (Harkness et al. 2012), North Slope (in progress), and the Central Yukon (in progress). Twelve additional REAs address regions in the lower 48 states (see https://gbp-blm-egis.hub.arcgis.com).

National and Regional Context

Given that REAs are a national program being implemented across the western U.S., there is an opportunity for comparison of landscape and resource condition across multiple scales. Each REA assesses how ecosystems are likely to change under various climate and land use change

GLOSSARY	
ACEC	Area of Critical Environmental Concern
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AKGAP	Alaska Gap Analysis Program
AKNHP	Alaska Natural Heritage Program, University of Alaska Anchorage
ALFRESCO	Alaska Frame-based EcoSystem Code
AMT	Assessment Management Team
AWC	Anadromous Waters Catalog
BLM	Bureau of Land Management
CA	Change Agent
CE	Conservation Element
DOD	Department of Defense
ESRI	Environmental Services Research Institute
GCM	Global Circulation Model
GIPL	Geophysical Institute Permafrost Lab
GIS	Geographic Information System
HUC	Hydrologic Unit Code
ISER	Institute of Social and Economic Research, University of Alaska Anchorage
LCM	Landscape Condition Model
MAGT	Mean Annual Ground Temperature
MQ	Management Question
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NPR-A	National Petroleum Reserve-Alaska
NPS	United States National Park Service
REA	Rapid Ecoregional Assessment
SNAP	Scenarios Network for Alaska and Arctic Planning, University of Alaska Fairbanks
Tech Team	Technical Team
TEK	Traditional Ecological Knowledge
TNC	The Nature Conservancy
USGS	United States Geological Survey
UA	University of Alaska
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
YKL	Yukon Lowlands – Kuskokwim Mountains – Lime Hills

scenarios, but the magnitude and nature of those impacts change across regional and national scales. Alaskan landscapes are largely considered intact and operating under natural conditions. Thus, REAs in Alaska present a unique opportunity to examine the regional effects of climate change (largely) without the influence of human modification.

At the regional scale, REAs generate a foundation for assessment by compiling disparate datasets that can be accessed by managers and GIS professionals for future assessments. Additionally, REAs assess the likely impacts on the landscape and provide a vision for future conditions. This information is already being used to inform regional land use planning efforts for the BLM and has led to multiple projects statewide to better understand the likely impacts of a changing landscape.

Audience

While the BLM has funded this assessment, and has been the primary collaborator in structure and content, the results from the Yukon-Kuskokwim-Lime Hills (YKL) REA are intended to assist a much broader array of groups in Alaska. The USFWS, NPS, DOD, and USFS are all federal agencies that manage land in the region, or assist with management on state and private lands. The state of Alaska owns more than 40% of the land in the YKL region. Regional corporations and Village corporations are also significant landholders in the region. Attempts were made to engage all land managers in the REA throughout the assessment (both formally through the Assessment Management Team and Technical Team, and informally). Thus, while BLM has provided the framework and funding for the assessment, it really belongs to the larger group of land managers.

Report Structure

This final report is intended for land managers and the general public to convey the intent, general methodology, primary results, and interpretation of the REA. Following the introduction we include a description of the study area, baseline conditions, perspective on landscape change, and future opportunities. Inset "case study" boxes are included in this document to highlight notable outcomes from the analysis.

This document is supported by the accompanying Technical Supplement. Refer to the Technical Supplement for detailed introduction, methods, results, and data gaps and limitations. The Technical Supplement provides additional discussion of resources of conservation concern, climate change, invasive species and disease, and socio-economic conditions. Full page figures are also included in the Technical Supplement. Finally, in the coming months all data associated with the REA will be available through the BLM REA data portal:
https://gbp-blm-egis.hub.arcgis.com

Study Area

The study area encompasses 230,872 square miles of the western interior of Alaska and is composed of three ecoregions: Yukon River Lowlands, Kuskokwim Mountains, and Lime Hills (Nowaki et al. 2001), as well as bordering watersheds (Figure1). The region includes major sections of the Yukon and Kuskokwim rivers, and ranges from low elevation wetlands to alpine barrens. Approximately 5,000 people live in 33 communities, while Galena, McGrath, Aniak, and Illiamna serve as primary population centers and air-transportation hub communities for the region.

The State Department of Natural Resources (41%), the BLM (26%), and the USFWS (18%) manage approximately 85% of the YKL study area. See the Technical Supplement for more complete physical, ecological, and socio-economic descriptions.

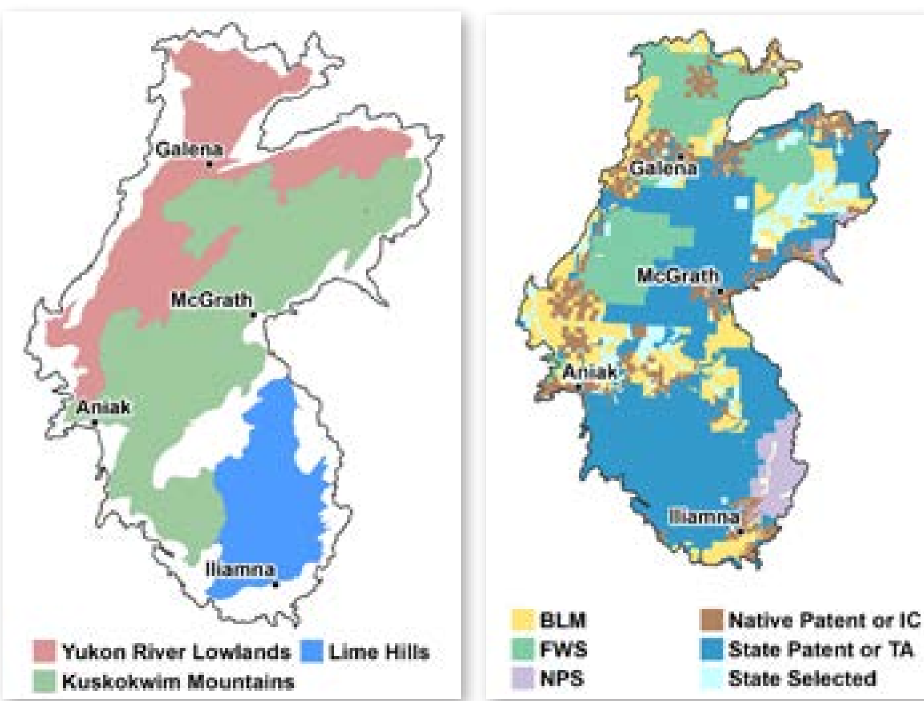

Figure 1. *(Left) Yukon River Lowlands, Kuskokwim Mountains, and Lime Hills Ecoregions and study area (black line); and (Right) land status of major land owners.*

Key Results

Landscape Condition

Landscape condition is highly intact overall and only modest reductions in condition are anticipated for 2025 and 2060

- For perspective, this region has higher landscape integrity than most national parks in the lower 48
- Areas with reduced landscape condition are highly localized around communities
- Even minor reductions in landscape integrity, however, may have impacts to resources locally

Climate

- Increases in mean annual temperature and winter temperatures are expected to increase measurably by 2060. Potential impacts include:
  - Elevated infection and mortality rates for salmon
  - Facilitate higher populations of beavers in the region
  - Changes in vegetation, although lag times, dispersal characteristics, competition, and other interactions make predictions for future vegetation highly uncertain
- Areas with the greatest projected warming are in the northern and eastern portions of the YKL
- Changes in patterns of precipitation are not expected to be dramatic
  - However a greater proportion of precipitation is expected to fall as rain rather than snow
- Increasing temperatures are expected to result in substantial loss of permafrost possibly impacting:
  - spruce forests, flood plains, discontinuous lakes, streams, fishes, and waterfowl
- Numerous communities will likely be affected by changes in permafrost

Fire

- The prevalence of fire on the landscape is expected to increase by 2025 and remain at an elevated level from current conditions to 2060
  - Increased fire frequency would likely result in greater dominance of shrub and deciduous forests, which would improve moose forage
  - Potential to accelerate permafrost loss (and facilitate invasive species establishment)

Invasive Species and Forest Defoliators

- Non-native plant species populations are present in the YKL, but tend to be of weakly invasive species
  - More problematic species (only a few infestations) are currently restricted to population centers
  - Only modest changes in invasion are likely and restricted to areas that are currently at some risk
- Native forest herbivorous insects historically have caused widespread mortality of spruce, birch, aspen, and willow in the YKL
  - Increasing temperatures may increase the frequency of insect outbreaks

Anthropogenic

- The population of 5,000 people is diffuse throughout the YKL
  - Most people are concentrated in McGrath and Galena
  - Populations are generally declining
- Economies are a mix of subsistence, cash, and government subsidies
  - Salmon, followed by moose, are the most important subsistence species
- Anthropogenic footprint is primarily restricted to communities
  - However, trails are extensive throughout the region
  - Smaller-scale placer mining occurs in the central portion of the YKL
  - Proposed larger-scale mines such as Donlin and associated infrastructure (e.g., gas pipeline) are likely to have broader impacts to natural resources
  - Population sizes are not expected to increase with large-scale mines

REA Approach

To address the regionally important questions, significant ecological resources and change agents, REAs focus on three primary elements:

- Change Agents (CAs), which are those features or phenomena that have the potential to affect the size, condition, and landscape context of ecological systems and components (Table 1).
- Conservation Elements (CEs), which are biotic constituents or abiotic factors of regional importance in major ecosystems and habitats that can serve as surrogates for ecological condition across the ecoregion (Table 2).
- Management questions (MQs), which are regionally specific questions developed by land managers that identify important management issues.

One important strength of this approach is the integration of current management concerns and current scientific understanding into a comprehensive regional assessment. MQs focus REAs on pertinent management and planning concerns for the region. MQs are also used to create CE and CA lists by identifying critical resources and management concerns for the region. In addition to the MQs, CEs are also identified via the ecoregional conceptual model. A complete list of MQs can be found in the Introduction to the Technical Supplement.

The core REA analysis refers to the status and distribution of CEs and CAs and the intersection of the two. The core REA analysis addresses the following five questions:

1. Where are conservation elements currently?
2. Where are conservation elements predicted to be in the future?
3. Where are change agents currently?
4. How might change agents change in the future?
5. What is the overlap between conservation elements and change agents now and in the future?

Assessment Elements

The primary REA analysis focuses on exploring the relationship of resources of conservation concern with specific agents of change. The change agents (CAs) are those features or phenomena that have the potential to affect the size, condition, and landscape context of the resources of interest. The change agents include broad factors that have region-wide impacts such as wildfire, invasive species, and climate change, as well as localized impacts such as development, infrastructure, and extractive energy development (Table 1, see Box 1).

CAs	
▶ Climate • Temperature • Precipitation • Thaw date • Freeze date • Cliomes ▶ Permafrost • Ground temperature • Active layer depth ▶ Fire (return interval)	▶ Invasive Species and Forest Defoliators ▶ Anthropogenic factors • Subsistence • Natural Resource Extraction • Transportation and communication infrastructure ▶ Recreation

Table 1. *Change Agents identified in the YKL REA. Bullets represent subcategories explored in the analysis*

The resources of interest are termed "Conservation Elements" (CEs) and are meant to represent key resources in the ecoregion that can serve as surrogates for ecological condition across the ecoregion (Table 2). The conservation elements were defined through the "coarse-filter/fine-filter" approach suggested by BLM guidelines; an approach used extensively for regional and local landscape assessments (Jenkins 1976, Noss 1987). Ecosystem representation are achieved by "coarse-filters" that are dominant habitats, with a limited subset of focal species as "fine-filters" to capture specific resources of interest and those not encompassed by the "coarse-filters."

Terrestrial Fine-Filter CEs	
▶ Moose (Alces alces) ▶ Caribou (Rangifer tarandus) ▶ Muskox (Ovibus moschatus) ▶ American beaver (Castor canadensis)	▶ Gray wolf (Canis lupis) ▶ American peregrine falcon (Falco peregrinus anatum) ▶ Trumpeter swan (Cygnus buccinators) ▶ Olive-sided flycatcher (Contopus cooperi)
Aquatic Fine-Filter CEs	
▶ Chinook salmon (Oncorhynchus tshawytscha) ▶ Chum salmon (Oncorhyncus keta)	▶ Sheefish (Stenodus leucichthys) ▶ Northern pike (Esox lucinus) ▶ Dolly Varden (Salvelinus malma)
Terrestrial Coarse-Filter CEs	
▶ Deciduous Forest ▶ White Spruce or Black Spruce Forest ▶ Tall Shrub ▶ Low Shrub	▶ Dwarf Shrub ▶ Herbaceous Wetlands ▶ Large Floodplains
Aquatic Coarse-Filter CEs	
▶ Streams ▶ Connected Lakes	▶ Disonnected Lakes

Table 2. *Terrestrial and Aquatic Coarse- and Fine-Filter Conservation Elements identified in the YKL REA.*

Box 1

Case Study: **Climate Warming**

A vast array of abiotic and biotic processes, from wildfire frequency to carbon and nutrient cycling, are underpinned by temperature. Analysis of areas most likely to experience the greatest change temperature and its impact on critical resources is useful to inform proactive ecoregional management.

Temperature has been steadily rising in the YKL study area over the historical record. While temperature changes are expected to be negligible in the near future, climate warming is projected to continue to increase substantially by the 2060s with temperature increases of more than 3°C (5°F) predicted in the more northern parts of the YKL study area (Figure 2).

Change is expected to be more pronounced in the winter than in the summer or shoulder seasons, but pronounced long-term changes are nonetheless expected in date of freeze and date of thaw. The warm season length is projected to increase, on average, anywhere from 8 to 24 days across the YKL study area, with the smallest increase in the south, and the greatest increase in the north.

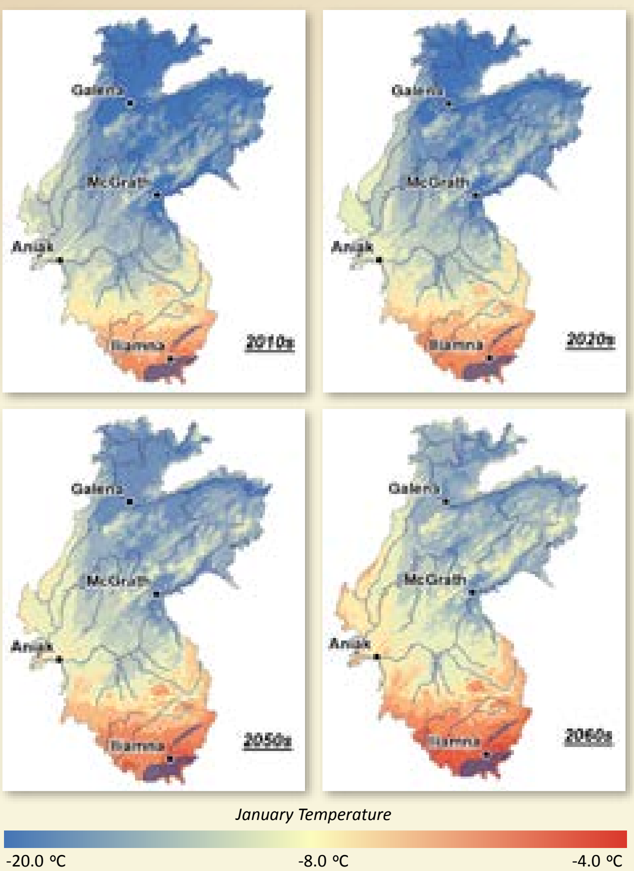

Figure 2. *(Top) Average January temperature forecasts are thought to drive most of the permafrost change expected in the region. (Right) Thermokarst thaw slump triggered by erosion of the Selawik River, northwest, Alaska. Photograph by Kenji Yoshikawa, University of Alaska Fairbanks.*

Warming temperatures are also expected to decrease the snow day fraction (the estimated percentage of days on which precipitation would occur as snow as opposed to rain) for fall, winter, and spring. In the long term, May and September snowfall are expected to be negligible almost everywhere in the YKL study area, and only colder areas (such as near McGrath and Galena) are projected to remain consistently snowy in mid-winter. By 2060 a substantial portion of the region is expected to experience climates that have no current analog in Alaska.

Driven by warming summers, fire appears to be already increasing in frequency (Kelly et al. 2013) and intensity (Genet et al. 2013). Our models predict that fire frequency will increase in the near term (2025) from a current fire return interval for forested lands between 112 and 182 years to a much shorter interval of 94 to 143 years. Changes in fuel loads in the future, however, will likely lead to variable return rate.

Most of the central portion of the YKL study area has discontinuous permafrost. Warming climate also is projected to increase the Mean Annual Ground Temperature between the current decade and future decades. Ground temperature forecasts show that the greatest degree of change can be expected in the intermediate areas; thus we expect to see a substantial loss of discontinuous permafrost in the next fifty years. Permafrost loss is expected to result in numerous changes on the landscape, such as thermokarst erosion (Figure 2), losses of discontinuous lakes, and alterations of vegetation.

Climate data, while modeled at a relatively fine-scale, do not always match the scale of phenomena that affect ecosystem resources and the direct and indirect relationships between climate, species, and habitats is inadequately studied. Regardless, understanding how major shifts in the physical landscape may alter species and habitat vulnerability offers opportunities to identify areas of greater and lesser concern and direct future study. Impacts of climate change are explored on specific conservation elements in greater depth in the Technical Supplement.

Ecoregional Conceptual Model

The Ecoregional Conceptual Model portrays an understanding of critical ecosystem components, processes, and interactions necessary for the maintenance of sustainable ecosystems. Specifically these models describe how ecosystem resources interact with one another and describe the relationships between ecosystem resources, agents of change, and ecosystem drivers.

The Conceptual Ecoregional Model for the Yukon-Kuskokwim-Lime Hills Ecoregion provides a coarse-level interpretation of key ecological resources, drivers, and CAs (Figure 3). The model is divided into the following components:

- **Principal ecosystem resources**, including vegetation, animals, soil resources, and freshwater resources.
- **Ecosystem drivers**, including climate and atmospheric conditions (i.e. precipitation, temperature, cloud cover etc.) and landscape setting (i.e. geology, elevation, and proximity to ocean)
- **Anthropogenic** (land use, commercial / sport harvests, recreation) and non-anthropogenic CAs (climate change, fire, and invasive species).
- **Relationships between ecosystem resources** with interactions between them identifying key ecosystem processes and functions (for example, soils resources provide habitat for animals).
- **Relationships of ecosystem drivers and CAs** as external forces for ecosystem resources (for example, climate change alters composition, structure, and productivity of ecosystem resources and climatic conditions provide carbon and nitrogen setting providing essential components to the ecosystem resources).

Land Owners and Stakeholders

In addition to working with the Assessment Management Team and Technical Team, the University of Alaska team and BLM State and Field offices also coordinated three community meetings, one each in Galena, Newhalen, and Aniak. The purpose of these meetings was to inform the general public about the REA process, its expected outcomes, and gather input on conservation elements, change agents, and management questions. Additional management questions and conservation elements were considered thanks to feedback from these community meetings.

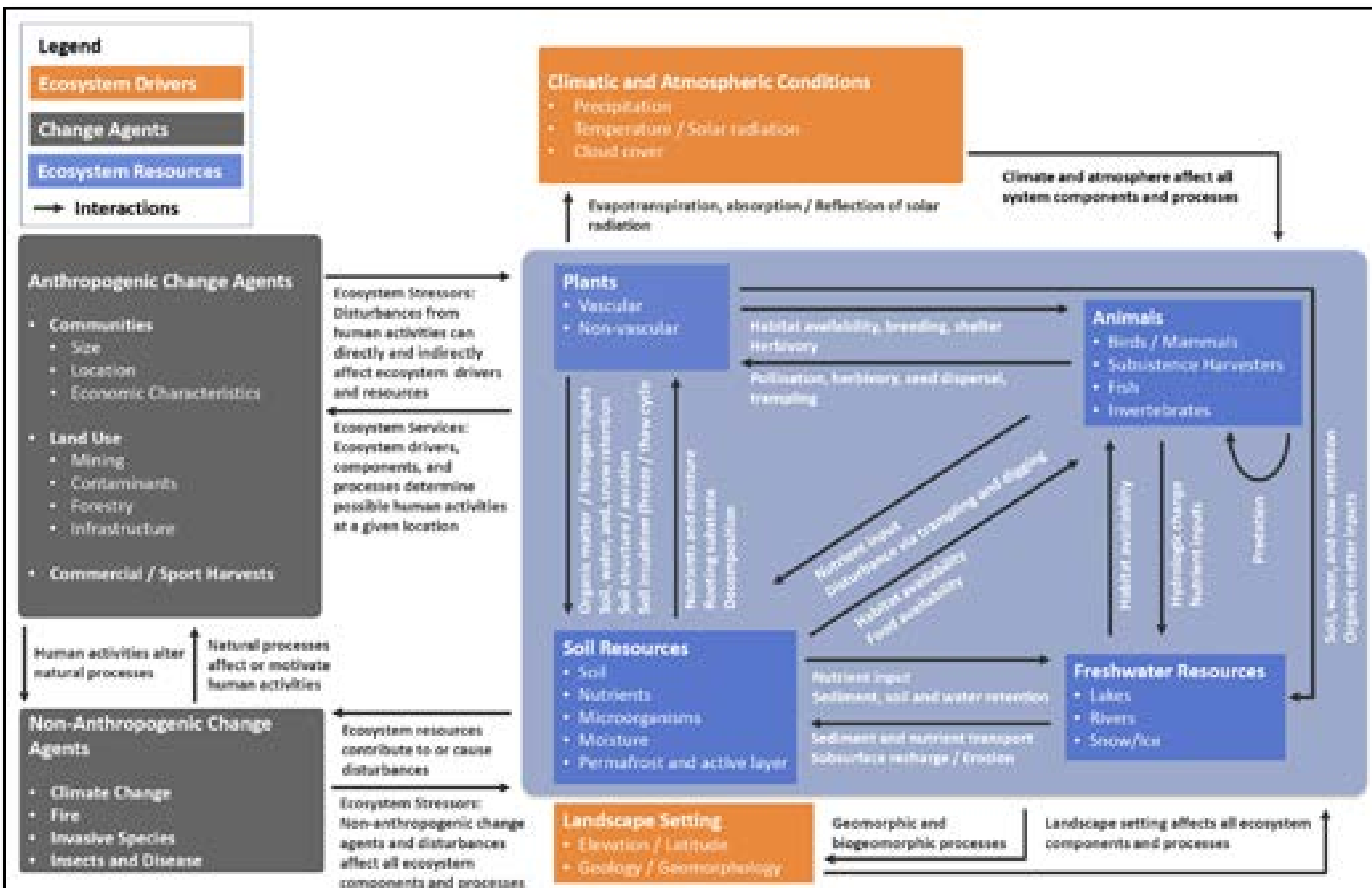

__Figure 3.__ Conceptual Ecoregional Model for YKL REA. Conceptual ecoregional model for YKL REA. Principal ecosystem resources, ecosystem drivers, anthropogenic CAs, non-anthropogenic CAs, and the relationships between ecosystem resources are all included to help understand the current system. Please see the Technical Supplement (Appendix C) for the full suite of CE conceptual models.

2 BASELINE

One of the primary goals of REAs is to develop seamless baseline datasets for the ecoregion of interest. This baseline data for species, habitats, and agents of change provides the foundation of the assessment, but also serves as a critical product for managers to understand the current status of the ecoregion, as well as providing a benchmark on which they can measure change. Thus, baseline data is an extremely important first step in the REA process.

Data Discovery

From the onset of this REA, the UA team was tasked with identifying, collecting, and synthesizing relevant existing information. This task was particularly challenging given the lack of data for the study area. Additionally, because this is a rapid assessment, most data needed to be in digital or in GIS-ready format. The YKL region is minimally inhabited, and although some larger projects have been proposed in the region, data collection for ecological resources has been exceptionally limited.

Given the apparent lack on information, substantial effort was spent on identifying datasets relevant for regional analyses. This included extensive online searches, data archive searches, interviews, phone calls, office visits, and primary literature reviews. Data from many state and federal agencies was collected and synthesized. Hundreds of datasets were examined for accuracy and clarity, quality and completeness, and utility for regional management. All data were presented to the AMT and Technical Teams in February of 2013 (the resulting document can be accessed via the BLM REA website).

Baseline Data Creation

One of the additional benefits provided through this REA is the development of unique baseline datasets for the region. Basic data relating to species distributions was sparse and when available, was typically limited to small areas within the assessment region. We developed, tested, and validated models depicting terrestrial habitats, terrestrial species, and aquatic species within the region. The result is a suite of newly developed spatial models depicting distributions for various vegetation assemblages and both terrestrial and aquatic species that did not previously exist for the region. These distribution models will be available through an online data portal hosted by the BLM.

Terrestrial Habitats

Prior to the YKL REA, there was no comprehensive land cover map available for the region that detailed anything more than basic life form classifications of vegetation. Unlike the rest of the U.S. there was no Anderson level II or III classifications for the ecoregions (or for the state at large). Additionally, the existing land cover maps were considered unreliable and inaccurate for most of the region. Thus, with support from additional projects, we combined multiple regional maps to create a vegetation map (Boggs et al. 2012) that covered the YKL study area in its entirety. This dataset provided baseline information about vegetation classes that were used to develop the broad ecosystem resources, as well as to address key management questions relating to specific vegetation resources (such as: "What is the current distribution of primary winter forage (lichen) for caribou in the region, and how is that expected to change?").

Terrestrial Species

Information regarding the distribution of key terrestrial species in the YKL was also limited (for a more detailed description please see Section D-2 in the Technical Supplement). For some species identified as important ecological resources, as few as ten records were documented for the YKL. To address this limitation, the UA team relied on statewide distribution models to represent the locations of species of interest. However, given that the models were developed for the whole state, each model went through an exhaustive review to ensure they were still relevant and accurate for the YKL region.

Aquatic Species

One of the primary data gaps in this assessment (and other REAs throughout the U.S) was information for aquatic ecological resources. This was especially evident in the coarse-filter aquatic conservation elements as there is no aquatic habitat classification for Alaska, and the National Hydrography Dataset (NHD) and Digital Elevation Models (DEM) for the study area are outdated (see Box 2). However, partial data existed for some regionally important fish species. Data from the anadromous waters catalog (AWC) was used to map the distribution of Chinook salmon, chum salmon, and sheefish. However, two additional fish species were identified as ecologically significant resources: northern pike and Dolly Varden. Limited data on the distribution of these species existed for the region, but for key river systems there was presence and absence data (see Section D-4 for details in the technical supplement). Using this information, the UA team built predictive models for both northern pike and Dolly Varden for the entire assessment area, providing the first look at the potential distribution of key fish resources in the region (Figure 5).

Box 2 Case Study: ***Vulnerability of Fish and Aquatic Habitats***

Fish and aquatic habitats represent critical resources that fuel much of the subsistence and commercial economies of the YKL region. Future changes in climate and development pose a suite of potential risks to these resources. Increases in temperature are projected to exacerbate impacts of disease; permafrost loss is expected to result in significant alterations to habitat quality and increased exposure to mercury. Mining and other development activities are also likely to increase mercury-levels in fish. Impacts to spawning habitats from currently active placer mining activity generally are localized to smaller streams in the Kuskokwim Mountains, while the larger-scale proposed mines in the region are projected to have higher potentials for disrupting fish habitat.

Increased water temperature elevates the frequency that Chinook salmon are infected by the microscopic parasite Ichthyophonus hoferi (Kocan et al. 2003; Zuray et al. 2012), and water temperatures above 15°C are known to be lethal for infected fish (Okamoto et al. 1987). Prior to the 1980s, this parasite was unreported in Chinook salmon in the Yukon River. Since the 1990s, however, infected Chinook salmon have increased to levels that warrant concern for subsistence harvest and commercial fishing in the Yukon River (Kocan et al. 2003). With projected climate warming, water temperatures will likely increase and the proportion of disease and pre-spawning mortality among infected fish may likewise increase (Zuray et al. 2012). Elevated pre-spawning mortality is expected to result in greater restrictions on subsistence and commercial fishing in order to meet escapement goals. Climate warming is anticipated to be greatest in the northern part of the YKL area and therefore Chinook salmon runs in this region are projected to be of greater vulnerability to infection (Figure 4).

With continued depressed salmon runs, subsistence users are likely to become increasingly reliant on resident fish species, such as northern pike. Future increases in mercury concentrations in aquatic habitats could reduce the value of pike as a subsistence resource. This is a growing concern within the YKL area due to the potential for increased mercury contamination related to permafrost thaw (Schuster et al. 2011), increased fire frequency (Kelley et al. 2006), cinnabar deposits and mining activities (Matz et al. 2012), as well as atmospheric deposition (AMAP 2002).

Thawing permafrost has been linked to declines in lake area, especially for disconnected lakes (Figure 4) within the Yukon River Basin (Roach et al. 2013). Alterations and loss of disconnected lakes, which represent important habitat for waterbirds and some fish species, is expected to be one of the larger changes in aquatic habitats in the long term.

Mining operations, especially those of a large scale, threaten to destroy feeding and spawning habitats. Large-scale mines (such as the proposed Pebble Mine and Donlin Mine) are currently absent from the YKL region, but have the greatest potential for disrupting salmon spawning habitat (U.S. EPA 2014). Small-scale placer mines also pose a threat to fish habitats though the impacts are generally more localized.

Overall, climate warming and increases in development are expected to impact fish populations and their habitat (see Technical Supplement for more details). In order to respond to these potential changes and provide more effective management of aquatic habitat resources, the development of an aquatic habitat classification, which was identified as a major data gap for this REA, is recommended. This data gap is particularly acute given the spatial inaccuracies and limited attribute information in the National Hydrography Dataset that is currently used to map aquatic habitats.

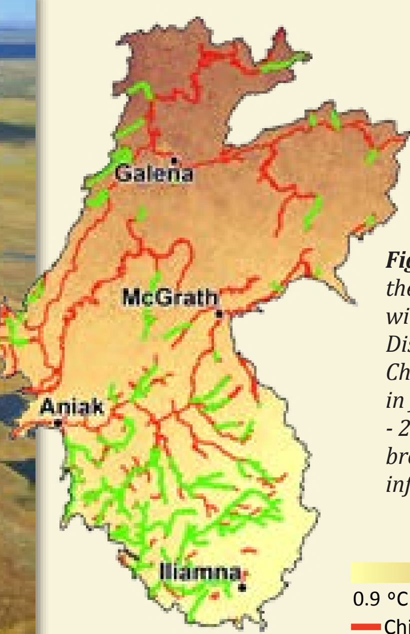

Figure 4. *(Left) Disconnected lakes in the YKL area are expected to decline with future loss of permafrost. (Right) Distribution and spawning habitat of Chinook salmon and modeled increase in July temperature change from 2010 - 2060– higher temperatures (darker brown) are associated with increased infection rates.*

New Baseline Products Developed for the YKL REA

Aquatics

- Distribution maps developed for Chinook salmon, chum salmon, and sheefish
- Predicted distribution models for northern pike and Dolly Varden
    - Developed in consultation with FWS, ADF&G, USGS & BLM

Terrestrial

- Distribution maps for deciduous forest, dwarf-shrub, herbaceous wetlands, low shrub, tall shrub, and white spruce and black spruce forest classes using a combined map of regional vegetation maps
- Distribution map of Large Floodplains
- Winter moose forage (willow) map
- Primary caribou forage (lichen) map for the YKL study area
- Approximate locations of caribou migration pathways for seven caribou herds
- Potential muskox habitat map developed in consultation with ADF&G biologists

Climate, Permafrost, Fire

- Calibrated model estimates of future fire frequency
- Estimates of permafrost change using the A2 climate scenario
- Model of snow day fraction
- Uncertainty estimates for climate models

Anthropogenic

- A comprehensive database of more than a thousand social and economic
- Subsistence use area maps developed for all species assessed under the YKL REA
- A searchable database of documents and reports containing TEK
    - Subsistence harvest data provided by ADF&G

Figure 5. *Modeled distribution of Northern Pike habitat within the YKL.*

3 LANDSCAPE CHANGE

An overall goal of the REA is to provide land managers with a vision of the direction and magnitude of change they can expect on their land and neighboring lands. By assessing the overlap of agents of change (CAs) and the critical ecosystem resources (CEs), land managers can better understand the locations and degree of impacts on resources (for example, fire impacts on a specific land cover), as well as the cumulative impacts of fire, climate change, invasive species, and development on the resources of interest.

To document the potential changes to the ecoregion, we first had to develop a comprehensive understanding of all the driving factors and context of the landscape. This was done at both the ecoregional scale (Figure 3) as well as the individual CE scale (Figure 6) using conceptual models and a description of the socio-economic condition (see Box 5).

The relationships identified in the conceptual models were then used to evaluate the various ways in which CAs might impact CEs. The simplest and most straightforward approach was by assessing the overlap between CEs and specific CAs identified as important through the conceptual model.

We also assessed the status of each CE by summarizing the landscape condition for each CE. Landscape condition was developed as a function of the degree of human modification, where some anthropogenic features, such as secondary roads, were assigned greater impacts that diffuse more slowly relative to other features, such as winter trails.

To better understand overall landscape status, landscape fragmentation and intactness was evaluated. Finally, we examined the potential cumulative impact of all the CAs by identifying the areas that are likely to experience the most change in the near and long term. A more complete description and examples of these various metrics of landscape change are listed below, as well as their potential importance for regional resource management.

Conceptual Models

Conceptual models were also built for each individual CE, in addition to the broader ecoregion. From the broader ecoregional conceptual model (Figure 3), we identified the key ecosystem resources that needed to be examined more closely (i.e. the Conservation Elements). By selecting CEs that represent key ecological resources, we provide a framework in which overall ecological integrity can be assessed. Thus, if all CEs in the ecoregion are considered to have good status and habitat quality, then we would assume the larger ecosystem has high integrity.

The individual CE conceptual models provided specific linkages between CAs and the CE. Not all relationships identified lend themselves well to measurement or monitoring, but they are important to include because they add to our overall understanding of complex interactions (Bryce et al. 2012). Every conceptual model was supported and referenced by scientific literature. These conceptual models represent the current state-of-the-knowledge for these species and systems and can be useful in future studies.

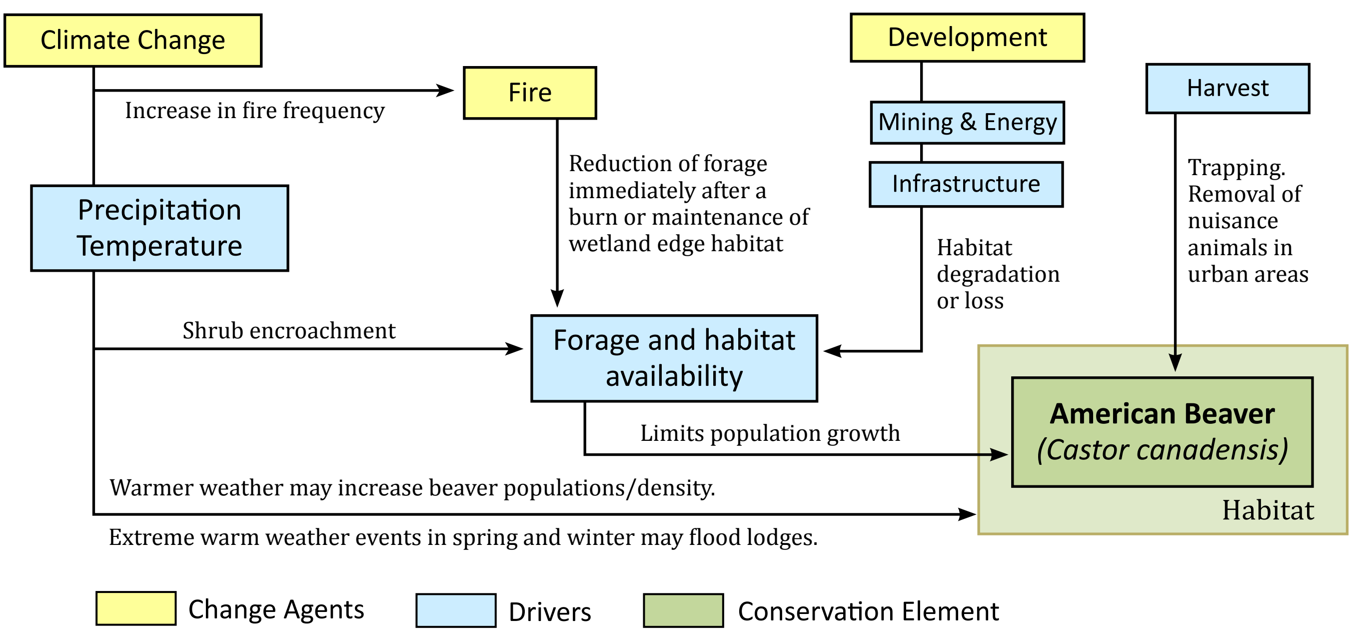

Figure 6. *Example conceptual model for American beaver (Castor canadensis). Arrows indicate specific interactions that are identified in red text.*

Quantifying Change

Overlap of Conservation Elements & Change Agents

For some species and habitats, overlays of simple climate variables (like July temperature or average annual precipitation) with the distribution of CEs were used to assess potential change (see Box 2 for an example of Chinook habitat and average July temperature). For other species, amalgamated climate variables were developed that more directly link potential changes to CE life history. An example of this is in Box 3, where we discuss the implications of mean summer temperature on American beavers. Many similar CE x CA overlaps were performed and can be found in Section D of our Technical Supplement.

Box 3 — *Case Study:* **Projected Increase in Beaver Habitat**

North American beavers drive ecosystem processes (see Figure 6). They are ecosystem engineers and are known to modify stream channel geomorphology and hydrology, alter nutrient cycling, and create and maintain wetlands (Baker and Hill 2003, Boyle and Owens 2007, Naiman et al. 1986). Because they exert such a strong influence on aquatic and riparian communities, the beaver is considered a keystone species, a species with disproportionally large effect on its environment. Beavers are widespread at lower elevations throughout the YKL study area.

Beaver densities are highly temperature dependent. Although populations exist across many temperature gradients, beavers occur in much greater densities in warmer locations (Jarema et al. 2009).

Currently, most of the YKL study area meets the minimum summer temperature threshold necessary for beavers to be present (summer temperature > 14.8°C). However, climate models suggest that areas with conditions that favor higher beaver densities may more than double in the YKL in the next 50 years (Figure 7). This effect is expected to be most pronounced in the northern half of the YKL region.

Adverse effects of a warming climate to beaver populations may also occur. Warming climates are expected to create more frequent sudden snowmelt events and violent ice breakups may raise water levels and destroy lodges (Hakala 1952). In addition, increased ambient temperatures may cause drying of wetlands. Beavers will likely be able to mitigate many of these effects with their ability to maintain open water and regulate pond and lake levels during cycles of drought and flooding (Hood and Bayley 2008, Bird et al. 2011).

Beavers typically occur in areas with low to moderate human activity and disturbance (Slough and Sadleir 1977). A potential landscape-scale threat to beavers is habitat fragmentation caused by development and associated water development projects. The majority of current beaver distribution in the YKL study area is regarded as highly intact and of very high landscape condition. Localized areas of reduced condition really only occur near McGrath and Galena. Future projections of landscape condition suggest only a minor decrease in habitat quality near the regional hubs and along the Yukon and Kuskokwim river corridors if development occurs. Please see the Technical Supplement for more details.

In general, with the predicted increase in suitable beaver habitat due to warming temperatures and the relative intactness of the landscape, land management agencies can expect beavers to continue to be an important driver on the landscape with the potential for even higher densities.

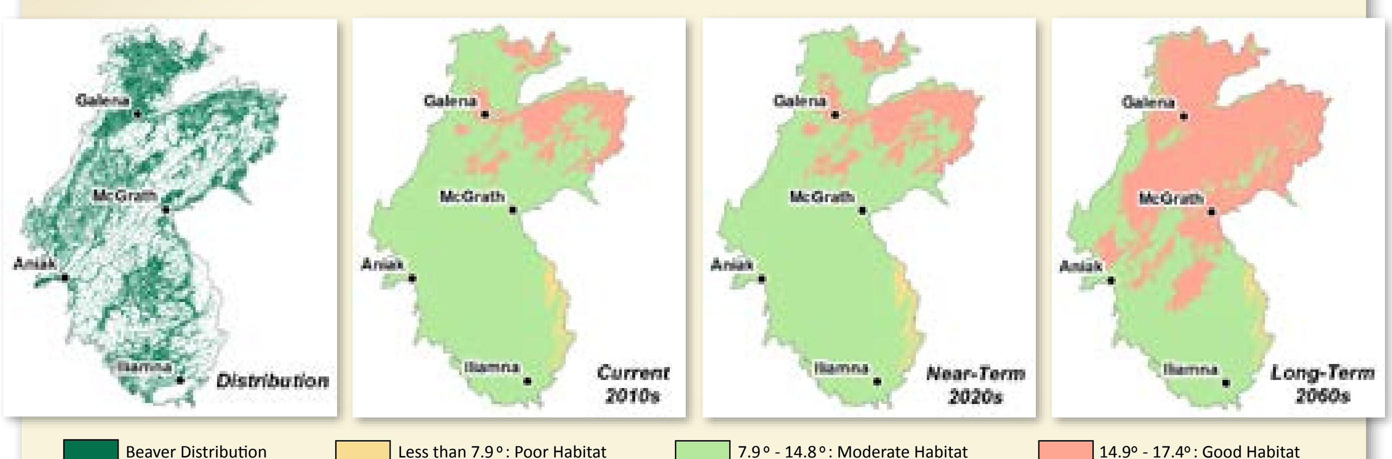

Figure 7. *Mean decadal summer (JJA) temperatures (°C) and beaver distribution thresholds modeled for the A2 Scenario.*

Landscape Condition

We understand from the literature that different land uses have different impacts on the ecosystem (Leinwand, Theobald et al. 2010, Theobald 2010, Theobald, Reed et al. 2012). Using thousands of studies documenting these impacts, NatureServe created a model called the Landscape Condition Model (LCM) that weights the different land uses according to their overall impact on the landscape, and assigns a distance at which the impact is no longer felt on the landscape. This produces a continuous dataset of landscape condition for the entire assessment area (Figure 8). This was then in turn used to inform landscape integrity and conservation element status (below). Additional details about the inputs and specific methods used in the LCM can be found in the Technical Supplement under Section C.

Landscape condition is a simple way of understanding the relative integrity of a given area. If human modification is minimal, we expect areas to be functioning well. Furthermore, landscape condition is something that can be assessed under future time steps and scenarios, making it a useful decision-support tool. For example, the LCM is providing information to the Western Governors Association on overall landscape integrity through their Critical Habitat Assessment Tool (CHAT) in all western states (including Alaska).

Landscape condition was modeled in the YKL for the current, near term (2025) and long term (2060) to identify what the current and future condition of the ecoregion is and might be (Figure 8). As expected given the geographical and political context, the YKL is extremely intact. Over 95% of the region is considered to be unmodified by humans, and is thus identified as the highest landscape condition. Assuming the degree of human modification continues at its current rate into the future, we only expect the percentage of high condition landscapes to fall to 93%. The anticipated degradation in landscape condition is likely to come from increased mining activity (specifically the Donlin and Pebble mines) and proposed roads and pipelines.

Given the highly pristine condition of the YKL, management needs in this REA are quite different than those in the contiguous U.S. Instead of monitoring and managing for increasing ecological condition, managers in Alaska have the opportunity to modify how and where land use activities impact the currently intact condition. This creates some novel opportunities for monitoring the effects of various land uses - the baseline condition can also be considered the reference condition, a luxury that most landscapes in the U.S. do not have. Furthermore, it provides an opportunity to identify ways in which land use plans can still move forward without compromising the overall landscape condition.

Land managers and scientists alike have an important question to ask about ecosystem thresholds, given the high condition of the YKL. The degradation from “very high” to “high” may seem numerically small, but could have larger ecological effects not captured by this analysis. It is very likely that degradation from “very high” to “high” has a different ecological meaning than degradation from “moderate” to “low”. Sensitive species that inhabit the high condition regions of the landscape could be lost with that small degradation. Thus, the very high condition could be an important resource to monitor and manage for in the future.

Finally, when examining the stewardship of the YKL REA in relation to landscape condition, we found that most major landowners have highly intact lands (Table 3). However, this is not the case across the board and calls attention to specific land use planning opportunities.

Land Management Status	Very Low Condition	Low Condition	Moderate Condition	High Condition	Very High Condition
Bureau of Land Management	35	54	139	399	34,942
Fish and Wildlife Service	24	29	87	884	38,910
Military	61	45	19	15	29
National Park Service	0	1	18	74	9,192
Native Patent or IC	555	682	974	1,973	23,304
Native Selected	0	9	49	104	2,796
Private	-	-	-	-	31
State Patent or TA	340	488	1,025	2,631	95,840
State Selected	24	29	65	196	14,772

Table 3. *Current landscape condition relative to land management status in the YKL REA (in km2).*

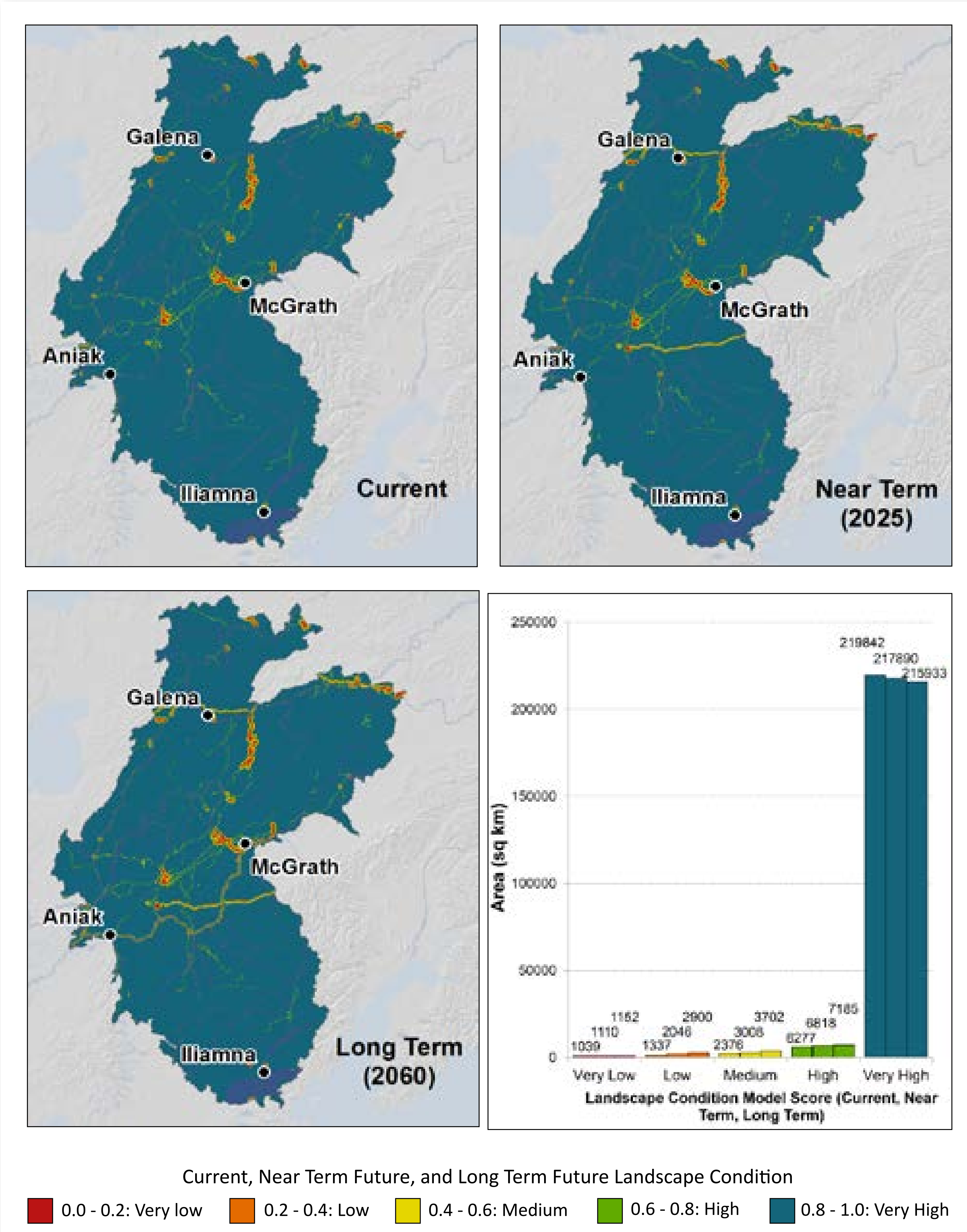

Figure 8. *Current, near-term and long-term landscape condition of the YKL REA.*

Landscape Integrity

We also calculated the level of fragmentation in the YKL. By lumping high condition landscapes together, we were able to set some context for the landscape condition and highlight ways in which the connectivity of landscapes may change over time.

First we assessed those patches of landscape with the highest landscape condition that were over 50,000 acres (Strittholt, Nogueron et al. 2006) to represent the highest integrity landscapes. We then assessed the high condition landscapes that were between 10,000 and 50,000 acres (Geck 2007) to represent high landscape integrity areas. Finally, we identified those high condition landscapes below 10,000 acres as being vulnerable to change. Figure 9 shows how landscape integrity is likely to change in the near and long term, while Table 4 breaks down the categories of landscape integrity.

Similar to overall landscape condition, we anticipate landscape integrity will remain very high for the YKL. Again, this is based on current rates of anthropogenic change (see Section B-5 in the Technical Supplement for more information). However, given the high integrity that currently exists in the region, it appears that most systems would remain intact. Although most of the region is highly intact, there are some key areas, such as McGrath and Ruby, and nearby mining districts, where landscape condition is high but fragmentation has rendered them vulnerable to change. If those areas are further compromised by human modification or abiotic change agents, then another 1% of the region could lose intact and valuable habitat.

One of the key outcomes from this and the other landscape change metrics is the ability to use the information provided here to focus monitoring efforts. Knowing where changes are most likely to occur (CE x CA overlap, cumulative impacts), managers can more intently focus monitoring efforts in those areas. Likewise, if certain areas are considered vulnerable to change, monitoring and possible protection of those places becomes an option before the resources are compromised.

Conservation Element Status

The UA team also assessed the status of each CE by overlaying the CE distribution with the landscape condition (see Box 4 for an example). Thus, status provides some idea of the quality of habitat for each CE, both currently and into the future.

Our analysis showed that all CEs (as modeled) have access to high condition habitats throughout the YKL. The only CE that showed a noticeable decrease in condition was Large Floodplains, due primarily to placer mining activity now and in the future. However, over 75% of the extents of Large Floodplains still have "very high" condition, suggesting that at the ecoregional scale even the most impacted CE is in very good condition.

By understanding the status of the habitat, then managers can better anticipate how vulnerable those species and habitats might be to future changes. If a species' habitat is already degraded due to human modification (for example, near a road and existing mining activities), the species may be more vulnerable to other changes (for example, increased summer temperature or introduction of an invasive species). Given that each CE represents a key ecosystem function, when all CEs have good status (meaning high landscape condition) then we expect overall ecosystem function, and integrity, to be high.

Cumulative Impacts

As a final approach to quantifying the likely changes to the landscape, the UA team performed a cumulative impact analysis. The cumulative impact analysis represents a 'rolled-up' dataset of all potential threats to the landscape to identify the locations within the REA that are likely to experience the most amount of change.

The cumulative impacts analysis identified important thresholds at which a particular CA would likely elicit a management response. All CAs were included (January Temperature, July Temperature, Annual Precipitation, Permafrost, Fire Frequency, Landscape Condition, Invasive Species Vulnerability), though details on the nature and value of these thresholds can be found in the Technical Supplement (Section C-4). The model results are summarized to identify how many CAs are likely to change in an important way for any given watershed (Figure 11).

The results from this part of the analysis tell a more comprehensive story about landscape change that differs from the individual CAs and landscape condition/integrity analyses. It is clear from the cumulative impact analysis

Landscape Integrity Designation	Current (km2)	Near Term (km2)	Long Term (km2)	Size Criteria
Highest Landscape Integrity	216,056 (93%)	213,581 (92%)	211,671 (91%)	≥ 50,000 acres
High Landscape Integrity	2,493 (1%)	2,976 (1%)	2,944 (1%)	< 50,000 acres, ≥ 10,000 acres
Vulnerable to change	1,312 (1%)	1,353 (1%)	1,363 (1%)	< 10,000 acres
Low Landscape Integrity	11,011 (5%)	12,962 (6%)	14,894 (7%)	Variable

Table 4. *Current, near term, and long term landscape Integrity in the YKL REA. Integrity size criteria are given in the right column.*

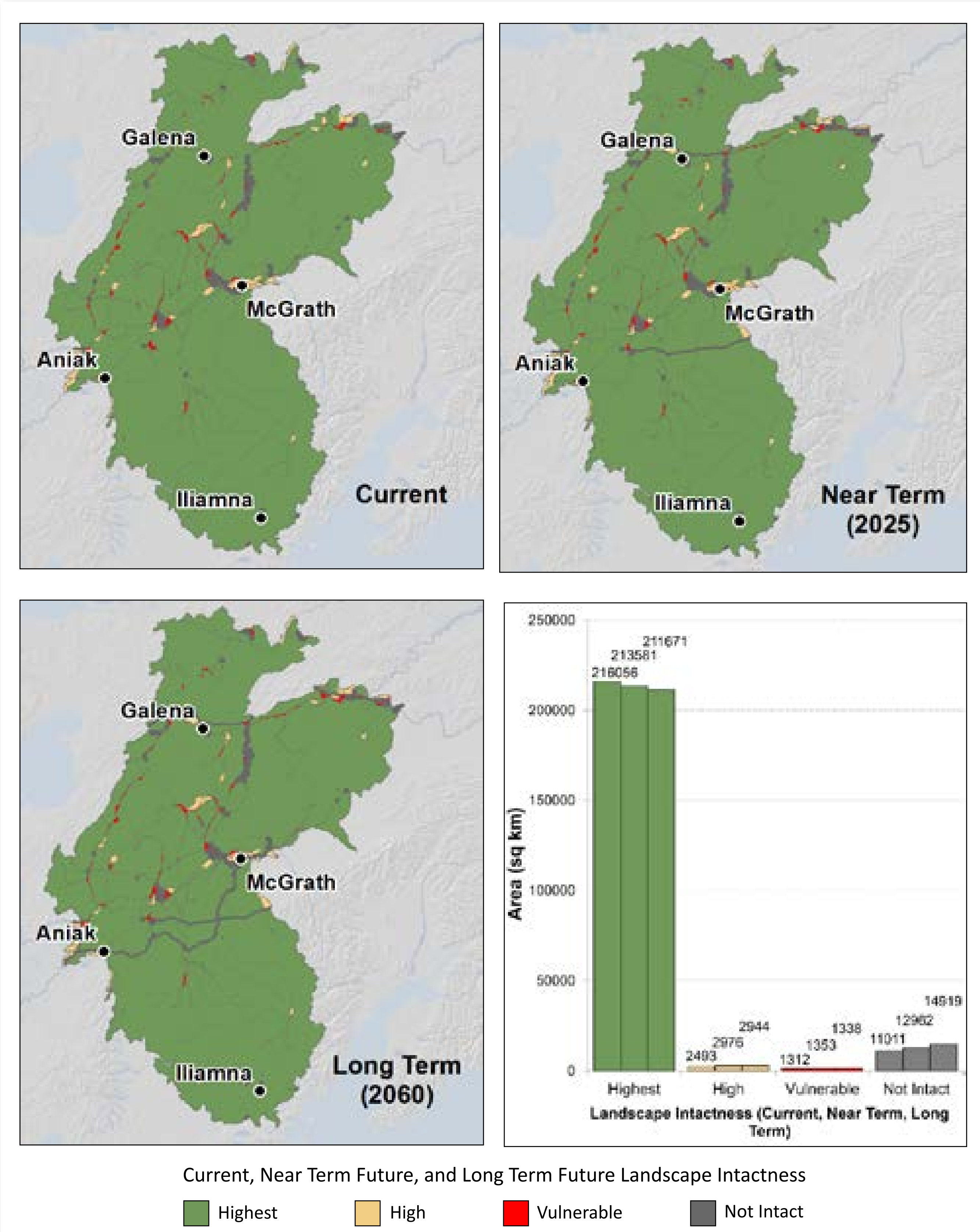

Figure 9. *Current, near-term and long-term landscape intactness for the YKL REA.*

Box 4

Case Study: **Floodplain**

Floodplains are the lands adjacent to a river, stretching from the banks of the channel to the base of the enclosing valley walls. These fluvial plains include meandering or straight streams, braided channels, abandoned channels, oxbows, alluvial terraces, and a broad range of associated vegetation types (Figure 10). Floodplains play an important role in linking aquatic and terrestrial systems; they harbor high concentrations of many important regional resources, including moose and timber; and human communities tend to be concentrated on floodplains.

The presence or absence of permafrost underlying ancient floodplains affects the current composition of species and ecology. In the colder northern third of the YKL study area, where permafrost is typically present, exposed alluvial deposits are first colonized by willows, then alders, poplars, and then birch and white spruce, followed by black spruce (Viereck 1973). Black spruce establishes after the accumulation of thick organic layers that reduce soil temperatures; many of these sites were initiated thousands of years ago (Mann et al. 1995). Thermokarst also commonly forms in forests when permafrost thaws (Osterkamp 2000), compromising the physical foundation of the forest floor and leads to the formation of wetlands and ponds in the resulting depressions.

Succession follows a similar trajectory in the warmer southern portion of the YKL area, but white spruce typically maintains dominance on the older sites. Black spruce communities are uncommon and thermokarst wetlands and ponds are largely absent (Boucher et al. 2014, in prep.).

Climate warming is expected to influence all floodplains in the YKL by 2060, with an anticipated warming of more than a 1°C in mean annual temperature and increases in growing season length by more than a week. The vegetation response to climate change may be relatively rapid because most floodplain sites are less than 200 years old (Chapin et al. 2006). We expect that in the future, the northern interior floodplains will transition to having characteristics more similar to of those to the south as permafrost is lost.

Relative to flooding and sediment deposition, fire currently plays a minor role in driving succession and ecosystem processes on floodplains. The current fire frequency in floodplains is considerably less than that of the surrounding terrain (Foote 1983). However, projected increases in fire frequency will likely result in a modest reduction in the proportion of floodplains that harbor mature stands of white and black spruce and increase the representation of willow, aspen, poplar, and birch.

Invasive plant species have the potential to outcompete native vegetation and impact wildlife in the region's floodplains. A number of non-native plant infestations are currently documented from floodplains in the YKL, but most of the species are not considered to be strongly invasive. A number of known populations of more damaging invasive species, such as white sweetclover, are known from areas adjacent to rivers in the YKL, however. Areas more likely to be affected are those adjacent to, and immediately downstream of, the larger population centers.

Despite communities and most infrastructure being concentrated in floodplains, human disturbance is currently minimal (0.04 %) and predicted future human disturbance remains minor (Figure 10). The projected reduction in status is associated with proposed open-pit mines and proposed or potential transportation corridors.

Overall, the landscape condition of floodplains is high and will likely remain high. Increases in temperature and growing season length and increases in fire frequency, however, are expected to alter the composition of vegetation in floodplains. Further this habitat is vulnerable to impacts from non-native plant species.

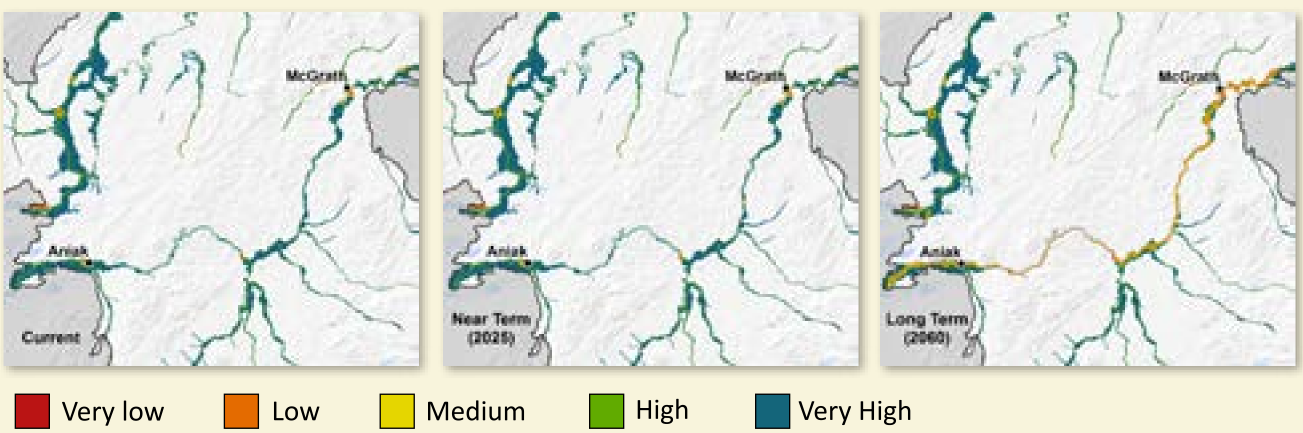

Figure 10. *Current, near-term (2025), and long-term (2060) status of large floodplains in a focus area of the YKL study area, warmer colors indicate lower condition.*

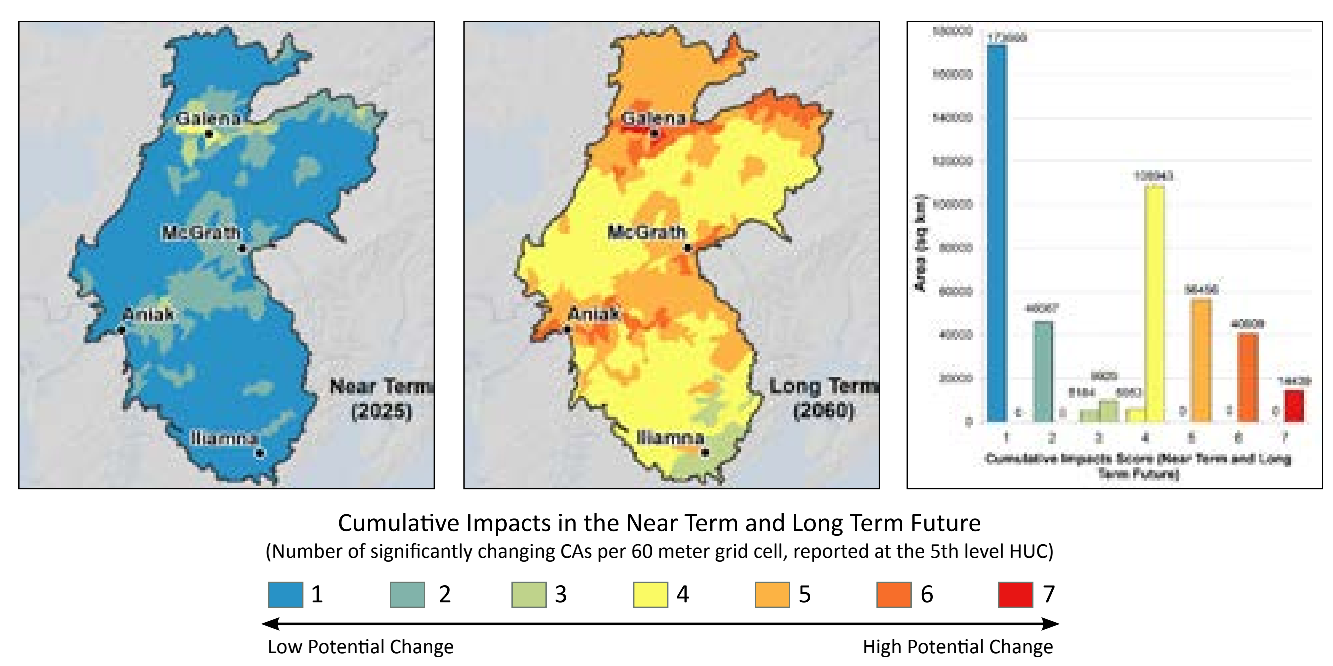

Figure 11. *Cumulative impact assessment for the YKL REA summarized at the watershed. All CAs were weighted equally, except for temperature increases over 2° C, which received a higher score.*

that, while changes are relatively minimal in the near term, most of the region is likely to change in significant ways in the long term. Areas near Galena are likely to experience three to four of the CAs acting on the landscape in the near term, while most of the northern part of the YKL is likely to see changes in six to seven CAs in the long term, potentially leading to novel climates and ecosystems. Segmenting these results into jurisdictional boundaries (Table 5) highlights the collaborative opportunity land managers have in the region to monitor and manage for these simultaneous changes that are not unique to any agency or stakeholder.

Landscape Change Summary

While the region maintains high ecological integrity, it is apparent that the YKL will change in the future. This assessment has highlighted some of the ways in which we expect ecosystem resources to respond, but substantial work is still required before we can fully understand the nature and impact of these changes. This is especially important given the most of the change will likely come from the combined change in climate, and climate-driven processes.

Land Management Status	1 CA	2 CAs	3 CAs	4 CAs	5 CAs	6 CAs	7 CAs
Bureau of Land Management	49	50	2,117	14,512	15,752	3,062	26
Fish & Wildlife Service	11	25	2	18,414	19,297	2,107	78
Military	-	-	9	21	105	19	15
National Park Service	32	10	2,372	6,405	466	1	-
Native Patent or IC	24	14	1,992	6,853	9,401	7,996	1,205
Native Selected	2	2	92	1,511	666	683	3
Private	-	-	-	23	8	-	-
State Patent or TA	91	30	3,254	58,461	33,072	5,197	218
State Selected	13	5	33	7,826	5,664	1,376	169

Table 5. *Total area expected to change (km2), by land management status, according to the number of change agents (CAs) expected to significantly change by 2060. Those areas with the highest number of CAs expected to change could be considered the most vulnerable landscapes in the YKL.*

Box 5

Case Study: **Socio-economic conditions**

The YKL region is sparsely populated with about 5,000 people living in 33 communities. Economies are a hybrid of cash from jobs, subsistence food harvests, and government transfers. Major economic challenges for residents of YKL communities started with the crash in the salmon population in the early 1990s. Since then, the populations of most communities have been decreasing. Population loss leads to additional job losses as schools are forced to close due to low enrollment, many remaining jobs disappear, and families with children move away. In the Yukon and Kuskokwim river sub-regions, population decline is likely to continue (Figure 12).

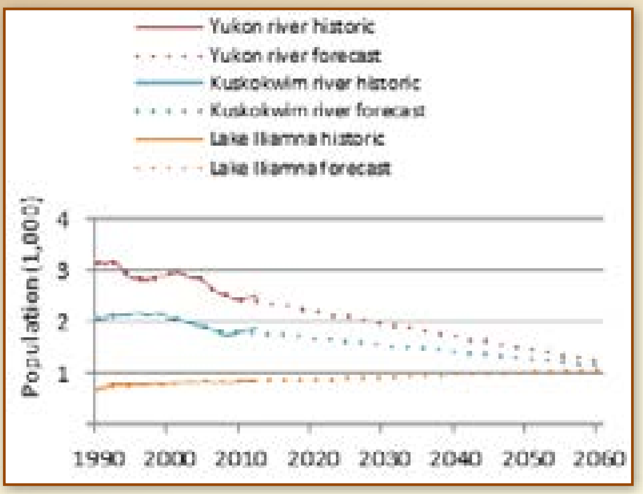

Figure 12. *Historic and projected populations for the YKL region.*

Difficulties due to lack of economic opportunities are exacerbated by high and rising fuel prices. High prices are due to global oil prices but are driven even higher in rural Alaska because of transportation costs. Fuel is delivered by barge to most places and barge costs are rising due to riverbank erosion, caused by in part by permafrost thaw. This makes rivers shallower and fuel delivery more difficult. Fuel costs are even greater for communities requiring airplane delivery.

Few jobs and high prices for store bought food make subsistence harvests important to help households make ends meet. However, high fuel price also make gasoline for subsistence more expensive. Historically, residents worked as commercial fishermen and used equipment and cash from commercial fishing for subsistence harvests. Lack of fish and lack of cash from commercial fishing put additional stress on subsistence users.

Job opportunities associated with Donlin Creek mine may slow out-migration, but are unlikely to result in larger populations. This is because large numbers of unemployed residents will need to be absorbed into the workforce before in-migration occurs. Donlin Creek will also be an enclave industry, similar to Prudhoe Bay and Red Dog mine, with fly-in fly-out arrangements that allow workers to live outside the region.

Figure 13 shows where permafrost loss is predicted for communities in the northern part of the REA. Permafrost loss can result in damage to buildings and infrastructure, leading to even higher transportation costs.

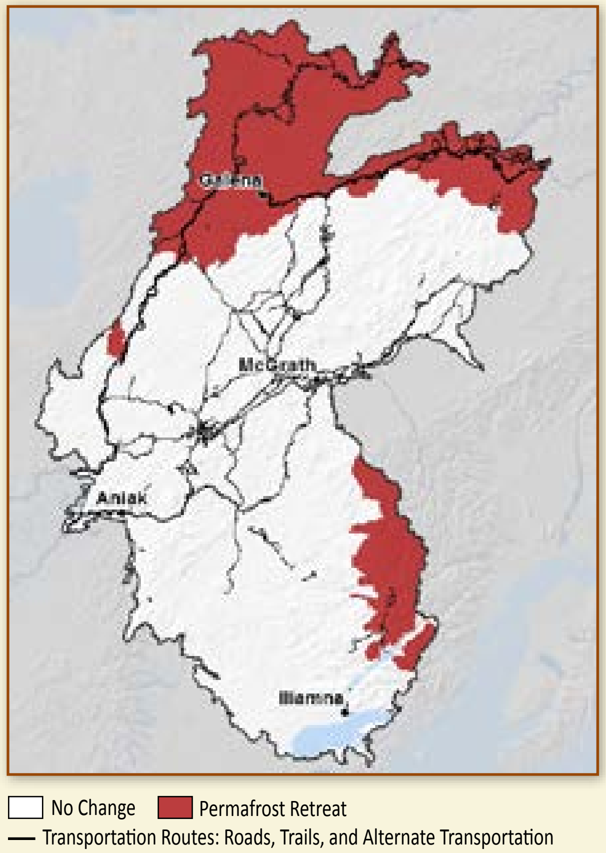

Figure 13. *Anticipated permafrost retreat between 2010 and 2060 in relation to regional transportation routes.*

4 FUTURE OPPORTUNITIES

The YKL ecoregion, and often Alaska as a whole, is data poor when it comes to essential baseline spatial data for landscape assessments. These data gaps were highlighted throughout the assessment (for a discussion of caveats, limitations and assumptions please reference the Technical Supplement), providing managers and researchers a tool to determine what data are lacking for the region and hopefully leveraging new projects for these efforts (see list of critical data needs below). Prior to this REA, many ecoregional datasets were not available spatially for this region and although we recognize the need to improve many of these, managers can now develop ecoregional models, using the best available data, and get an overall look at major change agents and their impact to species and habitats in the ecoregion. This REA has made every attempt to identify the key resource needs. The UA team is confident that the models and data used represent the best available knowledge about the system and the potential impacts of the "known and unknown unknowns". We hope this REA serves as a strong starting point for more forward looking regional resource management in the Yukon River Lowlands, Kuskokwim Mountains and Lime Hills ecoregions. This REA is an important first step for future land-use planning, and will hopefully lead to an examination of possible futures through scenario planning.

Crucial Data Needs for the YKL REA

Aquatics

- No existing aquatic habitat classification.
- The National Hydrography Dataset (NHD) extremely outdated.
- The Digital Elevation Model (DEM) is outdated and should be developed at a finer resolution scale.
- No information on stream order or stream gradient.
- Lack of data on long-term trends and temporal change in fish populations.
- Lack of data on subsistence and commercial fishing on salmon populations.
- Little data on sheefish spawning habitat in the region.

Terrestrial

- No seamless vegetation map.
- Lack of soil survey for the ecoregion.
- Minimal understanding of vegetation succession and climate change.
- No fine scale vegetation map to identify important habitat such as willow for moose browse.
- No caribou collar data for delineating migration corridors.
- No musk ox survey data for distribution models.
- No long-term beaver or peregrine falcon population data for population assessments over time.

Climate, Permafrost, Fire

- Limited water temperature data.
- No future climate data available at a finer scale than monthly mean data.
- No precipitation differentiation between rain and snow, or any direct measure of snow pack.
- Lack of long-term climate stations and permafrost bore holes to validate models.
- Climate data and permafrost data only available at a coarse resolution.
- Limited data on fire severity.
- Fire models limited to forested areas.

Invasive Species, Insect and Disease

- Invasive species survey data lacking for many regions.
- Forest damage surveys limited to less than half the study area over the past 15 years.

Anthropogenic

- Local roads not well mapped in available GIS datasets.
- Traditional Ecological Knowledge (TEK) not collected consistently.
- Authoritative and available mining data limited to single source of information that is inconsistently recorded.
- Subsistence use areas limited to one year's data and only consists of a small sample.

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Data Request Method

Rapid Ecoregional Assessments (REAs)—National Operations Center, CO

Individual REA data layers and some other products are still available but are no longer being published.

If you would like to obtain more information, including data and model zip files* (containing Esri ModelBuilder files for ArcGIS 10.x and relevant Python scripts), please email **BLM_OC_REA_Data_Portal_Feedback_Team@blm.gov**.
*Note that a few models require software that BLM does not provide such as R, Maxent, and TauDEM.

Models associated with individual REAs may require data links to be updated to function properly. REA reports, technical appendices, and model overviews (for some REAs) contain detailed information to determine what products are available and what datasets are necessary to run a certain model.

Please include the report name and any specific data information that you can provide with your request.

Other BLM data can be found on the Geospatial Business Platform Hub (https://gbp-blm-egis.hub.arcgis.com).