

Yukon Lowlands-Kuskokwim Mountains-Lime Hills
Rapid Ecoregional Assessment Project, Alaska

Memo 2: Conceptual models, data identification, and methodology

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Table of Contents

Introduction.....	1
Project Overview	1
Objectives	1
Review of proposed REA elements (CEs, CAs, MQs).....	2
The Conceptual Ecoregional Model	2
REA Tracks.....	2
Science / Ecosystem Track: Conceptual Ecoregional Model	3
Land Management Track: Management Questions	5
Summary of Data Discovery.....	5
Summary of Methodology	7
Products.....	7
Conceptual Models	7
Process Models	8
Ecoregional Data and Methods.....	9
Reporting Unit and Scale	9
Landscape Intactness	10
Introduction and background	10
Methods.....	11
Landscape Condition Model	11
Overall Landscape Intactness.....	11
Conservation Element Status	11
Limitations	11
Change Agents.....	13
Introduction.....	13
Climate Change.....	13

Model Methods	13
Process Model.....	15
Management Questions.....	15
Methods.....	15
Limitations	15
Wildfire.....	15
Management Questions.....	16
Methods.....	16
Limitations	17
Invasive Species.....	17
Limitations	18
Insects and Disease	18
Anthropogenic Uses.....	18
Management Questions.....	19
Methods.....	20
Limitations	21
Data Gaps.....	22
Conservation Elements	23
Introduction.....	23
Methods for Core REA CE Questions	23
Methods for CE Management Questions.....	23
Terrestrial Coarse-Filter Conservation Elements.....	23
Introduction.....	23
Distribution Models	24
Vegetation Map and Classification – Northern, Western, and Interior Alaska.....	28
Conceptual Model: Tall Shrub Example.....	29

Process Model.....	30
Limitations	30
Management Questions for CEs	30
Permafrost	30
Introduction.....	30
Conceptual Model.....	30
Process Model.....	31
Management Questions.....	32
Terrestrial Fine-Filter Conservation Elements.....	32
Introduction.....	32
Distribution Models	33
Attributes and Indicators.....	33
Example: Terrestrial Fine-filter Species Conservation Element: Caribou (<i>Rangifer tarandus</i>)	33
Conceptual Model.....	34
Management Questions.....	36
Aquatic Coarse-Filter Conservation Elements.....	39
Recommendation for removal.....	39
Aquatic Fine-Filter Conservation Elements.....	40
Introduction.....	40
Distribution Models	40
Attributes and Indicators	41
Limitations	41
Core REA Analysis.....	45
Introduction and background	45
Overlap of future CE and CA distributions	45
Scenarios	45

Methods.....	45
Biome Shift.....	46
Fire-CE Models.....	47
Permafrost.....	47
Anthropogenic-CE Models	47
Cumulative Impacts Analysis	48
Limitations	48
References.....	49
Appendices.....	52
Appendix 1: Revised List of Management Questions.....	52
Appendix 2: Data Presented to Tech Team	56
Appendix 3: Arctic Social Indicators.....	72
Appendix 4: Anthropogenic Management Questions.....	74

Figures

Figure 1: Conceptual Ecoregional Model for YKL REA.	4
Figure 2: Process for selection of MQs, determination of CEs and CAs.....	5
Figure 3: Diagrammatic conventions for conceptual models.....	8
Figure 4: Conventions for process models.....	9
Figure 5: 5th-Level Hydrologic Unit Codes (HUCs) for the YKL REA.	10
Figure 6: Process model of downscaled climate products	14
Figure 7: Process model of ALFRESCO fire simulation methodology.....	16
Figure 8: Process model for identifying the human footprint	20
Figure 9: Vegetation map and classification for northern, western and interior Alaska (Boggs et al 2013).	25
Figure 10.: Vegetation map and classification source data coverage.	26
Figure 11.: Conceptual model for tall shrub in the YKL region.	29
Figure 12.: Process model of GIPL permafrost modeling techniques.	31
Figure 13. Intersection of 11 caribou herds with the YKL Ecoregion boundary.....	34
Figure 14.: Conceptual model for caribou in the YKL REA.	35
Figure 15.: Process model for current distribution of primary winter forage (lichen) for caribou	37
Figure 16. Process model describing the cliome shift methodology.....	47

Tables

Table 1: Proposed REA Elements (MQs, CEs, CAs).	6
Table 2: Potential products using proposed methods. Not all products will be generated for each MQ, CE or CA.....	7
Table 3: Terrestrial course filter conservation elements for the YKL REA.	24
Table 4: Required datasets for vegetation class terrestrial course-filter conservation elements.....	27
Table 5: Source data layers necessary for addressing MQs for caribou.	36
Table 6: Attributes and indicators for caribou.	38
Table 7. Ecological status assessment indicators for fish habitat in the YKL REA	42
Table 8: Management Questions.....	52
Table 9: Data List for Data Discovery Webinar, February 26, 2013.....	56

Acronyms used in this document

AKNHP	Alaska Natural Heritage Program
ALFRESCO	Alaska Frame-based EcoSystem Code
AMT	Assessment Management Team
BLM	Bureau of Land Management
CA	Change Agent
CE	Conservation Element
ESRI	Environmental Services Research Institute
GCM	Global Circulation Model
HUC	Hydrologic Unit Code
ISER	Institute of Social and Economic Research
LCM	Landscape Condition Model
MQ	Management Question
REA	Rapid Ecoregional Assessment
SNAP	Scenarios Network for Alaska and Arctic Planning
Tech Team	Technical Team
TEK	Traditional Ecological Knowledge
YKL REA	Yukon Lowlands-Kuskokwim Mountains-Lime Hills Rapid Ecoregional Assessment
USGS	United States Geological Survey
NLCD	National Land Cover Database
USFWS	United States Fish and Wildlife Service
GIPL	Geophysical Institute Permafrost Lab
MAGT	Mean Annual Ground Temperature
AKGAP	Alaska Gap Analysis Program
NHD	National Hydrography Dataset
AWC	Anadromous Waters Catalog
ADF&G	Alaska Department of Fish & Game

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Introduction

Project Overview

The Bureau of Land Management (BLM) recently developed a landscape approach to enhance management of public lands. As part of this landscape approach, the BLM and collaborators are conducting Rapid Ecoregional Assessments (REAs) in the western United States, including Alaska. To address current problems and future projections at the landscape level, the REAs are designed to transcend management boundaries and synthesize existing data at the ecoregion (or in the case of Alaska, combinations of generally similar ecoregions) level. A synthesis and analysis of available data benefits the BLM, other federal and state agencies, and public stakeholders in the development of shared resources.

The assessment area includes three ecoregions in Interior Alaska, hereafter referred to as the YKL Ecoregion: Yukon Lowlands, the Kuskokwim Mountains, and the Lime Hills (Nowacki et al. 2001). YKL includes 32 isolated small communities located along major river systems (Yukon and Kuskokwim). Although none of the communities can be reached by road, Galena, McGrath, Aniak, and Iliamna serve as air-transportation hub communities for the region. These ecoregions have an interior climate, with cold winters and relatively warm summers, although climate patterns vary across the ecoregions based on latitude, elevation, and proximity to the coastline. With mean annual temperatures close to 32°F, permafrost is discontinuous. The ecosystems within the ecoregions are considered to be intact and undisturbed relative to most ecosystems at lower latitudes.

Objectives

The YKL REA will document the current and potential future status of selected ecological resources, referred to as Conservation Elements (CEs; see Table 1), at the ecoregional scale and their relationships to Change Agents (CAs). Additionally, the YKL REA will address Management Questions (MQs) that were selected by state and federal land managers to inform current and ongoing management decisions ([Appendix 1](#)).

Phase I of the REA included three tasks that were prerequisite to finalizing the components of the Workplan:

Task 1. Selection of MQs, CEs, and CAs and the development of a Conceptual Ecoregional Model.

Task 2. Collection and evaluation of data layers necessary to conduct the assessment, and the identification of current data gaps.

Task 3. Development of an approach to analyses, including methods, models, and tools.

Memo 1 discussed the selection of MQs, CEs, and CAs for the YKL REA, analogous to task 1 outlined above. Memo 2 documents the available data, current data gaps, and various methods proposed for the CEs, CAs, and MQs in the YKL REA, analogous to tasks 2 and 3 outlined above. The following objectives for task 2 and task 3 are combined in this document.

The objectives of task 2 were:

1. Identify available data for the REA and obtain samples or metadata.
2. Evaluate the data for utility (content, scale, completeness).
3. Evaluate the data quality (precision, consistency, documentation).
4. Make recommendations about data to be applied.
5. Identify data gaps and proposed revisions to MQs, CEs, and CAs.

The objective of task 3 were:

1. List the CEs to be addressed, describing the approaches and categories in which they will be treated.
2. Build prototype Conceptual Models for CEs.
3. Identify, describe and recommend models, methods, and tools for characterizing CEs, CAs, and their interactions.
4. Describe specific assessment methods to address MQs.
5. Evaluate methods and tools for their ability to perform as intended.

Because most of the data, methods, and models used to address many of the MQs are related to the core analyses involved in this REA, both are presented by disciplinary topic in this memorandum. Example methods for select MQs and the associated CEs or CAs in the topical sections are presented. Exhaustive methods for all MQs are not provided here because the examples provided adequately cover the array of data and methods selected for this REA. Methods for the MQs that we are not providing as examples can be found in the topical sections below.

Review of proposed REA elements (CEs, CAs, MQs)

The Conceptual Ecoregional Model

Figure 1: Conceptual Ecoregional Model for YKL REA. portrays an understanding of critical ecosystem components, processes, and interactions necessary for the maintenance of sustainable ecosystems. By summarizing existing information and hypotheses on the structure and function of ecosystems, the Conceptual Ecoregional Model provides the framework to assess ecological conditions and trends. The complex interactions of ecological resources, ecological drivers, and CAs is simplified in the Conceptual Ecoregional Model to clearly show ways in which CEs interact with one another and the relationships between CEs, CAs, and ecosystem drivers.

REA Tracks

The Conceptual Ecoregional Model and the MQs provide the justification for the selection of CEs and CAs for the YKL REA and are referred to here as two separate “tracks” (Figure 2). Ecological resources must be regionally-significant either to ecosystems or to land managers (or both) to warrant selection as a CE.

Science / Ecosystem Track: Conceptual Ecoregional Model

Ecological resources identified from the Conceptual Ecoregional Model are regionally important to ecosystems within the YKL ecoregion and have therefore been selected as CEs.

Legend

- Ecosystem Drivers
- Change Agents
- Ecosystem Resources
- Interactions

Anthropogenic Change Agents

- Communities
 - Size
 - Location
 - Economic Characteristics
- Land Use
 - Mining
 - Contaminants
 - Forestry
 - Infrastructure
- Commercial / Sport Harvests

Non-Anthropogenic Change Agents

- Climate Change
- Fire
- Invasive Species
- Insects and Disease

Climatic and Atmospheric Conditions

- Precipitation
- Temperature / Solar radiation
- Cloud cover

Landscape Setting

- Elevation / Latitude
- Geology / Geomorphology

Plants

- Vascular
- Non-vascular

Animals

- Birds / Mammals
- Subsistence Harvesters
- Fish
- Invertebrates

Soil Resources

- Soil
- Nutrients
- Microorganisms
- Moisture
- Permafrost and active layer

Freshwater Resources

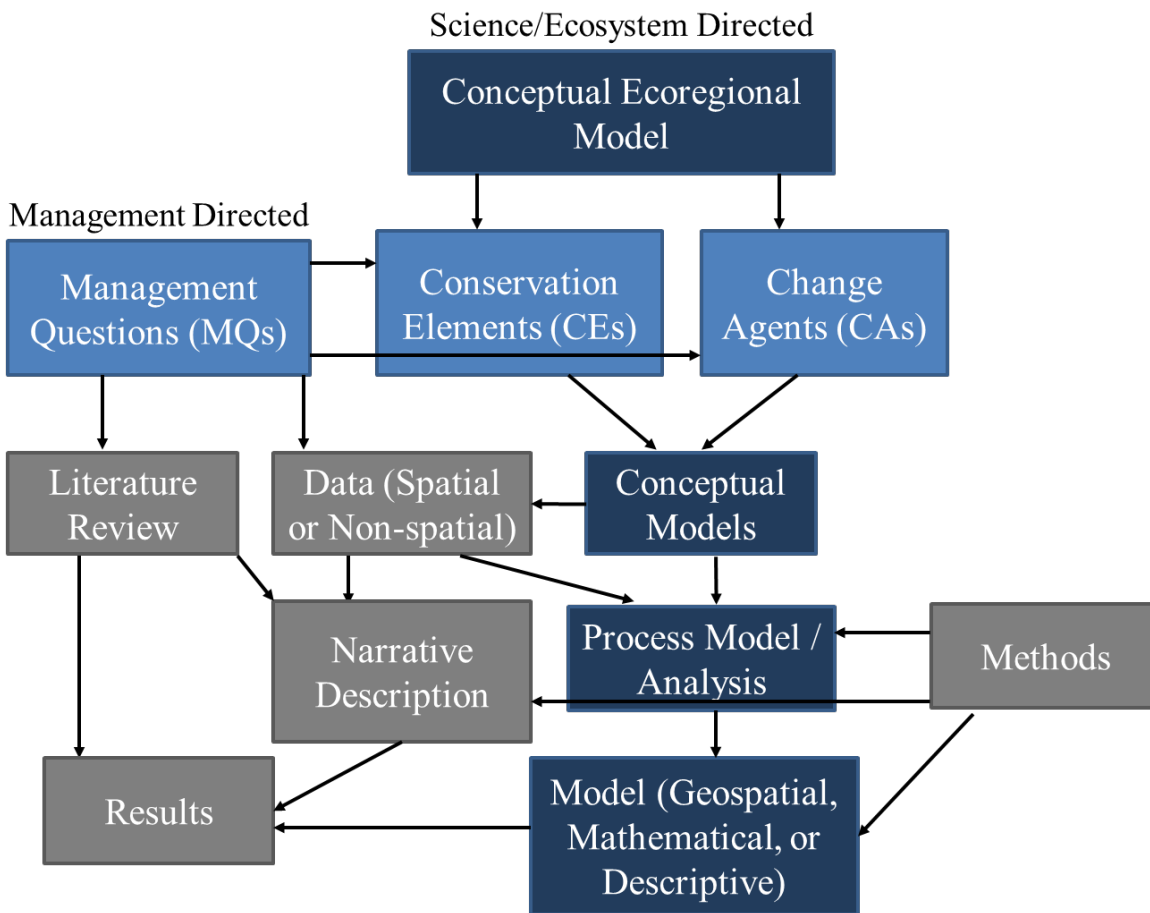
- Lakes
- Rivers
- Snow/Ice

Interactions:

- Anthropogenic Change Agents** interact with **Plants** through **Ecosystem Stressors** (Disturbances from human activities can directly and indirectly affect ecosystem drivers and resources) and **Ecosystem Services** (Ecosystem drivers, components, and processes determine possible human activities at a given location).
- Non-Anthropogenic Change Agents** interact with **Plants**, **Animals**, **Soil Resources**, and **Freshwater Resources** through **Ecosystem Stressors** (Non-anthropogenic change agents and disturbances affect all ecosystem components and processes) and **Ecosystem Resources** (Ecosystem resources contribute to or cause disturbances).
- Climatic and Atmospheric Conditions** affect all system components and processes.
- Landscape Setting** affects all ecosystem components and processes.
- Plants** interact with **Animals** through **Habitat availability, breeding, shelter** and **Herbivory**, and **Pollination, herbivory, seed dispersal, trampling**.
- Plants** interact with **Soil Resources** through **Organic matter / Nitrogen inputs**, **Soil, water, and, snowretention**, **Soil structure / aeration**, **Soil insulation (freeze / thaw cycle)**, **Nutrients and moisture**, **Rooting substrate**, and **Decomposition**.
- Animals** interact with **Soil Resources** through **Nutrient input**, **Disturbance via trampling and digging**, **Habitat availability**, and **Food availability**.
- Animals** interact with **Freshwater Resources** through **Habitat availability**, **Hydrologic change**, **Nutrient inputs**, and **Predation**.
- Soil Resources** interact with **Freshwater Resources** through **Nutrient input**, **Sediment, soil and water retention**, **Sediment and nutrient transport**, and **Subsurface recharge / Erosion**.
- Human activities alter natural processes** and **Natural processes affect or motivate human activities**.
- Climate and atmosphere affect all system components and processes**.
- Landscape setting affects all ecosystem components and processes**.
- Soil, water, and snowretention** and **Organic matter inputs** are shown as inputs to the system.

The model incorporates subsistence communities as part of the ecosystem. Subsistence communities (and other users) receive goods and services from the ecosystem: food, water, fuel, and transportation access. Ecosystem stressors are disturbances caused by human activities. Some ecosystem stressors are caused by subsistence communities, but most are larger scale disturbances caused by industrial and resource development.

Figure 2: Process for selection of MQs, determination of CEs and CAs



Land Management Track: Management Questions

CEs are also identified directly from the MQs because the corresponding ecological resources are regionally important to land managers in the area. MQs have been collected and vetted through BLM and other land management agency participants on the Assessment Management Team (AMT) and Technical Team. These questions represent current management needs and interests and, when addressed in the context of the larger ecoregion, can provide some opportunity for rapid integrated planning. A list of CEs and CAs, along with the number of corresponding MQs, is provided in Table 1.

Summary of Data Discovery

Data discovery followed the approval of CEs, CAs, and MQs by the AMT and involved literature review, searching for available data, and identifying gaps in available data. The results from the data discovery phase were presented to the technical team via a webinar. Thirteen technical team members attended the webinar, and many provided additional data suggestions. A complete list of the data presented to the technical team can be found in [Appendix 2](#). A summary of the data available, as well as key data gaps, are presented in the topical sections.

Table 1: Proposed REA Elements (MQs, CEs, CAs).

Management Questions		Terrestrial Conservation Elements		Aquatic Conservation Elements*	Change Agents
Category	#	Coarse-Filter	Fine-filter	Fine-filter	
Land Cover	4	Deciduous Forest	Moose	Chinook Salmon	Climate Change
Wildlife	9	Black Spruce or White Spruce Woodland	Caribou	Chum Salmon	Fire
Aquatics	4	Tall Shrub	Muskox	Sheefish	Invasive Species
Soil Thermal Dynamics	3	Low Shrub	Prey Species	Dolly Varden	Insects and Disease
Hydrology	1	Dwarf Shrub	Beaver	Northern Pike	Land Use and Development
Climate	2	Herbaceous Wetlands	Gray Wolf		Anthropogenic Sources
Fire	3	Large Floodplains	American Peregrine Falcon		Mining
Invasives	6	Permafrost	Trumpeter Swan		Contaminants
Socio-economic	5		Olive-sided Flycatcher		Recreation
Subsistence	3				Commercial and sport hunting and fishing
Sport and Commercial Hunting and Fishing	4				Transportation and communications infrastructure
Land Use	16				Energy development
Traditional Ecological Knowledge	1				Timber harvests
Total	61	8	9	5	5

* Although originally proposed, we no longer propose any coarse-filter aquatic CEs (please see aquatic CEs section).

Summary of Methodology

The data included in analyses were processed in accordance with the Data Management Plan outlined by BLM (BLM REA DMP 2012). Most datasets will be processed using ESRI Model Builder and Python scripts developed as ArcGIS tools, according to the policy adopted by BLM. The models and scripts are intended to be transparent and repeatable procedures that can be replicated at a later time with updated or additional data.

Several outputs are generated by tools not associated with ESRI Model Builder or python scripts, such as the GIPL modeling for future permafrost conditions or the Maximum Entropy (MaxEnt) modeling of future suitable habitat distribution for invasive plants. The data relationships inherent in the computational models are graphically represented in process models.

Products

The analysis of MQs, CEs, and CAs according to the methods outlined in this document will result in a diverse selection of final products ranging from literature reviews to geospatial or mathematical models (Table 2). The specific array of products developed for each MQ, CE, or CA will vary depending on the available data and the limitations of the data. For this reason, the data products are discussed specifically for each category of CE.

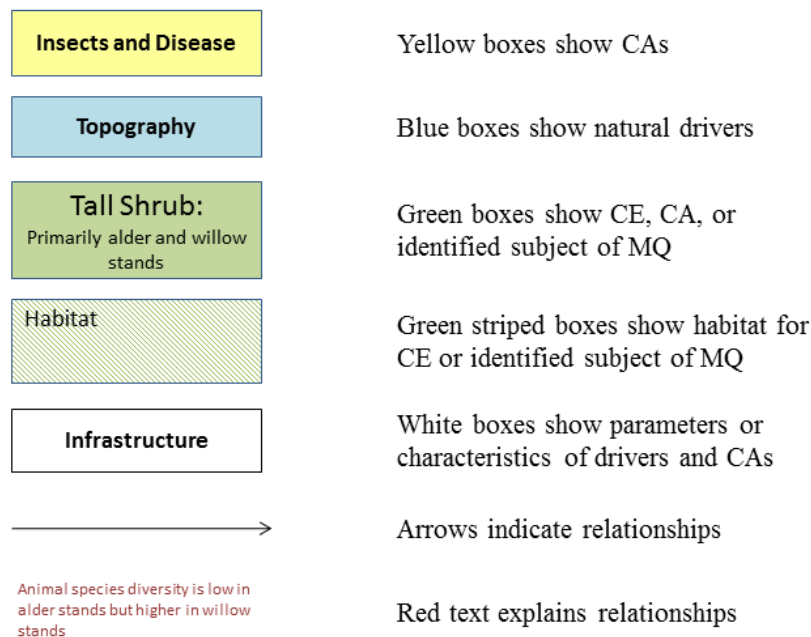
Table 2: Potential products using proposed methods. Not all products will be generated for each MQ, CE or CA.

Potential Products	Description
Literature Review	Relevant literature will be introduced and discussed in the final report and appendices, often integrated with the narrative descriptions.
Conceptual Model	Conceptual models will be developed for each CE and will portray an understanding of interactions of ecological resources and CAs in relation to the CE.
Process Model	Process models show the computational relationships in the analysis of data in a geospatial or mathematical model to produce an output.
Mathematical Model	A non-spatially explicit computational model that will analyze multiple datasets according to the relationships set forth in the corresponding process model.
Geospatial Model	A spatially explicit computational model that will analyze multiple datasets according to the relationships set forth in the corresponding process model.

Conceptual Models

Conceptual models represent the state of knowledge about the relationships between ecological resources (soils, freshwater, plants, animals), natural drivers, and CAs in relation to a particular 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). Conceptual models will be developed for each CE, supported and referenced by scientific literature.

Figure 3: Diagrammatic conventions for conceptual models.



Conceptual models are diagrammed according to the conventions outlined in Figure 3. The boxes indicate CEs, CAs, ecological resources, and natural drivers and arrows indicate regionally important interactions known to occur in the YKL ecoregions. Text in dark red is positioned next to arrows to indicate the most likely relationships between constituents.

Process Models

While conceptual models help inform the relationships between ecosystem components, drivers, and processes, process models illustrate computational relationships within the context of a spatial or mathematical model to produce an output. Process models diagram data sources, GIS analyses, and workflows but do not replicate all of the interactions shown in the conceptual models. Rather, they help inform the user about the technical procedure for spatial or mathematical analysis, providing important analytical transparency and allowing for repeatability of the process in the future (Bryce et al. 2012).

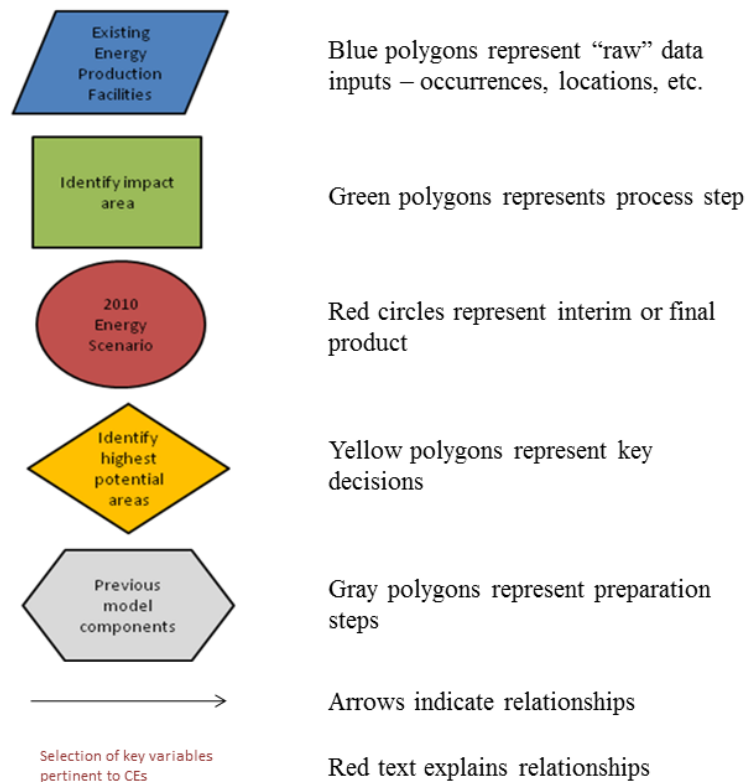
Process models fully capture the procedural steps of analysis without regard to specific software or calculations and will serve as the foundation for subsequent analysis and replication.

Each process model will contain the following:

1. A graphical diagram illustrating key elements (datasets representing key attributes of CEs, CAs, and MQs) and procedures in the computational process, the relationship among them, and the flow of information and analyses. Specific inputs, outputs, and processes are identified within boxes in the diagram with procedural relationships indicated by arrows.
2. Descriptive text explaining the graphical diagram to aid interpretation for the reader.

The basic method for developing each process model will be similar. Process models will be diagrammed according to the conventions shown in Figure 4.

Figure 4: Conventions for process models.



Ecoregional Data and Methods

Reporting Unit and Scale

As proposed in Memo 1, reporting units for this analysis will be at the landscape level in scale and intent. The BLM has specified that results should be reported at the 5th level 10-digit hydrologic unit code (HUC) and that raw data should be provided at 30 m (or some derivative of 30) grid cell resolution or other native resolution as appropriate. Given the resolution of most available data in Alaska, raw data will be provided at 60 m grid cell resolution, and results will be reported at the 5th level HUCs. HUC boundaries in the ecoregion are presented in Figure 5. The BLM acknowledges that most climate data is only available at the 4km scale; however, Alaska has access to future climate data at ~ 800 m grid cell resolution. The 800 m grid cell resolution for climate data was proposed to and accepted by the Technical Team via a webinar held in February of 2013.

Figure 5: 5th-Level Hydrologic Unit Codes (HUCs) for the YKL REA.



Landscape Intactness

Introduction and background

Ecological *integrity* was originally proposed in the scope of work. However, we feel it is not appropriate to assess ecological integrity in the YKL for the following reasons:

- The timeframe of an REA is insufficient to perform a proper classification of ecological condition (Rocchio and Crawford 2011).
- Measurements of ecological *integrity* requires indices of biological condition that require extensive data collection efforts, outside of the scope of the REA.

The concept of landscape *intactness*, on the other hand, is useful in meeting the primary objective of documenting the current and potential future status of selected ecological resources. Intactness can be easily calculated using existing datasets, yet is robust enough to be used in future and scenario geospatial models. Landscape intactness provides a quantifiable and readily assessable measure of naturalness. More

simply, landscape intactness is a measure of how contiguous a landscape is (i.e. how fragmented or unfragmented the ecosystem is). Landscape intactness will be modeled with parameters that are amenable to measurement, monitoring, scoring, and adaptive management. Future data will therefore have the potential to inform the landscape intactness model, producing updated results that will enable land managers to visualize the current and future status of the landscape. We propose calculating landscape intactness in three ways: Landscape Condition Model, Overall Landscape Intactness, and Conservation Element Status.

Methods

Landscape Condition Model

The Landscape Condition Model (LCM) is a simple yet robust way to measure the impact of the human footprint on a landscape (Comer and Hak 2009). The LCM weights the relative influence of different types of human footprints based on factors like permanence, nature of the activity, etc. Permanent human modification is weighted the highest, while temporary use (like snow roads, snow machine trails, etc) receive less weight. Intensive land uses like mining is also weighted higher than less intensive land uses like hunting cabins. These weights are summed across the landscape and coalesced into a single surface identifying how impacted a given area is due to human modification. The LCM was specifically requested by AMT members for this REA to compliment the LCM developed for the Seward Peninsula REA (Crist and Comer 2012). The LCM, unlike the other intactness models, will be provided at both its native resolution (60m) and as a 5th-level HUC summary for the final report.

Overall Landscape Intactness

Landscape intactness will be calculated by classifying the landscape into two categories, natural vegetation and other. The “other” category will be made up of the human footprint (used to calculate the LCM) and other non-vegetation land covers (like water). This “other” category will thus represent both *natural and anthropogenic fragmentation*. Within the natural vegetation category, three measurements of patch dynamics (number of patches, average mean distance to nearest neighbor, and percent natural core area) will be computationally related to develop a natural habitat fragmentation metric (Bryce et al. 2012). The habitat fragmentation metric will then be combined with the original LCM (including distance decay values) to produce an overall landscape intactness layer summarized at 5th-level HUCs.

Conservation Element Status

Landscape intactness for each CE will be modeled using the overall landscape intactness layer and the CE distribution layer to create a CE status dataset. In some cases, the intactness layer may be modified given specific attributes highlighted in the CE conceptual model. This CE status layer will be generated for the current, near-term, and long-term distributions of each CE. This data layer, like overall landscape intactness, will be provided at the 5th-level HUC.

Limitations

While considered a robust way to measure naturalness, there are some key assumptions made in the conceptualization of landscape intactness. Landscape intactness assumes that systems that are not

physically impacted by humans are indeed intact. While there are philosophical reasons to question this, there is also increasing evidence that the multitude of indirect impacts humans can have on an environment is substantially higher than previously thought. Impacts from climate change that has already occurred, as well as impacts from global systems (atmospheric nitrogen deposition, particulate matter deposition, etc.) all could be modifying systems in ways that are not captured by the human footprint. Additionally, while obvious at a local scale, human footprints are not always well mapped or captured in a geospatial framework. This is especially true for historical human use (i.e. aboriginal use, or even modern historical use prior to the establishment of environmental monitoring programs). Thus, our landscape intactness model assumes that 1) the current and historical human footprint is accurately modeled for the region and 2) areas not impacted by the human footprint are indeed intact. This is especially relevant as one of the key outputs from an REA is a better understanding of the indirect impacts of human activity on ecosystems.

Change Agents

Introduction

CAs are those features or phenomena that have the potential to affect the size, condition, and landscape context of CEs. CAs include broad regional agents that have landscape level impacts such as wildfire, invasive species, climate change, and pollution as well as localized impacts such as development, infrastructure, and extractive energy development. CAs act differentially on individual CEs and for some CEs may have neutral or positive effects but in general are expected to cause negative impacts. CAs can impact CEs at the point of occurrence as well as through offsite effects. CAs are also expected to act synergistically with other CAs to have increased or secondary effects. Even though they are listed separately, not all development CAs occur alone. Mining and energy development require other CAs, namely transportation and/or transmission infrastructure.

CAs in the YKL region can be broadly organized under the following headings:

- Climate Change
- Fire
- Invasive Species
- Insects and Disease
- Anthropogenic uses

Below are descriptions of each CA, several MQs relevant to that CA, and methods proposed to address those MQs.

Climate Change

Climate change will be assessed using downscaled models from SNAP, with subsets of the available data selected based on the needs of the project.

Model Methods

SNAP projections focus on the five available Global Circulation Models (GCMs) that perform best in the far north (Walsh et al. 2008). Global Climate Models (GCM) are developed by various research organizations around the world. At various times, the United Nations Intergovernmental Panel on Climate Change (IPCC) calls upon these organizations to submit their latest modeling results in order to summarize and determine the current scientific consensus on global climate change. There have been 4 assessment reports from the IPCC: in 1990, 1995, 2001 and 2007. In support of the more recent reports, the Coupled Model Intercomparison Project (CMIP) was initiated. Currently SNAP has utilized the CMIP3 model outputs from the IPCC's Fourth Assessment Report (AR4).

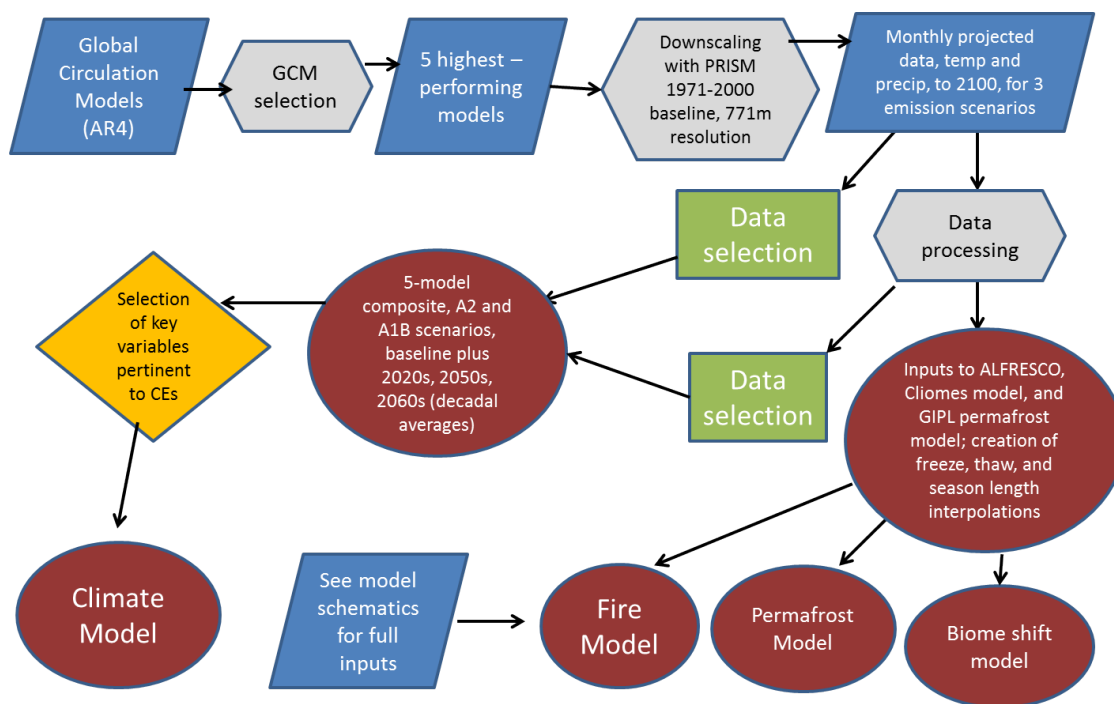
SNAP obtains GCM outputs from the Lawrence Livermore National Laboratory Program for Climate Model Diagnosis and Intercomparison (PCMDI) data portal. PCMDI supports Coupled Model Intercomparison Project (CMIP) and is dedicated to improving methods and tools for the diagnosis and intercomparison of Global Climate Models that simulate global climate. SNAP utilizes the first ensemble model run and the historical 20c3m scenario as well as the projected B1, A1B, and A2 datasets for downscaling.

SNAP climate datasets have been downscaled to 771 meter resolution using PRISM (Parameter-elevation Regressions on Independent Slopes Model) methodology ([PRISM 2012](#)), which takes into account slope, elevation, aspect, and distance to coastlines. This downscaling uses a historical baseline period of 1971-2000. This baseline will be carried over for use in the REA. SNAP’s downscaling is performed using the Delta method (SNAP 2012).

For this project, a composite (average) of the five GCMs selected and downscaled by SNAP will be used in order to minimize uncertainty due to model bias. This project will focus on the A1B and A2 scenarios, representing a somewhat optimistic (A2) and a slightly more pessimistic (A1B) view of future emissions. Decadal averages will be used, as opposed to data for single years, in order to reduce error due to the stochastic nature of GCM outputs, which mimic the true inter-annual variability of climate. Thus, the project will use climate data for the 2020s rather than just 2025, and the 2050s and the 2060s rather than the single year 2060.

SNAP climate outputs include temperature and precipitation data at monthly resolution. These data have also been analyzed, based on interpolation of running means, to create datasets estimating the date at which temperatures cross the freezing point in the spring and fall (termed “thaw date” and “freeze date” – although a direct correlation with ice on water bodies or in soils would not be expected). For the purposes

Figure 6: Process model of downscaled climate products



of most effectively examining the relationship between climate and selected CEs, SNAP will provide not only all monthly datasets and all freeze and thaw datasets as described above, but will also provide maps and/or tables depicting conditions in selected extreme months (July and January) as well as maps of freeze and thaw dates. Ultimately, these will be used in conjunction with maps of CE distribution as a basis for spatial analysis and/or qualitative discussion.

Process Model

Figure 6 illustrates the process steps described above. Climate model outputs can include GIS data, viewable maps, or tabular data. Climate data are also inputs to permafrost and fire models, described elsewhere in this report.

Management Questions

Two MQs directly relate to the role of climate change:

- What are the projected monthly, seasonal, and annual temperature, precipitation, and length of warm and cold seasons for the REA, and how do these projections vary across time, across the region, and across varying global greenhouse gas emissions scenarios?
- Where will climate change impact CEs, including subsistence species?

Methods

The first of the above MQs will be addressed using SNAP climate projections and spatial analysis of these projections. Results will be performed at 771 m grid cell resolution and presented in GIS, map, or tabular form, with analysis by HUC, as appropriate, to meet management needs. The second MQ will be addressed through complex spatial analysis of the relationship between SNAP projections and CEs, using both qualitative and quantitative methods. In some cases, overlay maps of CEs and climate model outputs will shed light on areas of greatest concern. Literature review will aid in determining which climate variables are the most important drivers for each CE. In addition, climate envelope modeling linked to biomes and land cover classes (“cliomes” modeling), developed by SNAP, will aid in this analysis; this methodology is described in detail later in this document.

Limitations

The following data relating to climate change are unavailable, although in some cases qualitative analysis will be possible:

- River/lake temperatures
- River flow/timing of runoff
- Hydrologic change based on changing permafrost and active layer
- River erosion
- Ocean acidification
- Ocean temperature
- Coastal erosion
- Frequency of rain-on-snow events
- Frequency of storm/wind events
- Frequency of extreme precipitation events
- Frequency of drought
- Frequency of flooding events
- Frequency of extreme heat/cold events
- Single-species climate-envelope based projections

Wildfire

Fire is both an integral ecosystem component and a key driver of change in Alaska, particularly in boreal ecosystems. Fire cycles drive natural succession in forested landscapes, creating complex mosaics of

hardwoods, conifers, and herbaceous early-succession vegetation. Wildlife – including important game species – are dependent upon these multi-age mosaics.

Warming climate is predicted to alter and shorten fire cycles, thereby changing vegetation patterns across the landscape. Increasingly, fire is also becoming a driver of change in tundra habitats, affecting species such as caribou that utilize these habitats.

Modeling and analysis of these changes can shed light on multiple aspects of future ecosystem function, including human/landscape interactions.

Management Questions

Two MQs directly relate to the role of fire in the ecoregion:

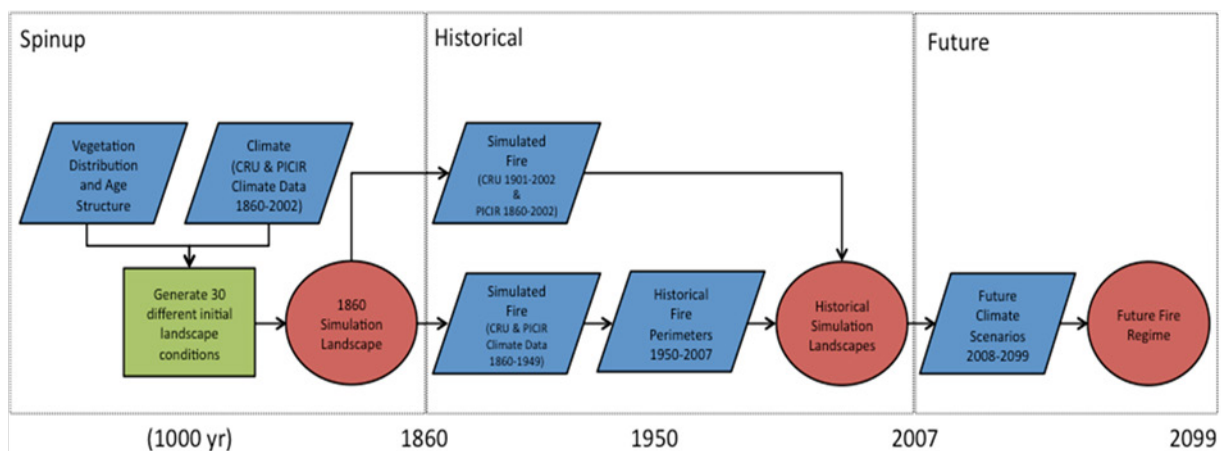
- What is the fire history of the ecoregion?
- What climatic conditions are likely to result in significant changes to fire activity?

As described below, the first can be addressed based on existing data and published literature. The second will be evaluated based on fire and vegetation modeling using the ALFRESCO model.

Methods

Fire will be modeled using ALFRESCO (Alaska Frame-based EcoSystem Code, shown in Figure 7) in the larger context of a projected future fire regime and its effects on major vegetation classes. Climate projections (as described above), past fire history, and current vegetation patterns will be used in part to model patterns of fire frequency across the landscape.

Figure 7: Process model of ALFRESCO fire simulation methodology.



Boreal ALFRESCO simulates the responses of subarctic and boreal vegetation to transient climatic changes. The model assumptions reflect the hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation in the circumpolar arctic/boreal zone. Furthermore, it assumes that vegetation composition and continuity serve as a major determinant of large, landscape-level fires. Boreal ALFRESCO operates on an annual time step, in a landscape composed of 1

× 1 km pixels. The model simulates five major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, deciduous forest, and grassland-steppe. SNAP climate data, as described above, will be included among the ALFRESCO inputs.

The “distribution” of varying fire frequencies is intimately tied to vegetation, as well as climate, but also involves stochastic elements such as the exact location of lightning strikes and the variability of weather patterns at finer time-scales than are available to modelers. Thus, multiple model runs yield varying results. Therefore, fire distribution per se will not be modeled; rather the model will project its average frequency and extent across the landscape to ultimately model changes in vegetation patterns and distribution. Outputs will include landscape-wide estimates of percent cover by type and age, as well as projected average area burned per year across the target time periods (from the present to 2025 and from the present to 2060) and fire return intervals on a regional and sub-regional basis.

Limitations

No data are readily available to address the following fire-related variables, although some can be indirectly of qualitatively addressed:

- A wider range of cover types
- Fine-scale calibration of shifts in cover types post fire

Invasive Species

Invasive species will be defined as those non-native plant species with invasiveness ranks of greater than 60 (see Carlson et al. 2008). Invasive species are included in this REA, as well as all other BLM REA's, due to their widespread capacity to disrupt ecological processes and degrade biological resources. While much of Alaska has not witnessed dramatic impacts of invasive species in natural systems, they are increasing in abundance, distribution, and ecological and economic harm (see Carlson and Shephard 2007, Schwörer et al. 2011). Core-REA and invasive species MQs are concentrated into three theme areas: 1) what is the current state of invasive species in the REA and which areas and resources are most at risk, 2) what is the predicted state of invasive species in the REA, and 3) what are the likely vectors of invasive species in the REA.

The first theme can be divided into the current state of invasive species, and highest risk areas. The first part will be addressed by summarizing known locations, densities, and diversities of non-native species in tabular form and in maps. Identifying areas of highest risk of invasion will be addressed by an analysis of the relationship of plant species invasion to environmental and anthropogenic variables more broadly in the state. Areas within the REA can then be identified that have values of predictor variables most associated with invaded areas elsewhere. Specifically, invasive species richness and abundance will be summarized by 5th level HUC across interior and southern Alaska and related to a range of environmental and anthropogenic variables. Thus, a more synthetic approach will be used rather than modeling individual invasive species that may or may not reflect the larger landscape level patterns. Environmental variables will include such things as growing season length, mean annual temperature, mean annual precipitation, average monthly temperatures, presence of forest fire, biome or landcover type, etc. Anthropogenic variables will include such elements as human population density, road and trail densities, proportion of land devoted to industrial land-use, mean annual income, average number of

flights per day, number of barge landings per year etc. The relationship of the response variables to the predictor variables will be explored using classification and regression tree analysis. Generating the areas of currently known invasive species and areas susceptible to invasion will allow an overlay of rare species and habitats of concern, and thereby highlight those CEs and locations that are of greatest risk.

The second theme of future conditions will build from the relationship of invasive species abundance and diversity with the predictor variables, such that we can model future climate and development scenarios in the REA to identify those regions most susceptible to invasion. In addition, we will review other studies (e.g., SNK REA, Jarnevich et al. submitted, Murphy et al. 2010, Bella 2009) that model current and future non-native species habitat suitability that overlap with the REA to identify those areas that appear most susceptible to invasion.

The third theme of describing the vectors most likely associated with invasive species introductions will primarily involve a literature review (e.g., Conn et al. 2012, Conn et al. 2010, Flagstad and Cortés-Burns 2010) and drawing inference from patterns reflected in the state non-native plant database.

Limitations

Survey points for invasive plants is not random and therefore relationships of predictor variables with the invasive species abundance and diversity is likely to partially reflect survey bias. Individual invasive species responses may be obscured by including all species together. However, we can model individual species with sufficient number of locations to gauge the variability among species. Additionally, the study area lacks a fine scale soil or substrate data layer that could provide mechanistic information regarding establishment potential.

Insects and Disease

Insect and disease epidemics are often the result of human induced changes. For example, climate change has likely increased the incidence and severity of some insect pests in Alaska (John Lundquist draft report Chugach NF Climate Vulnerability 2013). The United States Department of Agriculture (USDA) conducts annual forest damage surveys by flying—using fixed-wing aircraft—a predetermined route across Alaska’s forests and recording insect damage within one mile on either side of the flight path. They draw polygons on a digital elevation model (DEM) and, for tree, willow and alder defoliators, record degree of damage in three categories of increasing intensity. For spruce bark beetle damage they record tree mortality. We will address one management question “***What is the current distribution of forest pest outbreaks in the ecoregion?***” using aerial surveys of disease and insect activity identified in the last decade. We will also use available literature to identify current insect and disease outbreaks and possibly map areas of insect and disease susceptibility based on known relationships between insects and their hosts.

Anthropogenic Uses

Overall, anthropogenic uses in the region are minimal, but increasing. In addition to uses of land for general living purposes in and around the 32 geographically isolated communities along the rivers in the region, other forms of land uses by human populations in the region include: subsistence, mining,

recreation, energy development, sport hunting and fishing, transportation and communication infrastructure, and isolated timber harvesting operations.

Subsistence is a key factor in the local economy – 490 lbs of usable wild food per person was harvested in 2010 in the Western region that includes a majority of the YKL region (Division of Subsistence 2010). As they developed over centuries, subsistence practices are also a part of the culture and identity of local populations, and form an integral part of the ecological processes in the region. When asked about their future, communities said that continued subsistence is their highest priority (Bristol Bay Visioning Project 2011). Subsistence requires large tracts of undisturbed land.

In contrast, other major anthropogenic uses are more concentrated around resources that are being extracted/harvested. Mining, energy development, timber harvests, and other resource-extraction uses fall into this category. Although these uses have a smaller footprint than subsistence, their impact is often potentially more disturbing, and sustained, to the natural ecology of the region. Two large mining operations are proposed in the region – Donlin Creek gold mine near the village of Crooked Creek on the Kuskokwim river, and the Pebble mine near Lake Illiamna. No major energy development projects are currently proposed, but the mining operations at Donlin Creek will require a reliable energy source which has not been finalized at this time. Minor timber operations exist, and the potential for their growth is not clear.

Recreation and sport hunting/fishing are categorically different types of land uses. YKL region sees a flurry of activity with recreational and sport hunting/fishing seasonally. With the extreme climate in the region, most recreational activity is concentrated in the mid-summer to mid-fall during any year. Transportation and communication infrastructure is minimal in the region. None of the 32 communities in the region are connected by road or rail, with transport to and from any community in the region restricted to either snow mobiles/boats for ground-transportation and air transport. There have been several proposals to connect the region with the rest of the states' minimal road and rail network. While none of the major proposed projects came to fruition, connectivity between villages has been improving with some gravel roads between some of the communities. Communication infrastructure is composed of few communication towers for cell phone connectivity. The majority of the region does not have cell phone reception.

Management Questions

To ensure a smooth analysis phase, the research team proposed to reorganize the original 29 MQs concerning anthropogenic uses into 12 MQs organized into 5 sections:

- Socio-economic conditions
- Subsistence
- Sport, and commercial hunting and fishing
- Land use
- Traditional Ecological Knowledge (TEK)

While the majority of the questions require relatively simple methods, methodological challenges in addressing the following three particularly challenging questions are discussed below.

Methods

MQ Example 1: What are current socio-economic conditions in YKL communities?

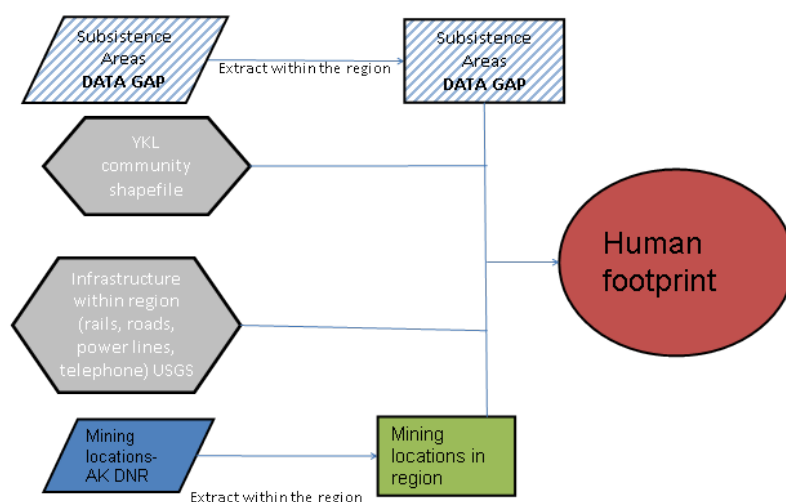
This is often accomplished by computing a composite measure from various social and economic indicators. For example, Socio-Economic Indexes for Areas (SEIFA) by Australian Bureau of Statistics, Human Development Report (HDR) by the United Nations Development Program, and Arctic Social Indicators (ASI) by Nordic Council, Denmark are all similar attempts. Each of these indices emphasize income, education, employment, occupation, and housing status for social indicators. While these variables are important, these may not reflect the context of the arctic environment and the subsistence lifestyles of the population in the YKL region.

Arctic Social Indicators (ASI), developed by the Nordic Council (Nordic Council of Ministers 2010), is the most appropriate index available given the biophysical context of these ecoregions. This list includes several variables organized into six broad domains: health and population/demographic; material well-being; education; cultural well-being; closeness to nature; and fate control. The complete list of indicators identified by ASI, along with potential variables that can be used for the REA, are included in Appendix 3: Arctic Social Indicators. Principal component analysis, typically used for data reduction, will be used to eliminate indicators that are duplicative, and assign relative weights to the variables to create an index of socioeconomic conditions. Although socioeconomic data like this is quite limited temporally, forecasts of socioeconomic conditions will be developed for the near and long-term modeled by extending the trend seen over the past 13 years.

MQ Example 2: What is the current human footprint in the region?

Land use and development will be modeled both to help address MQs and to feed into the Landscape Condition Model (see Ecoregional Methods section) for the Core-REA analysis. "Human foot print" is the combination of all anthropogenic land uses in the region. This includes the land used for

Figure 8: Process model for identifying the human footprint.



all uses listed as anthropogenic uses. While it is relatively easy to identify the land used for mining and transportation, it is hard to estimate the land used for subsistence. Most of this information is embedded in the traditional ecological knowledge accumulated by generations of people living in the region, and recorded in disparate reports prepared by various agencies and researchers. Figure 8 shows the process model for estimating the human footprint in the region.

MQ Example 3: What TEK is available for the region?

Several MQs from first few iterations were framed with the expectation that they will be addressed using the abundant traditional ecological knowledge. However, the limitations of TEK were evident at very early stages of the process. The principal limitation of TEK is its seemingly unorganized abundance. Given the proliferation of studies, it is important to examine the available TEK for quality and rigor in methodology, and identify a method to extract useful information and use it in the REA process. Thus, the team suggested, and AMT accepted, one overarching question that directs us to catalog available TEK, and identify a methodology to use it in the REA process.

There is no consensus on the definition of TEK or how it can be applied to environmental management issues (Usher 2000). The scope of TEK can include environmental knowledge, information about the use of the environment, values about the environment, or even the system of knowledge itself (Usher 2000).

TEK provides a qualitative summary of place-specific observations that can both inform the interpretation of data, and provide an alternative narrative to the data. Observations can include the availability of subsistence foods and a cultural interpretation of game management regulations that may result in some regulations being considered inappropriate or ignored. For example, bag limit restrictions and calendar openings and closings can be at odds with subsistence hunting, sometimes due to the cultural practice of a few skilled hunters harvesting game to distribute community-wide, while the high gasoline prices make hunting only a few animals cost prohibitive.

An ongoing search for TEK data within the YKL REA region has produced a variety of results, primarily focused on subsistence practices. The sources of TEK include recorded interviews, geocoded database of reports of unusual events, ethnographies and case studies, books and papers, and other reports. Methodology to address this question includes collecting, cataloguing, and identifying the parameters of inclusion and exclusion of sources for REA purposes. Qualitative analytic methods such as content analysis will be used to identify relevant sources of information.

Limitations

While community level data is relatively easier to obtain, the numbers are often too small, or data may not be available for several past years. Additionally, BLM requires the results be reported at the 5th-level Hydrologic Unit Code (HUC). This is not a political boundary and socioeconomic data is not available at this level. Aggregated data may not be accurate.

Data Gaps

Several limitations exist. Data for this large number of social and economic indicators is not always available. For example, there is no data source for self-employed fishermen, which make up a large share of local workers. Employment data from Dept of Labor only include only wage earners. Other data, such as subsistence harvests, and the Bristol Bay visioning project only cover a subset all the communities in the REA.

Conservation Elements

Introduction

CEs are defined as biotic constituents (i.e. wildlife and plant species or assemblages) or abiotic factors (i.e. soils) of regional importance in major ecosystems and habitats across the ecoregion. Selected CEs are meant to represent key resources in the ecoregion and may serve as surrogates for ecological condition across the ecoregion.

During Task I we identified both terrestrial and aquatic CEs for the ecoregion using a *coarse-filter-fine-filter* approach. This approach focuses on ecosystem representation as *coarse-filters* with a limited subset of focal species and species assemblages as *fine-filters*. The *coarse-filter-fine-filter* approach is closely integrated with many ecoregional and conservation modeling exercises (Bryce et al. 2012).

Methods for Core REA CE Questions

Generally, we propose developing the following products to address the core REA questions:

1. Mapping or modeling the **current distribution** of each CE and each resource identified by MQs.
2. Creating a **conceptual model** based on the ecology of the species or landcover class and its relationship to CAs.
3. Identifying measureable **attributes and indicators** (environmental predictors) to assist with evaluation of landscape intactness for each fine-filter CE. For coarse-filter CEs, attributes and indicators are predefined within the classification of these units.
4. Developing a **process model** to design computational relationships between datasets to produce an output.
5. Assessing **status** by overlaying landscape intactness with the CE specific distribution model.

Details of the methods for each of these products are outlined in the sections below.

Methods for CE Management Questions

Generally, we propose developing all the following outputs to address the core REA questions:

1. Developing a **process model** to design computational relationships between datasets to produce an output.
2. **Literature review.**

Terrestrial Coarse-Filter Conservation Elements

Introduction

Terrestrial coarse-filter CEs are regionally important vegetation classes that represent the characteristic vegetation assemblages of the YKL ecoregion and the dominant ecological patterns of the ecoregion. They adequately address the habitat requirements of most characteristic native species, ecological functions, and ecosystem services. After several iterations of review by the AMT and Tech Team, seven aggregated vegetation classes were selected for analysis as CEs because of their representation of ecosystem function. In addition, permafrost was selected for analysis as a CE because it is a regionally

important and potentially fragile soil characteristic. Table 3 below shows the current list of terrestrial coarse-filter CEs and the related major ecosystem functions.

Table 3: Terrestrial coarse filter conservation elements for the YKL REA.

Terrestrial Coarse-Filter CEs	Ecosystem Function
Deciduous Forest (Open-Closed)	Habitat for birds, mammals, and invertebrates
Black Spruce or White Spruce (Woodland)	Habitat for birds, mammals, and invertebrates; alters fire regime
Tall Shrub (Open-Closed)	Habitat for birds, mammals, and invertebrates; alder is an important source of nitrogen
Low Shrub	Habitat for birds, mammals, and invertebrates
Dwarf Shrub (Mesic)	Habitat for birds, mammals, and invertebrates
Herbaceous Wetlands	Nutrient inputs from soil resources to freshwater resources; important habitat for waterfowl and beavers in addition to other birds, mammals, and invertebrates
Floodplain (Large floodplains)*	Oxbows and floodplain springs provide fish habitat
Permafrost	Sediment, soil, and water retention

*This class is not mapped yet, but it is a basic ecological unit in the YKL Ecoregion.

Distribution Models

Prerequisite to the delineation of the vegetation class CEs was the production of a single landcover map that provides an adequate resolution of vegetation cover classes at the best available accuracies. A land cover map is a core component of the REA for a variety of purposes including modeling species distributions and producing landscape intactness assessments. The USGS National Land Cover Database (NLCD) is the only available map that covers the entire YKL ecoregion and has a good accuracy assessment. The NLCD is a 2001 Landsat-derived, 30 meter spatial resolution digital land cover map that describes the land cover for the 50 U.S. states and Puerto Rico using twenty consistent land cover classes. However, the NLCD within Alaska has a limited number (ten) of natural vegetation classes, which are not adequately refined for the species modeling and intactness model requirements of this REA. Various regional maps exist that cover parts of the YKL ecoregion, and, when mosaicked together, these regional maps extend over the YKL ecoregion in its entirety. In order to provide a comprehensive land cover map, these separate maps were integrated into one comprehensive map: the Vegetation Map and Classification – Northern, Western, and Interior Alaska (Boggs et al. 2013). Although not CEs themselves, willow habitat and lichen habitat will be modeled and provided as geospatial products. The analyses of the moose CE and MQs require a spatial distribution of willow across the YKL ecoregion. Similarly, the analyses of the caribou CE and MQs require a spatial distribution of lichen habitat across the YKL ecoregion.

Figure 9: Vegetation map and classification for northern, western and interior Alaska (Boggs et al 2013).

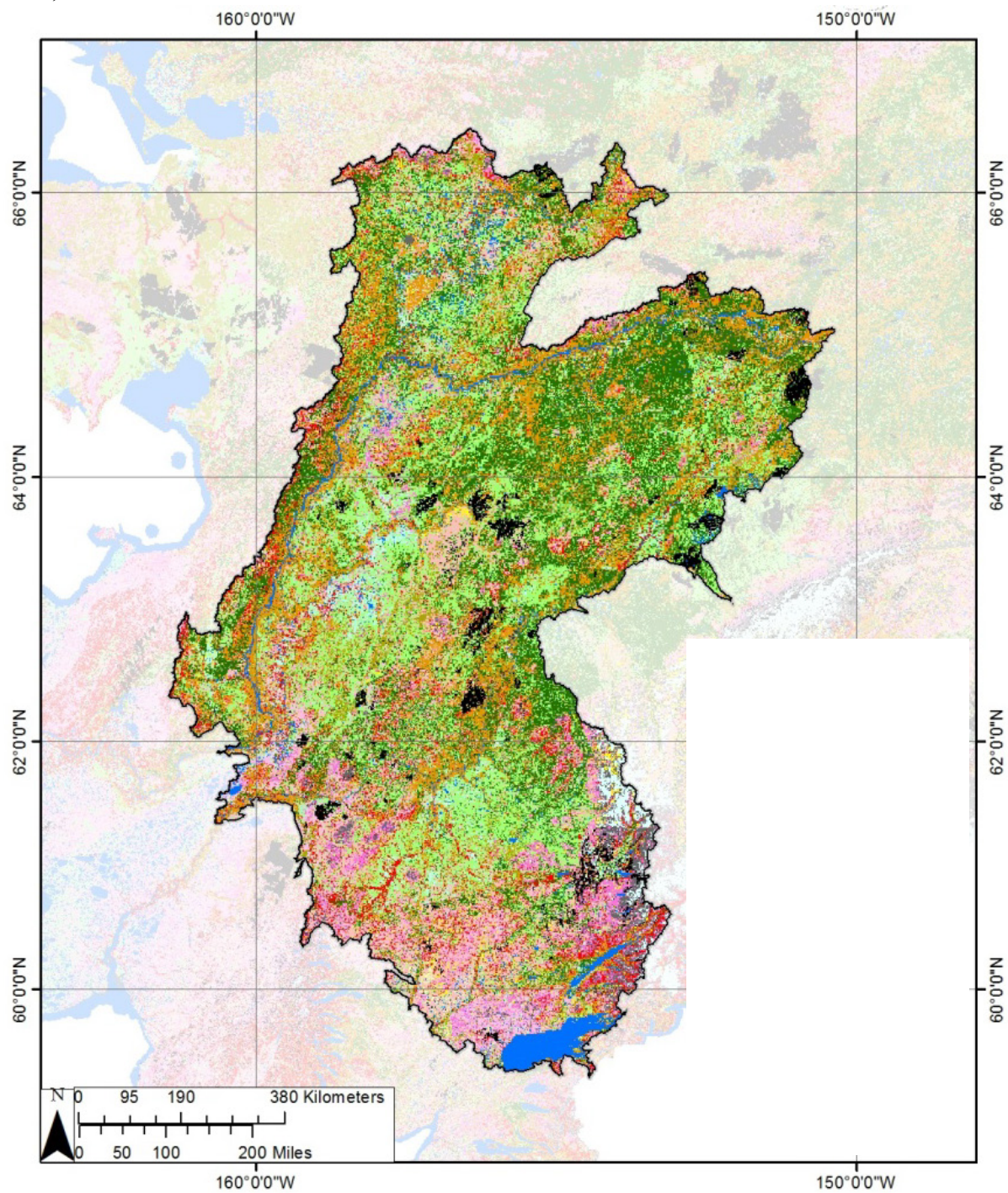
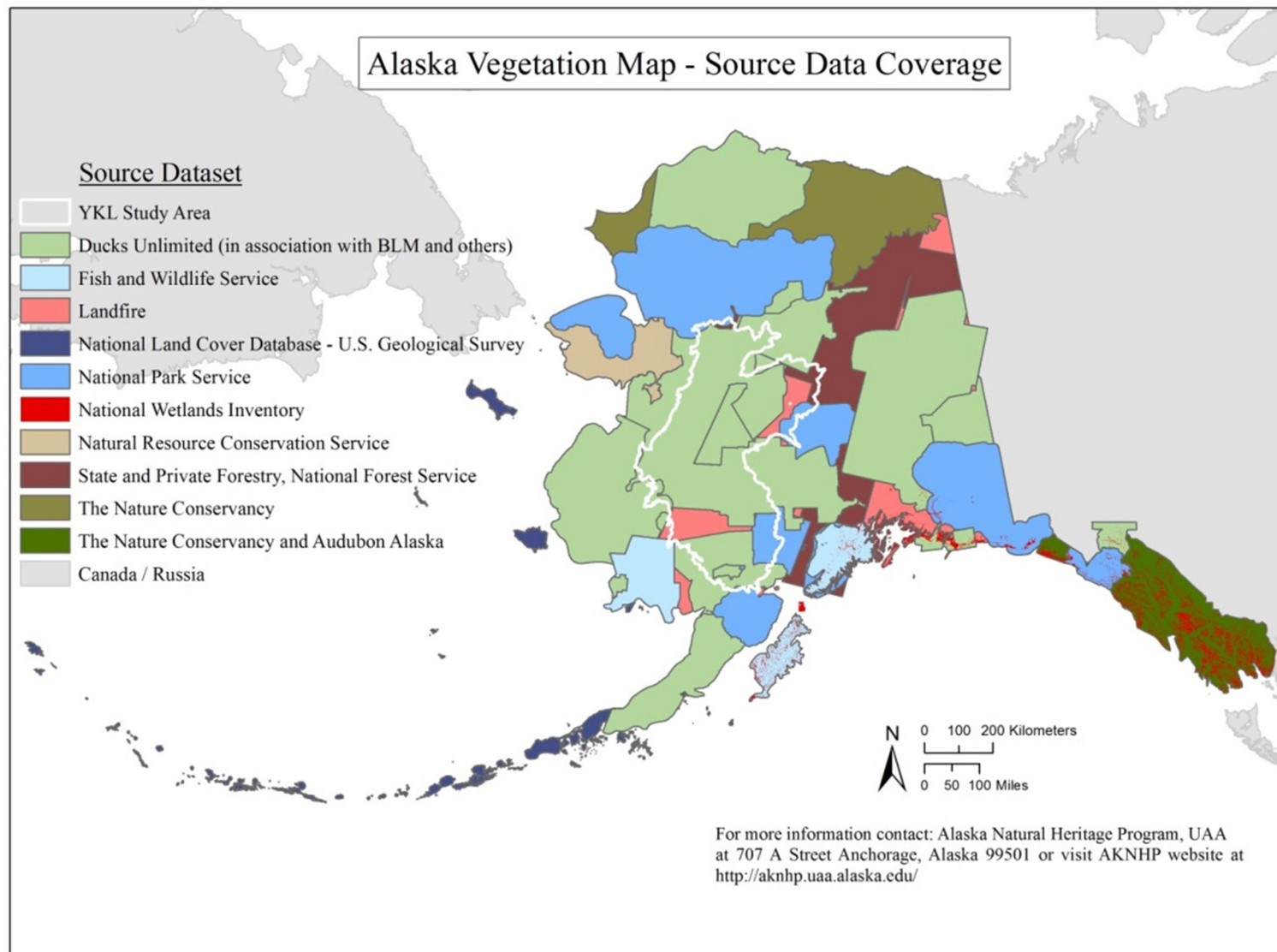


Figure 10.: Vegetation map and classification source data coverage.



The Boggs et al. (2013) map will delineate the spatial extent of the majority of vegetation classes selected as CEs in the YKL ecoregion. As indicated above, the mosaicked map includes multiple source maps in a single aggregated map that displays the best data for a region. However, the mosaicked map does not provide the spatial extent of floodplains. Figure 10 shows the spatial selection of data from source maps that provide the data for the Boggs et al. (2013) map.

Table 4: Required datasets for vegetation class terrestrial course-filter conservation elements.

Dataset Name	Description	Data Type	Source Agency
Vegetation Map and Classification - Northern, Western, and Interior Alaska	Mosaic of 18 regional maps developed over the past 1 to 14 years and one map developed 27 years ago. All original cover classes converted to a uniform schema.	Raster	AKNHP
National Wetlands Inventory (NWI)	This data set represents the extent, approximate location and type of wetlands and deepwater habitats in the Alaska, United States. These data delineate the areal extent of wetlands and surface waters as defined by Cowardin et al. (1979).	Polygon	USFWS
National Hydrography Data	The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system.	Vector	USGS
Alaska State Bedrock Geology Map	State-wide map of bedrock geology.	Polygon	USGS
Alaska State Surficial Geology Map	State-wide map of surficial geology.	Polygon	USGS
Alaska Fire History	Fire history for the state categorized in decadal increments for the past 70 years.	Polygon	BLM
LANDFIRE Reference Vegetation Data	Georeferenced & labeled samples of vegetation gathered by Landfire to use as training data for their mapping & modeling efforts.	Point	LANDFIRE
Geology Map of the lower Yukon River	Geologic map of the lower Yukon River region, AK.	Polygon	USGS

In addition to the Boggs et al. (2013) map, several other data sources, including Landsat imagery, USGS bedrock geology dataset, USGS surficial geology datasets, and NLCD, will inform the spatial extent of terrestrial course-filter CEs. Although a very limited area of the YKL ecoregion has been surveyed for the National Wetlands Inventory, the available data will provide an accuracy check for the spatial extent of herbaceous wetlands. The National Hydrography Database (NHD) will be assessed for potential modeling of willow riparian stringers, necessary to generating a willow habitat model. Table 4 provides a list of datasets that will be included in the analysis of terrestrial course-filter CEs.

Vegetation Map and Classification – Northern, Western, and Interior Alaska

A coarse-scale legend common to all of the selected regional maps was first developed. The legend drew primarily from the variety of Ducks Unlimited (DU) maps developed in cooperation with various federal agencies (primarily the BLM and USFWS). The DU maps contained nearly identical legends based on a variation of levels III and IV of the Viereck et al. (1992) classification and, together, extended across most of Alaska. The legend was further refined with the addition of other regional classifications to the original DU/BLM legend. Regional mapping efforts by NPS, USFS State and Private Forestry, LANDFIRE, The Nature Conservancy of Alaska, and USFWS provided other source data for the vegetation classifications. The additional classifications fit within the schema provided by the DU maps because they were either derived from or directly used some variation of levels III and IV of the Viereck et al. (1992) classification.

Once the legend was prepared, 18 regional maps that have been developed over the past 1 to 14 years were mosaicked with priority to the map providing the most accurate data with an appropriately scaled legend. Regional map spatial resolutions ranged from 30 x 30 m pixel or finer for satellite imagery and 1:63,360 or finer for aerial photography. Each satellite image map and aerial photography polygon was converted to a 30 x 30 m pixel resolution raster format.

The fine-scale legend consists of all of the original classes at the level of detail from each source regional map. Some of the regional maps used an ecosystem or landscape classification approach (e.g. Ecotypes), and the fine-scale classes also retain this landscape detail. The mosaicked map describes 28 coarse-scale vegetated classes and six non-vegetated classes and extends across the YKL ecoregion. A floodplain data layer will be heads-up digitized from existing LandSat Imagery and will be cross-checked against the National Wetlands Inventory, USGS bedrock geology and surficial geology maps to improve accuracy. This floodplain map will comprise the floodplain CE.

The six remaining vegetation class terrestrial coarse-filter CEs generally parallel the vegetation classes available from the Boggs et al. (2013) map. The coarse scale Deciduous Forest (Open-Closed) class will delineate, without modification, the Deciduous Forest (Open-Closed) CE. It includes sites dominated by aspen, balsam poplar and paper birch but does not include deciduous forests that occur on floodplains.

The Boggs et al. (2013) coarse scale tall shrub (open-closed) class will delineate, without modification, the tall shrub (open-closed) CE. It includes sites dominated by alder and tall willow but does not include tall shrubs that occur on floodplains. For the low shrub class, we will combine the coarse scale low shrub and low shrub/lichen classes because of their similarity in species composition. These combined classes do not include floodplains but do include mesic sites, peatlands, and wetlands. The dwarf shrub class will be derived from the combination of the coarse scale dwarf shrub and dwarf shrub/lichen classes because of their similarity in species composition. These combined classes do not include floodplains, peatland plateaus, or wetlands.

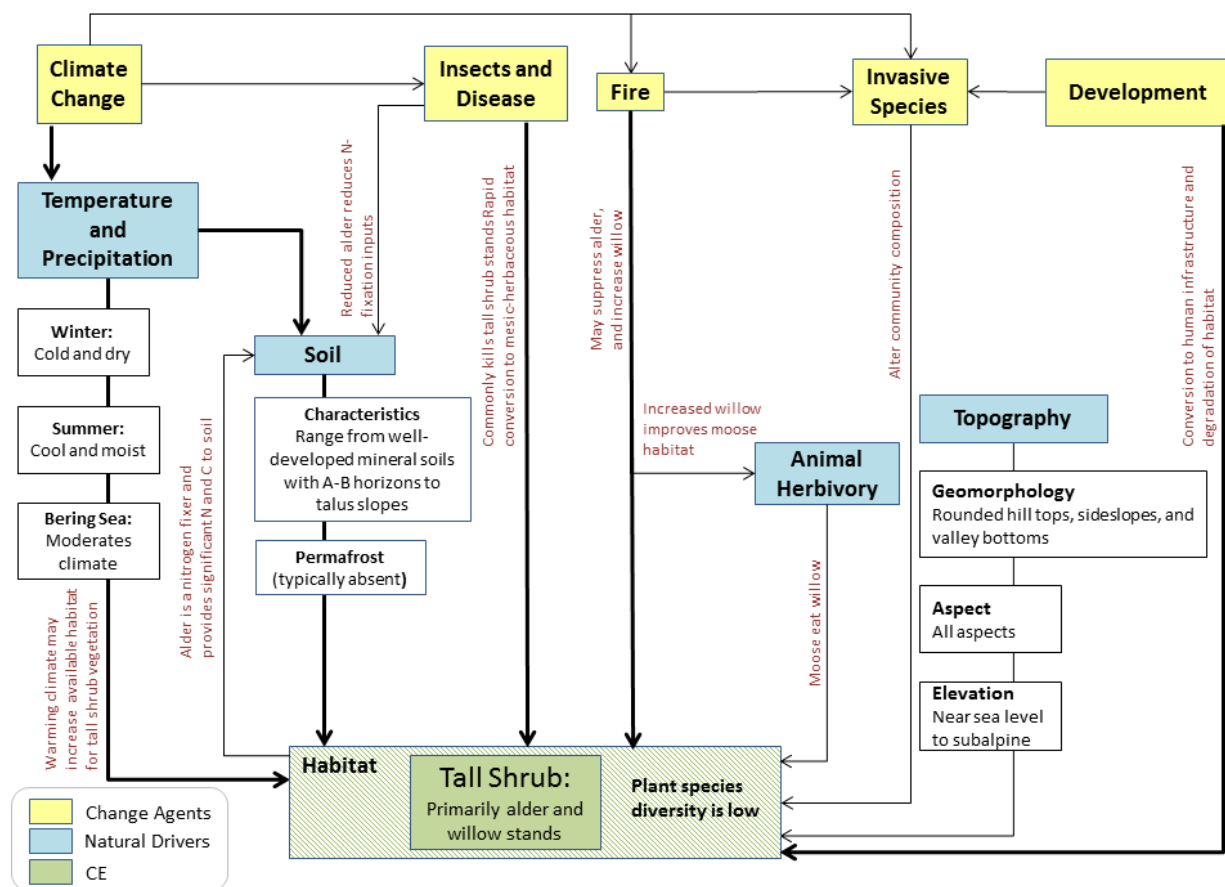
For the herbaceous wetlands class, we will combine several coarse scale classes. The Herbaceous (Aquatic) and Herbaceous (Marsh) classes encompass a small area and we chose to combine them with the Herbaceous (Wet) class. This combined Herbaceous Wetlands class includes herbaceous peatlands but not tussock tundra or floodplain wetlands.

Conceptual Model: Tall Shrub Example

The tall shrub class is comprised primarily of alder and/or willow greater than 1.5 m tall and with greater than 25% canopy cover. The primary CAs with regards to the tall shrub CE are climate change and insects and disease. Increase in mean annual temperature for the YKL ecoregion will likely expand the area of suitable habitat to include higher elevations for tall shrub in the Kuskokwim Mountains and Lime Hills. Insect defoliators and disease commonly kill alder and willow stands. In some areas of the YKL ecoregion, large stands of alder and willow have already been defoliated. Alder are primary nitrogen-fixers in the YKL ecoregion, and reduction in alder decreases the amount of nitrogen fixed into soil. Figure 11 illustrates the relationships between natural population drivers, CAs, and tall shrub in the YKL region. Yellow boxes depict CAs, cyan boxes depict natural drivers. Arrows represent relationships between the various CAs and natural drivers on the community overall and, where appropriate, on the dominant species more directly.

The diversity of plant and animal species in tall shrub is typically low. Moose browse tall willow, and recently burned areas with tall shrub can provide high quality moose habitat.

Figure 11.: Conceptual model for tall shrub in the YKL region.



Process Model

The process model for tall shrubs is simply an extraction of this class from the mosaicked vegetation map, as outlined above.

Limitations

The Alaska LANDFIRE map was used to fill significant portions of the Boggs et al. (2013) map. Its class accuracy is poor and, consequently for regions where LANDFIRE was used, the spatial accuracy of the various classes is suspect. Developing a new map for these areas would require gathering additional aerial and ground plot data and is therefore beyond the scope of the REA. The lack of aerial and plot data is a major factor contributing to the poor class accuracy of the LANDFIRE map.

The Boggs et al. (2013) map contains some edge discontinuities that resulted from mosaicking different landcover classification schemes into a single system. Although all regional source maps were linked to Viereck et al. (1992) classification and cross-walked to the same coarse-scale legend, some datasets recorded mismatched vegetation classes at their edges with other datasets.

Tall and low willow were not typically mapped as unique classes and were combined into more general Tall Shrub and Low Shrub classes. The distribution of willow will be modeled by mapping ecosystems in which willow typically occurs: streams and floodplains. Consequently, the general location but not precise location of willow on the landscape will be delineated.

Management Questions for CEs

There are four MQs related to vegetation class terrestrial coarse-filter CEs (Appendix 1: Revised List of Management Questions). All MQs are included in the core REA analysis and will be addressed using the methods outlined above.

Permafrost

Introduction

Current permafrost conditions vary within the YKL Ecoregion, with some areas of continuous or nearly continuous permafrost and some areas lacking permafrost. Within the Yukon River Lowlands, permafrost is absent along the younger floodplains, but is thin, discontinuous, and relatively “warm” on the abandoned floodplains in the adjacent lowlands. Poor drainage caused by permafrost contributes to the prevalence of wet, organic-rich soils. Collapse-scar features from thawing permafrost are common. Permafrost-dominated lowlands support black spruce woodlands, and birch-ericaceous shrubs and sedge-tussock bogs. In the Kuskokwim Mountains, thin to moderately thick permafrost underlies most of the area. The Lime Hills are underlain by isolated masses of permafrost.

Conceptual Model

The main components of the permafrost model are represented in the general ecosystem conceptual model. Permafrost modeling will incorporate both [SNAP climate projections](#) and the Geophysical Institute Permafrost Lab (GIPL) permafrost model for Alaska, which relies on spatial data related to soil,

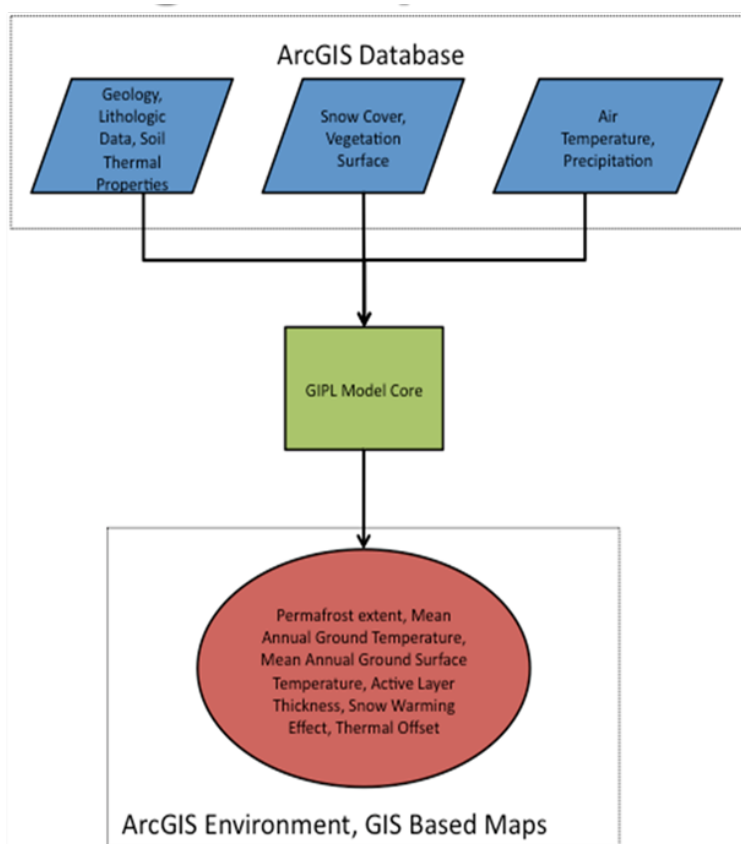
vegetation, and climate. GIPL model outputs include mean annual ground temperature (MAGT) and active layer thickness (ALT), linked by appropriate algorithms.

Process Model

The permafrost distribution model is illustrated in Figure 12. The Geophysical Institute Permafrost Laboratory (GIPL) model was developed specifically to predict the effect of changing climate on permafrost. GIPL model is a quasi-transitional, spatially distributed equilibrium model for calculating the active layer thickness (the thin layer above permafrost that seasonally freezes and thaws) and mean annual ground temperature.

The GIPL permafrost model calculates permafrost extent, mean annual ground temperature, mean annual ground surface temperature, active layer thickness, snow warming effect, and thermal onset from data inputs relating to the geologic and soil properties, effects of ground insulating snow and vegetation layers, and predicted changes in air temperature and annual precipitation. The primary outputs relevant to the YKL REA are the mean annual ground temperature and the active layer thickness. Together, these properties delineate the presence and local extent of permafrost. The model is ground-truthed and validated using cores from around the state, as shown on the GIPL website (GIPL 2013).

Figure 12.: Process model of GIPL permafrost modeling techniques.



Algorithms to determine MAGT and ALT are dependent on calculations of the insulating properties of varying ground cover and soil types, as well as on climate variables, and vary spatially across the

landscape at a resolution of 1km. Outputs provide a general approximation of areas likely to undergo some degree of thaw and associated hydrologic changes. Model results will be presented in map and tabular form.

Management Questions

Four MQs relate directly to permafrost:

1. How and where will changes in permafrost impact vegetation?
2. What are the current soil thermal regime dynamics?
3. Based on the predictions of the best available climate models and soil temperature models, how will soil thermal regimes change in the future?
4. Where are predicted changes in soil thermal regimes associated with communities and transportation routes?

Methods

The above MQs will be addressed first by applying the GIPL model to estimate current and future MAGT and ALT, as described above. Outputs will be presented and discussed to address the second and third MQ above. Next, resulting GIS outputs will be combined with GIS data on vegetation, communities, and transportation routes in order to determine where significant changes are likely in relation to these features. Significant change is most likely to occur in areas where permafrost is predicted to undergo a shift from current below-freezing conditions at 1 meter to future above-freezing conditions at that depth, or in locations that are close to such a transition point. In addition, significant permafrost-driven change may occur indirectly, due to changes in drainage spurred by thaw, thermokarst, and slumping elsewhere on the landscape. Such change cannot be directly spatially analyzed, but will be discussed qualitatively, with literature review as an additional resource.

Limitations

The GIPL permafrost model provides a general and coarse approximation of permafrost conditions across the landscape. Fine-scale changes in permafrost micro-conditions cannot be accurately predicted by the GIPL model. For example, the GIPL model cannot predict the formation of specific thermokarst features or the drainage of specific lakes from permafrost thaw. However, the predicted changes in permafrost at the landscape level indicate where such phenomena will be most likely.

Terrestrial Fine-Filter Conservation Elements

Introduction

Nine species or species assemblages were selected as terrestrial fine-filter CEs (wildlife) during Task I. Distribution of each of the nine terrestrial fine-filter CEs will be mapped and the potential change in distribution, caused by the individual CAs, will be assessed. For each CE we intend to assess current status as well as forecast changes in status at two future time horizons: 2025 and 2060. Distribution models will also aid in the analysis for specific MQs. There are eight wildlife MQs that will be addressed.

As described above, a **distribution model**, a **conceptual model** will be produced for each fine-filter CE, **attributes and indicators** identified, and **status** assessed. A **process model** that maps out data sources and workflow will be developed for each MQ. The methods used to develop distribution models for wildlife differ from those used for coarse-filter CEs and fine-filter aquatic CEs (described later), therefore, they are described separately below. Attributes and indicators are unique to the assessment of terrestrial and aquatic fine-filter CEs, and are also described in more detail below.

Distribution Models

Distribution models for individual terrestrial CEs were obtained from the Alaska Gap Analysis Program (AKGAP; www.akgap.info) (Gotthardt et al. 2013). AKGAP models are spatial representations of a species predicted distribution, within known range limits, at 60 m pixel resolution. Models were produced through a combination of deductive and inductive modeling techniques to produce a final distribution model. AKGAP models were assessed for accuracy and were also expert reviewed. Models were developed to depict the species distribution across its full range in Alaska, not specifically within the YKL REA boundary. In order to ascertain that the AKGAP models are suitable at the scale of the YKL REA, we will have models for the nine terrestrial CEs reviewed by appropriate Tech Team members or outside experts familiar with each species and associated habitat. If AKGAP models are not deemed useful or representative at the REA scale, we will then use alternative data sources to help describe distribution. Alternative data sources include species specific occurrence data, AKNHP element occurrence data, or seasonal range maps. As this analysis is based on existing data, we do not intend to rerun the AKGAP models or create new distribution models for the individual CEs.

Attributes and Indicators

Attributes and indicators can be utilized to better address specific MQs and help parameterize CE conceptual models. Attributes define a characteristic of a geographic feature or entity (e.g., habitat quality helps define the status of habitat availability for a given CE), and are categorical in nature. Indicators are defined as components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., presence of /or distance to infrastructure is an indicator of habitat quality) that are too difficult, inconvenient, or expensive to measure (REA DMP version 2, 2012). Attributes and indicators will be identified in the conceptual models for the CEs. When applicable, documentation on attributes and indicators will be provided in summary table format.

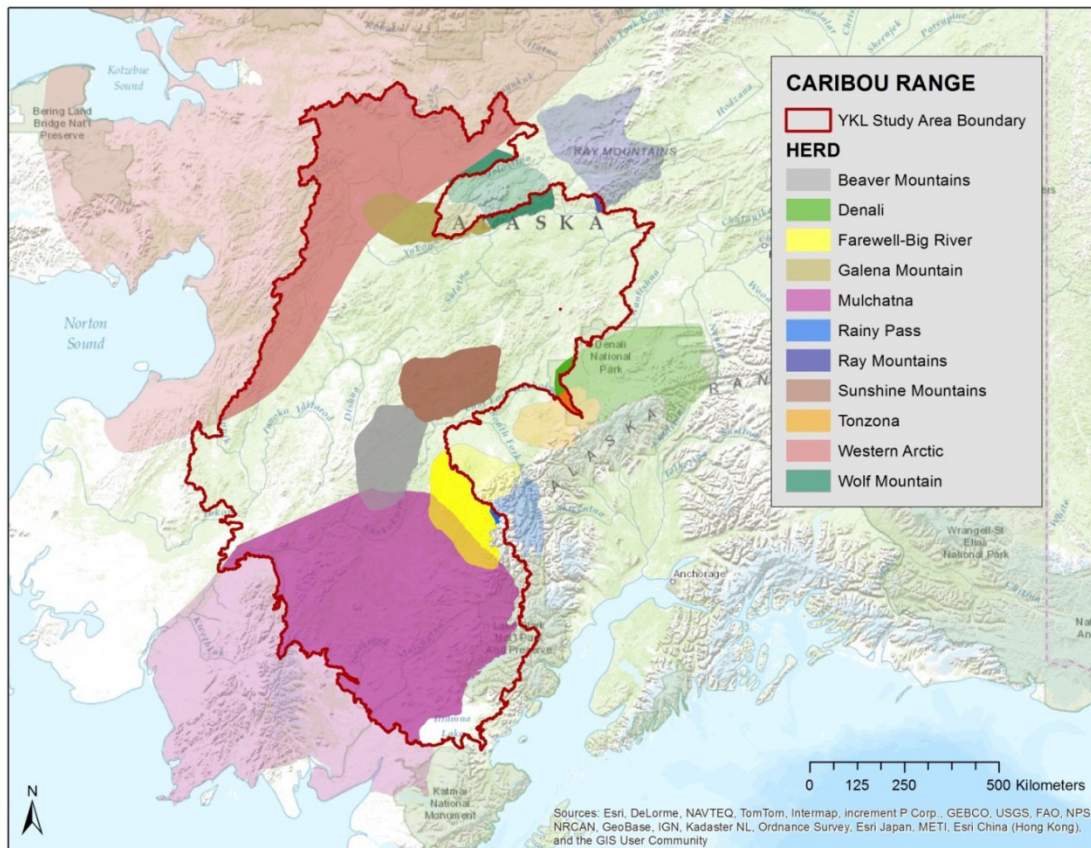
Below is an example of the process that will be used to address caribou as a CE and its related MQs.

Example: Terrestrial Fine-filter Species Conservation Element: Caribou (*Rangifer tarandus*)

Caribou are circumpolar in their distribution, occurring in arctic tundra and boreal forest regions in North America and Eurasia (MacDonald and Cook 2009). In Alaska there are 31 recognized herds of which 11 are found within the YKL REA boundary, including the: Mulchatna, Farewell-Big River, Beaver Mountain, Sunshine Mountains, Rainy Pass, Tonzona, Denali, Ray Mountains, Wolf Mountain, Galena Mountain, and Western Arctic herds (Figure 13).

In the summer, caribou typically calve in treeless tundra in the mountains or open areas along the coast. Summer forages include leaves of willows, sedges, flowering plants, and mushrooms (ADF&G 2013) and

Figure 13. Intersection of 11 caribou herds with the YKL Ecoregion boundary.



provide energy for body and antler growth, pelage replacement, and rebuilding nutrient stores for the upcoming winter (Joly and Klein 2011). Post calving, caribou often form large aggregations and move to avoid predators and escape from insects. As winter approaches, caribou move to lower elevations and many herds migrate long distances to areas with an adequate quantity of winter forage (ADF&G 2013), which is primarily comprised of ground dwelling lichens. The quality of winter forage can affect body condition, fetal development, birth weights and growth rates of calves, and milk production (White 1983, Parker et al. 2005). Thus poor winter range conditions can have a large impact on reproduction and recruitment (Joly et al. 2010).

Conceptual Model

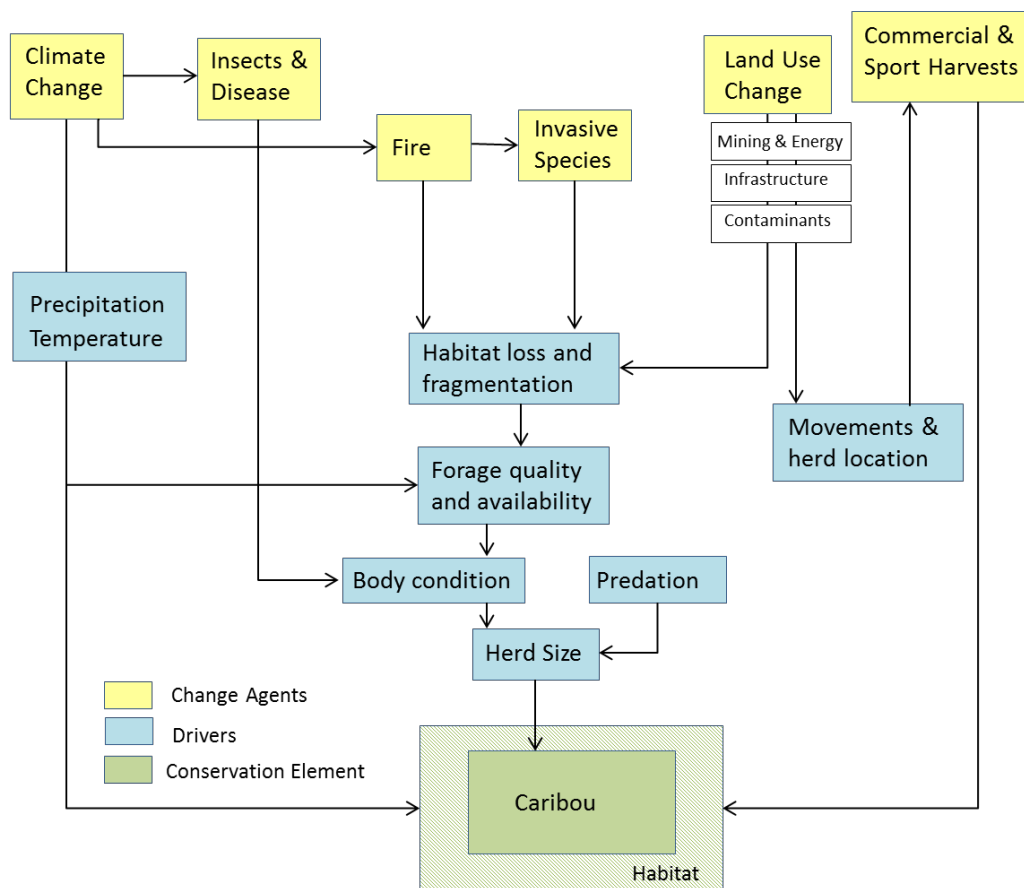
Wildfires in the region have the ability to burn ground dwelling lichens which can take several decades to regenerate to pre-burn levels (Jandt et al. 2008). These fires can thus reduce potential caribou winter range by burning (removing) the lichens that are the primary winter forage for caribou (Rupp et al. 2006). Fire frequency is likely to increase with climate change. (Higuera et al. 2008)

Climate change is likely to negatively impact lichens by reducing lichen abundance from competition with vascular plant species (e.g., shrub encroachment), wildfire, warming and drying, and grazing by reindeer (Joly et al. 2009; Joly et al. 2010). Since lichens are a critical component of winter diet, a reduction in lichen abundance and thus a deterioration of winter range can lead to shifts in winter

distribution (Joly et al. 2010). Additionally, climate change has the potential to influence insects, parasites, diseases, snow depth and condition, wind, temperature, and cloud cover, all of which have consequences either directly or indirectly on survival and reproductive success (Joly and Klein 2011).

Human and resource development has caused the fragmentation of caribou habitat and patch sizes are likely to decrease with increased development. Caribou generally avoid areas of human activity although it is dependent on the type and intensity of the activity and caribou can be displaced from preferred calving grounds by disturbance (Joly and Klein 2011; Wolfe et al. 2000). Human activities may result in increased vigilance, avoidance behaviors, and redistribution of animals (Wolfe et al. 2000). Human harvest tends to remove larger healthier animals, with sport hunters generally taking males and subsistence hunters taking both males and females.

Figure 14.: Conceptual model for caribou in the YKL REA.



Invasive flora and fauna have the potential to negatively impact caribou. For example, reindeer herds can transmit disease and compete with caribou for forage resources (i.e., grazing on lichens in winter ranges) (Joly and Klein 2011).

The conceptual model (Figure 14) illustrates the relationships between natural population drivers, CAs, and caribou populations. Yellow boxes depict CAs, cyan boxes depict natural drivers. Arrows represent

relationships between the various CAs and natural drivers on the community overall and, where appropriate, on the dominant species more directly.

Management Questions

1. What is the current distribution of primary winter forage (lichen) for caribou in the region and how is that expected to change?
2. Where are caribou calving grounds in the region and how are they expected to change?
3. What is the current distribution of migration corridors for caribou and how are they likely to change in the future?
4. What are the current types and potential impacts of diseases in ungulate populations (caribou, moose) and how are these impacts expected to change in the future?

Required Input Data Layers

To address the MQs above, we need to know the current seasonal distribution for all herds including calving and wintering; we also need to know the migration routes of the larger herds (Mulchatna and Western Arctic), as these two herds undergo large scale seasonal movements within the REA; we also need to identify factors that could potentially affect distribution (both natural and anthropogenic). We need to be able delineate lichen distribution from the landcover map, as well as identify factors that influence it's distribution and abundance, such as wildfire and known fire frequency (Table 5).

Table 5: Source data layers necessary for addressing MQs for caribou.

Tentative Data Needs	Data Class	Management Question
Vegetation Map- northern, western, and interior Alaska	VEGETATION	1
AKGAP predicted distribution model - caribou yearround distribution	TERRESTRIAL	1,2,3
Seasonal range polygons of all caribou herds in Alaska	TERRESTRIAL	1,2
Winter kernel range of the western arctic caribou herd	TERRESTRIAL	1
*Location (radio collar) data for specific herds. Currently have data for Galena and Wolf Mountain herds, but do not have data for any other herds.	TERRESTRIAL	1,2,3
Fire perimeters – burn scars	WILDFIRE	1
ALFRESCO fire models (SNAP)	WILDFIRE	1
Road Infrastructure	DEVELOPMENT	2, 3
Energy Infrastructure	DEVELOPMENT	2, 3
Human Footprint	DEVELOPMENT	2, 3
DEM	TOPOGRAPHY, SLOPE	1, 2, 3

*Data layers with asterisks indicate data that may not be readily available.

Data Gaps

No spatial data are available that describe the distribution of ungulate diseases, therefore MQ #4 will be addressed exclusively through literature review and expert communication. Radio collar data that would allow us to delineate migration corridors for the Western Arctic and Mulchatna herds have been requested, but are currently pending. An adequate snow cover layer for the ecoregion is lacking; therefore, we are unable to incorporate snow depth/cover into our assessment of lichen availability during winter (MQ #1). Icing is also known to influence winter distribution, but spatial data is lacking.

Methods and Tools

Below we provide an example of the processing steps used to address one of the caribou specific MQs: *What is the current distribution of primary winter forage (lichen) for caribou in the region?*

Modeling Caribou Habitat

The first step in this process will be to combine all the landcover classes from the vegetation map that contain lichen. Some of the YKL ecoregion has burned since the various maps that were used to produce the YKL vegetation map were developed. We know that lichen take roughly 50 or more years to recover following a fire (Holt et al. 2008, Jandt et al. 2008, Klein and Shulski 2009, Joly et al. 2010, Collins et al. 2011); therefore, we plan to conduct a literature review to understand lichen recovery rates for different vegetation types; vegetation types that do support lichen within the decided upon recovery time will then be selected and become the intermediate map of lichen distribution. We will then apply the BLM fire scar map to the intermediate lichen map to determine what recently burned areas no longer

Figure 15.: Process model for current distribution of primary winter forage (lichen) for caribou

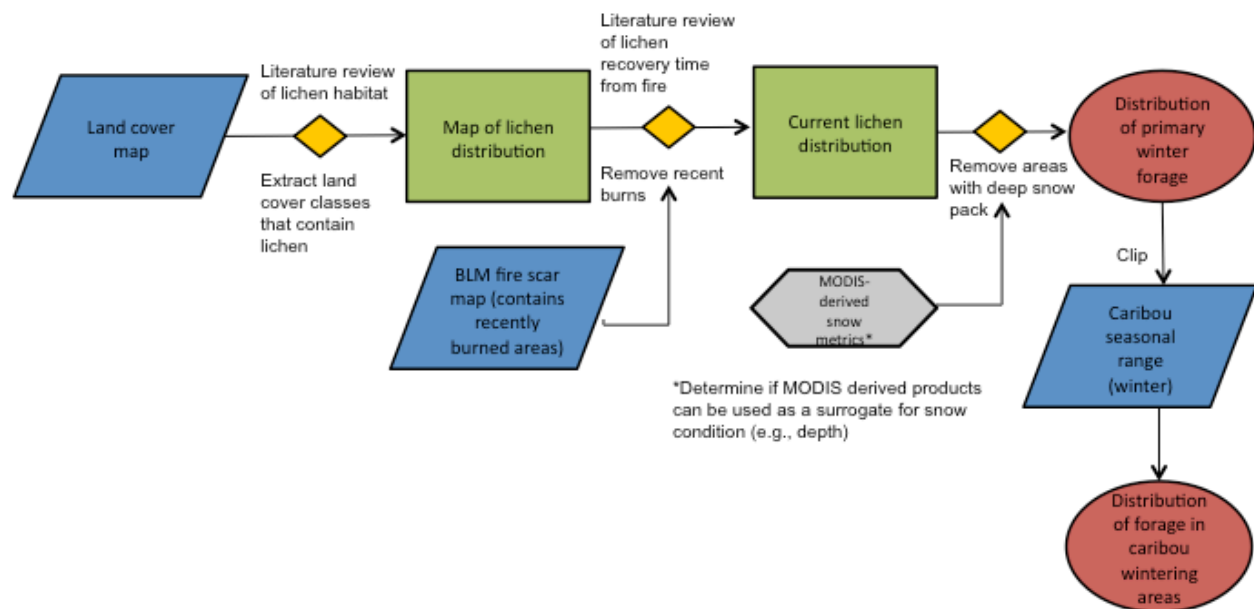


Table 6: Attributes and indicators for caribou.

Species	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
Caribou	Habitat degradation	Infrastructure (roads)	Road near calving grounds	High use road in areas no used for calving	Low use roads in areas not used for calving	Undeveloped	Cronin et al. 1994	During calving, cows and calves avoid roads, even with low traffic use (<100 vehicles per day), and as a result, are not typically found within one km of the roadway.
Caribou	Habitat degradation	Fire	Recently burned (<30)			Unburned	Jandt et al. 2008	Lichen is often consumed or killed even by light burn severity wildfires. Lichens have a much longer recovery time compared to vascular plants.
Caribou	Habitat availability	Vegetation	Non-lichen habitats, such as riparian lowlands			Lichen	Joly et al. 2010	Lichens are a critical component of winter diet. In the winter, caribou select sites with high lichen abundance and lower moss, forb, and shrub cover than random locations.
Caribou	Habitat availability	Winter Weather-Snow/ Ice/ Wind	Avoids deep and dense snowpack			Utilizes areas with shallow snow, including windblown areas	Joly and Klein 2011	Icing events or rain or snow restricts access to forage species. Additionally icing and wind events can harden the snowpack. Areas that are windblown with low snow levels provide easy access to forage.

support lichen. This will become the final lichen distribution layer. We also know that caribou avoid dense snowpack during winter. In order to further refine the model, we are exploring options to obtain a snow depth layer, or an appropriate surrogate for snow depth, for the YKL REA. If available, we will overlay this snow depth layer with the lichen distribution map to further refine availability of lichen during winter. If not available, snow depth will be flagged as a data gap. Lastly, we will overlay the current known winter distribution of caribou with the lichen distribution map to assess how well the lichen map aligns with known winter distribution.

Figure 15 illustrates the process model for the caribou MQ described above. All processing will be done in ArcGIS utilizing existing datasets.

Model Assumptions

1. Caribou make seasonal movements between wintering areas and calving grounds. For two herds, the Mulchatna and the Western Arctic, these represent broad-scale movements. For the other smaller herds associated with the REA, seasonal movements are less pronounced, but there are generally defined calving grounds.
2. During calving, caribou avoid roads and other areas of human disturbance.
3. While the larger herds (Western Arctic and Mulchatna) are generally considered distinct, there is some overlap in movement between herds.
4. Caribou use lichen habitat preferentially during winter.
5. Lichen takes 50 years to recover following a fire, therefore preferred lichen would occur outside of 50 years or less burn scars.

Attributes and Indicators

There are a number of potential attributes listed in Table 6 that could be utilized to parameterize the conceptual model or to aid in specific geoprocessing steps to address specific MQs

Aquatic Coarse-Filter Conservation Elements

Recommendation for removal

The aquatic coarse-filter CEs have been identified as a data gap due to the lack of an aquatic habitat map for the REA study area. In previous memos, a small group of aquatic habitat types had been proposed, but during the data discovery webinar and in a meeting with BLM fisheries biologists on March 19, the limitations of this mapping effort were discussed and are summarized below.

The National Hydrography Dataset (NHD) is the best available spatial data of aquatic resources for the REA study area. It is a digital representation of the stream network and lakes shown on USGS topographic maps, which were created from historic aerial photos. It has several limitations:

- The NHD underrepresents small streams because they are often masked by vegetation cover and not visible on aerial photography.
- The NHD is very outdated (most topographic maps were created in the 50's and 60's) and stream locations and lake areas have likely changed due to natural hydrologic disturbances and climate change.

- Both stream order and stream gradient are needed to map aquatic habitats; the NHD is not attributed with stream order and does not align with valley bottoms in the digital elevation model (DEM) so stream gradient cannot be calculated accurately.

Additionally, the best available DEM for the study area is the National Elevation Dataset (60 m pixels). Due to the limitations of the NHD, aquatic habitats must be mapped by creating a stream network from the DEM, which has its own set of drawbacks.

- Utilizing a coarse DEM to map streams results in a gross oversimplification of the stream network length and complexity.
- The DEM does not match the NHD, which is the best available representation of what exists on the ground.
- When creating a stream network from a DEM, a decision must be made regarding the size of the watershed required to initiate a first order stream. There is no available data relating area to perennial flow initiation for the study area and due to the diversity of topographic, geologic, and permafrost characteristics across the REA ecoregions, this relationship is expected to vary.

In addition to the limitations of the data available for mapping aquatic habitats, it is beyond the scope of this project to create an aquatic habitat classification relating aquatic habitat types to physical, chemical, and biological conditions for the REA study area. Instead of creating a map of aquatic habitats that would have spatial inaccuracies and lack necessary field descriptions, we have proposed to summarize available data for 5th level HUC across the study area. This would include published information on hydrologic regime, water quality, physical habitat, and biological communities. Therefore, we propose excluding any coarse-filter aquatic CEs from this REA.

Aquatic Fine-Filter Conservation Elements

Introduction

The fish fine filter CEs (species) will be treated similarly as the terrestrial species and a list of the methods and products completed for each CE species in the assessment are outlined in the section above. Five fish species have been selected for the assessment and an effort was made to select representative species from different taxonomic groups (either family or sub-family):

- Chinook salmon (*Oncorhynchus tshawytscha*)
- chum salmon (*Oncorhynchus keta*)
- inconnu or sheefish (*Stenodus leucichthys*)
- northern pike (*Esox lucius*)
- Dolly Varden (*Salvelinus malma*)

Distribution Models

For each species, a distribution map will be created. The Alaska Department of Fish and Game (ADF&G) maintains the Anadromous Waters Catalog (AWC), which contains the spatial distribution of anadromous fish species across the state. The AWC will be used to represent the distribution of Chinook and chum salmon in the REA study area. The distribution of sheefish in the AWC will be amended with additional occurrence points and spawning sites using published data from the study area (personal

communication Lisa Stuby, ADF&G). Due to the lack of distribution maps or models for northern pike or Dolly Varden, distributions will be modeled from occurrences for each species documented in ADF&G's Alaska Freshwater Fish Inventory, Alaska Lake Database (for northern pike), and BLM resident fish tagging data in the Kuskokwim drainage (personal communication Matt Varner) using Random Forests (Cutler et al. 2007). Variables used to predict fish distribution will be calculated using the best available data in GIS and will include geographic (e.g. elevation), hydrologic (e.g. stream order), climatic (e.g. temperature and precipitation), topographic (e.g. watershed and stream gradient), and biologic (e.g. presence of salmon) information.

Random forest models are built by combining the predictions from many classification trees (~500). A bootstrapped sample of the data is used for each classification tree (~63% of the data). Each tree is built by finding the best predictor variable for each split in the tree that results in the most homogenous groups with respect to the response variable (presence or absence of a fish species). At each split in the tree, only a small number of the predictor variables (square root of total) are available for evaluation. Each tree is fully grown and used to predict the out-of-bag observations (data not included in the bootstrapped samples). The predicted class for each observation is calculated by majority vote from the out-of-bag observations. Random forest models and predictions will be built using the R statistical package randomForest (Liaw and Wiener 2002, R Development Core Team 2012).

Attributes and Indicators

There are a number of indicators that will be used to assess the current ecological status of fish habitats in the REA ecoregions (Table 7). For each indicator, a rating will be attributed to each 5th level HUC across the study area. The indicators will be weighted and combined for an overall ecological status assessment for each 5th level HUC. Due to lack of data describing impacts of indicators on each of the target fish species, the rating system will be developed generally for fish habitat for an overall aquatic ecological status assessment. Many of the indicators lack data quantifying threshold effects to fish or fish habitats with which to define the ratings categories. Due to this data gap, the indicator ratings will be scaled based on densities of impacts across the 5th level HUCs in the REA study area and best professional judgment will be used to define the ratings categories. The fisheries technical team will have an opportunity to review the rating system during the assessment phase of the project.

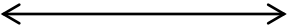
Limitations

To date, there is no statewide aquatic habitat classification. As mentioned above, this represents a huge data gap that could be preventing more effective management of aquatic habitat resources. This is especially important given the spatial inaccuracies in NHD and limited attribute information in NHD that can be used to map aquatic habitats. Additionally, due to the spatial resolution of the most current DEM, we are not able to build a stream network that could aid mapping of aquatic habitats. Furthermore, no aquatic habitat descriptions are available to justify creating an aquatic habitat map.

No complete spatial distribution data for fish species outside of salmon currently exists, limiting habitat distribution modeling efforts. Additionally, outside of commercial salmon species, almost no information on population sizes for other fish species. The extent of anadromy or amphidromy for Dolly Varden and whitefish populations, respectively, has very limited information.

Table 7. Ecological status assessment indicators for fish habitat in the YKL REA .

Species	Scenario	Key Ecological Attribute	Indicator	Indicator Rating				Comments
				Poor	Fair	Good	Very Good	
Fish	Current	Habitat	Landscape Condition Model	High human footprint	←→		Low human footprint	See landscape intactness section.
Fish	Current	Habitat and connectivity	Culverts	Many culverts rated Red	←→		No culverts or all culverts rated Green	ADF&G has conducted culvert inventories on road systems across the state and ranked passage into three categories for juvenile salmonids. Additional information on physical failures may be used to indicate impaired passage for resident fish.
Fish	Current	Habitat and connectivity	Dams	Many small to medium dams or few large dams	←→		No dams	ADNR maintains a dam inventory for the state. Since dams restrict or block fish passage, density of dams will be used for the ratings. Many dams are missing height information in the inventory, so either dam length or storage volume could be used as a proxy for size to weight the impacts in each HUC.
Fish	Current	Habitat and water quality	Placer mining ditches	Many ditches	←→		No ditches	The NHD includes ditches in the flowline feature class. These ditches indicate areas of historic placer mining. There is no information on ditch status or condition.

Fish	Current	Habitat and water quality	Active and inactive mines	Many mines  No mining activity	The USGS maintains the Alaska Resources Data File, which includes information on active and inactive mining projects across the state.
Fish	Current	Water quality	Discharge permits	Many APDES permits  No discharges	The ADEC regulates discharges to aquatic habitats through the Alaska Pollution Discharge Elimination System program.
Fish	Current	Water quality	State impaired waters	TBD	ADEC maintains a list of impaired waterbodies in the state that are listed under the 303(d) program for not meeting water quality standards. The indicator rating will depend on the pollutant in the listed water and whether or not it meets the growth and propagation of fish, shellfish, other aquatic life, and wildlife designation.
Fish	Current	Habitat	Invasive species	Large infestations or small infestations of highly ranked species  No infestations	The Alaska Natural Heritage Program maintains a database of invasive species occurrences across the state. Aquatic invasive species and terrestrial species that invade riparian areas will be used for this indicator. The invasiveness ranking of a species and sizes of infestations will be used to develop the ratings categories (Nawrocki et al. 2011).

Limited information also exists on threshold effects of indicators on key ecological attributes exist. Currently there are no climate change predictions specific to aquatic habitats, such as changes to water temperature or hydrologic regime. There is limited survey information on aquatic invasive species for the study area, even though the assumption is they are not there. There is also limited information on the status and condition of mining activities in the region.

Core REA Analysis

Introduction and background

An overall goal of Rapid Ecoregional Assessments is to provide land managers with a glimpse of the direction and magnitude of change they can expect on their, and neighboring, lands. By assessing the overlap between the CEs and the CAs, land managers can better understand the ‘known unknowns’ (i.e. fire impacts on a specific land cover), as well as the ‘unknown unknowns’ (the cumulative impact of fire, climate change, and land use development on the land cover).

Overlap of future CE and CA distributions

The science track is driven by what is defined in this REA as core-REA analyses, meaning those analyses that are inherent to the REA process. These core analyses look at the intersection of CEs and CAs (CAs) in the current landscape, as well as future landscapes. For this REA, we propose using a modified scenario approach to highlight the various future conditions that may arise from the intersection of CEs and CAs.

Central to landscape assessments is the ability to address basic questions about current and future conditions of ecological resources. In this REA, we consider five questions to be core to the ecoregional approach:

1. Where are CEs distributed currently?
2. Where are CAs currently located?
3. Where might CEs occur in the near and long-term?
4. Where might CAs differ in the near and long-term?
5. Where do CEs and CAs overlap in the near-term (2025) and far-term (2060)?

Scenarios

Forecasting the future is an uncomfortable, but necessary planning tool. Although uncertainty can riddle future forecasting, scenario analysis can provide a framework for comparing and quantifying the uncertainty to better inform planning decisions. Although previous REAs have chosen to present only one future forecast, we propose presenting alternative scenarios of how this ecoregion might change. We propose assessing *high* and *low* land use and development scenarios to highlight the varying degrees in which the region may change due to anthropogenic activities. The alternative scenarios will provide an opportunity to highlight the range of possible anthropogenic changes that could occur, without locking in on one single option. The alternative scenarios will also provide an opportunity to explore the sensitivity of some of the climate models so land managers will have a better idea of the range of possible changes.

Methods

Given the geospatial nature of the core REA questions, the majority of analysis will occur within a GIS. The methods for the mapping of current CE and CA distribution, as well as future CA distribution have been documented in the respective sections. Here we discuss the methods for assessing the overlap between CEs and CAs in the near and long-term. Results for all the core-REA analyses will be summarized at the 5th-level HUC.

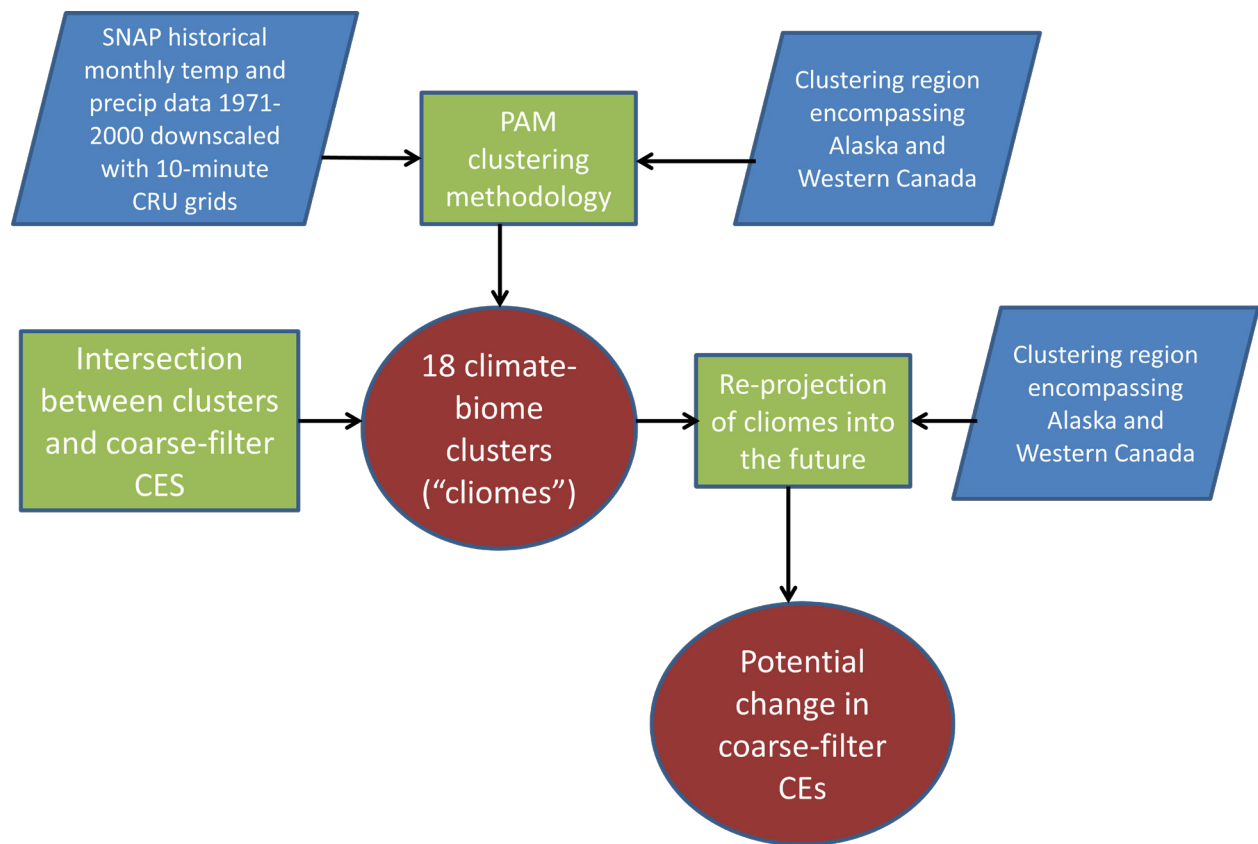
Biome Shift

We propose using a biome model to model the overlap between climate as a CA, and the modeled coarse-filter CEs. The Alaska Climate-Biome Shift Project (AK Cliomes) was a collaborative effort that used clustering methodology, existing land cover designations, and historical and projected climate data to identify areas of Alaska that are likely to undergo the greatest or least ecological pressure, given climate change (SNAP and EWHALE 2012).

The clusters or “cliomes” used in the model are machine-generated groupings of areas with similar climates, representing climate-biomes on the landscape. The eighteen cliomes were identified using the combined Random Forests™ and PAM clustering algorithms, and are defined by 24 input variables (monthly mean temperature and precipitation) used to create each cluster. Cliomes can be considered to be broadly defined regions of temperature and precipitation patterns that reflect assemblages of species and vegetation communities (biomes) that occur or might be expected to occur based on linkages with climate conditions. They are not the same as actual biomes, since actual species shift incorporates significant and variable lag times, as well as factors not directly linked to climate. However, results serve as indicators of potential change and/or stress to ecosystems, and can help guide stakeholders in the management of areas of greatest and lowest resilience to changing climate.

Forward-projecting these cliomes using SNAP climate projections and cross-tabulating them with coarse-filter CEs will yield predictions about broad-scale ecosystem change. Outputs will include maps of projected cliome shift, as well as spatial and qualitative analysis of the projected change. Although ALFRESCO also models vegetation change, it does so based on successional pathways, not spatial climate shifts. Currently the two models (ALFRESCO and AK Cliomes) are not linked, but a comparison of the outputs will help elucidate areas of highest change potential based on the different change agents.

Figure 16. Process model describing the cliome shift methodology.



Fire-CE Models

Once areas of change in fire frequency are identified (using methods outline in the fire section), these areas will be spatially compared to the distribution and status of CEs. For terrestrial CEs, we propose a simple overlay to assess the potential for ecosystem change and/or stress. For aquatic CEs, we propose summarizing the change in fire frequency by 5th level HUC as a measure of potential change in erosion and sediment deposition.

Permafrost

While permafrost is considered a CE, it can also act like a CA. Thus, the impacts of climate change on permafrost extent will be modeled (see permafrost section), as well as the impacts due to changing permafrost locations on certain CEs. Specifically, the impacts of permafrost change will be assessed for the coarse-filter CEs, as well as for lakes and rivers that support aquatic CEs. These will again be simple overlays to assess the potential changes in distribution of both the permafrost, and the systems supported by permafrost.

Anthropogenic-CE Models

Anthropogenic activities will be modeled using the human footprint generated for the Landscape Condition Model. The attributes and indicators of each CE will determine the nature of overlap between the human footprint and the CE. If no literature exists to quantify the impact of specific human activities

on a specific CE, then a simple overlay of the human footprint and the CE status will be performed. Since the coarse-filter CEs have no established attributes and indicators, we propose a simple overlay of the human footprint and the coarse-filter CE status.

Cumulative Impacts Analysis

As a final measure of potential impacts to the ecoregions, we will summarize all the potential impacts to CEs by 5th-level HUC. We propose developing a ‘rolled-up’ dataset of all potential threats to the landscape, weighted according to magnitude of change, to provide a more comprehensive picture of how the landscape may change in the future. The inverse of this dataset could be seen as a landscape vulnerability index (LVI) that could be used to assist in future resource planning efforts. This analysis is specially designed to identify some of the “unknown unknowns” (i.e. the interactive impacts of multiple CAs on critical ecoregional resources).

Limitations

Given the cross-disciplinary nature of the core REA analyses, there exists a high potential for error. Modeled outputs will be placed into other models, each with different assumptions, potentially propagating errors throughout. Using GIS as a common platform can assist in identifying errors early in the modeling process, and (by creating intermediate data products) provides a transparent process in which critical review of our assumptions can be made. Thus, while many of these models were never designed to interact, we feel confident that all our modeling efforts represent the best available knowledge about the system and the potential impacts of the “known and unknown unknowns”.

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Appendices

Appendix 1: Revised List of Management Questions

The BLM defined a preliminary set of MQs in the Statement of Work (SOW) for this REA. These questions were generally broad in scope, and too numerous for the BLM target of 30-50 MQs for the REA. Review of several iterations of each question resulted in a list of questions that were most relevant to land managers. With the review and input of the Assessment Management Team (AMT), a volunteer team of representatives from various agencies and organizations that are responsible for land management within the assessment boundary, 61 MQs were ultimately chosen for analysis as part of this assessment. A list of the 61 MQs is provided below.

Table 8: Management Questions

#	Management Question	Category
1	What are the possible impacts on vegetation communities from climate change?	Landcover
2	What is the current distribution of vegetation communities?	Landcover
3	Where is habitat for sensitive species that are also conservation elements?	Landcover
4	How and where will changes in permafrost impact vegetation?	Landcover
5	What is the current distribution of primary winter forage (lichen) for caribou in the region, and how is that expected to change?	Wildlife
6	Where are caribou calving grounds in the region, and how are they expected to change?	Wildlife
7	What is the current seasonal distribution of moose in the region?	Wildlife
8	What is the current distribution of primary winter forage (willow) for moose in the region, and how is that expected to change?	Wildlife
9	Is there is musk ox habitat in the region, and, if so, how might it change in the future?	Wildlife
10	What is the current distribution of migration corridors for caribou, and how are they likely to change in the future?	Wildlife
11	Where are key prey species located in the region?	Wildlife
12	What are the current types and potential impacts of diseases in ungulate populations (caribou, moose), and how are these impacts expected to change in the future?	Wildlife
13	What is the current distribution of the American Peregrine Falcon in the region, and how is that expected to change?	Wildlife
14	How, where, and when could Essential Fish Habitat (EFH) be affected by predicted changes in climate?	Aquatics
15	Where and how might mineral resource development affect fishery habitat?	Aquatics
16	How and where could changes in water temperature impact aquatic species (especially fish)?	Aquatics

#	Management Question	Category
17	How might water chemistry change as a result of future CA (fire, development/mining, warming, etc.)?	Aquatics
18	What are the current soil thermal regime dynamics?	Soil Thermal Dynamics
19	Based on the predictions of the best available climate models and soil temperature models, how will soil thermal regimes change in the future?	Soil Thermal Dynamics
20	Where are predicted changes in soil thermal regimes associated with communities and transportation routes?	Soil Thermal Dynamics
21	How might changes in temperature, precipitation, evapotranspiration, and soil thermal dynamics affect general hydrology and hydrology-dependent CEs such as waterfowl in the region?	Hydrology
22	What are the projected monthly, seasonal, and annual temperature, precipitation, and length of warm and cold seasons for the REA, and how do these projections vary across time, across the region, and across varying global greenhouse gas emissions scenarios?	Climate
23	Where will climate change impact CEs, including subsistence species?	Climate
24	What is the fire history of the ecoregion?	Fire
25	What climatic conditions are likely to result in significant changes to fire activity?	Fire
26	What is the current frequency (return interval) and the likely future frequency for fire in the ecoregion and broad sub-regions?	Fire
27	What is the current distribution and area (percent of land with infestations) of introduced and invasive species in the YKL?	Invasives
28	Which areas are most likely to be susceptible to infestation by invasive plant species currently?	Invasives
29	Which areas are most likely to be susceptible to infestation by invasive plant species in the future, specifically in relationship to climate change and proposed development?	Invasives
30	What is the current distribution of forest pest outbreaks in the ecoregion?	Invasives
31	What are the likely vectors for new infestations or spread of existing infestations?	Invasives
32	Which plant and animal species of conservation concern (present on federal or state conservation lists, e.g., Threatened – USFWS, Sensitive Species - BLM) may be impacted by highly invasive species?	Invasives
33	What are current socio-economic conditions in YKL communities?	Socio-economic
34	What are the projected socio-economic conditions in the future?	Socio-economic
35	How could community economic profiles vary with respect to development scenarios (including mines) in the near future (including access to subsistence, energy sources, and other resources)?	Socio-economic

#	Management Question	Category
36	What are the potential impacts of renewable energy projects on local economies the region?	Socio-economic
37	How might change in transportation corridors impact communities?	Socio-economic
38	Where are current subsistence harvest areas?	Subsistence
39	What do ADFG harvest data and TEK/LTK show about how harvest amounts, types of fish/animals/plants, harvest seasons changed in the recent past (including beavers)?	Subsistence
40	How could larger community populations affect subsistence resources?	Subsistence
41	What are general (sport) harvest levels of salmon, moose, and caribou in the recent past?	Sport and Commercial Hunting and Fishing
42	Where are current sport hunt areas?	Sport and Commercial Hunting and Fishing
43	What have been the commercial harvest levels of salmon over the past 10 years?	Sport and Commercial Hunting and Fishing
44	Where are current commercial fish harvest areas?	Sport and Commercial Hunting and Fishing
45	Where is the current human footprint in the region?	Land Use
46	Where are communities?	Land Use
47	Where are current timber harvests?	Land Use
48	Where are current and recent mine sites?	Land Use
49	Where is the current transportation and communication infrastructure (including local trails)?	Land Use
50	Where are alternative and renewable energy sites?	Land Use
51	What is current land status in the region?	Land Use
52	Where are unsettled land claims?	Land Use
53	Where is recreation activity highest?	Land Use
54	Where are areas of highest mineral potential?	Land Use
55	Where will mines be located? Can we estimate the total footprint (including tailings and associated infrastructure)?	Land Use
56	Where are areas of potential for wind, hydro, biomass energy (and where do they overlap with communities)?	Land Use

#	Management Question	Category
57	Where is planned transportation/communication infrastructure to be located?	Land Use
58	Where are planned sites for alternative/renewable energy?	Land Use
59	How might recreational use in the region change over time?	Land Use
60	Are there areas in the REA that are impacted by mercury contamination?	Land Use
61	What TEK is available for the region?	Traditional Ecological Knowledge

Appendix 2: Data Presented to Tech Team

The following data was presented to the technical team via webinar to provide the results of the data discovery process and to solicit expert opinion on the selected datasets and suggestions for additional datasets.

Table 9: Data List for Data Discovery Webinar, February 26, 2013.

Topic	Dataset Name	Description
Aquatic	Lake Habitat and Fish Surveys on Interior Alaska Wildlife Refuges, 1984-1986	135 lakes were sampled for habitat and fish species in six NWRs, three of which are in the YKL study area: Koyukuk, Innoko, and Nowitna. The location of the lakes is provided in maps along with water quality, habitat, and fish species found in each lake.
Aquatic	A fisheries inventory of waters in the Lake Clark National Monument area	27 lakes and 13 rivers were inventoried for fish in 1978-79. Maps and information on species found area provided in the report. Data might be available upon request or could be digitized based on maps in the report.
Aquatic	Migration timing and seasonal distribution of broad whitefish, humpback whitefish, and least cisco from Whitefish Lake and the Kuskokwim River, Alaska, 2004 and 2005	60 humpback whitefish were tagged at whitefish lake and migrations were monitored. Suspected spawning habitats were identified in the Holitna, Swift, and Big rivers.
Aquatic	Fish Surveys in the Honhosa River, North Fork Huslia River, and Billy Hawk Creek, Koyukuk National Wildlife Refuge, Alaska, 1993	Fish species found on the Koyukuk refuge are documented. Data could be requested from USFWS or digitized based on maps in the report.
Aquatic	Spawning Locations, Seasonal Distribution, and Migratory Timing of Kuskokwim River Sheefish Using Radiotelemetry, 2007-2011	Lisa Stuby has offered to provide excel datasheets from her telemetry work that detail spawning locations, summer feeding locations, and upstream distribution of sheefish in the Kuskokwim.
Aquatic	A Radiotelemetry Investigation of the Spawning Origins of Innoko River Inconnu (sheefish)	Need to request latitude/longitude information for spawning areas found from telemetry work performed by John Burr and Randy Brown. Other option is to digitize from maps in report.
Aquatic	National Hydrography Dataset Waterbodies	The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system.

Aquatic	National Hydrography Dataset Flowlines	The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system.
Aquatic	ADF&G Alaska Freshwater Fish Inventory Points	This dataset contains survey locations from the Alaska Freshwater Fish Inventory Database (AFFID). The AFFID houses freshwater fish (both anadromous and resident) occurrence data compiled from a variety of sources, but mostly from ADF&G field work.
Aquatic	ADF&G Anadromous Waters Catalog: Species and Life Stages	This dataset has the same coverage as the Anadromous Waters Catalog, except that it has additional attribute fields identifying species and life stages for individual stream segments.
Climate	Historical Day of Freeze 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of annual day of freeze for each decade from 1910-2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Historical Day of Thaw 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of annual day of thaw for each decade from 1910-2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Historical Length of Growing Season 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of annual length of growing season (days) for each decade from 1910-2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771 m resolution. Each file represents a decadal mean of an annual mean calculated from mean monthly data
Climate	Historical Decadal Averages of Annual Mean Temperatures 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of annual mean temps (C) for each decade from 1910-2006(CRU TS 3.0) or 2009(CRU TS 3.1) at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Historical Decadal Averages of Annual Total Potential Evapotranspiration 2 km CRU TS 3.0	Downscaled historical decadal means of annual total potential evapotranspiration (mm) for each decade from 1910-2006 at 2x2 kilometer spatial resolution in Alaska. Each file represents a decadal mean of an annual total calculated from monthly totals.
Climate	Historical Decadal Averages of Monthly Mean Temperatures 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of monthly mean temperatures (C) for each month of every decade from 1910-2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771 m spatial resolution in Alaska. Each file represents a mean monthly mean in a given decade.

Climate	Historical Decadal Averages of Monthly Total Potential Evapotranspiration 2 km CRU TS 3.0	Downscaled historical decadal means of monthly total potential evapotranspiration (mm) for each month of every decade from 1910-2006 at 2x2 kilometer spatial resolution in Alaska. Each file represents a mean monthly total in a given decade.
Climate	Historical Decadal Averages of Seasonal Mean Temperatures 771 m CRU TS 3.0 / 3.1	Downscaled historical decadal means of seasonal mean temperatures (Celsius) for each season of every decade from 1910-2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771 m spatial resolution in Alaska. Each file represents a seasonal mean in a given decade.
Climate	Historical Decadal Averages of Seasonal Total Potential Evapotranspiration 2km CRUTS3.0	Downscaled historical decadal means of seasonal total potential evapotranspiration (mm) for each season of every decade from 1910-2006 at 2x2 kilometer spatial resolution in Alaska. Each file represents a mean seasonal total in a given decade.
Climate	Historical Monthly Temperature 771 m CRU TS 3.0 / 3.1 / 3.1.01	Downscaled historical monthly mean temperatures (Celsius) for each month of every year from Jan 1901 - Dec 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1) at 771x771 m spatial resolution in Alaska. Each file represents a single month in a given year.
Climate	Historical Monthly Total Potential Evapotranspiration 2 km CRU TS 3.0	Downscaled historical monthly total potential evapotranspiration (mm) for each month of every year from January 1901 - December 2006 at 2x2 kilometer spatial resolution in Alaska. Each file represents a single month in a given year.
Climate	Projected Monthly Temperature 771 m CMIP3 / AR4	Downscaled projections (B1, A1B and A2 scenarios) of monthly mean temperatures (Celsius) for each month of every year from Jan 2001 - Dec 2100 at 771x771 m spatial resolution in Alaska. Each file represents a single month in a given year.
Climate	Projected Day of Freeze 771 m AR4	Downscaled projections decadal means of annual of day of freeze for each decade from 2010-2100 at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Projected Day of Thaw 771 m AR4	Downscaled projections decadal means of annual of day of thaw for each decade from 2010-2100 at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Projected Length of Growing Season 771 m AR4	Downscaled projections of decadal means of annual length of growing season (days) for each decade from 2010-2100 at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.

Climate	Projected Decadal Averages of Annual Mean Temperatures 771m AR4	Downscaled projections of decadal means of annual mean temperatures (in degrees Celsius) for each decade from 2010-2100 at 771x771 m spatial resolution in Alaska. Each file represents a decadal mean of an annual mean calculated from mean monthly data.
Climate	Projected Decadal Averages of Annual Total Potential Evapotranspiration 2 km AR4	Downscaled projections of decadal means of annual total potential evapotranspiration (mm) for each decade from 2010-2099 at 2x2 km spatial resolution in Alaska. Each file represents a decadal mean of an annual total calculated from monthly totals.
Climate	Projected Decadal Averages of Monthly Mean Temperatures 771 AR4	Downscaled projections of decadal means of monthly mean temperatures (in degrees Celsius) for each month of every decade from 2010 - 2100 at 771x771 m spatial resolution in Alaska. Each file represents a mean monthly mean in a given decade.
Climate	Projected Decadal Averages of Monthly Total Potential Evapotranspiration 2 km AR4	Downscaled projections of decadal means of monthly total potential evapotranspiration (millimeters) for each month of every decade from 2010-2099 at 2x2 km spatial resolution in Alaska. Each file represents a mean monthly total in a given decade.
Climate	Projected Decadal Averages of Seasonal Mean Temperatures 771m AR4	Downscaled projections of decadal means of seasonal mean temperatures (in degrees Celsius) for each season of every decade from 2010 - 2100 at 771x771 m spatial resolution in Alaska. Each file represents a seasonal mean in a given decade.
Climate	Projected Decadal Averages of Seasonal Total Potential Evapotranspiration 2 km AR4	Downscaled projections of decadal means of seasonal total potential evapotranspiration (mm) for each decade from 2010-2099 at 2x2 km spatial resolution in Alaska. Each file represents a mean seasonal total in a given decade.
Climate	Projected Monthly Potential Evapotranspiration 2 km CMIP3 / AR4	Downscaled projections of monthly total potential evapotranspiration (in millimeters) for each month of every year from Jan 2001 - Dec 2099 at 2x2 km spatial resolution in Alaska. Each file represents a single month in a given year.
Climate	Historical Day of Freeze or Thaw 2 KM CMIP5/AR5	Estimated Julian days of freeze and thaw (dof, dot) are calculated by assuming a linear change in temperature between consecutive months. Mean monthly temperatures are used to represent daily temperature on the 15th day of each month.
Climate	Historical Day of Freeze or Thaw 771 m CMIP5/AR5	Estimated Julian days of freeze and thaw (dof, dot) are calculated by assuming a linear change in temperature between consecutive months. Mean monthly temperatures are used to represent daily temperature on the 15th day of each month.

Climate	Projected Day of Freeze of Thaw 771 m CMIP5/AR5 (2006-2100)	Estimated Julian days of freeze and thaw (dof, dot) are calculated by assuming a linear change in temperature between consecutive months. Mean monthly temperatures are used to represent daily temperature on the 15th day of each month.
Climate	Projected Day of Freeze or Thaw 2 KM CMIP5/AR5	Estimated Julian days of freeze and thaw (dof, dot) are calculated by assuming a linear change in temperature between consecutive months. Mean monthly temperatures are used to represent daily temperature on the 15th day of each month.
Climate	Historical (1850-2005) monthly temperature data CMIP5/AR5	Historical (1850-2005) monthly average temperature 5 AR5 GCMs that perform best across Alaska and the Arctic, downscaled to 771m via the delta method.
Climate	Historical (1850-2005) Monthly Precipitation 2 KM CMIP5/AR5	Historical (1850-2005) Monthly Precipitation 2 KM CMIP5/AR5 downscaled using the delta method.
Climate	Historical Monthly Precipitation 771m CRU TS 3.1/3.1.01	Historical (1901–2009) monthly total precipitation from CRU TS 3.1.01 climate data, downscaled to 771m via the delta method.
Climate	Historical Decadal Averages of Annual Total Precipitation 771 m CRU TS 3.0 1910-1999	Historical (1910–1999) derived precipitation products from CRUTS 3.0 climate data, downscaled to 771m via the delta method.
Climate	Historical Decadal Averages of Monthly Total Precipitation 771 m CRU TS 3.0	Historical (1910–1999) derived precipitation products from CRUTS 3.0 climate data, downscaled to 771m via the delta method.
Climate	Historical Decadal Averages of Seasonal Total Precipitation 771 m CRU TS 3.0 1910-1999	Historical (1910–1999) derived precipitation products from CRUTS 3.0 climate data, downscaled to 771m via the delta method.
Climate	Historical Decadal Averages of Annual Total Precipitation 2km CRUTS3.1.01 1910-2009	Includes downscaled historical estimates of decadal means of annual total precipitation (in millimeters) for each decade from 1910 - 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Historical Decadal Averages of Monthly Total Precipitation 2km CRUTS3.1.01 1910-2009	Includes downscaled historical estimates of decadal means of monthly total precipitation (in millimeters) for each month of every decade from 1910 - 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Historical Decadal Averages of Seasonal Total Precipitation 2km CRUTS3.1.01 1910-2009	Includes downscaled historical estimates of decadal means of seasonal total precipitation (in millimeters) or each season of every decade from 1910 - 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Projected Decadal Averages of Annual Total Precipitation 771m AR4 2001-2100	Includes downscaled projections of decadal means of annual total precipitation (in millimeters) for each decade from 2001-2100 at 771x771 m spatial resolution. Each file represents a decadal mean of an annual total calculated from monthly totals.

Climate	Projected Decadal Averages of Annual Total Precipitation 2km AR4 2001-2100	Includes downscaled projections of decadal means of annual total precipitation (in milimeters) for each decade from 2010 - 2100 (see exceptions below) at 2x2 kilometer spatial resolution.
Climate	Projected Decadal Averages of Monthly Total Precipitation 771m CMIP3/AR4	includes downscaled projections of decadal means of monthly total precipitation (in milimeters) for each month of every decade from 2010-2100 at 771x771 m spatial resolution.
Climate	Projected Decadal Averages of Seasonal Total Precipitation 771m AR4 2001-2100	Includes downscaled projections of decadal means of seasonal total precipitation (in millimeters) for each season of every decade from 2001-2100 at 771x771 meter spatial resolution. Each file represents a mean seasonal total in a given decade.
Climate	Projected Decadal Averages of Seasonal Total Precipitation 2km AR4 2001-2100	includes downscaled projections of decadal means of seasonal total precipitation (in millimeters) for each season of every decade from 2010-2100.
Climate	Projected Monthly Precipitation 771 m CMIP3/AR4 2001-2100	Includes downscaled projections of monthly total precip for each month of every year from January 2001 - December 2100 at 771x771 meter spatial resolution.
Climate	Projected Monthly Total Precipitation 2km AR4 2001-2100	Includes downscaled projections of monthly total precipitation (in milimeters) for each month of every year from January 2001-December 2100 at 2x2 kilometer spatial resolution. Each file represents a single month in a given year.
Climate	Projected (2006-2100) Monthly Temperature 2 KM CMIP5/AR5	Projected (2006-2100) Monthly Temperature 2 KM CMIP5/AR5 data downscaled using the delta method.
Climate	Projected Monthly Precipitation 771 m CMIP5/AR5 2006-2100	Projected monthly total precipitation from 5 AR4 GCMs that perform best across Alaska and the Arctic, downscaled to 771m via the delta method. A 5-Model Average is also included.
Climate	Projected Alaska Climate-Biome Shift 2 KM (2001-2099)	Projected shifts in statewide climate-biomes (cliomes) based on climate projections derived from the RandomForest model.
Climate	Historical Length of Growing Season (1850-2005) 2KM CMIP5/AR5	The length of growing season (logs) refers to the number of days between the days of freeze and thaw.
Climate	Historical Length of Growing Season 771 m CMIP5/AR5 (1850-2005)	The length of growing season (logs) refers to the number of days between the days of freeze and thaw.
Climate	Projected Length of Growing Season 2 KM CMIP5/AR5 (2006-2100)	The length of growing season (logs) refers to the number of days between the days of freeze and thaw.
Climate	Projected Length of Growing Season 771 m CMIP5/AR5 (2006-2100)	The length of growing season (logs) refers to the number of days between the days of freeze and thaw.

Climate	Historical Decadal Averages Of Monthly Snow-day Fraction 771m CRUTS3.1 1910-2009	These snow-day fraction estimates were produced by applying equations relating decadal average monthly temperature to snow-day fraction to downscaled decadal average monthly temperature.
Climate	Alaska Projected Decadal Averages of Monthly Snow-day Fraction 771 m CMIP3/AR4	These snow-day fraction estimates were produced by applying equations relating decadal average monthly temperature to snow-day fraction to downscaled decadal average monthly temperature. .
Climate	Historical Decadal Averages of Annual Total Precipitation 2 km CRU TS 3.0	This set of files includes downscaled historical estimates of decadal means of annual total precipitation (in milimeters) for each decade from 1910 - 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Historical decadal averages of Monthly Total Precipitation 2 km CRU TS 3.0	This set of files includes downscaled historical estimates of decadal means of monthly total precipitation (in milimeters) for each month of every decade from 1910-2006 at a 2x2 km spatial resolution.
Climate	Historical Decadal Averages of Seasonal Total Precipitation 2km CRUTS3.0 1910-2009	This set of files includes downscaled historical estimates of decadal means of seasonal total precipitation (in millimeters) for each season of every decade from 1910 - 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Historical Monthly Total Precipitation 2km CRUTS 3.1.01 1901-2009	This set of files includes downscaled historical estimates of monthly total precipitation (in milimeters) for each month of every year from January 1901 - December 2006 (CRU TS 3.0) or 2009 (CRU TS 3.1.01) at 2x2 kilometer spatial resolution.
Climate	Historical Monthly Total Precipitation 2km CRU TS 3.0 1901-2009	This set of files includes downscaled historical estimates of monthly total precipitation (in milimeters) for each month of every year from January 1901 - December 2006.
Climate	Historical Monthly Total Precipitation 771m CRU TS 3.0	This set of files includes downscaled historical estimates of monthly total precipitation (in milimeters) for each month of every year from January 1901-December 2006.
Ecosystem	Protected Areas Database	All protected areas for the U.S. defined using Gap Analysis Program criteria
Fire	Historical ALFRESCO Outputs (1901-2005)	1km resolution, annual outputs of historical (1901-2005) data. Variables include veg type, veg age, burned area, fire severity.
Fire	Projected (2006-2100) ALFRESCO outputs	1km resolution, annual outputs of projected data (3 RCPs, 2006-2100) variables include veg type, veg age, burned area, fire severity

Invasives	AKEPIC - Alaska Exotic Plants Information Clearinghouse	AKNHP maintains an updated georeferenced non-native plant data for the state. Roughly 100,000 collection points for 150 or so species, including all the potentially relevant species in the REA.
Socioeconomics	AK Dept of Environmental Conservation: Contaminated Sites with Mercury	ADEC Contaminated Sites Program (CSP) manages the cleanup of contaminated soil and groundwater in Alaska. This list contains mercury contaminated sites within the CSP Database. It includes Active sites as well as those with Cleanup Complete or Cleanup Complete - Institutional Controls status.
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Industries	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides data about the industries that employ the most local labor specific to an Alaska community.
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: 2010 Census	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides data about the 2010 Census Data demographic profile of Alaska communities
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Unemployment rate	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides data about the unemployment rate in Alaska communities.
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Tax	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides data about various forms of tax revenue for Alaskan communities.
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Worker characteristics	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides data about worker characteristics of a community. It includes a breakdown of the working population by age, sex, number employed, wage, and number of residents.
Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Population Estimates	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides descriptive data about the unemployment rate in Alaska communities

Socioeconomics	Department of Labor and Workforce Development, Research and Analysis: Alaska Local and Regional Information: Occupations	Department of Labor's Research and Analysis section created the Alaska Local and Regional Information (ALARI) database as a profile generator of different datasets. This particular dataset provides descriptive data about the unemployment rate in Alaska communities
Socioeconomics	Alaska Resource Data File, U.S. Geological Survey	description of mines, prospects, and mineral occurrences
Socioeconomics	Alaska Resource Data File, U.S. Geological Survey	descriptions of mines, prospects, and mineral occurrences
Socioeconomics	USGS: Alaska Infrastructure	historic trails in the state, including the Iditarod trails
Socioeconomics	American Community Census 2011: Net In-Migration	In depth profile of change in population net of estimated births and deaths as a percent of population
Socioeconomics	American Community Census 2011: Age and Sex	In depth profile of various age and sex variables for communities in the state. Variables include age reported by sex and child dependency ratios
Socioeconomics	American Community Census 2011: Education Profile	In depth profile of various economic variables for communities in the state. Variables include employment status, median earnings, employment breakdown, insurance and other benefits received, percent living below poverty line, and per capita income
Socioeconomics	American Community Census 2011: Economic Profile	In depth profile of various education variables for communities in the state. Variables include educational attainment by age and by sex
Socioeconomics	AK General Land Status	Land ownership and status records used to create this coverage are extracted from two major sources: Bureau of Land Management (BLM) and the State of Alaska Department of Natural Resources (ADNR). This coverage uses data extracted from BLM's records, stored in Alaska Land Information System (ALIS) on July 2, 2012; and ADNR's land records stored in the Land Administration System (LAS) on July 12, 2012.
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Infrastructure, Natural Gas Lines	locations of natural gas lines in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Infrastructure, Electric Transmission Lines	locations of transmission lines in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Solar	monthly breakdown of quantity of solar exposure areas in the state receive
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Hydroelectric, Existing	point locations of existing hydroelectric facilities

Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Energy Infrastructure	point locations of energy infrastructure. Variables include utility type, megawatts (MWh) of oil, gas, coal, hydro, wind, biodiesel, and geothermal.
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Geothermal, Hot Springs	point locations of hot springs in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Biomass, Fish Processors	point locations of known fish processing plants in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Biomass, Landfills	point locations of known landfills in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Biomass, Sawmills	point locations of known sawmills in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Hydroelectric, Potential	point locations of potential areas for hydroelectric facilities
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Geothermal, Thermal Areas	point locations of thermal areas in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Geothermal, Volcano	point locations of volcanoes in the state
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Energy Development Regions	regions in the state that have been classified as possible regions for future energy development
Socioeconomics	Alaska Energy Authority Renewable Energy Atlas of Alaska: Renewable Energy Fund Sites	site locations of renewable energy plants, variables include grant amount and project name
Socioeconomics	USGS: Alaska Infrastructure 1: 63,362	Statewide roads were selected from the USGS 1:2,000,000 Digital Line Graphs (DLGs) database with the following arc attributes for MIN: 5020 Primary 4028 Secondary (all weather, hard surface) 5031 Light Duty (all weather, improved) 5041 Unimproved (fair or dry weather) 5051 Proposed 5062 Ferry Auto
Socioeconomics	Area Cost Differential Studies, McDowell Group	table of numbers for the cost of living differentials of the communities in the YKL area; numbers computed relative to cost of living in Anchorage

Socioeconomics	AK Hair Mercury Biomonitoring Program	The Statewide Hair Mercury Biomonitoring Program was started to obtain information about exposures to mercury among women of childbearing age in Alaska. In high doses, mercury can have subtle harmful effects on the neurodevelopment of an unborn fetus. The Alaska Hair Mercury Biomonitoring Program focuses on all women of childbearing age, ages 15-45 years.
Socioeconomics	USGS: Environment Geochemistry of Mercury Mines in AK	The U.S. Geological Survey (USGS), in cooperation with the U.S. Bureau of Mines, U.S. Fish and Wildlife Service, and Calista Corporation (an Alaska native corporation), is investigating potential environmental contamination around naturally occurring, mercury-rich mineral deposits in Alaska.
Socioeconomics	USGS: Alaska Infrastructure 1: 63,361	This data depicts telephone line locations in Alaska as digitized primarily from 1:24,000, 1:63,360, and 1:250,000 USGS quadrangles.
Socioeconomics	USGS: Alaska Infrastructure 1: 63,360	This data depicts trail locations in Alaska as digitized primarily from 1:24,000, 1:63,360, and 1:250,000 USGS quadrangles.
Socioeconomics	FAA Alaska Airports and Runways 1995	This information was received from the FAA in February 1995. This information was processed in SAS to create points for the airports and lines for the runways.
Socioeconomics	TIGER/Line Shapefile, 2010, 2010 state, Alaska, 2010 Census Place State-based	TIGER/ Line Files are shapefiles and related database files (.dbf) that are an extract of selected geographic and cartographic information from the U.S. Census Bureau's MAF/ TIGER database. This data provides geospatial locations of boroughs in Alaska
Socioeconomics	TIGER/Line Shapefile, 2010, 2010 state, Alaska, 2010 Census Place State-based	TIGER/ Line Files are shapefiles and related database files (.dbf) that are an extract of selected geographic and cartographic information from the U.S. Census Bureau's MAF/ TIGER database. This data provides geospatial locations of places in Alaska.
Soils	Historical (1850-2005) Permafrost variables (AR5, 5 top models, 5 model avg)	Permafrost variables: max active layer thickness, warming effect of snow against frost, snow depth, annual ground surface temp, ground temp at bottom of active layer, thermal offset between surface and bottom of active layer
Soils	Projected permafrost variables (2006-2100) AR5, 5 top models, 5 model average	Permafrost variables: max active layer thickness, warming effect of snow against frost, snow depth, annual ground surface temp, ground temp at bottom of active layer, thermal offset between surface and bottom of active layer
Subsistence	AK Dept of Fish and Game: Hunting Maps and Area Information	reported by game management unit (GMU) and species, annual harvest levels

Subsistence	AK Dept of Fish and Game: Commercial Fishing	reported by management areas and limited amount of species, annual harvest levels
Subsistence	AK Dept of Fish and Game: Sport Fishing,	reported by place name, this database includes the fish count data search and sport fishing survey
Subsistence	AK Dept of Fish and Game: Community Subsistence Information System, CSIS	The CSIS is the repository of Alaska community harvest information gathered by the Alaska Department of Fish and Game, Division of Subsistence.
Terrestrial	Important birds areas for the state of Alaska	Alaska's IBAs are part of a growing global network of designated IBAs, spanning 156 countries around the world and 26 countries in the Western Hemisphere alone. Because every IBA across the planet has been designated and ranked against the same criteria, we often refer to IBAs as a Global Currency for Conservation. Globally, thousands of IBAs and millions of acres of avian habitat have received recognition and better protection as a result of the IBA program. So far Audubon has identified and designated 145 IBAs in Alaska, the majority of which are ranked as globally significant.
Terrestrial	Kuskokwim River Peregrine Falcon Survey 2008	Breeding pair survey of Peregrine Falcon along the Kuskokwim River between Aniak and McGrath from July 9-14th, 2008
Terrestrial	Kuskokwim River Peregrine Falcon Survey 2011	Breeding pair survey of Peregrine Falcon along the Kuskokwim River between McGrath and Aniak from July 11-14th, 2011.
Terrestrial	Western Arctic caribou herd seasonal ranges and fire perimeters	Burn perimeters within caribou seasonal rangees and acreage within Kobuk-Seward Peninsula RMP planning area.
Terrestrial	Location data for Galena Mountain caribou	Excel spreadsheet with the data on herd size, distribution, seasonal ranges, and movement patterns of radio collared caribou in the Galena Mountain Caribou Herd (GMH) from 1992-2011.
Terrestrial	Gap analysis final distribution model for the Olive-sided Flycatcher.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the Peregrine Falcon.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the Trumpeter Swan	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the American beaver.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.

Terrestrial	Gap analysis final distribution model for Caribou.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the dusky shrew.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for moose.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for muskox.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the nearctic brown lemming.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the northern red-backed vole.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Gap analysis final distribution model for the gray wolf.	Gap distribution models represent the areas where species are predicted to occur based on habitat associations. Models have a 60 meter resolution and are delimited by Gap species ranges.
Terrestrial	Element Occurrence (EO) data for fine filter terrestrial vertebrate CEs	NatureServe, in collaboration with its member Natural Heritage Programs and Conservation Data Centres, maintains a database of rare and imperiled species and plant communities across the United States and Canada. The Element Occurrence (EO) records that form the core of the NatureServe database include information on the location, status, characteristics, numbers, condition, and distribution of elements of biological diversity using established Natural Heritage Methodology developed by NatureServe and The Nature Conservancy (TNC). An Element Occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present. An EO should have practical conservation value for the Element as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location.

Terrestrial	Element Occurrence (EO) data for rare terrestrial vertebrate taxa in Alaska	NatureServe, in collaboration with its member Natural Heritage Programs and Conservation Data Centres, maintains a database of rare and imperiled species and plant communities across the United States and Canada. The Element Occurrence (EO) records that form the core of the NatureServe database include information on the location, status, characteristics, numbers, condition, and distribution of elements of biological diversity using established Natural Heritage Methodology developed by NatureServe and The Nature Conservancy (TNC). An Element Occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present. An EO should have practical conservation value for the Element as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location.
Terrestrial	Seward Peninsula muskox population survey	PDY report summarizing the 2012 Seward Peninsula muskox survey effort.
Terrestrial	Central Kuskokwim River Peregrine Falcon Survey	Peregrine Falcon nesting surveys from 2000 to 2004 along the Kuskokwim River between McGrath and Aniak.
Terrestrial	Ray Mountains caribou: distribution, movements, and seasonal use areas from 1994-1997	Preliminary findings of habitat use patterns for the Ray Mountain caribou herd using three years of radiotelemetry observations. This dataset is a pdf report with several maps displaying seasonal caribou locations.
Terrestrial	Western arctic caribou seasonal range	Seasonal useage polygons and telemetry data for the Western Arctic Caribou Herd (WACH), including winter, migration, calving, summer, and peripheral ranges.
Terrestrial	Alaska Natural Heritage Program vertebrate polygon range maps	This dataset contains individual bird and mammal species range polygon shapefiles, compiled by the Alaska Natural Heritage Program. Whenever possible, shapefiles indicate seasonal occurrence (e.g. breeding, wintering, spring/fall migration).
Terrestrial	Alaska Gap analysis terrestrial vertebrate occurrence database	This dataset contains point occurrence records for individual bird and mammal species aquired from numerous data sources for the Alaska Gap Analysis Project.
Terrestrial	Seasonal range polygons of all caribou herds in Alaska	This dataset provides a statewide perspective on location of recognized caribou herds in Alaska based on an inclusive composite of telemetry data, survey observations, and local knowledge. The data set describes the extent of seasonal and total range for 33 caribou herds in Alaska.
Terrestrial	Western Arctic caribou herd migration routes	Western Arctic caribou fall migration routes collected by ADF&G from satellite collares from 1987-2004.

Terrestrial	Western Arctic caribou herd calving grounds	Western Arctic caribou herd calving ground (June 4-20) created from kernel analysis of satellite collar locations from August 1988 through August 2007. Data from the Alaska Department of Fish and Game.
Terrestrial	Western Arctic caribou herd spring migration routes	Western Arctic caribou herd spring (April 1 to June 3) migration routes from data collected from Aug 1998 to Aug 2007.
Terrestrial	Western Arctic caribou herd winter range	Western Arctic caribou winter (Nov 1- March 31) range from data collected from Aug 1998- Aug 2007.
Terrestrial	Winter kernel range of the Western Arctic caribou Herd	Winter of 2010 to 2011 and 2011 to 2012 kernel range polygons for the Western Arctic Caribou Herd.
Terrestrial	Vegetation Map and Classification - Northern, Western, and Interior Alaska	Mosaic of 18 regional maps developed over the past 1 to 14 years and one map developed 27 years ago. All original cover classes converted to a uniform schema.
Terrestrial	Alaska Fire History	Fire history for the state categorized in decadal increments for the past 70 years.
Terrestrial	Alaska State Bedrock Geology Map	State-wide map of bedrock geology.
Terrestrial	Alaska State Surficial Geology Map	State-wide map of surficial geology.
Terrestrial	National Land Cover Database - Alaska	The National Land Cover Database (NLCD) 2006 is a Landsat-derived, 30 meter spatial resolution digital land cover map that describes the land cover for the 50 U.S. states and Puerto Rico using twenty consistent land cover classes.
Terrestrial	Forest Insect and Disease Conditions in Alaska	This data represents areas of forest damage due to insect infestation, fire, flood, landslides, and windthrow. The information was collected, cooperatively by aerial surveys by both the USFS, Forest Health Protection (FHP) and ADNDR, Div. of Forestry. Surveys are conducted primarily in July and August so that pest "signatures" may be identified during the optimal period for symptom development of ocular estimation. The aerial survey is coordinated such that the maximum extent of recent bark beetle damage (fading trees) and insect defoliation (discoloration, foliage loss) patterns may be determined. Surveys are flown in Southeast Alaska, Southcentral Alaska and Interior Alaska. The data represents a 10 year cumulative effect for 1989-2010.
Terrestrial	National Wetlands Inventory (NWI)	This data set represents the extent, approximate location and type of wetlands and deepwater habitats in the Alaska, United States. These data delineate the areal extent of wetlands and surface waters as defined by Cowardin et al. (1979).
Terrestrial	Geology Map of the lower Yukon River	Geologic map of the lower Yukon River region, AK.

Terrestrial	LANDFIRE Reference Vegetation Data	Georeferenced & labelled samples of vegetation gathered by Landfire to use as training data for their mapping & modeling efforts. Each sample is labeled with an ecological system. Includes species composition & cover, structural variables, some disturbance information, and calculated fuels data. Environmental data (elev, aspect, slope, soils, etc) are not included.
Terrestrial	Geologic Map for the Yukon-Koyukuk Basin, AK	Digital data for the reconnaissance geologic map for the Yukon-Koyukuk basin, Alaska
Terrestrial	Biotics Database - Vascular Plants	AKNHP maintains georeferenced G3-G1 vascular plant collection locations for AK. Habitat descriptions are included in some cases. ArcMap shape file is in the process of being updated with new collection records from UAM - projected time for completion in 31 May 2011. Currently, file is not separated by individual species.

Appendix 3: Arctic Social Indicators

1. Health and Population / Demography Domain:

Health:

- *Infant mortality (best option if one needs to use only one indicator)*
- Child mortality
- Access to health care
- Suicide rate
- Self-assessed health
- Obesity rate
- Smoking rate

Population/Demography:

Primary Indicators:

- Total population
- Number of birth
- Number of death
- *Net migration (best option if one needs to use only one indicator)*

Secondary Indicators:

- Birth rates
- Mortality rates
- Infant or child mortality rates
- Population growth or decline rates and projections
- Age/sex/ethnicity composition of the population including age and sex ratios

2. Material Well-being Domain:

- *Per capita household income (constant \$) (best option if one needs to use only one indicator)*
- Net migration
- Subsistence harvest
- A composite index that takes into account above three sectors

3. Education Domain:

- Proportion of students pursuing post-secondary education
- *Ratio of students successfully completing post-secondary education (best option if one needs to use only one indicator)*
- Proportion of graduates who are still in their own community (or have returned to it) 10 years later

4. Cultural Well-being Domain:

- Cultural autonomy (e.g. do laws and policies recognize institutions that exist to advocate for cultural autonomy or national minority populations?)
- Language retention (e.g. what percentage of a population speaks its ancestral language?) (2nd best option if one needs to use only one indicator)
- Belonging (e.g. what percentage of people are engaged in recreational or subsistence activities?)

- *A composite index that takes into account above three sectors (best option if one needs to use only one indicator)*

5. Closeness to Nature Domain:

- *Harvest of country foods (best option if one needs to use only one indicator)*
- *Consumption of country foods (best option if one needs to use only one indicator)*
- Number of people or households engaged in the traditional economy

6. Fate Control Domain

- Percentage of indigenous members in governing bodies (municipal, community, regional) relative to the percentage of the indigenous people in the total population
- *Percentage of surface lands legally controlled by the inhabitants through public governments, Native corporations, and communes (best option if one needs to use only one indicator)*
- Percentage of public expenses within the region (regional government, municipal taxes, community sales taxes) raised locally
- Percentage of individuals who speak a mother tongue (whether Native or not) in relation to the percentage of individuals reporting corresponding ethnicity

Appendix 4: Anthropogenic Management Questions

For ease of analysis 29 original anthropogenic MQs are broadly classified into five groups – socio-economic (5); subsistence (3); sport, and commercial hunting and fishing (4); land use (16); and Traditional Ecological Knowledge (TEK) (1).

Socio-economic:

- **MQ 33- What are current socio-economic conditions in YKL communities?**
- **MQ 34- What are the projected socio-economic conditions in the future?**
 - MQ 35- How could community economic profiles vary with respect to development scenarios (including mines) in the near future (including access to subsistence, energy sources, and other resources)?
 - MQ 36- What are the potential impacts of renewable energy projects on local economies the region?
 - MQ 37- How might change in transportation corridors impact communities?

Subsistence

- **MQ 38- Where are current subsistence harvest areas?**
- **MQ 39- What do ADFG harvest data and TEK/LTK show about how harvest amounts, types of fish/animals/plants, harvest seasons changed in the recent past (including beavers)?**
- **MQ 40- How could larger community populations affect subsistence resources?**

Sport, and commercial hunting and fishing

- **Sport fishing and hunting areas and levels:**
 - MQ 41- What are general (sport) harvest levels of salmon, moose, caribou in the recent past?
 - MQ 42- Where are current sport hunt areas?
- **MQ 43- What have been the commercial harvest levels of salmon over the past 10 years?**
- **MQ 44- Where are current commercial fish harvest areas?**

Land Use

- **MQ 45- What is the current human footprint in the region?**
 - MQ 46- Where are communities?
 - MQ 47- Where are current timber harvests?
 - MQ 48- Where are current and recent mine sites?
 - MQ 49- Where is the current transportation and communication infrastructure?
 - MQ 50- Where are alternative and renewable energy sites?
 - MQ 51- What is current land status in the region?
 - MQ 52- Where are unsettled land claims?
 - MQ 53- Where is recreation activity highest?
- **What is the future human footprint in the region?**
 - MQ 54- Where are areas of highest mineral potential?
 - MQ 55- Where will mines be located? Can we estimate the total footprint (including tailings and associated infrastructure)?
 - MQ 56- Where are areas of potential for wind, hydro, biomass energy (and where do they overlap with communities)?
 - MQ 57- Where is planned transportation/communication infrastructure to be located?
 - MQ 58- Where are planned sites for alternative/renewable energy?

- *MQ 59- How might recreational use in the region change over time?*
- *MQ 60- Are there areas in the REA that are impacted by mercury contamination?*

TEK

- *MQ 61- What TEK is available for the region? TEK to include but not limited to ADFG case studies, and ethnographies. This project will collect and catalog TEK by community, and CA and CE where relevant.*