B. Change Agents

Subsections:

1. Climate
2. Fire
3. Soil Thermal Dynamics (Permafrost)
4. Invasive Species
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1. Climate Change

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Summary

Section B-1. *Climate Change* provides the detailed descriptions, methods, datasets, results, and limitations for the assessments of changes in climate, including cliomes and relationships to vegetation.

1.1. Introduction

This portion of the Technical Supplement addresses climate as a change agent on the YKL landscape, and is primarily concerned with assessing how climate may change over time. Climate variables assessed in this section include temperature, precipitation, snow day fraction, day of freeze, and day of thaw. Other climate-linked variables, including climate clusters (“cliomes”), fire, and permafrost are each addressed in separate sections. Given that human effects on climate are global rather than proximal, for the purposes of this project, climate is considered a non-anthropogenic CA.

This section describes landscape-level model outputs, including the data sources, methods, and analysis. It also touches briefly on feedbacks between climate and other CAs (fire, cliomes, and permafrost); additional information on these feedbacks can be found in the applicable sections. It also provides an overview of potential impacts to conservation elements. Further information on these interactions can be found in sections devoted to CEs (Sections D-1 to D-4).

The Role of Climate Change

The climate of far northern ecosystems is changing rapidly, resulting in thawing permafrost, altered hydrology, and shifting biological processes, and warming is predicted to continue to be more extreme at high latitudes than almost anywhere else on the planet. Predicting the magnitude and effects of these changes is crucial to planning and adapting (Hinzman et al. 2005). Not only are arctic and sub-arctic systems vulnerable to climate shifts, but they are also central to feedbacks important to global systems (Chapin et al. 2005).

Climate change will likely drive multiple types of change in the YKL area. Climate variables can directly impact coarse-filter and fine-filter CEs, but are also part of feedback loops with other CAs, such as fire and invasive species. Understanding the relationship between climate change and these elements is a complex problem, but ultimately a crucial one for decision-making by policymakers and land managers.

Computer models that simulate relationships between climate, vegetation, and fire are important tools for understanding and projecting how the future may appear (Rupp et al. 2007, Kittel et al. 2000). Here we employ simulation models to assess climate change in the context of historical, current, near-term (2025), and long-term (2060). Climate data were primarily derived from datasets created and managed by the Scenarios Network for Alaska and Arctic Planning (SNAP), with subsets of the available data selected based on the needs of the project.

Historical Climate

This region has an interior climate, with cold winters and relatively warm summers, although climate patterns vary across the YKL area based on latitude, elevation, and proximity to the coastline, as can be seen in Figure B-1. With mean annual temperatures close to 0°C (32°F), permafrost is discontinuous.

Historical weather station data for the broad region surrounding the REA study area show a broad range of mean maximum/minimum annual temperatures and precipitation, and shown in Table B-1 (WRCC 2011). These data reflect the longest available recorded climate histories for the region, although the reporting period varies greatly from station to station. For example, Big Delta has operated a weather station since 1937, but the Emmonak station did not start recording until 1981.

Table B-1. Historical climate station data for sites in and around the REA area. Data from WRCC 2011.

Climate station	Mean annual temperature (°C)		Total annual precipitation (mm)	
	min	max	min	max
Ambler	-11.1	-0.1	586	3404
Bethel	-5.3	2.6	440	1400
Bettles	-10.5	2.6	359	2116
Big Delta	-6.9	2.7	289	1113
Caswell	-7.6	6.5	602	3066
Emmonak	-5.9	2.2	471	1666
Teller	-8.1	-0.9	247	1173
Wales	-9.1	-3.0	292	968

Mean monthly temperature values, using a baseline from 1971-2000, are shown in Figure B-1. Note that winter temperatures are more variable between communities than spring, summer, or fall temperatures.

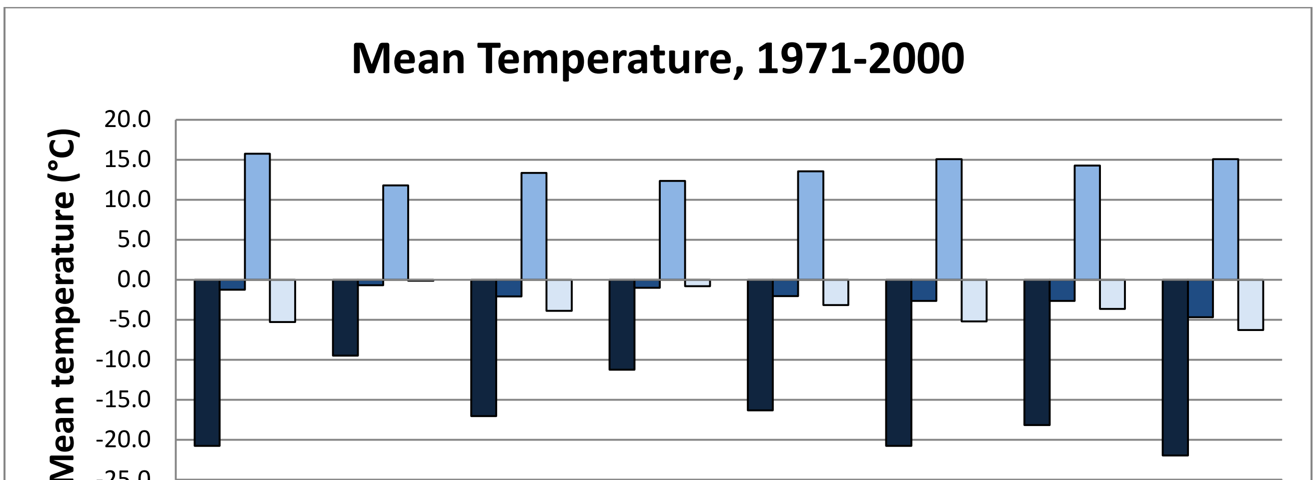
Similar data are shown for monthly precipitation in Figure B-2. Precipitation varies by more than 100% across the region, with an average of only about 112 mm of precipitation annually in the Tanana River watershed and about 243 mm annually in the Kvichak-Port Heiden watershed.

1.2. Methods

Given the relatively short time frame available for each REA, these projects must largely rely on preexisting data. Thus, in selecting climate models and data, we looked at available datasets for Alaska. While several global climate models offer data for the area, it is extremely coarse in resolution, and not validated specifically for Alaska. The finest-scale and most reliable climate models and data were found via The Scenarios Network for Alaska and Arctic Planning (SNAP), at the International Arctic Research Center at the University of Alaska Fairbanks.

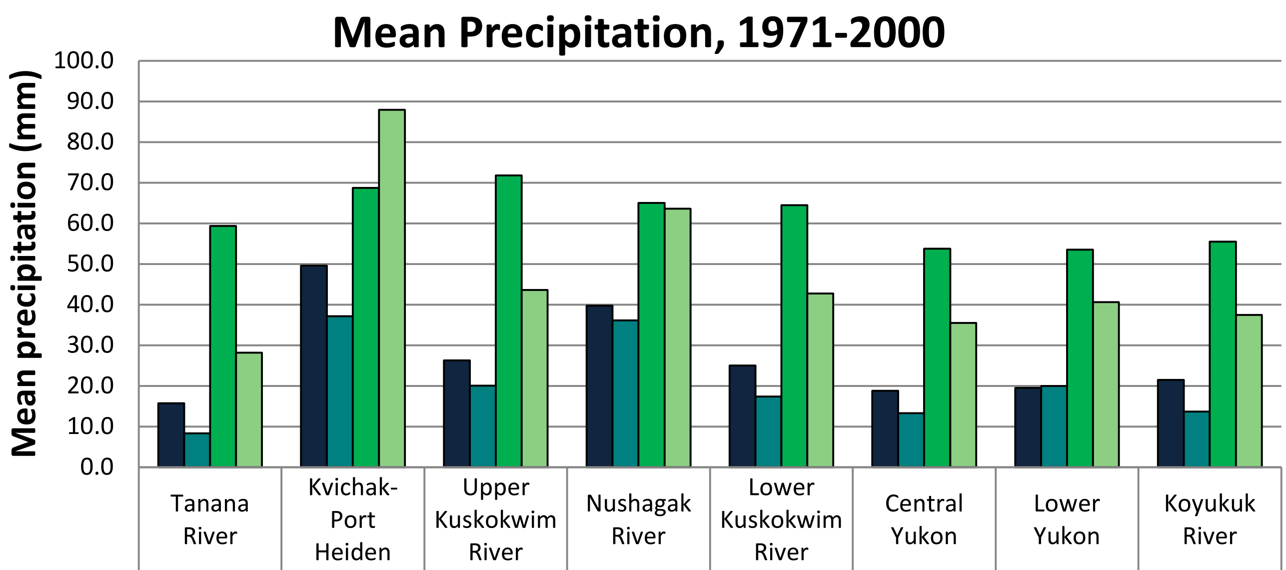
SNAP Climate Data

SNAP projections focus on the five available Global Circulation Models (GCMs) that perform best in the far north. 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 five assessment reports from the IPCC (in 1990, 1995, 2001, 2007, and 2014). 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).



	Tanana River	Kvichak-Port Heiden	Upper Kuskokwim River	Nushagak River	Lower Kuskokwim River	Central Yukon	Lower Yukon	Koyukuk River
Jaunary	-20.8	-9.5	-17.0	-11.2	-16.3	-20.8	-18.1	-22.0
April	-1.2	-0.7	-2.1	-1.0	-2.1	-2.6	-2.6	-4.7
July	15.8	11.8	13.3	12.3	13.6	15.1	14.3	15.1
October	-5.3	-0.1	-3.9	-0.8	-3.2	-5.2	-3.6	-6.3

Figure B-1. Recent historical mean temperatures by major watersheds (3rd-level HUC).



	Tanana River	Kvichak-Port Heiden	Upper Kuskokwim River	Nushagak River	Lower Kuskokwim River	Central Yukon	Lower Yukon	Koyukuk River
January	15.7	49.6	26.3	39.8	25.1	18.8	19.5	21.5
April	8.3	37.1	20.1	36.1	17.4	13.3	20.0	13.7
July	59.3	68.7	71.8	65.0	64.5	53.8	53.5	55.5
October	28.2	88.0	43.7	63.6	42.8	35.5	40.6	37.5

Figure B-2. Recent historical total monthly precipitation by major watersheds (3rd-level HUC).

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, representing optimistic, mid-range, and slightly more pessimistic (but not extreme) emissions scenarios (IPCC SRES 2000).

SNAP climate datasets have been downscaled to 771 meter resolution using PRISM (Parameter-elevation Regressions on Independent Slopes Model) methodology (Daley et al. 2008), which takes into account slope, elevation, aspect, and distance to coastlines. This downscaling uses a historical baseline period of 1971-2000. This baseline was carried over for use in the YKL REA project. SNAP's downscaling is performed using the Delta method (Fowler et al. 2007, Prudhomme at al. 2002).

Climate outputs derived from these climate datasets include temperature and precipitation data at monthly resolution. These data have also been analyzed to create derived climate datasets. Based on interpolation of running means, we created 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 is not expected). In addition, we used temperature data to create spatial estimates of monthly estimated snow fraction.

For this project, a composite (average) of the five downscaled GCMs was used in order to minimize uncertainty due to model bias. This project focused on the A2 emissions scenario, although the A1B scenario was used for comparison in some analyses.

The A2 emissions scenario describes a heterogeneous world with high population growth, slow economic development, and slow technological change. As such, it ultimately predicts high carbon emissions, as less developed nations are driven to higher burning rates of dirty fuels, with few population checks or cleaner technologies to check these emissions. However, the most rapid change does not occur until later in this century, with considerable lag time, since slow economic development suggests few immediate increases in worldwide fuel use.

In contrast, the A1B scenario assumes a world of rapid economic growth, a global population that peaks mid-century, rapid introduction of new and more efficient technologies, and a balance between fossil fuels and other energy sources. Although A1B is more optimistic than A2 in the long-term, it predicts marginally higher emissions rates in the very near-term (as represented by the next decade, in this assessment), due to the assumption of more rapid economic growth. At around 2060, the “long-term” outlook examined in this study, the two scenarios are quite similar in terms of emissions. By the end of this century the A2 is markedly more extreme than A1B.

Based on economic and social variables, the A2 emissions scenario seems more probable than the A1B. Meta-analysis of several studies shows that many risks now appear greater than they were generally calculated to be at the time the above-mentioned scenarios were crafted, including biological and geological carbon-cycle feedbacks and actual measurable increases in greenhouse gas emissions, which have accelerated recently. (Fussel 2009).

We used decadal averages, 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 used climate data for the 2020s rather than just 2025, and the 2050s and the 2060s rather than the single year 2060.

Source Datasets

For the purposes of addressing both the MQs and the core analysis (i.e., examining the relationship between climate and selected CEs), we provided both primary and derived climate data as described above and as listed below in Table B-2. These datasets were used in general discussion and analysis of climate change. A subset of these data were also selected to analyze the potential impacts of climate change on CEs, based on attributes and indicators determined from the literature, as described in this document. These datasets were used in conjunction with maps of CE distribution as a basis for spatial analysis and for qualitative discussion.

Table B-2. Climate source data used in the REA analysis.

Dataset Name	Data source
SNAP (PRISM) baseline temperature data, 1971-2000, 771m resolution.	SNAP/PRISM
SNAP (PRISM) baseline precipitation data, 1971-2000, 771m resolution.	SNAP/PRISM
SNAP monthly precipitation projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP
SNAP monthly temperature projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP
SNAP date of thaw (DOT) projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP
SNAP date of freeze (DOF) projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP
SNAP length of growing season (LOGS) projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP
SNAP monthly snow day fraction projections, CMIP3/AR4, A2 emissions scenario, single-model outputs for five models, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP

Interpretation and Analysis

The process model of downscaled climate products (Figure B-3) demonstrates the linkages between source data, intermediate results, and final products or outputs. Fire, permafrost, and climate-biome models will be discussed separately. Outputs included under “Climate Model” are described below.

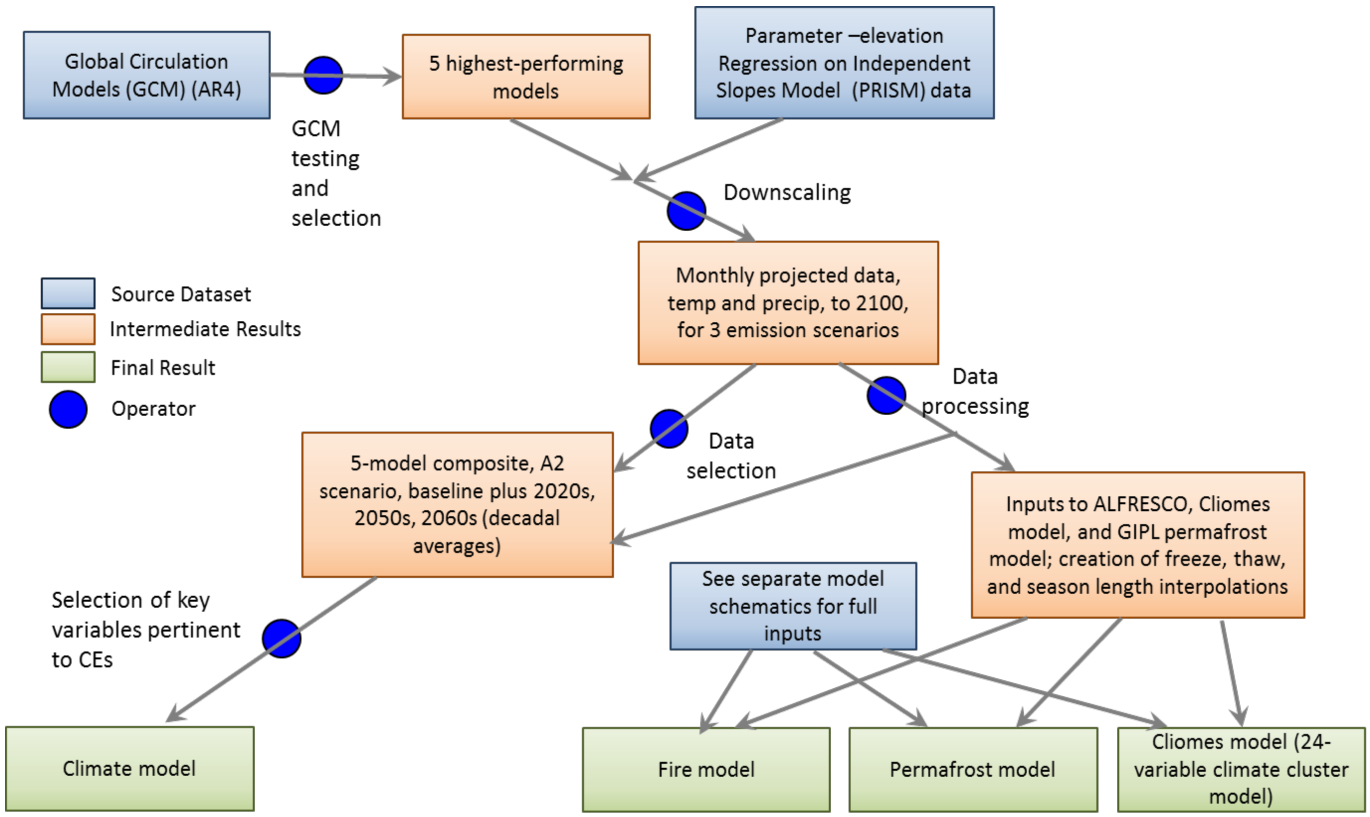


Figure B-3. Process Model of Downscaled Climate Products.

Temperature

All twelve months of temperature data have been provided as part of this project. However, given that it would be impractical to include all these datasets as map outputs in this document, we focused our analysis on outputs for the hottest month (July) and coldest month (December). Note that other months (or averages across months) were used as appropriate based on attributes and indicators when analyzing temperature in relation to specific CEs.

Precipitation and Snow-Day Fraction

We similarly focused our analysis of precipitation and snow-day fraction on a subset of the data. In this case, we present map outputs for three-month averages for summer (June, July, August) and winter (December, January, February) precipitation, as well as mean annual precipitation.

Precipitation data do not distinguish between rainfall and snowfall. However, assessing many crucial ecosystem effects and impacts to CEs requires clearer knowledge of snow patterns, particularly with regard to the total length of the snow season, the likelihood of rain-on-snow events, and potential changes in snow cover, snow pack, and timing and season of snowmelt and runoff. While some of these issues remain as data gaps, estimates of snow-day fraction (the percentage of days in which any precipitation that falls is likely to be snow, as opposed to rain, for a given month) helped inform the core analysis and address management questions for this assessment. These estimates were produced by applying equations relating snow-day fraction to downscaled decadal average monthly temperature. In order to provide the greatest accuracy, separate equations were used to model the relationship between decadal monthly average temperature and the fraction of wet days with snow for seven geographic regions in the state: Interior, West, and SW Interior (included in this REA area) and SW Islands, Arctic, Cook Inlet, and S/SE Coast (not included in this REA area) (McAfee et al. 2013).

Day of Freeze, Day of Thaw, and Growing Season

Estimated ordinal days of freeze and thaw 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. When consecutive monthly midpoints have opposite sign temperatures, the day of transition (freeze or thaw) is the day between them on which temperature crosses 0°C. The length of growing season refers to the number of days between the days of thaw and freeze. These calculations are only an estimate of the true occurrence of freeze and thaw. True transitions across the freezing point may occur several times in a year, or not at all. Moreover, it should be kept in mind that these metrics are not equivalent to notions of freeze and thaw (or “freezeup” and “breakup”) in common parlance, since these generally refer to the behavior of river ice, sea ice, or frozen soils. Lag times can be expected before these occurrences take place, and these lag times will vary based on characteristics of the water body in question.

1.3. Results

Here we examine the relationship between current, near-term, and long-term climate variables. We also addresses climate-specific MQs. Due to the formatting of climate data as decadal means, “current” data will be considered to be the decade 2010-2019, while the year 2025 will be represented by data from 2020-2029, and 2060 will be represented by data from 2060-2069. Because the year 2060 is at the beginning rather than the end of a decade, and because the A2 emissions scenario offers model outputs that tend to accelerate in magnitude toward the end of this century data from the 2050s is also included. This helps demonstrate to what degree the expected long-term change is likely to take place later rather than earlier in the time period.

Due to the resolution of the climate data and the most appropriate and manageable level to discuss and analyze it, given inherent uncertainties, some outputs are given at the resolution of major watersheds (3^{rd}-level Hydrologic Unit Code [HUC]). There are eight such watersheds in the REA region, as shown in Figure B-4.

Throughout our climate analysis, we attempt to demonstrate two different types of uncertainty. First, we show uncertainty in terms of our inability to precisely predict future anthropogenic releases of greenhouse gases by presenting the A1B emissions scenario in comparison to the A2 scenario. The latter is referenced in the majority of this analysis and more closely reflects current estimates of projected greenhouse gas emissions (Fussel 2009). Note, however, that differences between outputs for the A2 and A1B scenarios are slight for the given future decades.

The reader must also keep in mind the uncertainty and stochasticity inherent to the predictive models used to create climate projections. Not only is prediction imperfect, but these models intentionally incorporate variability similar to the natural month-to-month, year-to-year and even decade-to-decade variability seen in real climate data. Model sensitivity will be discussed further below, in the separate Temperature and Precipitation sections.

As previously noted, all data shown in the maps below has been served in raw form at 771 m resolution. It was determined that producing tabular output for all 5^{th}-level HUCs would be cumbersome and of little use to managers. However, given the particular interest in changing climate in communities and immediately surrounding areas, we extracted data for all 5^{th}-level HUCs that contain communities. Many of these outputs are presented in tabular form in the results below.

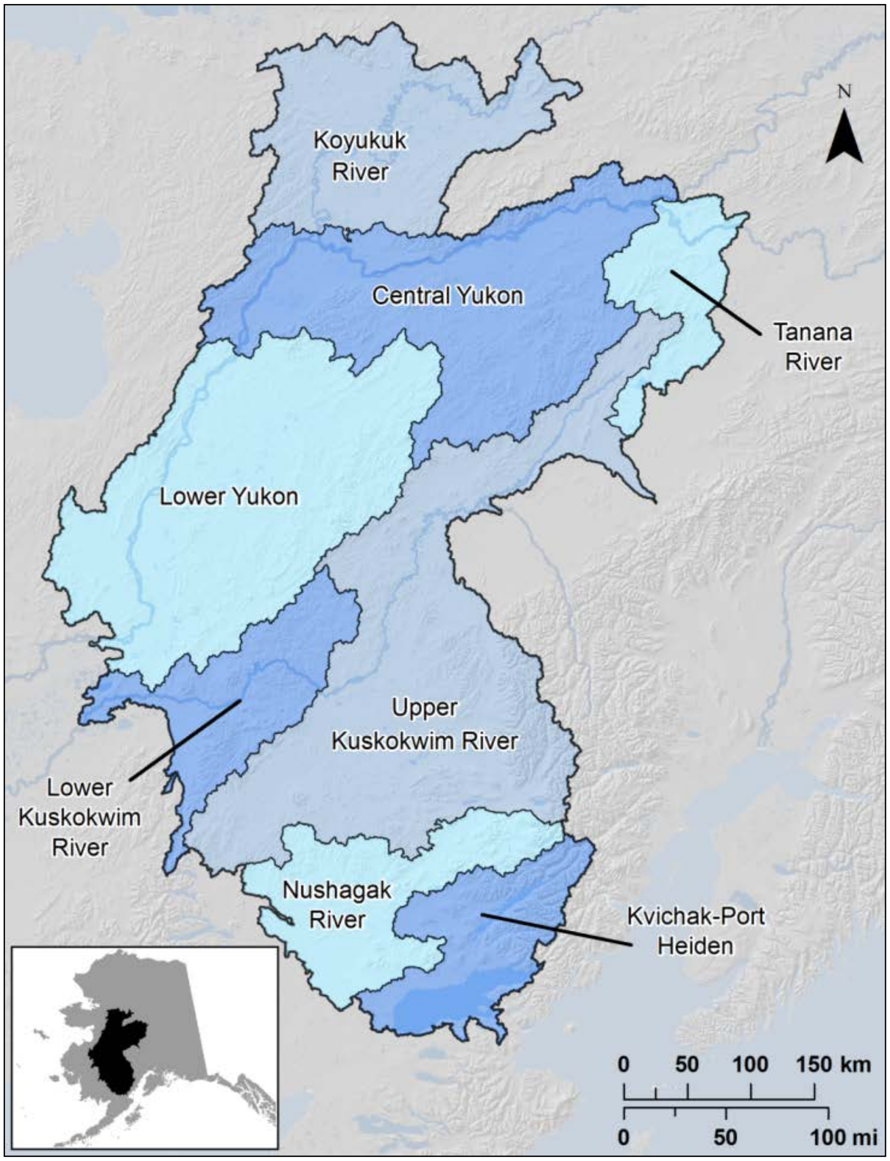


Figure B-4. Major watersheds (3^{rd}-level HUCs) for REA region.

Projected Change in Climate

MQ 20	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?

Monthly, seasonal, and annual temperatures and precipitation are all expected to increase in the REA, with higher uncertainty associated with precipitation than with temperature. Temperature increase is expected to be negligible in the near future, particularly under the A2 emissions scenario, which shows non-significant cooling for some warm-season-months in some regions. In the long-term, however, climate warming trends are clear and significant. Slightly greater changes are projected under the A2 scenario than under the A1B scenario.

Precipitation increases are more pronounced in the near-term, with the rate of change appearing to decelerate in the long-term.

Temperature Sensitivity Analysis

In order to provide a sensitivity analysis for the GCM model outputs used as the core of SNAP climate analyses, we analyzed the variability of model outputs across the five GCMs used to create the composite outputs used in this report. The standard deviation among these models can serve as a measure of uncertainty, encompassing both the uncertainty associated with model calibration and accuracy, and the uncertainty associated with the natural stochasticity built into all GCMs. GCMs are designed and intended to replicate not only accurate mean values for climate variables, but also normal variability in weather patterns across short and long time periods (attributable to such factors as daily and monthly weather variations and longer-term fluctuations such as the Pacific Decadal Oscillation). Thus, assessments based on mean GCM values can be considered to be more robust if trends in those mean values fall outside two standard deviations of the means of multiple models.

Cross-model standard deviations for temperature are shown in Table B-3. These values are averaged across decades and across all pixels in the YKL spatial area. Thus, the true mean has an approximately 95% probability of occurring within two standard deviations, or 2.4°C. Projected shifts of greater magnitude of 2.4°C from baseline temperatures can be considered statistically significant. Projected shifts of 1.2-2.4°C can be considered marginally significant.

Table B-3. Inter-model standard deviations in projected monthly temperature, A2 emission scenario (°C).

Time Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2010s	2.1	1.4	3.0	1.8	0.8	1.0	0.4	0.5	0.4	0.7	1.9	1.2	1.3
2020s	1.5	3.7	2.1	1.4	0.8	0.9	0.2	0.2	0.2	0.4	1.3	2.4	1.3
2060s	2.7	1.4	1.9	0.6	0.9	1.3	0.7	0.8	0.5	0.7	1.6	1.5	1.2
Mean	2.1	2.2	2.3	1.3	0.8	1.1	0.4	0.5	0.4	0.6	1.6	1.7	1.2

Winter Temperature

Model outputs for January temperature (Figure B-5) show that warming is predicted throughout the YKL area in the coldest month of the year. As can be seen in Table B-4, January temperatures are expected to warm the most in the more northern parts of the YKL area, with increases of more than 3°C (5°F) by the 2060. In the more southern areas, increases of about 2.5°C (4°F) are expected. Based on the above sensitivity analysis, this can be considered a significant trend over the long-term and a possibly significant trend in the near-term. Inclusion of minimum and maximum values for each decade shows that significant variability exists within each dataset, but that the trend for mean values is also the trend for maximum and minimum values.

Table B-4. January temperature projections, A2 and A1B emissions scenarios, by 3rd level HUC (°C).

Watershed (3rd Level HUCs)	emission scenario	2010s			2020s			2050s			2060s			change from 2010s		
		MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	2020s	2050s	2060s
Tanana River	A2	-23	-14	-20	-22	-13	-19	-21	-12	-17	-19	-11	-16	0.8	2.1	3.3
Kvichak-Port Heiden	A2	-13	-4	-8	-12	-4	-8	-11	-3	-7	-10	-2	-6	0.5	1.5	2.4
Upper Kuskokwim River	A2	-22	-8	-15	-21	-7	-15	-20	-6	-14	-19	-5	-13	0.6	1.7	2.7
Nushagak River	A2	-14	-6	-10	-13	-6	-9	-12	-5	-8	-11	-4	-7	0.6	1.5	2.5
Lower Kuskokwim River	A2	-19	-9	-15	-18	-9	-14	-17	-8	-13	-16	-7	-12	0.7	1.8	2.9
Central Yukon	A2	-23	-13	-19	-22	-12	-19	-21	-11	-17	-20	-10	-16	0.7	2.1	3.2
Lower Yukon	A2	-22	-12	-17	-21	-11	-16	-20	-10	-15	-19	-8	-13	0.7	1.8	3.2
Koyukuk River	A2	-23	-15	-21	-22	-14	-20	-20	-13	-18	-19	-11	-17	0.8	2.1	3.5
Tanana River	A1B	-23	-15	-20	-22	-14	-19	-19	-11	-16	-19	-10	-15	1.3	4.3	4.9
Kvichak-Port Heiden	A1B	-14	-6	-9	-13	-5	-8	-10	-2	-5	-9	-1	-4	1.1	3.9	4.9
Upper Kuskokwim River	A1B	-23	-9	-17	-21	-8	-15	-18	-5	-12	-17	-4	-11	1.5	4.6	5.5
Nushagak River	A1B	-15	-8	-11	-14	-7	-10	-11	-4	-7	-10	-2	-6	1.3	4.4	5.4
Lower Kuskokwim River	A1B	-20	-11	-16	-19	-9	-14	-15	-6	-11	-14	-5	-10	1.7	5.0	6.0
Central Yukon	A1B	-24	-14	-20	-22	-13	-19	-19	-9	-16	-19	-9	-15	1.6	4.7	5.5
Lower Yukon	A1B	-23	-13	-18	-21	-11	-16	-18	-8	-13	-17	-7	-12	1.8	5.1	6.0
Koyukuk River	A1B	-23	-16	-22	-22	-14	-20	-19	-11	-17	-18	-10	-16	1.7	4.8	5.6

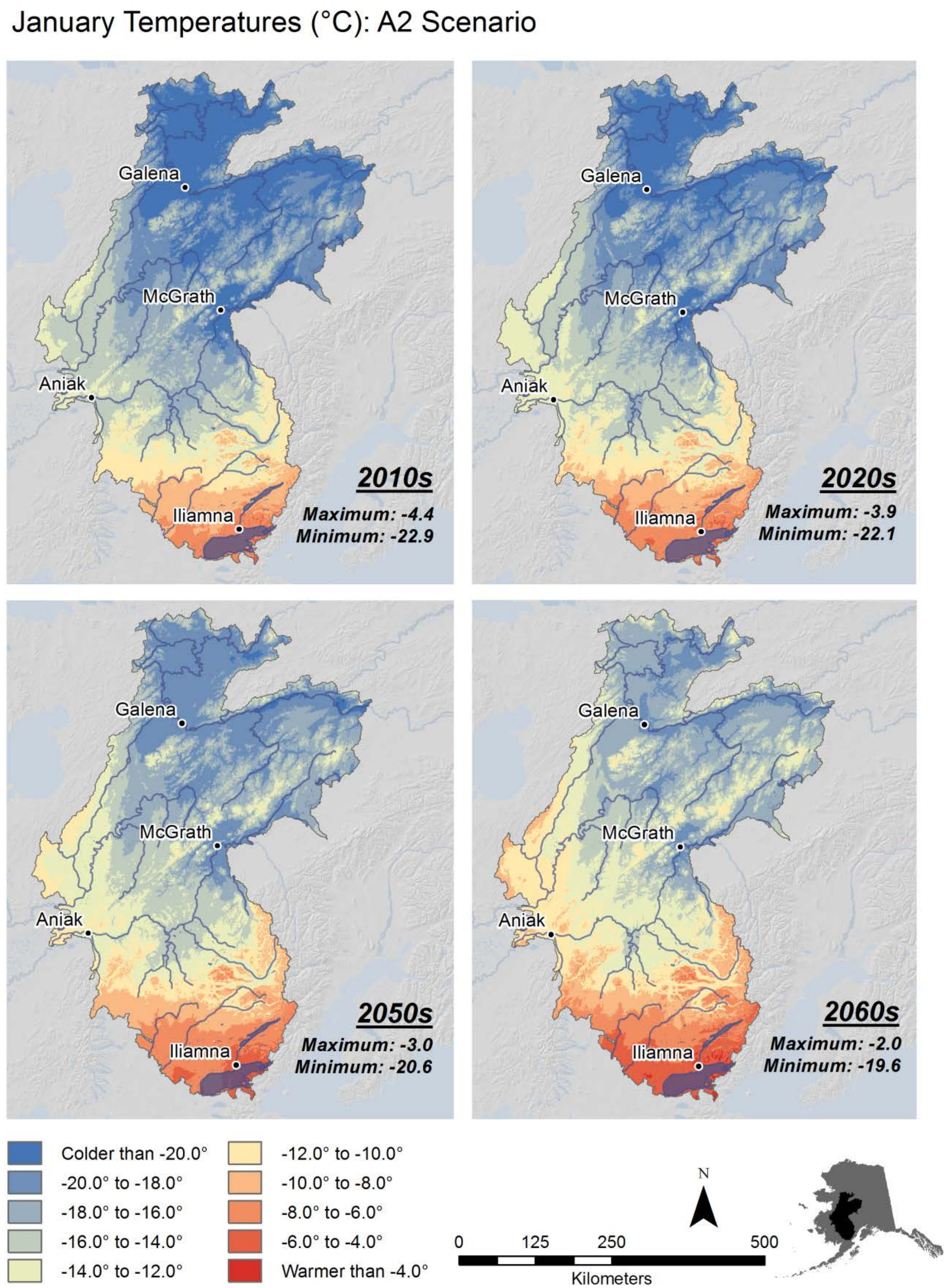


Figure B-5. Projected mean January temperatures depicting the A2 climate scenario.

Summer Temperature

July temperature projections are shown in Figure B-6, and summarized in Table B-5. Our models project warming across the YKL during the warmest month of the year. However, this warming trend is less pronounced than winter warming, and is not apparent in the near-term. This is likely due to a combination of factors, including the inherent stochasticity and variability of the models, the short time frame, and the nature of the A2 emissions scenario, which tends to predict accelerating change later in the century. No significant warming or cooling can be expected in the near-term during July, but highly significant warming is expected by the 2060s.

In general, summer warming is expected to follow the same geographic patterns as winter warming, with greater changes in the northern part of the YKL (particularly the Koyukuk River region), and less change to the south (e.g. Kvichak-Port Heiden). Note that the projected maximum and minimum values for each decade demonstrate greater inter-annual variability than the magnitude of the trend from decade to decade.

Table B-5. July temperature projections, A2 and A1B emissions scenarios, by 3rd-level HUC (°C).

Watershed (3rd Level HUCs)	emission scenario	2010s			2020s			2050s			2060s			change from 2010s		
		MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	2020s	2050s	2060s
Tanana River	A2	13	17	17	13	18	17	13	18	17	14	19	18	0.2	0.5	1.3
Kvichak-Port Heiden	A2	3	15	13	3	15	13	4	16	13	4	16	14	-0.2	0.4	1.0
Upper Kuskokwim River	A2	-1	17	14	-1	17	14	-1	18	15	0	18	15	-0.1	0.4	1.1
Nushagak River	A2	2	15	13	2	15	13	3	15	14	3	16	14	-0.2	0.4	1.0
Lower Kuskokwim River	A2	9	16	15	8	16	14	9	16	15	10	17	16	-0.2	0.3	1.1
Central Yukon	A2	10	17	16	10	17	16	10	18	16	11	19	17	0.1	0.5	1.3
Lower Yukon	A2	10	17	15	10	17	15	10	17	16	11	18	16	-0.1	0.4	1.2
Koyukuk River	A2	10	17	16	10	18	16	11	18	16	11	19	17	0.2	0.6	1.4
Tanana River	A1B	12	17	16	13	18	17	14	19	18	14	19	18	0.9	2.0	1.6
Kvichak-Port Heiden	A1B	3	14	12	4	15	13	4	16	14	5	16	14	0.9	1.5	1.9
Upper Kuskokwim River	A1B	-2	17	14	-1	17	15	0	18	15	0	18	15	1.0	1.8	1.9
Nushagak River	A1B	2	14	13	2	15	14	3	16	14	3	16	15	1.0	1.6	1.9
Lower Kuskokwim River	A1B	8	15	14	9	16	15	10	17	16	10	17	16	1.1	2.0	1.9
Central Yukon	A1B	9	17	15	10	18	16	11	19	17	11	18	17	1.0	2.1	1.7
Lower Yukon	A1B	9	16	14	10	17	15	11	18	17	11	18	16	1.1	2.2	1.8

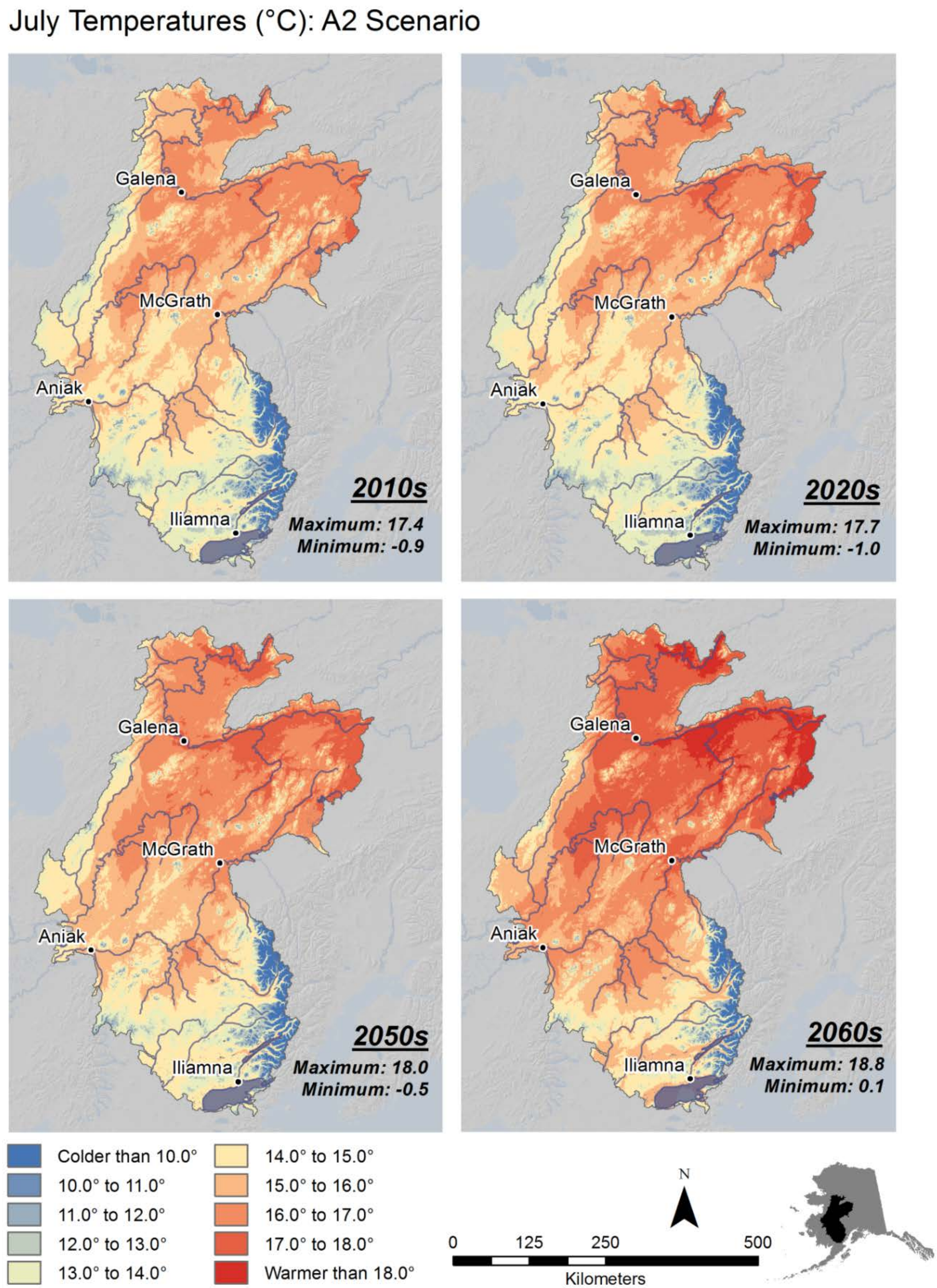


Figure B-6. Temperature projections for July (A2 scenario).

Precipitation Sensitivity Analysis

Cross-model standard deviations for precipitation are shown in Table B-6. The rationale for producing these metrics is similar to that explained for temperature, above. Given that precipitation is more variable than temperature, across both space and time, standard deviations among models tend to be higher. Based on these values, variation in monthly, seasonal, or annual precipitation of less than 7.5 mm is not statistically distinguishable from baseline values. Projected shifts of 7.5 – 15 mm can be considered possibly significant, and a shift of more than 15 mm can be considered significantly different from baseline values.

Table B-6. Inter-model standard deviations in projected monthly precipitation, A2 emission scenario, mm rainwater equivalent.

Time Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mean
2010s	5	3.2	4.9	2.9	3.8	9.8	5.7	14	17.1	6.8	5.6	5.8	7.1
2020s	6.4	5.4	3.7	3.1	3.1	14.2	3.8	16.9	9.1	4.5	5.2	7.1	6.9
2060s	10.3	6.6	2.7	5.6	5.6	12.7	10.8	15.5	11.4	4.5	9	6.7	8.5
mean	7.2	5.1	3.8	3.9	4.2	12.2	6.8	15.5	12.5	5.3	6.6	6.5	7.5

Annual Precipitation

General geographic patterns of precipitation are likely to remain unchanged across the REA, even as total precipitation increases slightly (Figure B-7). The northern part of the REA experiences a more interior climate, with only half the precipitation seen further south. As can be seen in Figure B-8, those regions that currently receive the most precipitation may see slightly greater increases than those that are currently drier.

Summer Precipitation

Slight to moderate increases in summer (June, July, and August) precipitation are projected (Figure B-9), with non-significant increases in precipitation in the near-term, but a significant trend appearing by 2060. A comparison of summer precipitation projections under the A1B and A2 two greenhouse gas emissions scenarios is shown in Table B-7. By 2060, precipitation may increase by approximately 6-16%, although model variability is relatively high, and the apparent slight decrease in precipitation between the 2050s and 2060s is likely not significant, based on the sensitivity analysis described above.

The pattern of change for summer months is geographically opposite to that seen for temperature. Northern (more interior or inland) areas in the YKL area are likely to see smaller percentage increases in precipitation but greater increases in temperature; the reverse is likely to be true in the more southern sub-regions. Thus it should be noted that, particularly to the north, although summer precipitation is expected to increase, increased temperature and associated evapotranspiration may offset the effects of increased moisture. However, as can also be seen in the table, inter-annual variability is extremely high. This variability, which mirrors the true variability in seasonal rainfall, poses a challenge for land managers and local residents alike.

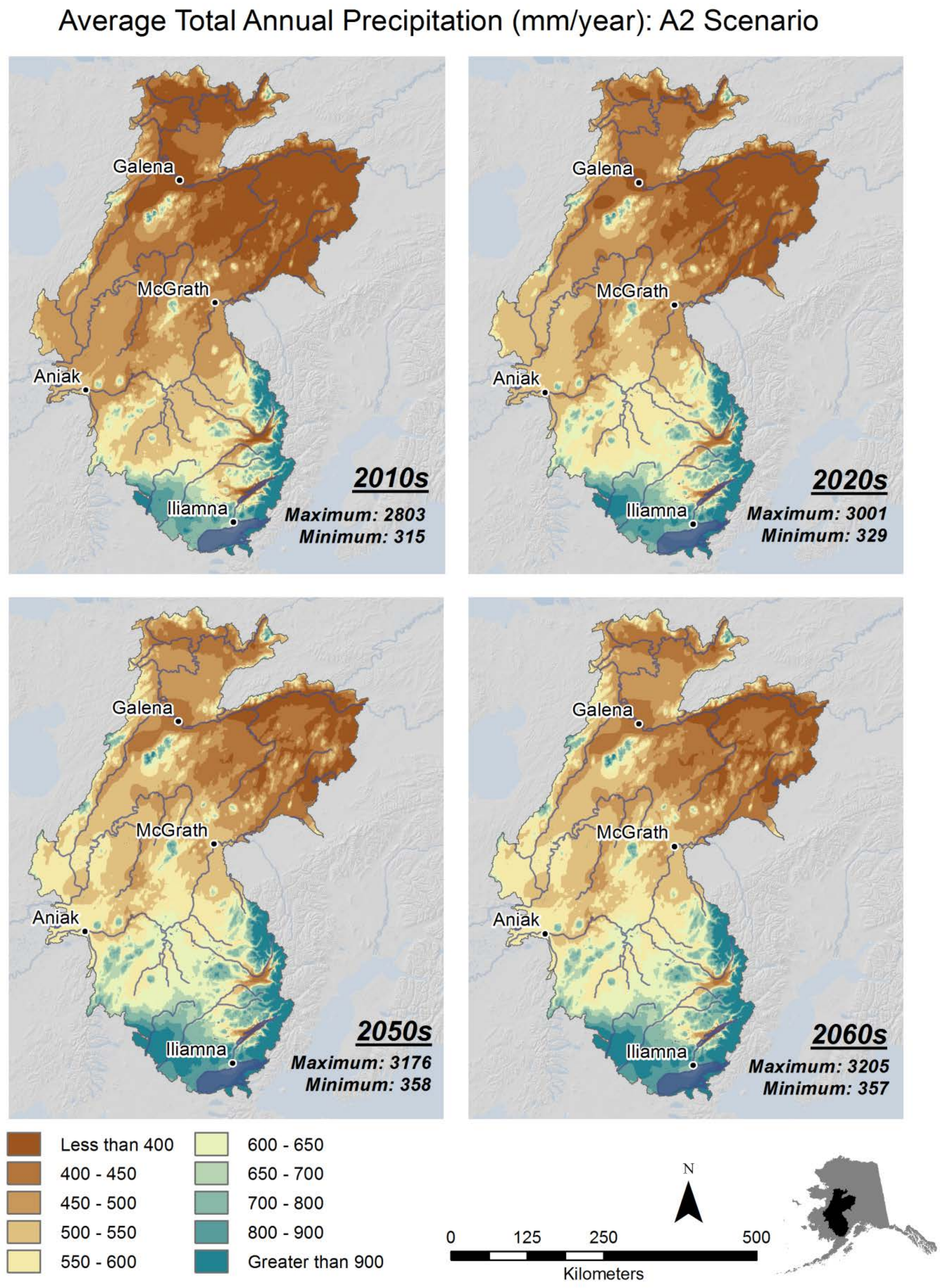
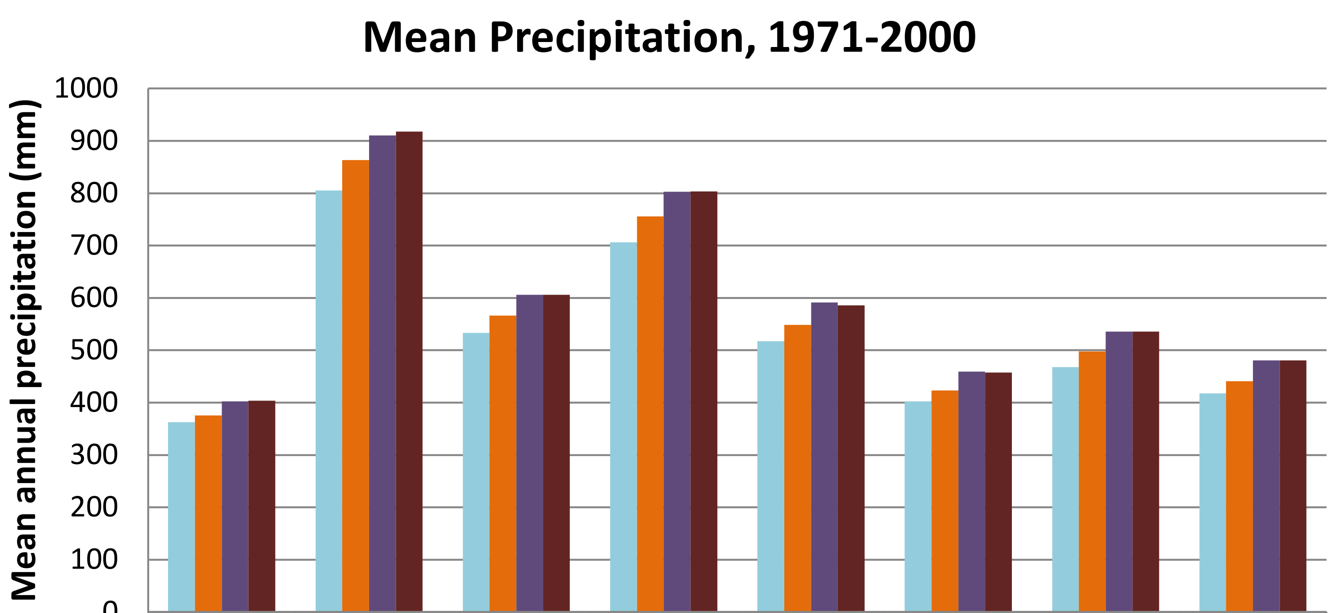


Figure B-7. Projected annual precipitation, A2 scenario (mm, rain water equivalent).



	Tanana River	Kvichak-Port Heiden	Upper Kuskokwim River	Nushagak River	Lower Kuskokwim River	Central Yukon	Lower Yukon	Koyukuk River
2010s	363	805	533	706	517	402	468	418
2020s	376	863	567	756	549	423	498	441
2050s	403	910	606	803	591	459	536	481
2060s	404	918	606	803	586	457	536	480

Figure B-8. Annual precipitation projections by 3rd-level HUC (mm rain water equivalent), A2 scenario.

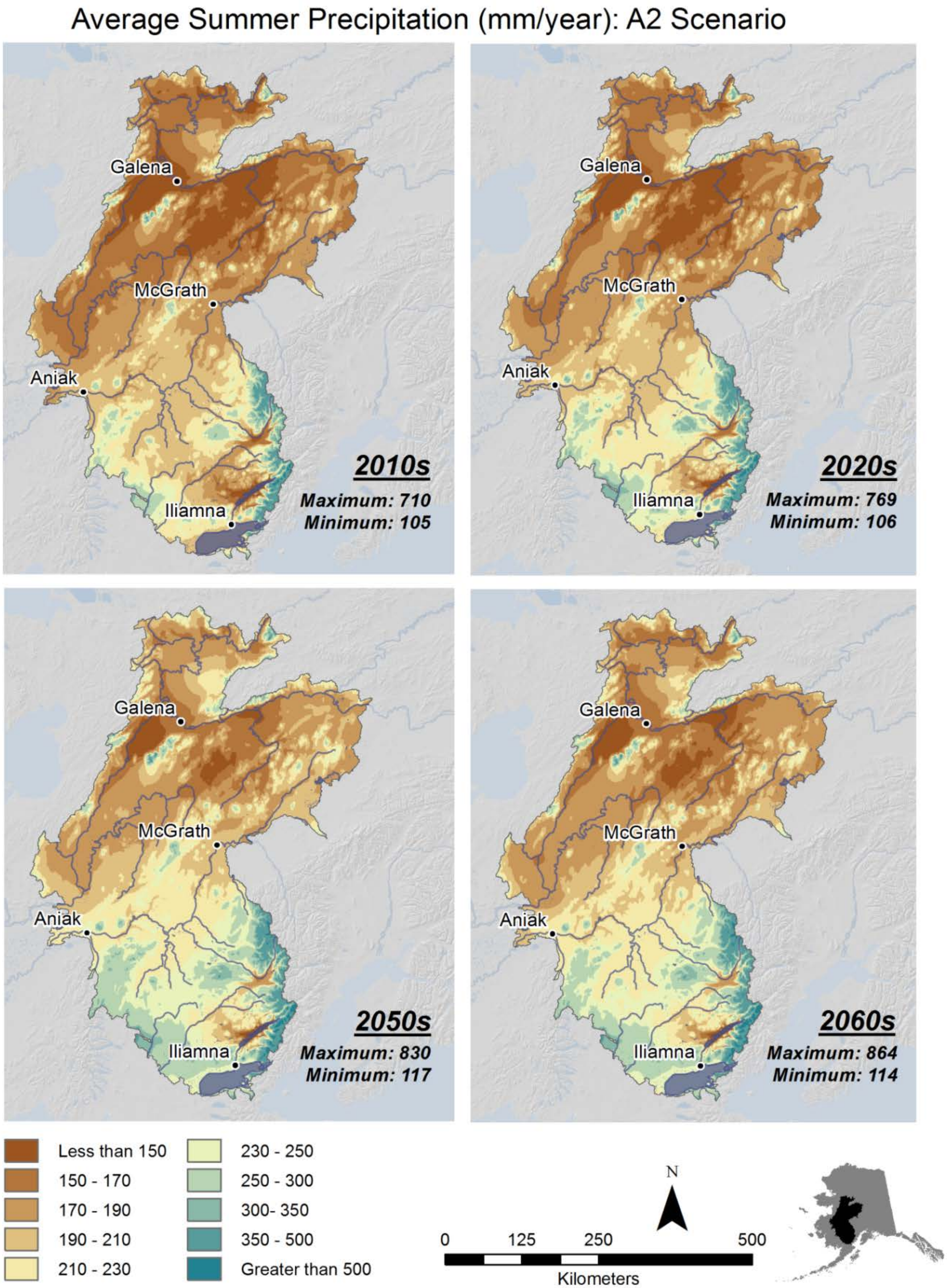


Figure B-9. Precipitation projections, June-August, A2 scenario.

Table B-7. Summer precipitation projections by 3rd level HUC (mm).

3rd Level HUCs	emission scenario	2010s			2020s			2050s			2060s			change from 2010s			% change from 2010s		
		MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	2020s	2050s	2060s	2020s	2050s	2060s
Tanana River	A2	158	242	175	159	240	175	172	264	192	168	254	185	0	17	10	0	10	6
Kvichak-Port Heiden	A2	112	692	228	121	749	245	131	808	264	133	842	268	18	37	40	8	16	18
Upper Kuskokwim River	A2	145	460	211	154	480	218	167	524	238	170	531	234	8	28	24	4	13	11
Nushagak River	A2	162	435	222	175	465	239	189	501	258	188	515	254	16	35	32	7	16	14
Lower Kuskokwim River	A2	171	324	209	174	341	216	190	373	236	184	357	226	6	27	17	3	13	8
Central Yukon	A2	105	370	162	106	377	163	117	413	181	114	400	174	2	19	12	1	12	8
Lower Yukon	A2	123	379	174	123	386	179	137	423	195	132	410	189	4	20	14	3	12	8
Koyukuk River	A2	136	388	173	138	398	176	153	443	195	148	422	187	3	22	14	2	13	8
Tanana River	A1B	154	234	171	155	236	172	166	251	183	179	274	199	1	12	28	0	7	17
Kvichak-Port Heiden	A1B	120	745	243	116	715	234	132	823	266	131	817	265	-9	24	22	-4	10	9
Upper Kuskokwim River	A1B	152	475	215	150	468	211	166	517	230	170	535	241	-4	15	26	-2	7	12
Nushagak River	A1B	173	458	235	166	449	227	187	505	252	188	509	256	-8	17	21	-3	7	9
Lower Kuskokwim River	A1B	171	338	213	170	328	209	180	352	222	194	370	237	-4	9	25	-2	4	12
Central Yukon	A1B	105	371	161	104	366	160	106	377	167	124	436	190	0	6	29	0	4	18
Lower Yukon	A1B	121	380	175	122	376	173	126	387	180	143	446	201	-2	5	26	-1	3	15
Koyukuk River	A1B	138	399	176	135	395	173	138	401	175	163	460	207	-3	-1	30	-2	-1	17

Winter Precipitation

The units (mm) in this section refer to rain-water equivalent, as "winter precipitation" does not necessarily mean snow (Figure B-10). A comparison of winter precipitation under the A1B and A2 emissions scenarios is shown in Table B-8. Models project slight increases in winter (December, January, and February) precipitation under the A1B emission scenario, as well as in the A2 scenario. It should be noted that most of the increase in winter precipitation is predicted in the near-term (2025), with little or no additional increase in the more long-term (2060). This is in contrast to the pattern seen in the temperature data. It should also be noted, that changes in precipitation across both the near-term and long-term are only of moderate significance. That is, projected increases are greater than one standard deviation of inter-model variability, but for the most part less than two standard deviations.

Variability from year to year is of greater magnitude than the projected trend associated with climate change. Moreover, the slight increases in winter precipitation predicted by these models may not result in increased snowfall or greater snowpack, since associated warming may mean that a greater percentage of this precipitation falls as rain.

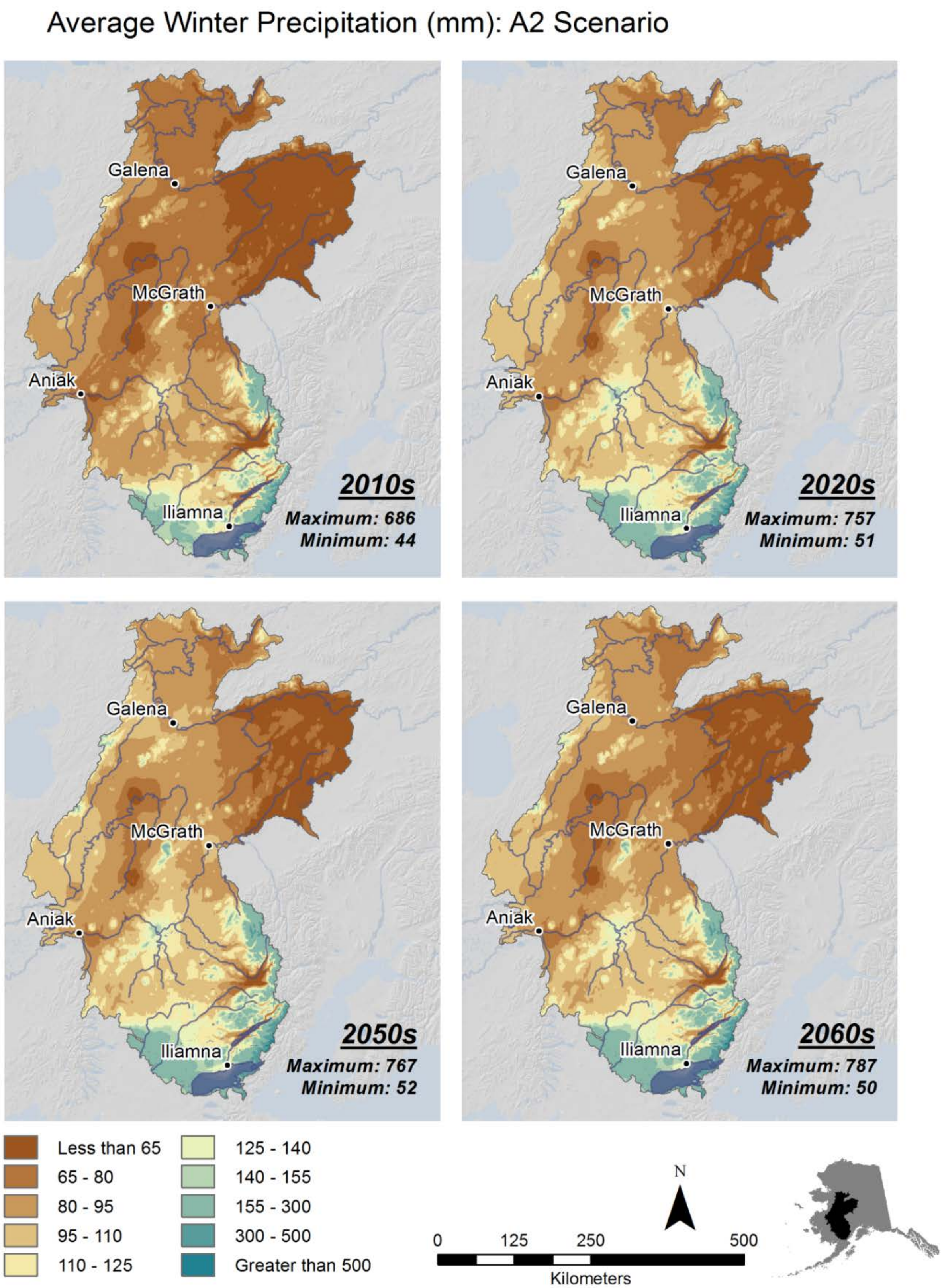


Figure B-10. Winter precipitation projections, A2 scenario.

Table B-8. Projected winter precipitation by 3rd level HUC (mm rain equivalent).

3rd Level HUCs	emission scenario	2010s			2020s			2050s			2060s			change from 2010s			% change from 2010s		
		MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	2020s	2050s	2060s	2020s	2050s	2060s
Tanana River	A2	46	79	53	52	89	61	52	89	60	51	89	59	7	7	6	13	13	11
Kvichak-Port Heiden	A2	63	686	158	70	757	175	69	767	175	71	787	178	17	16	20	11	10	13
Upper Kuskokwim River	A2	46	325	91	53	370	105	53	366	105	51	368	102	14	14	11	15	15	12
Nushagak River	A2	60	204	125	68	224	140	68	225	140	68	229	141	15	16	16	12	12	13
Lower Kuskokwim River	A2	59	138	85	68	162	99	68	161	99	66	155	96	13	14	10	15	16	12
Central Yukon	A2	46	141	69	51	160	79	52	172	81	51	162	77	11	13	9	15	18	13
Lower Yukon	A2	44	161	78	52	190	91	52	195	91	50	183	87	13	13	9	16	17	11
Koyukuk River	A2	60	123	74	68	140	85	71	146	89	70	145	85	11	15	12	15	21	16
Tanana River	A1B	48	83	56	46	80	53	55	96	65	56	96	65	-2	10	9	-4	17	17
Kvichak-Port Heiden	A1B	62	683	157	62	677	156	74	811	186	77	847	193	0	29	37	0	19	24
Upper Kuskokwim River	A1B	48	333	93	46	326	91	57	391	112	57	403	114	-3	19	20	-3	20	22
Nushagak River	A1B	60	202	125	60	200	123	72	240	149	75	251	155	-2	25	31	-1	20	25
Lower Kuskokwim River	A1B	60	140	87	59	138	85	73	172	106	74	175	107	-2	19	20	-2	22	23
Central Yukon	A1B	48	151	73	45	144	69	55	174	85	55	177	85	-4	13	12	-5	17	17
Lower Yukon	A1B	46	170	81	44	162	78	56	204	99	56	205	98	-3	18	17	-3	22	21

Snow-Day Fraction

Snow-day fraction refers to the estimated percentage of days on which precipitation, were it to fall, would occur as snow as opposed to rain. Model outputs for all nine months of the year for the current decade (2010s) are shown in Figure B-11. Summer months (June, July, and August) are omitted, since projected snow for these months is absent or negligible.

Not surprisingly, clear spatial and temporal patterns are evident. It should be noted that the spatial heterogeneities visible in many of these maps can be attributed to the model partitioning the state along regional boundaries. This REA happens to cross the area where the SW Interior, Interior and West regions converge.

For all but the most southern portion of the REA, all or almost all (>90%) of precipitation is currently likely to fall as snow for all months from November to March. However, to the south, around Iliamna, this percentage is as low as 50% in November. Even in January, the coldest month, the snow-fraction in this region ranges from about 70-90%, meaning that as much as 30% of January precipitation falls as rain at some sites.

In the shoulder-season months of April and October, snow-day fraction varies regionally from about 20% to about 90%. Regional differences are greater in the fall than in the spring, implying that there is more variation across the REA in when the snowpack starts to form than in when it starts to melt.

In early fall and late spring (September and May) most precipitation falls as rain, except at high elevations. In these months, north-south differences in snow-day fraction all but disappear. Figure B-12 shows how snow-day fraction may shift in the near future. Given that these model outputs are only one decade in the future, as compared to Figure B-11, the change is relatively subtle. Nonetheless, some shifts can be seen, such as November snow-fraction around Iliamna dropping clearly below 50%, and May precipitation around Galena dropping from 10-20% snow to less than 10%.

In the more distant future, as seen in Figure B-13, more marked changes are expected. May and September snowfall are expected to be negligible almost everywhere in the REA. Around Iliamna, only 31-40% of November precipitation is expected to fall as snow, and this percentage rises only to 51-60% even in January.

Colder towns such as McGrath and Galena are projected to remain consistently snowy in the depths of winter, but the shoulder seasons will see significant changes, as shown in Figure B-14. October precipitation in Aniak is expected to shift from being 51-60% snow to being only 31-40% snow.

Day of Freeze (DOF) and Day of Thaw (DOT)

DOF refers to the interpolated day on which the running mean temperature crosses the freezing point in the fall. DOT refers to the equivalent day in the spring. Figure B-15 and Figure B-16 provide a statewide context for the YKL area, in order to demonstrate how patterns seen within the study area fit with overall trends.

As discussed above, DOF and DOT can be expected to correlate in general with the condition of ice on rivers, streams, and wetlands. Likewise, projected changes in the number of days between DOT and DOF cannot be expected to precisely reflect the number of ice-free days on any particular water body, but can serve as a reasonable proxy value of growing season or warm season length.

Table B-9 offers a tabular summary of DOF, DOT, and the current and projected number of days between these two dates. It also shows the projected change in the length of the warm season between the 2010s and the 2060s. Minimum and maximum values are included for the current decade as a reminder of the variability in these data. The table is arranged by community, in order to give managers a sense of how these changes may affect people on the landscape. However, the values for each community are not point data; they represent the average values for the 5th-level HUC in which the community is located. This averaging helps reduce error, while maintaining a relatively fine scale. Warm season length is projected to increase, on average, anywhere from 8 to 24 days across the YKL area, with the smallest increase seen in communities to the south such as Iliamna, and the greatest increase seen in communities in the north such as Manley Hot Springs.

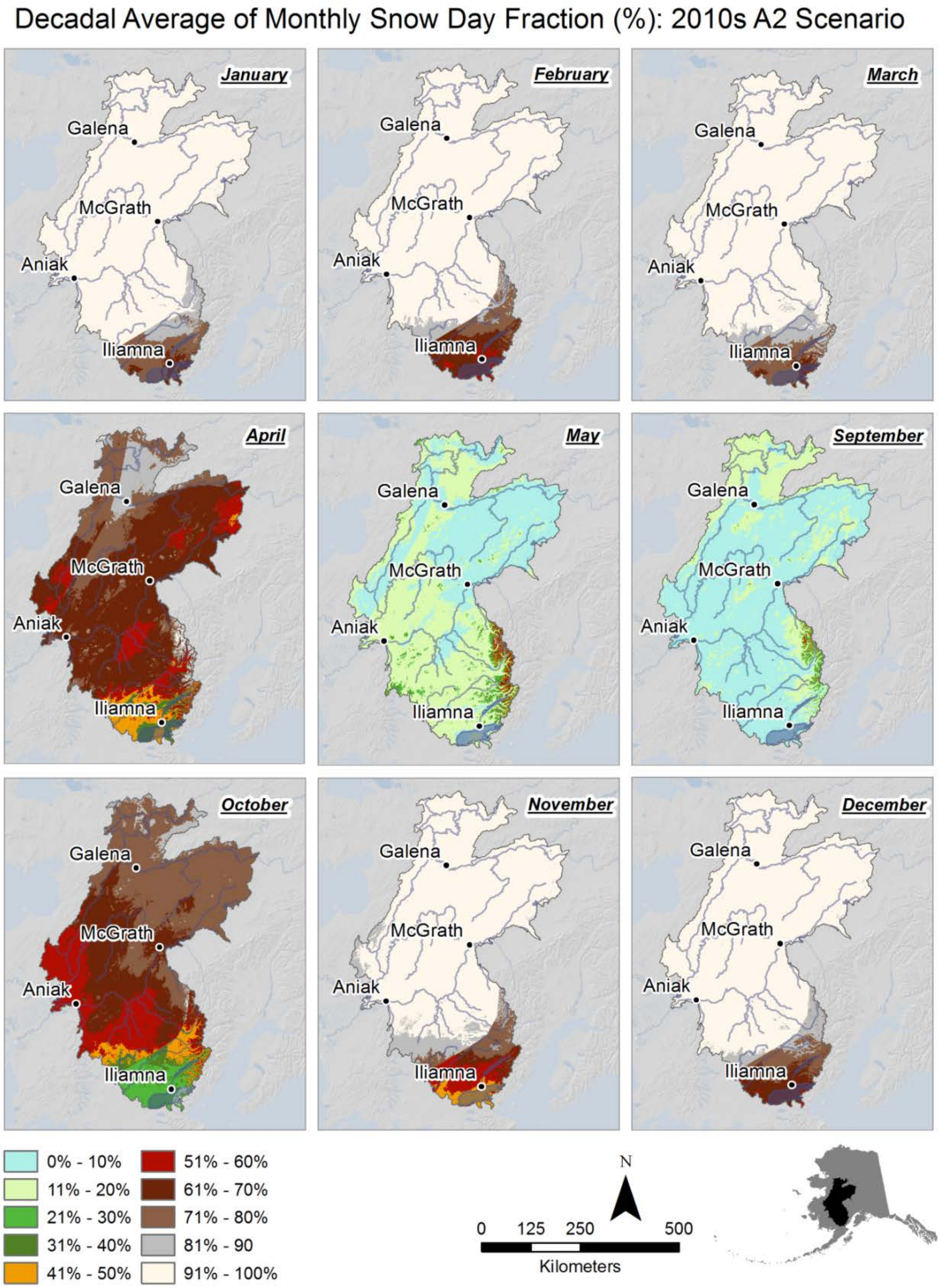


Figure B-11. Projected monthly snow-day fraction for the current decade (2010s).

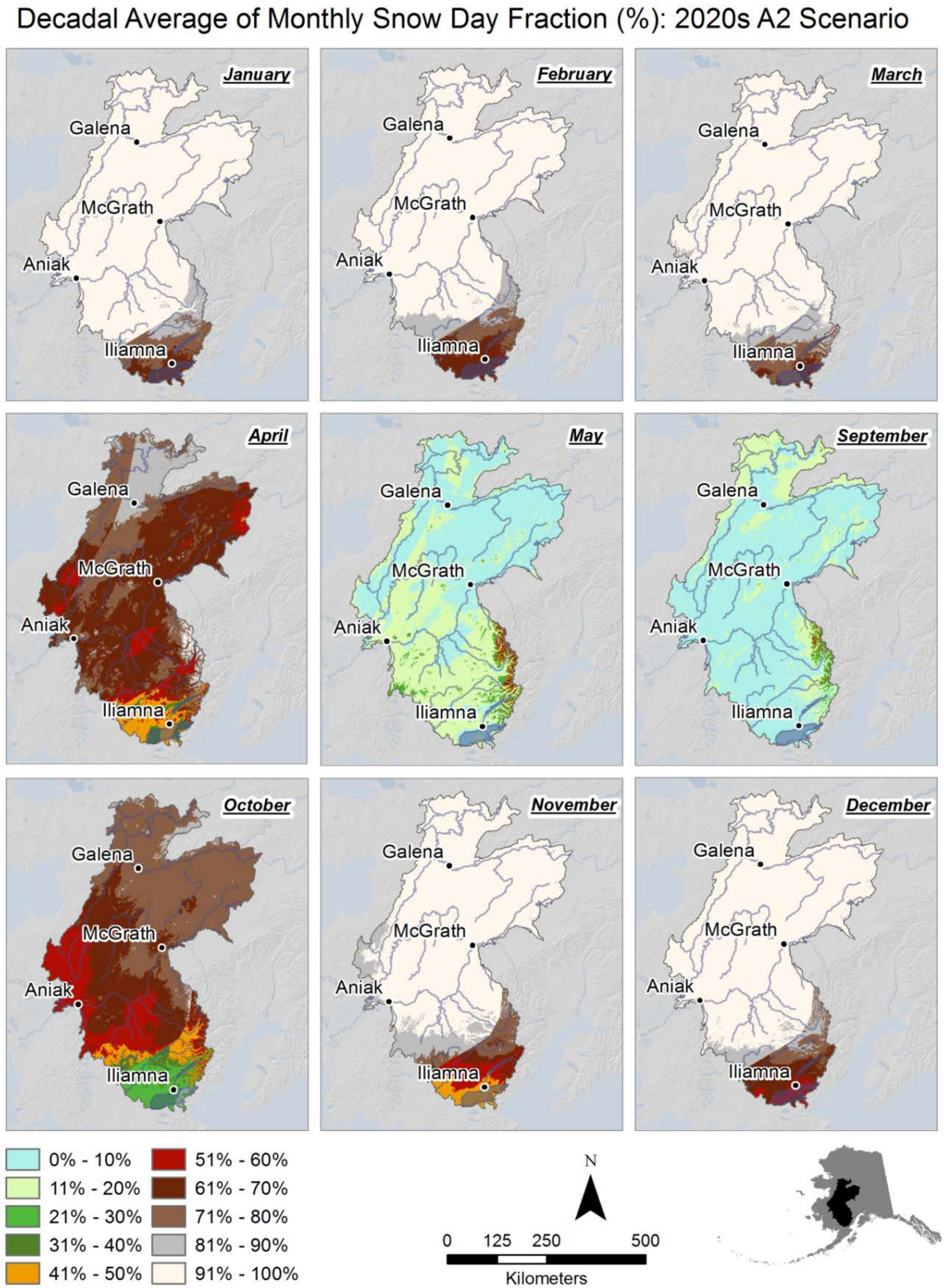


Figure B-12. Projected monthly snow-day fraction, 2020s.

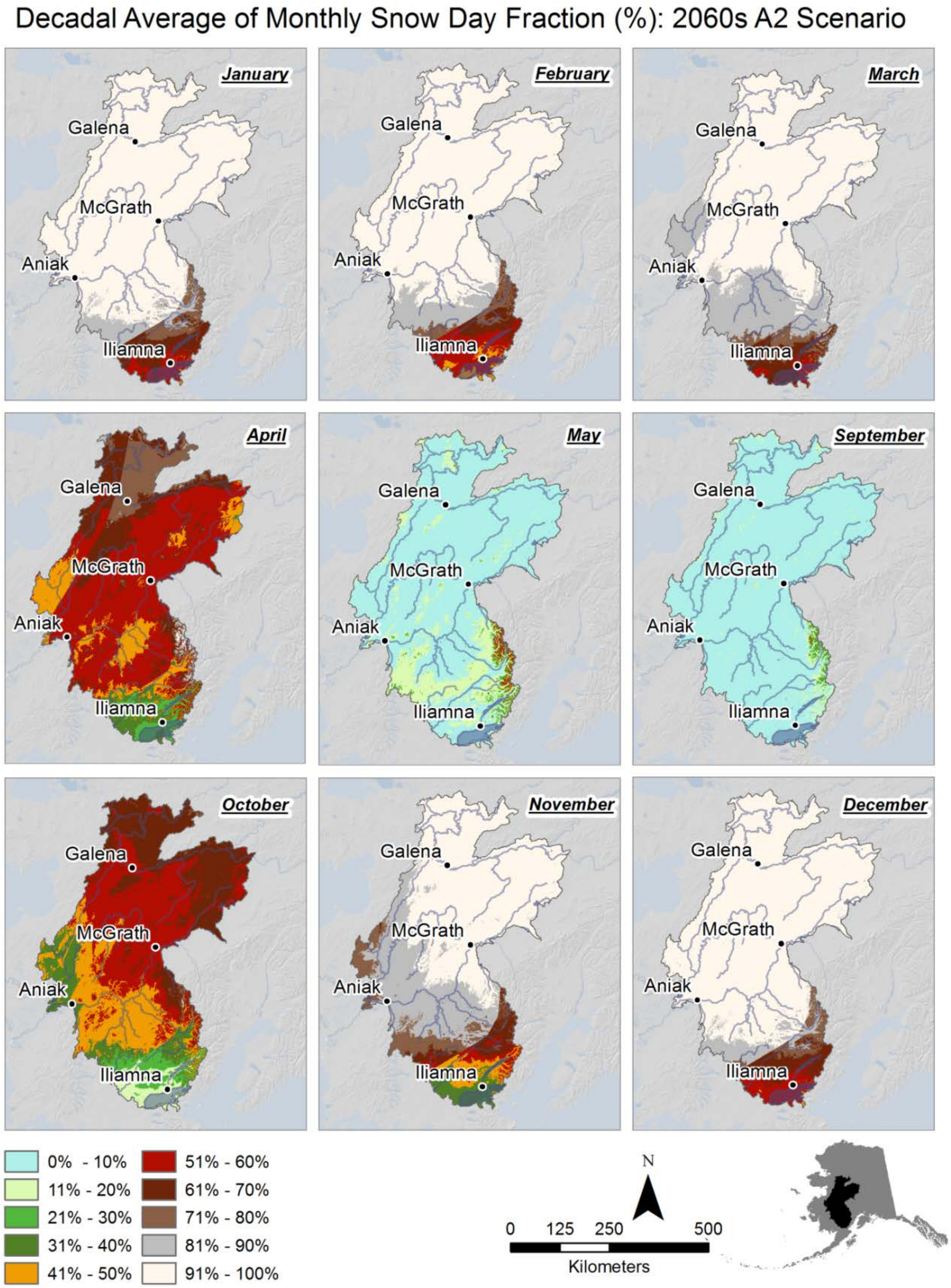


Figure B-13. Projected snow-day fraction, 2060s.

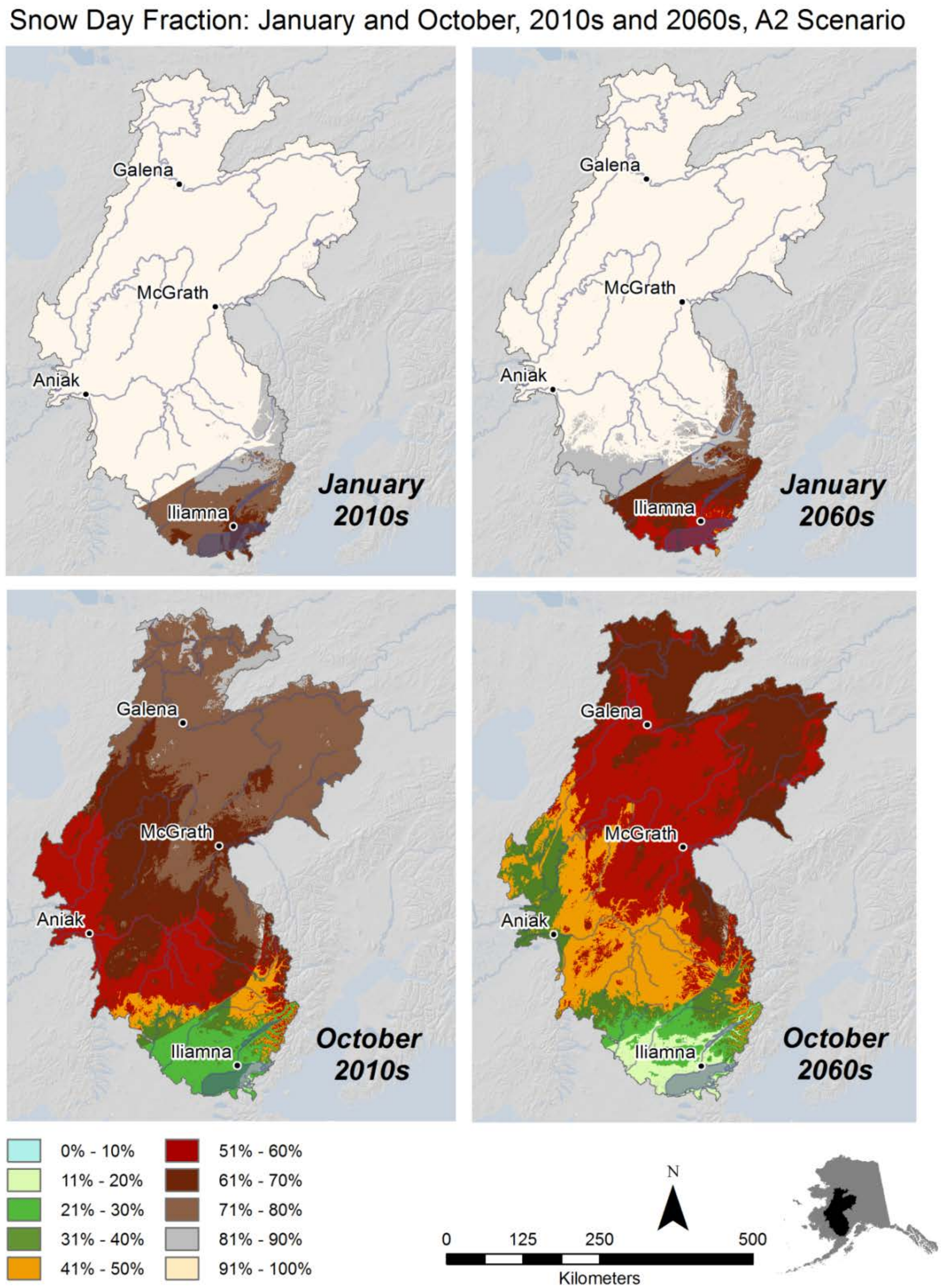


Figure B-14. Comparison of current and future snow-day fraction for selected months.

Applications

Many of the implications of the changes described above are detailed in sections of this report dedicated to specific CEs. Indeed, in some cases, climate variables not presented in this overview proved to be pertinent to a particular species, and were thus separately modeled in order to provide the clearest possible picture of climate effects on a single species.

In many cases, changing climate is likely to affect human uses of the landscape, either indirectly (e.g., as ecosystem changes alter subsistence harvest patterns) or directly (e.g., as longer summer seasons make travel across snow or ice impossible during shoulder seasons). For example, the slow freeze-up of rivers has lengthened the interval of unsafe river ice in autumn, an important season for hunting moose and trapping marten. In addition, wildfires burn shelter cabins (Kofinas et al. 2010.) Such changes are addressed in the sections of this report dedicated to social issues (Section B-5).

Limitations and Data Gaps

The baseline climate data used in SNAP's downscaling procedure (e.g. PRISM and CRU data) have been peer reviewed and accepted by the climate community (Daley et al. 2008, New et al. 2002), and the downscaling have been validated by directly comparing twentieth century scenario (20C3m) GCM data to actual weather station data (WRCC 2011) and summarizing the outcomes in a validation report (SNAP 2008). Nonetheless, data inputs, as well as subsequent analysis and interpretation, includes multiple sources of error. Thus uncertainty is inherent in all climate projections; much of this uncertainty is addressed by using averages across multiple models and across decades and by comparing A2 and A1B emissions scenario model outputs; regardless all projections must still be understood in the context of the methodology.

As described under temperature sensitivity analysis and precipitation sensitivity analysis, climate results are deemed significant when trends are outside the range of variability that can be expected within and between models. While between-model variability does not capture all sources of uncertainty, it serves as a reasonable proxy.

Temperature

Available temperature data at the scale, coverage, and resolution necessary for this analysis were monthly rather than daily resolution. This imposed limitations, especially when trying to relate temperature change to communities, species and habitats. Extreme temperatures and temperature variability from day to day are sometimes more important variables than mean temperatures, when predicting the effects of heat stress, cold tolerance, and resilience.

Precipitation

Precipitation data do not differentiate between rain and snow; nor is any direct metric available for snowpack depth, rain on snow events, or other parameters that directly or indirectly impact certain CEs. However, we were able to add snow day fraction to the climate-related datasets in order to partially meet this need.

Snow-Day Fraction

Although the equations provide a reasonable fit to the data, model evaluation demonstrated that some weather stations are consistently less well described by regional models than others. Very few weather stations with long records are located above 500 m elevation in Alaska, so the equations were developed primarily from low-elevation weather stations, and thus may not be completely appropriate in the mountains. Finally, these equations summarize a long-term monthly relationship between temperature and precipitation type that is the result of short-term weather variability. In using these equations to make projections of future snow, we are assuming that these relationships remain stable over time.

Day of Freeze and Day of Thaw

Day of freeze, day of thaw, and season length do not correspond to metrics of freeze and thaw for particular water bodies or soils. Varied lag times apply. Change in DOF or DOT can reasonably be used as a rough proxy for related measures, however. For example, if DOT is projected to shift one week later in the area surrounding a wetland or lake, it is reasonable to expect that the wetland or lake would lose its ice cover approximately one week later (as compared to current averages). If land managers or local residents have a feel for what is "normal" then such metrics can prove useful for future decision-making.

Additional Data Gaps

Climate data, while relatively fine-scale, do not always match the scale of phenomena that affect CEs. Moreover, available data do not always match, in scale or detail, the climate-related attributes and indicators most closely linked to particular fine or coarse CEs. Even when linkages between CEs and climate variables are relatively clear, in many cases, the literature does not provide precise information regarding threshold values.

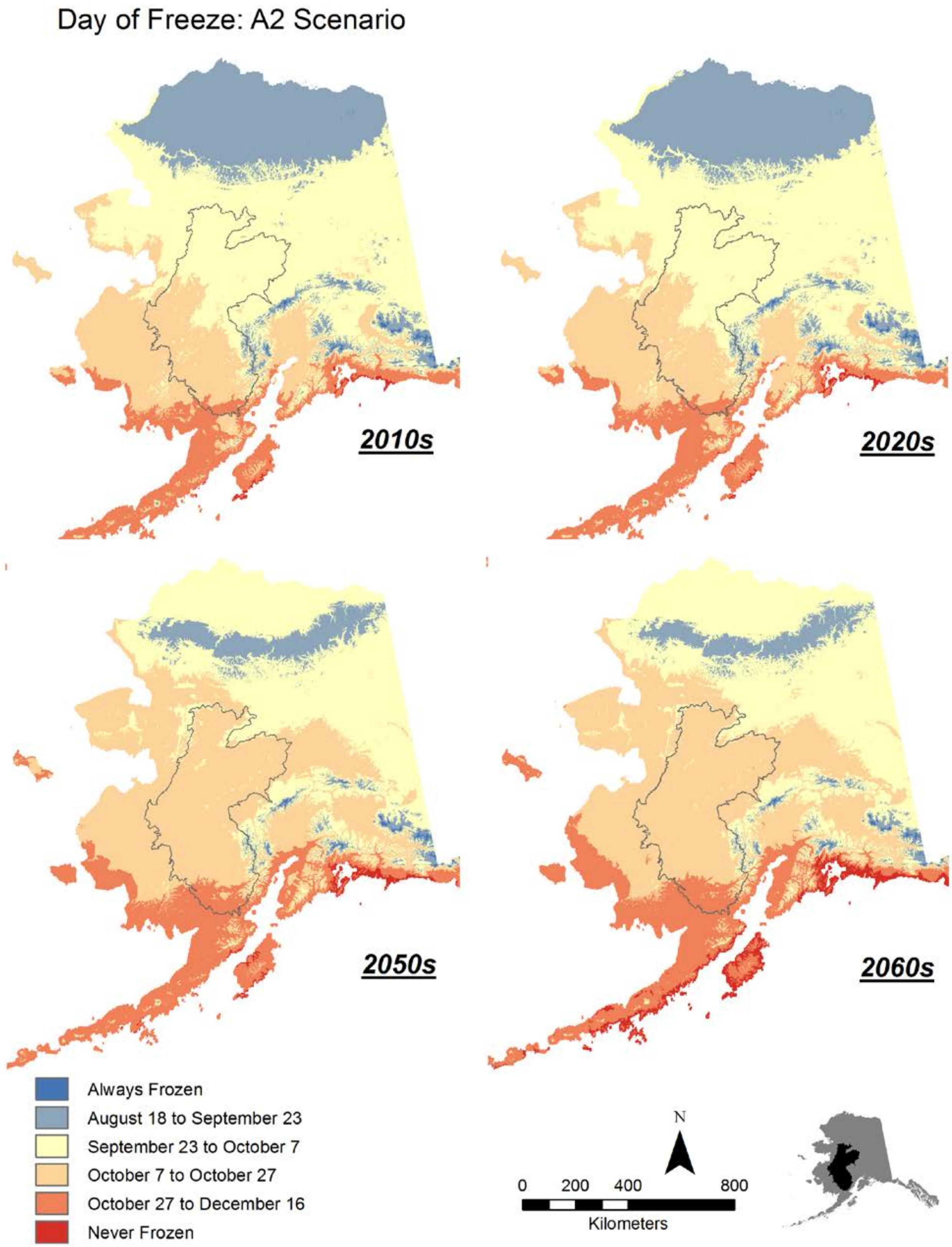


Figure B-15. Projected day of freeze, A2 scenario.

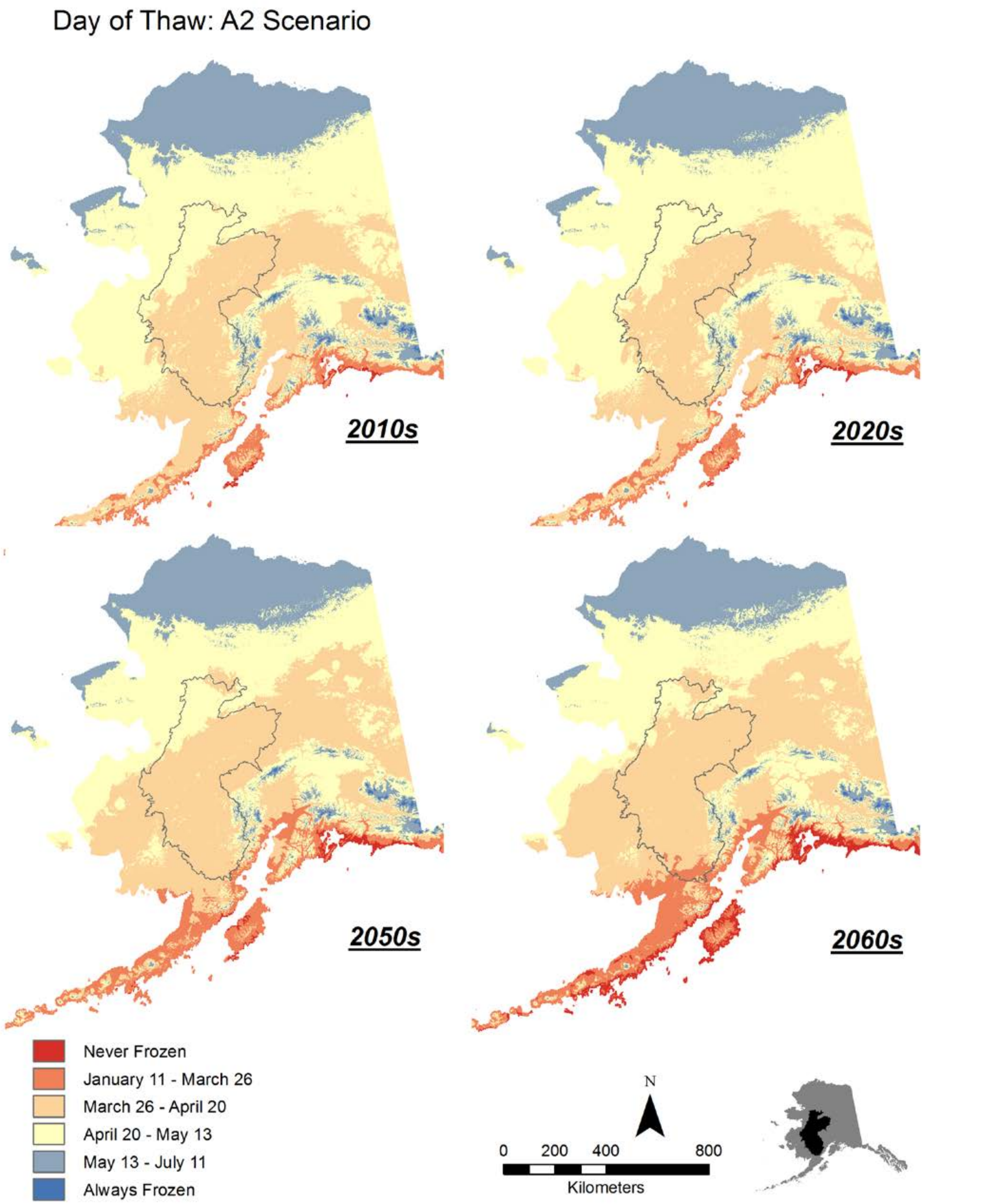


Figure B-16. Projected day of thaw, A2 scenario.

Table B-9. Projected days of thaw and freeze and change in warm season length, A2 emissions scenario.

Communities	2010s			2020s	2060s	2010s			2020s	2060s	warm season		
	MIN	MAX	MEAN	MEAN	MEAN	MIN	MAX	MEAN	MEAN	MEAN	2010s	2060s	change
Kokhanok	29-Sep	2-Nov	28-Oct	29-Oct	11-Nov	30-Mar	11-May	4-Apr	5-Apr	24-Mar	207	231	24
Iliamna	29-Sep	2-Nov	28-Oct	29-Oct	11-Nov	30-Mar	11-May	4-Apr	5-Apr	24-Mar	207	231	24
Pedro Bay	29-Sep	2-Nov	28-Oct	29-Oct	11-Nov	30-Mar	11-May	4-Apr	5-Apr	24-Mar	207	231	24
Port Alsworth	17-Sep	27-Oct	20-Oct	20-Oct	31-Oct	1-Apr	29-May	7-Apr	8-Apr	30-Mar	196	215	19
Newhalen	7-Oct	29-Oct	24-Oct	24-Oct	5-Nov	2-Apr	26-Apr	5-Apr	6-Apr	25-Mar	202	225	24
Nondalton	7-Oct	29-Oct	24-Oct	24-Oct	5-Nov	2-Apr	26-Apr	5-Apr	6-Apr	25-Mar	202	225	24
Telida	30-Sep	5-Oct	3-Oct	3-Oct	8-Oct	15-Apr	22-Apr	16-Apr	17-Apr	13-Apr	170	178	8
Takotna	29-Sep	7-Oct	5-Oct	5-Oct	11-Oct	13-Apr	25-Apr	15-Apr	16-Apr	10-Apr	173	183	10
McGrath	2-Oct	7-Oct	5-Oct	5-Oct	10-Oct	15-Apr	22-Apr	16-Apr	17-Apr	12-Apr	172	182	9
Lime Village	30-Sep	10-Oct	9-Oct	8-Oct	14-Oct	11-Apr	29-Apr	14-Apr	16-Apr	8-Apr	177	188	11
Sleetmute	7-Oct	11-Oct	9-Oct	9-Oct	15-Oct	10-Apr	16-Apr	12-Apr	13-Apr	6-Apr	180	192	12
Stony River	7-Oct	11-Oct	9-Oct	9-Oct	15-Oct	10-Apr	16-Apr	12-Apr	13-Apr	6-Apr	180	192	12
Red Devil	2-Oct	10-Oct	8-Oct	8-Oct	13-Oct	14-Apr	27-Apr	16-Apr	17-Apr	9-Apr	175	187	13
Crooked Creek	29-Sep	11-Oct	8-Oct	8-Oct	13-Oct	14-Apr	1-May	16-Apr	16-Apr	9-Apr	175	188	13
Napamiute	29-Sep	13-Oct	9-Oct	9-Oct	15-Oct	13-Apr	1-May	16-Apr	17-Apr	9-Apr	176	190	14
Chuathbaluk	29-Sep	13-Oct	9-Oct	9-Oct	15-Oct	13-Apr	1-May	16-Apr	17-Apr	9-Apr	176	190	14
Lower Kalskag	7-Oct	14-Oct	12-Oct	11-Oct	19-Oct	18-Apr	24-Apr	19-Apr	19-Apr	10-Apr	176	192	16
Upper Kalskag	7-Oct	14-Oct	12-Oct	11-Oct	19-Oct	18-Apr	24-Apr	19-Apr	19-Apr	10-Apr	176	192	16
Aniak	7-Oct	14-Oct	12-Oct	11-Oct	19-Oct	18-Apr	24-Apr	19-Apr	19-Apr	10-Apr	176	192	16
Lake Minchumina	2-Oct	6-Oct	4-Oct	4-Oct	9-Oct	13-Apr	18-Apr	15-Apr	16-Apr	12-Apr	172	180	8
Holy Cross	8-Oct	12-Oct	11-Oct	11-Oct	19-Oct	17-Apr	22-Apr	17-Apr	17-Apr	9-Apr	177	192	16
Manley Hot Springs	30-Sep	5-Oct	3-Oct	4-Oct	9-Oct	9-Apr	19-Apr	13-Apr	14-Apr	10-Apr	173	181	8
Hughes	22-Sep	3-Oct	1-Oct	2-Oct	8-Oct	19-Apr	2-May	21-Apr	21-Apr	17-Apr	163	174	10
Tanana	25-Sep	4-Oct	2-Oct	2-Oct	7-Oct	16-Apr	27-Apr	18-Apr	19-Apr	15-Apr	167	175	9
Huslia	30-Sep	3-Oct	1-Oct	2-Oct	7-Oct	23-Apr	25-Apr	24-Apr	24-Apr	20-Apr	160	170	10
Ruby	2-Oct	5-Oct	4-Oct	4-Oct	10-Oct	16-Apr	23-Apr	20-Apr	20-Apr	16-Apr	167	176	10
Galena	1-Oct	5-Oct	4-Oct	4-Oct	10-Oct	21-Apr	26-Apr	22-Apr	22-Apr	18-Apr	165	175	10
Nulato	2-Oct	6-Oct	4-Oct	5-Oct	10-Oct	23-Apr	24-Apr	23-Apr	23-Apr	19-Apr	165	175	10
Koyukuk	2-Oct	6-Oct	4-Oct	5-Oct	10-Oct	23-Apr	24-Apr	23-Apr	23-Apr	19-Apr	165	175	10
Kaltag	1-Oct	6-Oct	5-Oct	5-Oct	11-Oct	24-Apr	29-Apr	25-Apr	25-Apr	20-Apr	163	174	11
Anvik	4-Oct	11-Oct	9-Oct	10-Oct	17-Oct	18-Apr	25-Apr	19-Apr	19-Apr	12-Apr	173	188	15
Grayling	4-Oct	11-Oct	9-Oct	10-Oct	17-Oct	18-Apr	25-Apr	19-Apr	19-Apr	12-Apr	173	188	15
Shageluk	3-Oct	11-Oct	10-Oct	10-Oct	17-Oct	18-Apr	25-Apr	18-Apr	18-Apr	11-Apr	175	189	14

1.4. Climate Clusters (Cliomes)

This portion of the Technical Supplement addresses climate clusters or "cliomes" as a change agent on the YKL landscape, and is primarily concerned with assessing how these climate groupings may change over time, with respect to associated broad classes of vegetation. The climate modeling methods described in Section B-1.2 above were used and are not repeated here.

This section describes landscape-level model outputs, including the data, methods, and analysis involved in this modeling. It touches briefly on feedbacks between cliomes and fire and permafrost. Additional information on these feedbacks can be found in the applicable sections. This section also provides an overview of potential impacts to conservation elements. Further information on these interactions can be found in sections devoted to CEs (Section D-1 to D-4).

Climate and Vegetation

Linking climate change to changes in vegetation, biomes, and ecosystems is complex. While climate is ultimately a key determinant of biome characteristics, in the short term such characteristics may be more closely impacted by spatial features (e.g., mountains and rivers) and the mechanics and time-delays associated with processes such as disturbance propagation and seed dispersal. Shifts in vegetation are occurring in the far north along with changes in climate; however, it is also clear that, the connections between these two variables are neither even nor obvious. Studies show that shifts may occur as unstable, nonlinear threshold shifts rather than as smooth transitions (Scheffer et al. 2012).

Although this report offers detailed discussion of climate change modeling outputs in terms of changes in discrete climate variables (i.e., monthly temperature and precipitation), it can be difficult to view the impacts of 24 discrete variables on a complex system without additional modeling tools. This section attempts to simplify this effort, as part of the core analysis of this REA, linking change agents with conservation elements.

See Terrestrial Coarse-Filter section D-1 for a treatment of specific vegetation classes and their perceived interaction with climate change and other CAs.

Methods

Climate-biomes or "cliomes" were initially created as part of a collaborative effort between multiple agencies in Alaska and Canada (SNAP 2012). At the core of the project was the idea of using progressive clustering methodology, existing land cover classifications, and historical and projected climate data to identify areas likely to undergo ecological pressure, given climate change. Cliome results and data are intended to serve as a framework for research and planning by land managers and other stakeholders with an interest in ecological and socioeconomic sustainability.

Using climate projection data from SNAP and input from project leaders and participants (SNAP 2012), the project modeled projected changes in cliomes. The eighteen cliomes used in this project were identified using the combined Random Forests™ and Partitioning around medoids (PAM) clustering algorithms, which are defined by 24 input variables (monthly mean temperature and precipitation) used to create each cluster.

Data for this analysis were derived from SNAP data outputs from the cliomes project described above (Table B-10).

Table B-10. Source dataset used for climate cluster analysis in the REA.

Dataset Name	Data source
18-cluster data, 2km resolution, based on SNAP monthly temperature and precipitation date	SNAP

Interpretation and Analysis

Cliomes, as depicted in Figure B-17, can be considered to be assemblages of species and aggregated communities that might be expected to occur based on linkages with prevailing climate conditions – they should not be understood to be climate-linked biome types. 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. We used these clusters as proxies for how much climate might change.

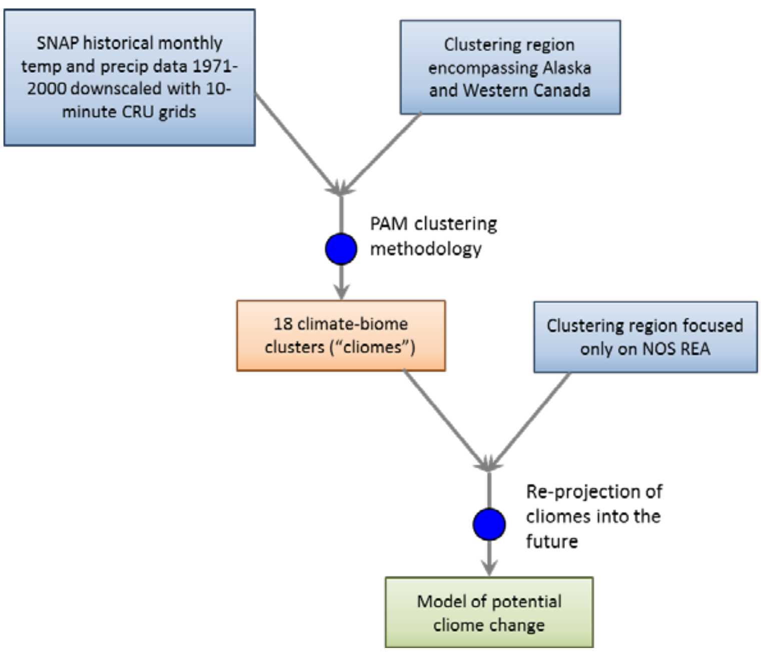


Figure B-17. Process Model for Cliome Shift Methodology.

A projected shift from one cliome to another does not mean that all vegetation types are expected to undergo a profound shift; it instead indicates that systems are likely to experience additional stress due to significant changes in climate conditions. As a result, species assemblage may change, in terms of the percentages of various vegetation types. A one-to-one correspondence between these is not expected, since they represent very different ways of looking at habitat. As an example, land managers might understand what was meant by a "cold interior boreal Alaska climate" and might be familiar with the types of vegetation to expect in such a zone, although that vegetation would differ at a micro-scale according to slope, aspect, soil drainage, and other factors. Likewise, land managers would understand what was meant by "black spruce forest". The two categories would certainly overlap, but are representative of different elements.

Thus, in comparing cliomes with vegetation types, we looked at the percentage breakdown for the YKL vegetation classes in each cliome. Vegetation changes can only be posited with reference to these breakdowns, at a relatively broad scale. The most useful way to view a projected cliome shift is to note the projected movement of cliomes with reference to what managers and land stewards know about the ecosystems in the areas where that cliome is found currently. Projections imply that those species assemblages are likely to dominate in areas that show that same cliome in the future. However, differing methods for classifying land cover and vegetation can yield different interpretations of cliome composition (SNAP 2012). Fundamentally, the cliome shift maps are not necessarily suggesting radical habitat shifts, but rather suggesting the possibility of gradual changes in regional vegetation composition with changing climate.

Results

Partially clipped results of this modeling effort are shown in Figure B-18. The area outlined in black delineates the boundary of the YKL study area. As can be seen in this figure, the YKL has only a small subset of the eighteen clusters used in the original project. Cliomes are projected to shift over time (Figure B-18). As can be seen here, the spatially dominant cliomes in the YKL are numbers 8, 10, 12, 14, and 15. Thus, although some of our analysis included cliomes that occurred in lesser percentages, as seen in other figures, the bulk of our discussion below focuses on these cliomes.

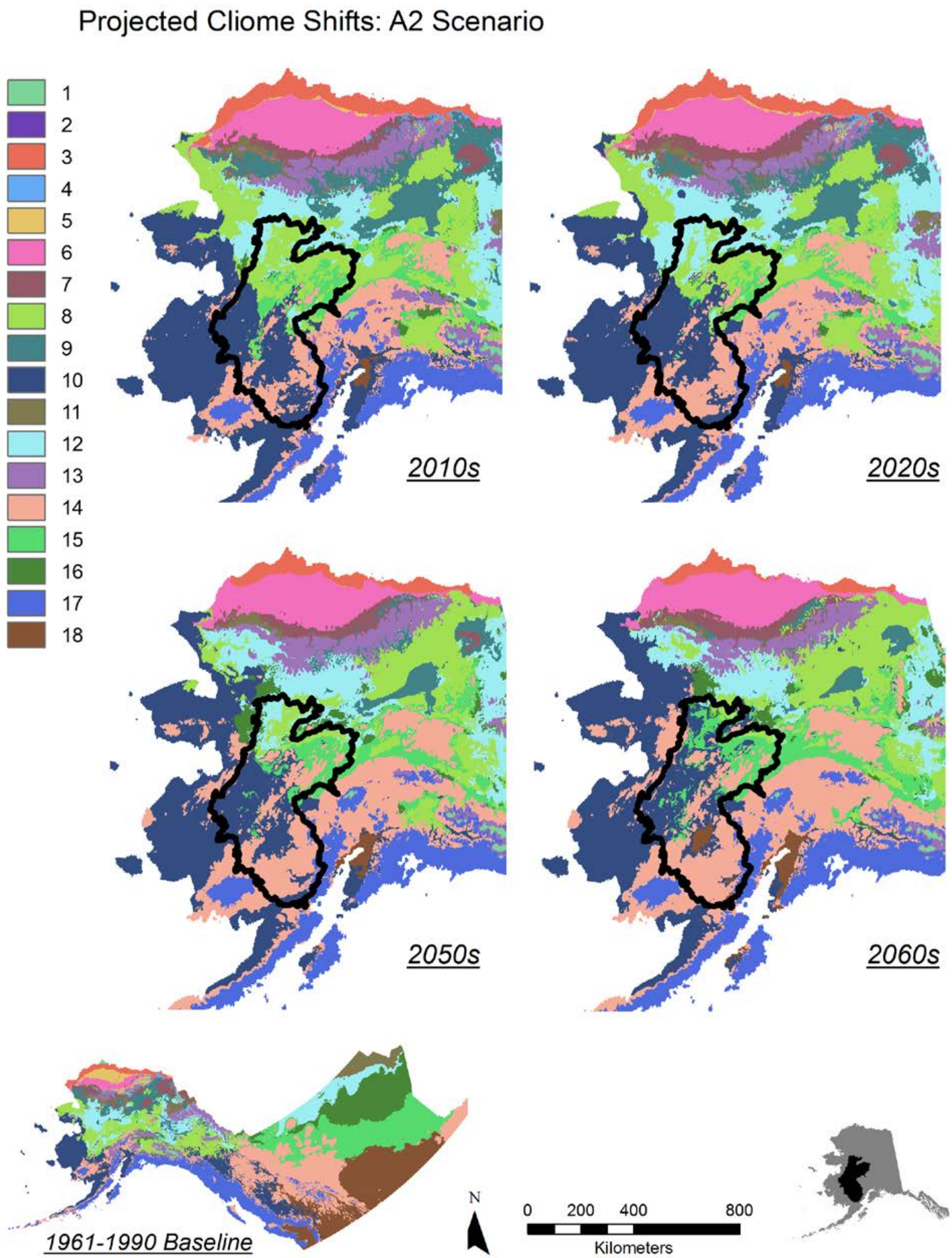


Figure B-18. Projected cliome shifts over time. "Cliomes" or "climate-biomes" are based on computer-generated clusters in which pixels are grouped according to all 12 months of precipitation and temperature data. As such, each color group represents an area of similar climate characteristics.

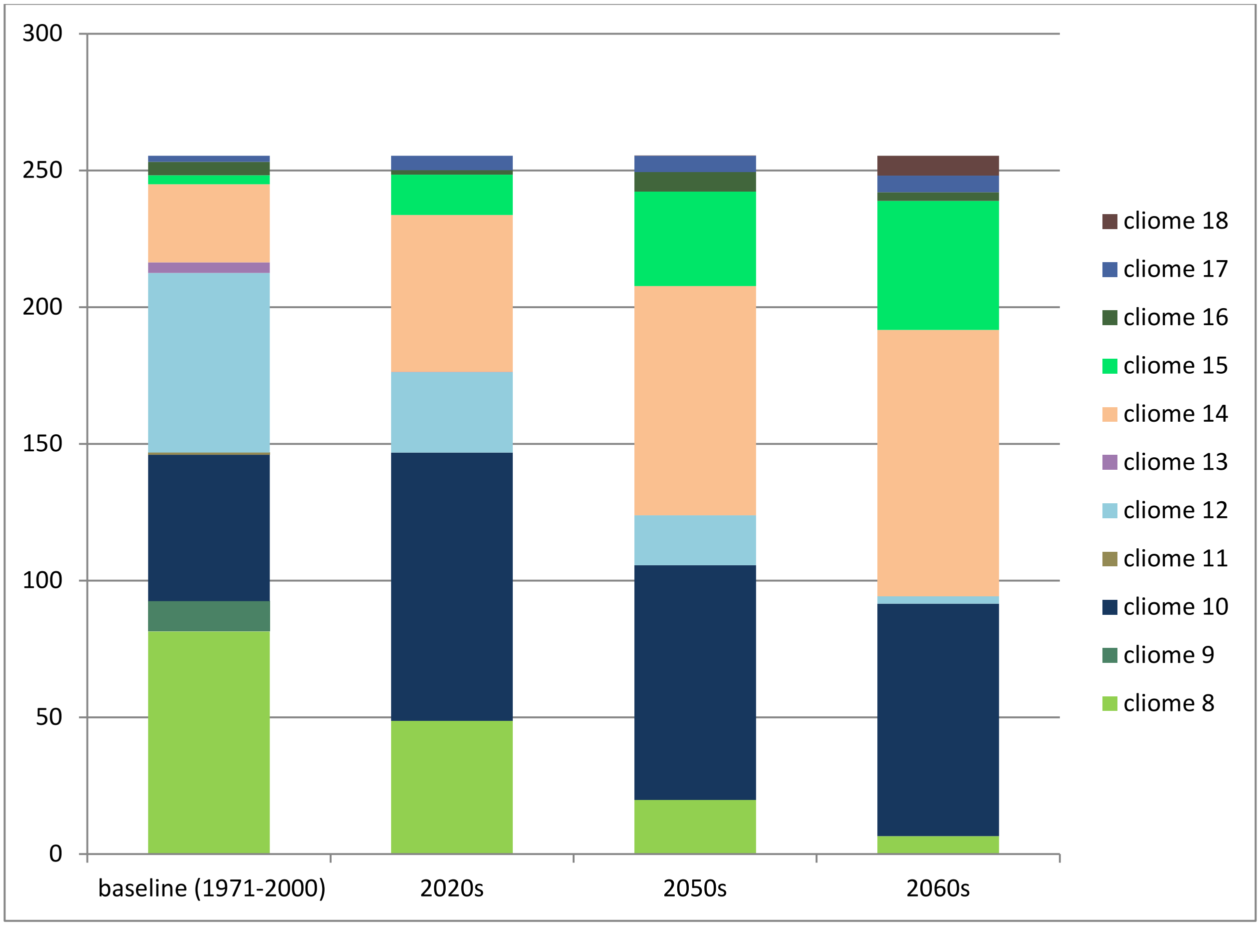


Figure B-19. Change in climate cluster (cliome) percentage over time across the REA.

Cliome Descriptions

How can we define the prevailing conditions in our cliomes of interest? Cliomes were spatially compared to four different land cover designation systems (see SNAP 2012). While each of these used differing classification systems, this comparison helped in the creation of textual descriptions of the cliomes. In addition, each cliome can be viewed in terms of the 24 input variables used to create it, and described in these terms. These variables (twelve months of temperature and twelve months of precipitation) are shown graphically in Figure B-20 and Figure B-21.

The dominant cliomes are described as follows:

- **Cliome 8**: Dry boreal wooded grasslands with mixed coniferous forests and grasses. Moderate precipitation (355 mm) and relatively temperate fall, winter, and spring temperatures.
- **Cliome 10**: Boreal forest with coastal influence and intermixed grass and tundra. Much milder winter, spring, and fall conditions than Cliome 8, but with comparable summers. Fairly high precipitation (561 mm).
- **Cliome 12**: Densely forested closed-canopy boreal. Moderate precipitation (420 mm) with slightly warmer summers and colder winters than Cliome 8.

- **Cliome 14**: Densely forested southern boreal. Slightly warmer than Cliome 10 in all seasons, with even higher precipitation (857 mm).
- **Cliome 15**: Southern boreal/aspen parkland. Early springs, late falls, hot summers (16°C), and moderately cold winters. Moderate precipitation (474 mm).

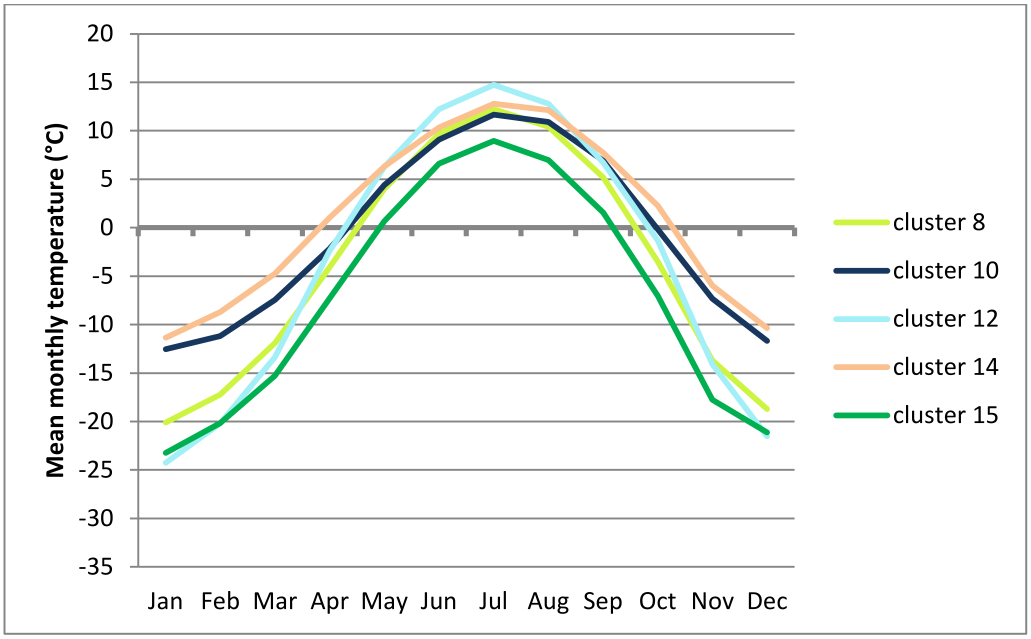


Figure B-20. Dominant cliomes by mean monthly temperature distribution.

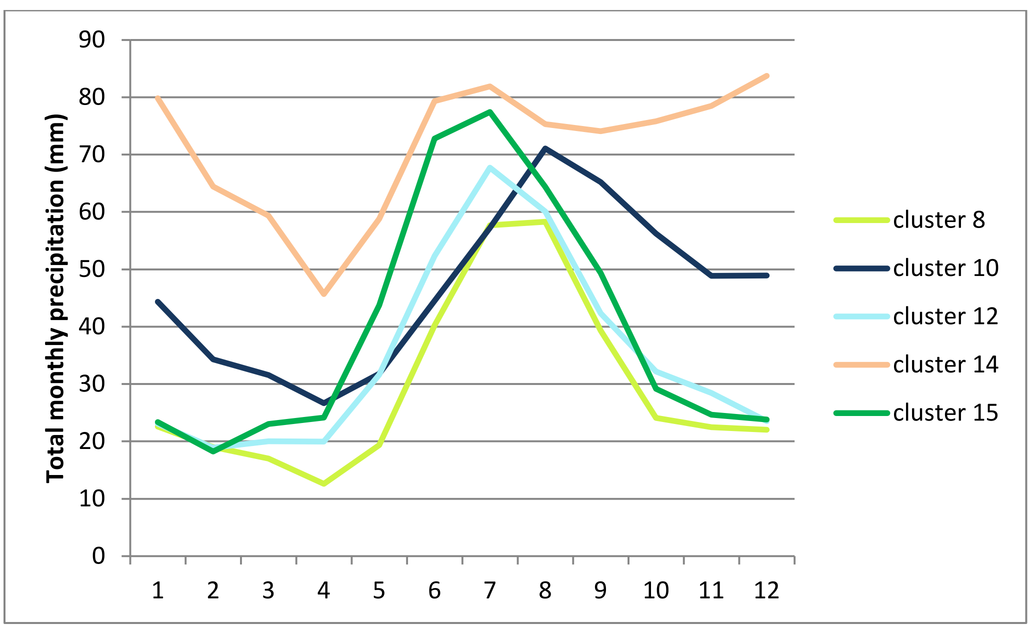


Figure B-21. Dominant cliomes by mean monthly precipitation distribution (numbers correspond to months).

Cliomes and REA Land Cover Classes

To compare cliomes with vegetation types, we looked at the percentage breakdown of vegetation classes in each cliome. These vegetation classes include coarse-filter conservation elements, as well as aggregated categories that are not CEs, such as "unvegetated" land. Vegetation changes can only be posited with reference to these breakdowns, at a relatively broad scale. For this reason, we primarily aggregated these changes at the level of the entire REA, although we also provided some model outputs at the 3rd-level HUC.

Cliome/Land Cover Relationship

The most useful way to view projected cliome shift is to note the projected movement of cliomes with reference to what land managers and local residents know about the ecosystems in the areas where that cliome is found currently. Conclusions may be affected by the relative similarity or dissimilarity of clusters to one another. If no other similar cliome exists to shift into an area when the climate changes, then the model may predict no cliome shift, even though prevailing climate is changing. Conversely, if two cliomes are fairly similar to one another, then a shift between the two may represent only a small ecosystem change.

While there is not a one-to-one correspondence between cliomes and CEs, some patterns are present (Figure B-22). Five cliomes are dominated by spruce forests (8, 9, 10, 12, and 15) with similar proportions of other vegetation classes. Cliomes 11, 14, 16 encompass some spruce forests, but are composed of greater proportions of shrub habitats. Cliomes 13 and 17 represent largely unvegetated habitats.

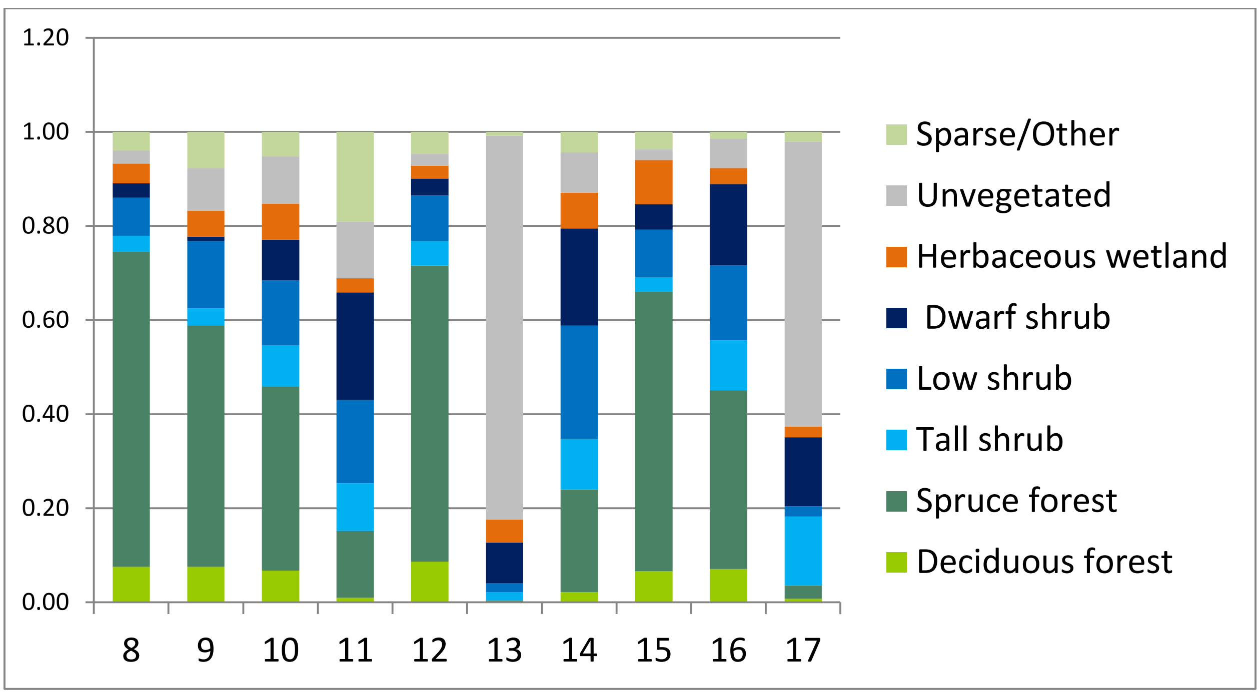


Figure B-22. Cliomes by CEs, unvegetated class, and other classes combined.

While the assumption that a projected shift from one cliome to another results in a shift from the vegetative patterns of the former cliome to the vegetative patterns of the latter is likely not appropriate, we do see a value in exploring the potential for vegetation change associated with alterations to climatic patterns. One should also keep in mind that even if climate is the overriding factor ultimately determining vegetation composition, vegetation patterns may be dissimilar due to a lag time in dispersal and establishment. This lag time can be shortened somewhat if disturbance takes place, such as fire, but change is still slow when viewed at the time scale under consideration.

Projected changes in vegetation classes associated with the cliome shifts are shown for the YKL area in Figure B-23 (where the proportions of vegetation classes are determined by spatial extent of each cliome at the three time steps). The primary pattern from this analysis is an overall decline in spruce forest (and to a lesser extent deciduous forest), and increase in shrubs and other non-forest cover. Examining this result on a cliome-by-cliome basis suggests that the projected loss of area for Cliomes 8 and 12 and a gain in Cliome 14 is primarily responsible for the predicted changes.

While the projected climate change modeling that underlays these results is robust, the response of vegetation communities is speculative. Note that Cliome 10 is projected to expand to the north and east initially and then begins to contract in extent as climate patterns change (Figure B-18). When Alaska and western Canada were modeled as a whole, coastal western Alaska turned out to be one of the most unpredictable areas, due to the difficulty of finding any one cluster that was a perfect fit for new climate conditions. Last, novel climate conditions that do not easily fit in any existing cliome may yield unexpected ecosystem changes.

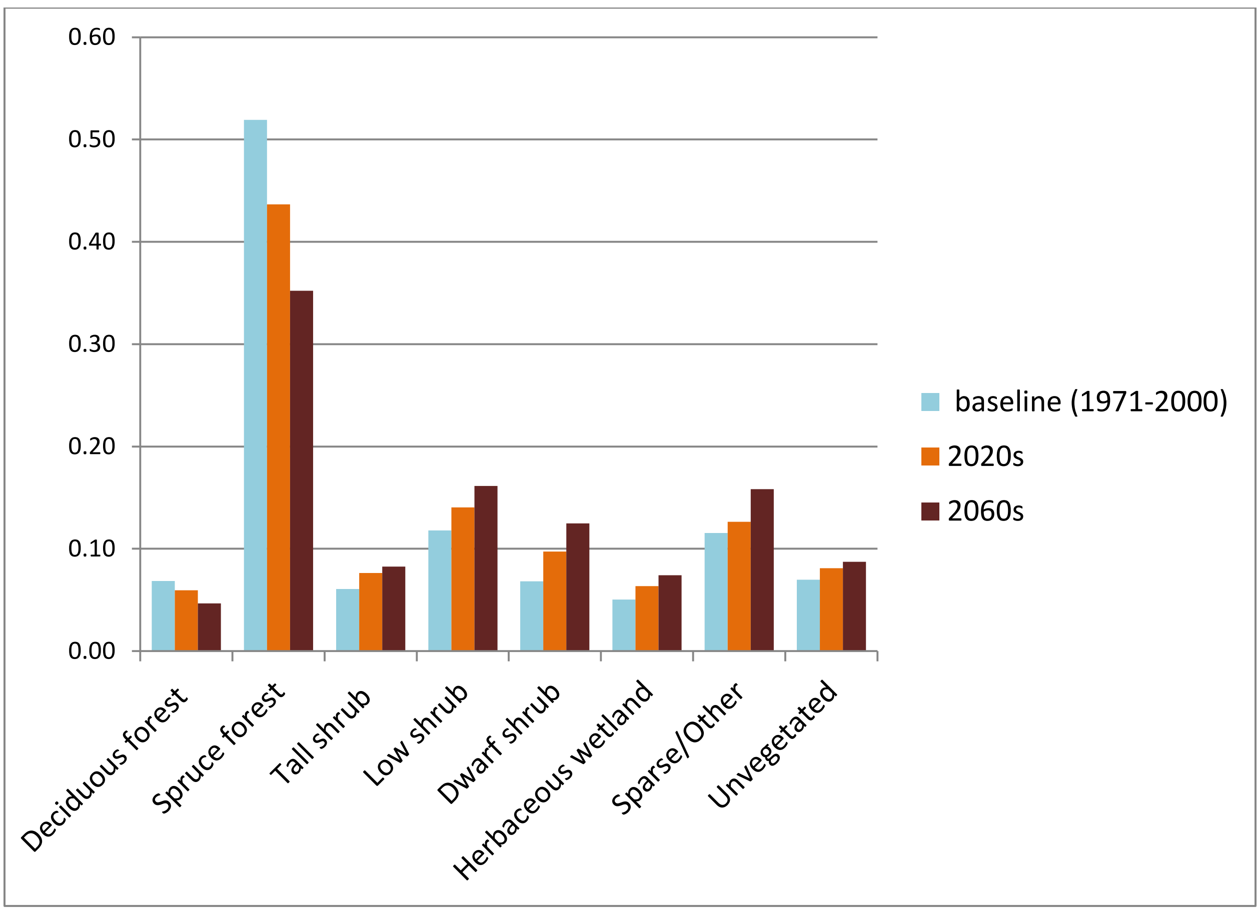


Figure B-23. General projected change in CEs and other land cover classes based on projected cliome shifts.

Impact of Climate Change on CEs

MQ 21	Where will climate change impact CEs, including subsistence species? [Note: this question is also addressed under CEs.]

Despite its limitations, the cliomes model does shed light on potential shifts that may be of interest to managers. The final stage of this analysis included grouping land cover types into those that might be considered preferred habitat for particular species. We then assessed, for the entire YKL, how these categories might increase or decrease, based on linkages between cliomes and land cover types.

These shifts may be abrupt, especially following disturbance. Studies show that some of the larger biomes (e.g., closed-canopy boreal forest and treeless tundra) are rare in intermediate states, suggesting rapid threshold shifts (Scheffer et al. 2012). Because of this stochastic and non-linear element, projections must be assumed to be long-term estimates rather than year-to-year predictors of change.

Figure B-24 shows estimates of current habitat of varying quality for moose, caribou and musk oxen. (Additional outputs based on similar methods are included in report sections on individual CEs in Section D.) Note that these model outputs do not show the precise area of habitat for each species, but rather show the area of land cover classes that include habitat perceived to be poor, moderate, or good for the given species.

Projecting these habitat linkages into future decades yields estimates of potential habitat change. Results for moose, caribou, and musk oxen are shown in Figure B-25 at the level of the entire YKL area. The combined model predicts an overall (although relatively modest) increase in preferred habitat for all three CE species. This can be attributed to projected increases in the shrubby and herbaceous area that provide browse for moose and the grasslands that provide habitat for musk oxen.

Habitat improvements for caribou may be more difficult to validate; although the linkage between cliomes and land cover indicates increases in shrubby categories that include lichen, in reality lichen is slow to establish after fire or other disturbance (Jandt et al. 2008). Moreover, fire destroys existing lichen and shortened fire cycles can hamper the effective reestablishment of lichen (Joly et al. 2012).

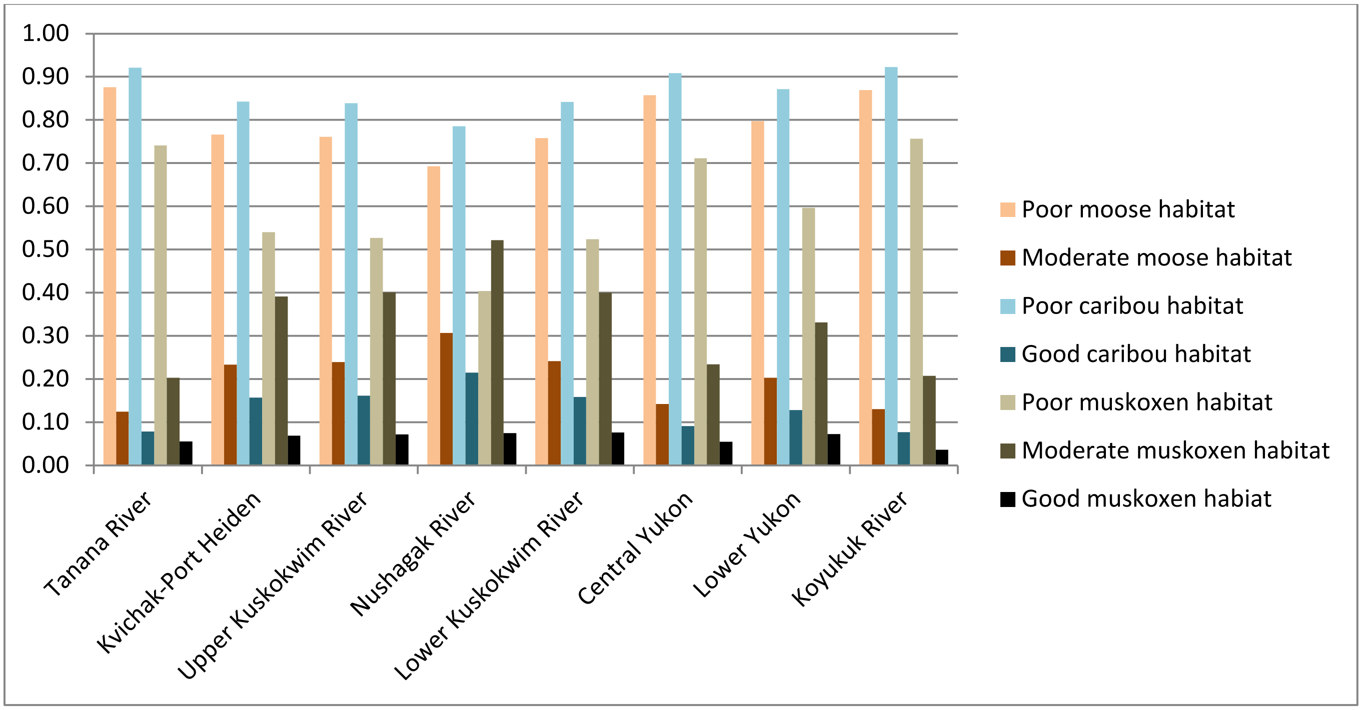


Figure B-24. Habitat quality for selected species on a regional basis (3rd-level HUC) for the current decade (2010s).

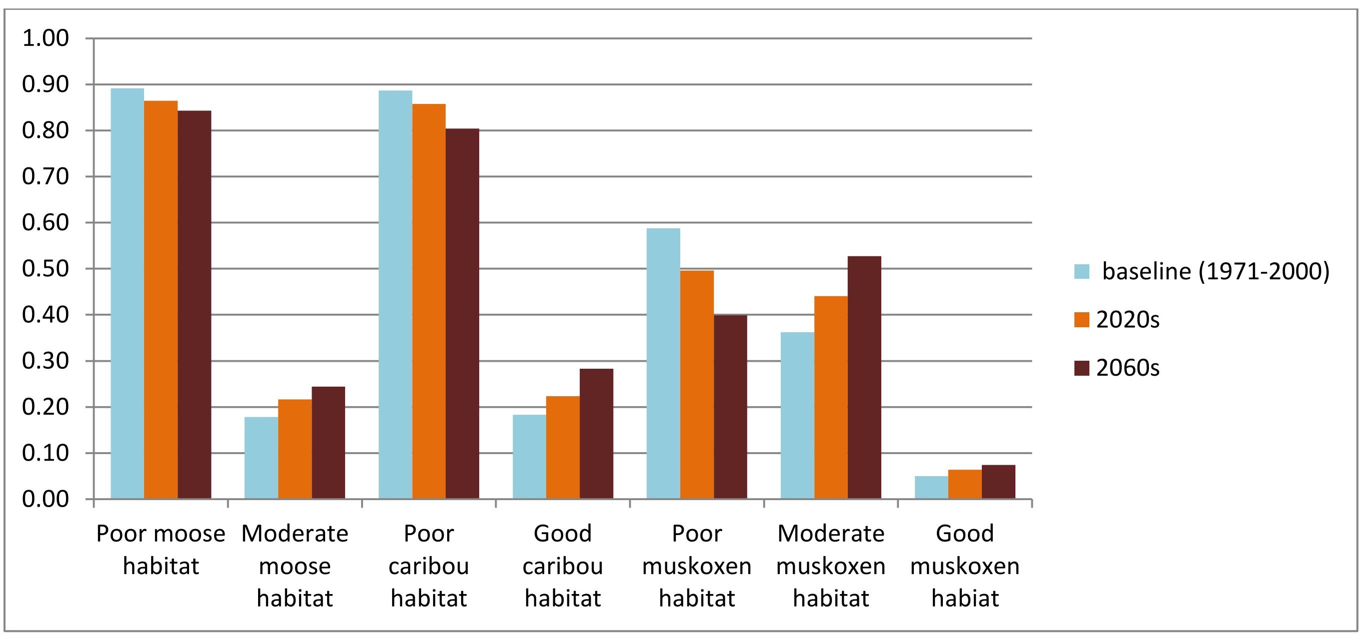


Figure B-25. Projected percentage change between the baseline time period and 2060 in cover types that might serve as habitat for moose, caribou, and musk oxen for the entire REA as modeled by the cliome analysis.

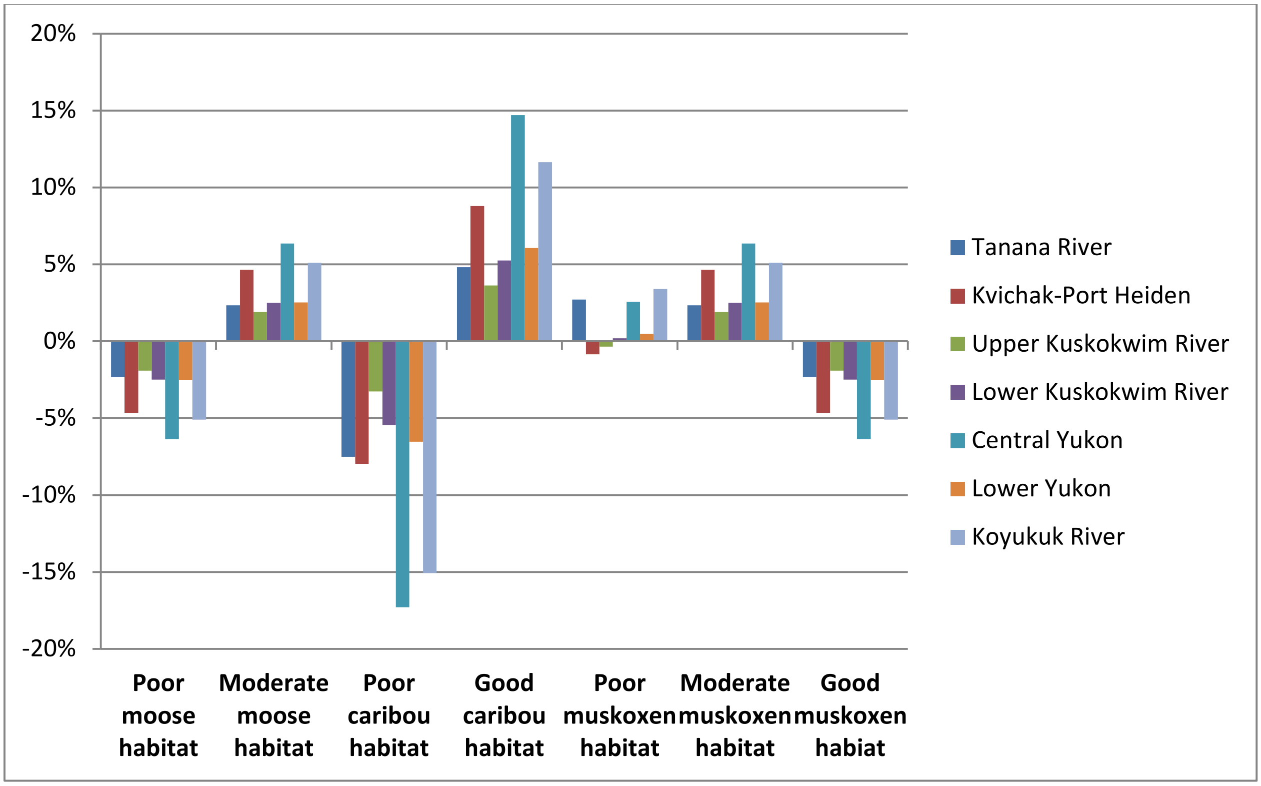


Figure B-26. Projected percentage change in habitat for selected species between the current decade (2010s) and the 2060s.

Applications

Ultimately, the cliomes model is a tool for looking at changing climate variables as an aggregate rather than as distinct monthly datasets. This approach offers a starting point for managers and researchers to develop more specific predictions regarding how vegetation and important habitats may change in the future. Additionally, projected shifts from one cliome to another may not be reflected by immediate vegetation change, but rather by increased stress to existing ecosystem components, or disconnections and asynchronies among species currently on the landscape and those best evolved for newly emerging weather patterns in the region. Projected shifts are likely to increase vulnerability at the landscape level. Conversely, areas projected to undergo little or no cliome change may prove to be more ecologically resilient.

Limitations and data gaps

Given that vegetation categories are broad and encompass many species, this analysis should be viewed only as a very general perspective. Percentage-based relationships between cliomes and land cover classes can be appropriately viewed only as estimates. Time lags can be expected between changes in climate and associated changes in vegetation. In some cases, climate-driven vegetation shift is limited by physical boundaries such as mountains or rivers. Hydrologic change based on warming temperatures may be driven more by thawing permafrost associated soil dynamics than directly by changes in air temperature.

This model also does not take into account the projected increase in fire on the landscape. This factor is particularly important with regard to caribou, since any increase in fire is likely to trigger loss in caribou habitat. While deciduous forest is relatively low across the YKL area, it should be noted that fire is expected to increase, and that vegetation that returns after fire is typically deciduous-dominated in early succession.

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2. Fire

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Summary

Section B-2. *Fire* provides the detailed descriptions, methods, datasets, results, and limitations for the assessments of fire.

2.1. Introduction

This portion of the Technical Supplement addresses fire as a change agent on the YKL landscape, and is primarily concerned with assessing how patterns of fire may change over time, as driven by changes in climate. As such, it links directly to the Climate Change Section (B-1); climate modeling methods described there are not repeated here. Although some fires may be started by humans, fire is considered a non-anthropogenic CA.

This section describes landscape-level model outputs, including the data, methods, and analysis. It touches briefly on feedbacks between fire and other CAs (climate, cliomes, and permafrost); though further information on these interactions can be found in the applicable sections. Here we also provide an overview of potential impacts to conservation elements, although further information on these interactions can be found in sections devoted to CEs (Sections D-1 to D-4).

The Role of Fire on the Landscape

As a change agent, fire can be specifically examined in terms of changing fire dynamics on the landscape, driven by changing climate and ecosystem feedback loops. Fire is a natural feature of the landscape in this region and part of historical and existing ecosystem processes (DeWilde and Chapin 2006).

Fire disturbance plays a key role in the interplay between vegetation and changing environmental conditions, because fire initiates cycles of secondary succession and creates opportunities for landscape change at the level of biomes or ecosystems (Johnstone et al. 2010). A system that has been primed for change by shifting climate may not change gradually, but rather in a threshold shift after a fire event, as a novel successional pathway replaces the previous pathway.

Connecting Past, Present, and Future

Assessment of fire as a change agent includes both modeling potential change in fire behavior and linking that potential change to possible associated changes in landscapes and ecosystems. Thus, the effort must include three key components:

1. analysis of spatially and temporally explicit historical fire data, in order to ascertain what fire patterns have created the current assemblages of post-fire-successional landscapes, and can thus be considered historically typical;
2. review of pertinent literature looking at post-fire succession and linking fire with landscape change and ecosystem change, thus allowing connections to be made between data on fire return intervals and data on ecosystem characteristics;
3. creation and analysis of model outputs of projected fire frequency by region, on a spatial basis and/or a percentage/risk basis.

The Role of Modeling

Modeling and analysis of changes in fire frequency can shed light on multiple aspects of future ecosystem function, including human/landscape interactions. Fire modeling allows for some assessment of impacts on terrestrial habitats (with mammals and birds secondarily influenced by habitat change), including fire-induced changes in broad habitat type (deciduous forest, black spruce forest, white spruce forest, grass/tundra, and snow/ice/rock), as well as in mean age or successional stage of each cover type. Fire modeling does not allow for assessment of impacts to most vegetation at the species level or at the level of fine-scale vegetation classifications used elsewhere in the project.

Fire modeling can also be coupled with analysis of fire impacts on permafrost, based on qualitative information from the literature on the influence of fire on permafrost. This analysis does not include separate fire-linked spatial predictions (see soil thermal dynamics for permafrost modeling section B-3).

2.2. Methods

Fire was modeled using ALFRESCO (Alaska Frame-based EcoSystem Code, shown in Figure B-27) in the larger context of a projected future fire regime and its effects on major vegetation classes. Climate projections, past fire history, and current vegetation patterns were used to model patterns of fire frequency across the landscape.

ALFRESCO simulates the responses of 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, the model assumes that vegetation composition and continuity serve as a major determinant of large, landscape-level fires.

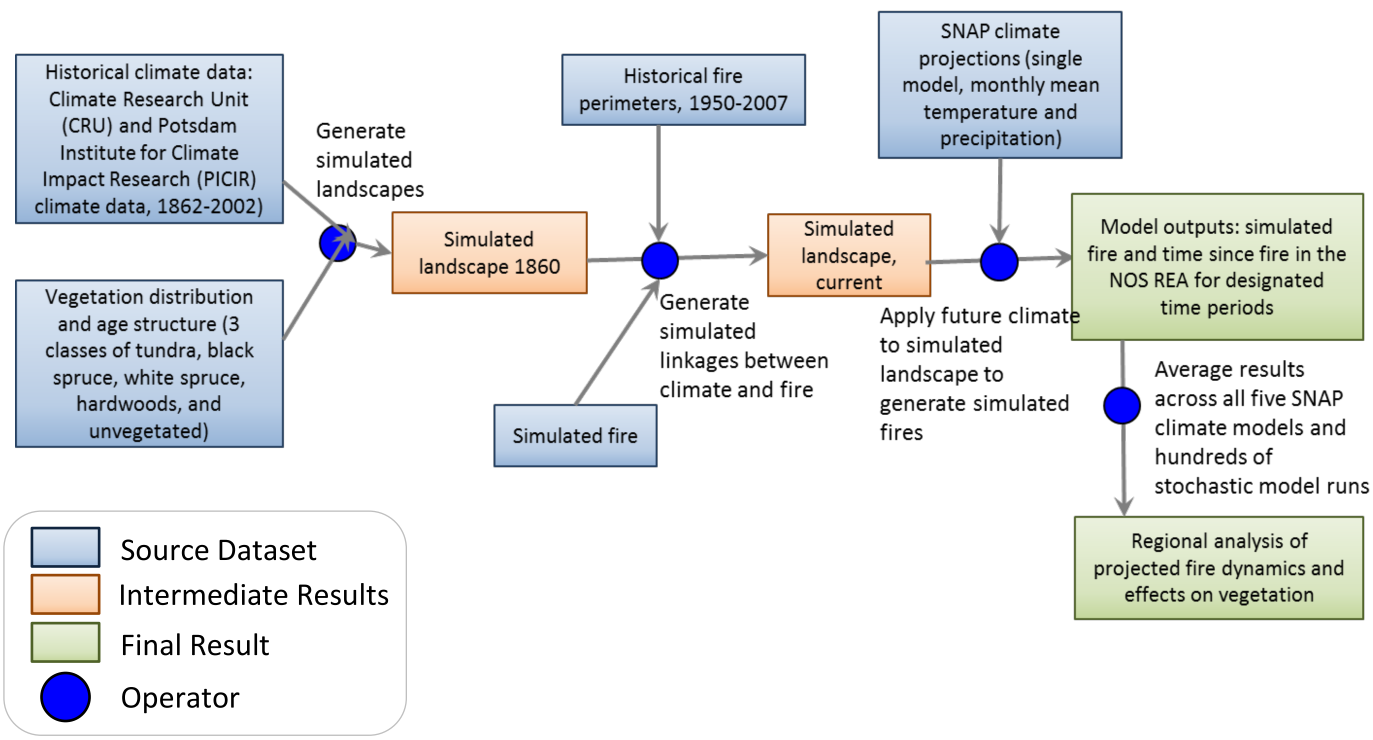

Figure B-27. Process Model of ALFRESCO Fire Simulation Methodology.

ALFRESCO operates on an annual time step, in a landscape composed of 1 × 1 km pixels. The model simulates a range of ecosystem types, including three distinct types of tundra, black spruce forest, white spruce forest, deciduous forest, and grassland-steppe.

SNAP climate data can be used as ALFRESCO inputs, thus creating projections of the impacts of changing climate on fire regime. ALFRESCO does not model fire behavior but rather models the empirical relationship between growing-season (May–September) climate (e.g., average temperature and total precipitation) and total annual area burned (i.e., the footprint of fire on the landscape). ALFRESCO also models the changes in vegetation flammability that occur during succession through a flammability coefficient that changes with vegetation type and stand age (i.e., succession) (Chapin et al. 2003).

The model focuses on system interactions and feedbacks. The fire regime is simulated stochastically and is driven by climate, vegetation type, and time since last fire (Rupp et al. 2007). ALFRESCO employs a cellular automaton approach, where simulated fire may spread to any of the eight surrounding pixels. "Ignition" of a pixel is determined as a function of the flammability value of that pixel and a randomly generated number (Rupp et al. 2002). The flammability of each pixel is a function of vegetation type and age, meaning that ignitions will be concentrated in pixels with the highest fuel loads and the driest climate conditions. Fire spread depends on the flammability (i.e., fuel loading and moisture) of the receptor pixel. Some pixels, e.g., non-vegetated areas and large water bodies, do not burn and thus serve as fire breaks. Suppression activities were not simulated.

ALFRESCO has been calibrated using available literature regarding burn rates and stand compositions (Rup et al. 2007). However, most of these data came from interior Alaska. In addition, the model is calibrated through use of a "spinup" period of 1000 years of simulated fire history, in order to match outputs as closely as possible to historical fire patterns. The model parameters derived during this spinup period are then used to create future projections.

ALFRESCO outputs do not include fire severity (for which there is no data) or exact spatial/temporal predictions of future fires, since the stochastic nature of fire starts and fire behavior is better represented via averaging outputs across multiple model runs. Outputs also do not include historical or projected lightning, except in broadly qualitative terms based on literature review, due to lack of consistent past data and lack of reliable models for projected lightning. Although some ALFRESCO iterations allow for vegetation shifts between classes (rather than merely between successional stages) after fire, such shifts could not be properly calibrated for this project. Thus, areas that were assessed (forested areas only) are assumed to remain in the forest class throughout, albeit in different stages of forest succession (deciduous or spruce) depending on time since last fire.

Model Inputs

ALFRESCO inputs include historical climate data obtained from the Climate Research Unit (CRU) and Potsdam Institute for Climate Impact Research (PICIR). In the original version of the model (1.0), vegetation types included white spruce and black spruce (each with an early-succession deciduous stage), upland tundra, and grassland.

In ALFRESO 2.0, tundra classes are differentiated into upland, graminoid, and shrub tundra. Fire modeling for tundra systems had been successfully calibrated; however, calibration results for model projections for mixed forested and non-forested areas with complex transitions between all cover classes proved to be unsatisfactory. Thus, these outputs were not used in this report; results described below are limited to projections of forest fire.

Model Stochasticity and Implementation

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 were not modeled; rather the model projected average fire frequency and extent across the landscape to ultimately model changes in vegetation patterns and distribution.

Outputs include 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.

Given limited time for model calibration and limited data on tundra fire (due to the extreme rarity of such fires in the past), tundra modeling results were not considered robust enough for inclusion in this assessment. Boreal forest outputs, however, were well calibrated across the REA region. In addition, model limitations did not allow for one-to-one correspondence between the cover types (vegetation classes) used in the ALFRESCO model and the vegetation classes identified as coarse-filter CEs.

Table B-11. Source datasets used in the analysis of fire as a CA for the YKL REA.

Dataset Name	Data source
Stochastic ALFRESCO model runs, mean of five separate models and 100+ runs, based on SNAP climate projections; vegetation outputs	SNAP, ALFRESCO
Stochastic ALFRESCO model runs, mean of five separate models and 100+ runs, based on SNAP climate projections; fire frequency outputs	SNAP, ALFRESCO
BLM Fire Scar Map	BLM

2.3. Results

Fire History

MQ 22	What is the fire history of the ecoregion?

Historical data on fire in this region are available from the BLM. The available reliable data starts in 1940. Given that remote sensing, GIS, and other fire detection and mapping technology has improved radically during the past 75 years, historical analysis of fire are limited to assessing overall size of burn scars. Although burn severity is a very important factor in determining long-term ecological outcomes post-fire, detailed information on patchiness of burns or severity of burns is, unfortunately, not available.

In Figure B-28, fires are grouped by decade, from the 1940s to the 2010s (the current decade being incomplete, with data through 2013). As can be clearly seen from this map, fires are highly variable in both size and location, and some decades saw markedly more fire activity than others. This variability adds to the challenge of fire modeling, and means that model outputs must be viewed on a broad rather than a fine scale, both temporally and spatially. Nonetheless, some clear historical patterns do emerge. For example, fire has been far less frequent – indeed, mostly absent – in the southern portion of the REA. However, even in the most fire-prone areas (e.g., to the northwest) some significant land areas have not burned in the last 73 years.

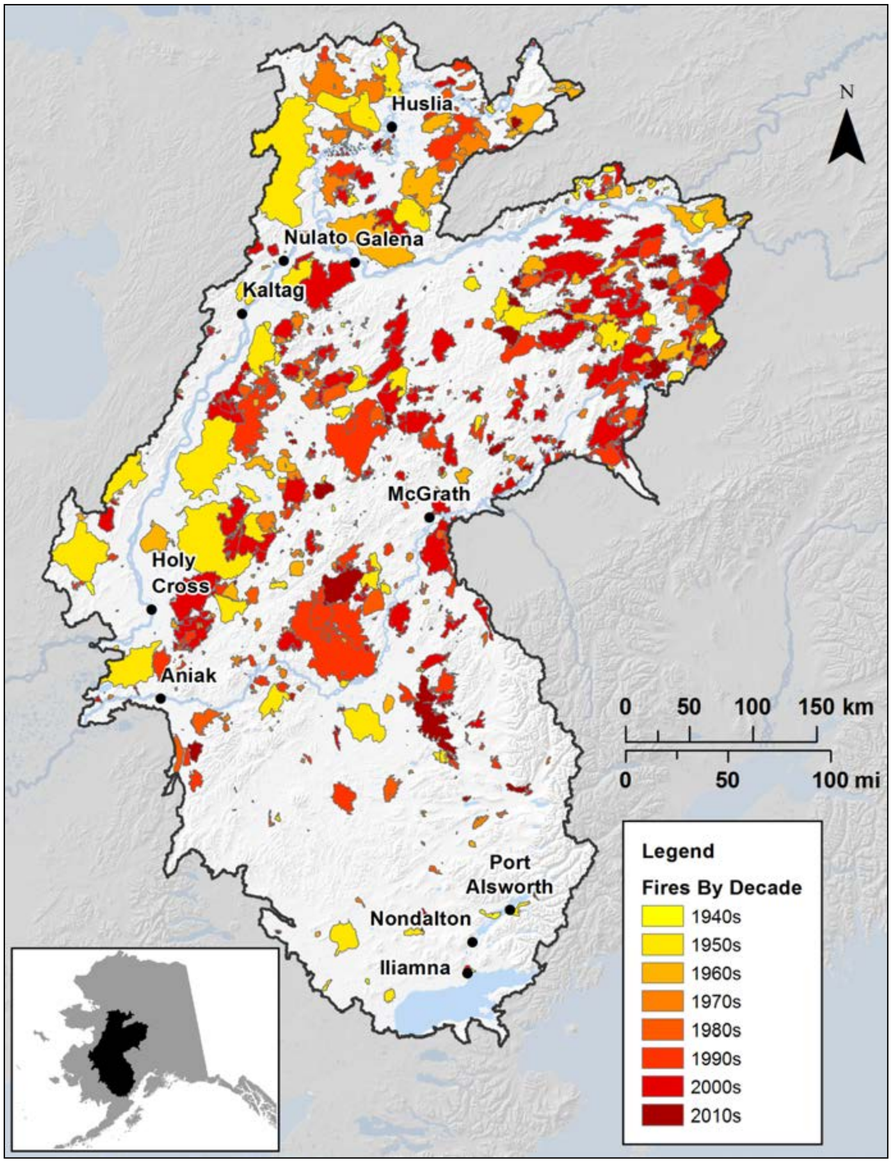

Figure B-28. Historical fire scars in the REA show greater fire activity in the northern portion of the REA, which is both drier and more forested.

Fire Frequency and Return Interval

MQ 24	What is the current frequency (return interval) and the likely future frequency for fire in the ecoregion and broad sub-regions?

Overall, ALFRESCO predicts increased fire frequency for forested areas across the YKL area, or in other terms, a shortening of fire return intervals, as seen in Figure B-29 and summarized in Table B-12. The percentage of each sub-region that was considered “forested” under the starting conditions was dictated by the adapted NALCMS data used as vegetation input in ALFRESCO. All regions except for Kvichak-Port Heiden were more than 80% forested. Percent burned represents the percentage of forest burned per year for that decade. The percent burned for the entire ten-year period (i.e., decadal burn) is thus ten times that percentage.

For the current time period, annual percentage of forested land burned was 0.55% to 0.89% for all sub-regions. This equates to an average fire-return interval of 112 to 182 years.

Future projections show fire cycles shortening markedly in forested areas of the study region. In just one decade (between the 2010s and 2020s) fire is projected to increase to 0.71% or more for all sub-regions in the YKL area, and by the 2050s and 2060s, the predominant categories show between 0.81% and 1.25% burning annually. This translates to a fire return interval of roughly 80-120 years. Given that this represents an average across 3rd-level HUCs, some more flammable areas within these broader regions would likely be expected to experience even shorter return intervals.

The fact that the ALFRESCO model predicts a higher rate of burn in the 2020s and 2050s than in the 2060s could be an artifact of the stochastic nature of the model. However, it might also reflect the fact that when an area burns, it is less likely to burn again for many decades thereafter. Thus, if fire increases for a period of time, it will eventually stabilize at a new, shorter fire return interval. ALFRESCO models predict that this may occur throughout the boreal zone.

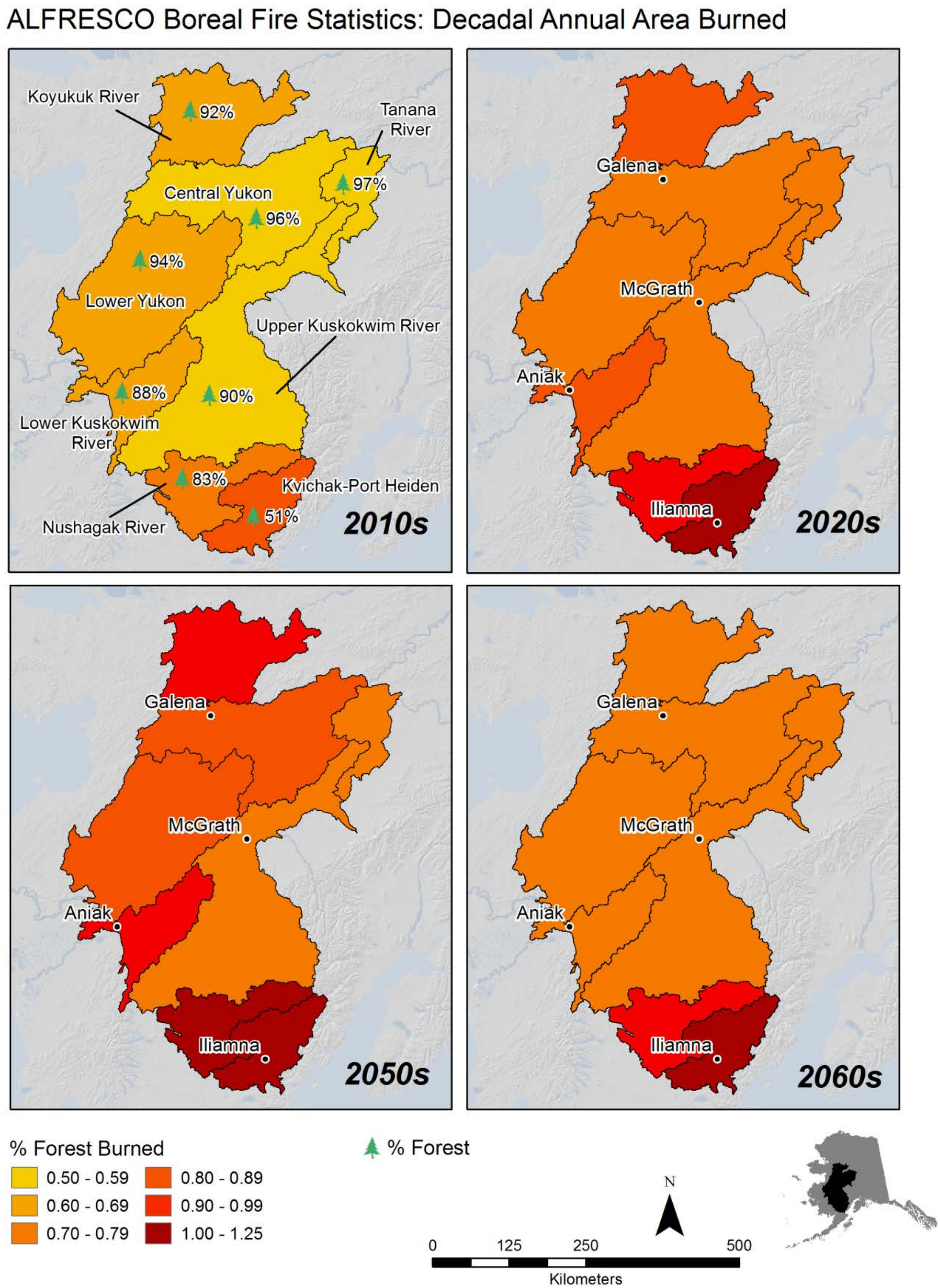

Figure B-29. Projected average annual burned area on forested land within sub-regions, based on ALFRESCO model outputs averaged across 500 stochastic runs. Percentage of sub-regions classified as forested is indicated for the current condition.

Table B-12. Summary of ALFRESCO fire modeling outputs by watershed (3rd-level HUC).

Watershed (3rd-level HUC)	**Percent annual burn, forested land**				**Fire return interval, forested land**			
	2010s	2020s	2050s	2060s	2010s	2020s	2050s	2060s
Tanana River	0.55	0.72	0.75	0.75	182	139	133	134
Kvichak-Port Heiden	0.89	1.06	1.23	1.01	112	94	81	99
Upper Kuskokwim River	0.57	0.73	0.76	0.72	174	137	131	138
Nushagak River	0.77	0.99	1.08	0.95	130	101	92	105
Lower Kuskokwim River	0.69	0.82	0.90	0.78	146	122	111	127
Central Yukon	0.57	0.70	0.80	0.73	175	143	125	137
Lower Yukon	0.62	0.77	0.82	0.73	161	129	122	137
Koyukuk River	0.61	0.82	0.92	0.73	164	122	108	137

Recent analyses suggest that changes in fire frequency on Alaska's landscapes may be driven at least as much by climate-induced changes in vegetation as they are by climate-induced changes in fire frequency (Starfield and Chapin 1996). ALFRESCO is directly linked to both climate and vegetation, and is also capable of modeling shifts in post-fire trajectories of succession that are climate-derived. This model does not directly incorporate vegetative change that may occur in intermediate successional stages. As fire cycles shorten, it is expected that fire frequency will ultimately stabilize at new, more frequent intervals. Historical evidence suggests that such a regime can persist, under warm conditions (Kelly et al. 2013).

Climate Impacts on Fire

MQ 23	What climatic conditions are likely to result in significant changes to fire activity?

Not only does fire play a crucial role in governing ecosystem processes in interior and arctic Alaska (Johnstone et al. 2010) but, driven by warming summers, fire appears to already be increasing in frequency (Kelly et al. 2013) and intensity (Genet et al. 2013), resulting in altered ecosystems and processes (Wolken et al. 2011). July temperature is the most frequently occurring predictor across all models linking climate variables and area burned in the Western boreal forests of North America (Balshi et al. 2009). Fuel moisture for all summer months was a key predictor of area burned. Moreover, the results of this analysis suggest that average area burned per decade will double by 2041-2050, relative to 1991-2000. However, the complex feedbacks between increased fire frequency, resulting vegetation shifts, and subsequent fire are poorly understood and require further study (Balshi et al. 2009).

Climate-driven changes in fire have been estimated to have greater impacts on ecosystems than the direct impacts of warming climate, particularly for black spruce forests. The interplay between fire, vegetation, and other ecosystem variables is complex, and can best be addressed using a combination of long-term ecological studies and modeling. Transitions may be abrupt following fire. Boreal forest does not decline gradually in tree cover toward its limits, but may instead shift rapidly into a sparse woodland or treeless state (Scheffer et al. 2012). Black spruce are expected to retain dominance in many areas of the boreal zone, and both black spruce and deciduous forest may expand in range, while white spruce are likely to be moisture limited on drier sites (Calef et al. 2005).

In tundra systems, more frequent fires are expected, but data on long-term effects are limited. Examination of post-fire succession on the North Slope suggests that partial replacement of tundra by graminoid-dominated ecosystems is likely (Barrett et al. 2012).

Applications

Results from this section are not directly interlinked with results from cliome/vegetation modeling and permafrost modeling. However, outputs tend to corroborate cliome outputs with regard to predicting some decline in forest cover in favor of shrub cover. If forest cover declines substantially, or if early-succession forests become much more prevalent, fire frequency is likely to stabilize, since these landscapes are less fire-prone than stands of black spruce and white spruce. Feedbacks with changes in soil thermal dynamics are not clear-cut, but will be discussed further in the permafrost section of this report.

Tundra

ALFRESCO outputs presented in this assessment do not include quantitative analysis of tundra fire, due to imperfect model calibration. However, qualitative assessment via literature review suggests that fire has been increasing in tundra systems, and is likely to continue to do so in the foreseeable future. Moreover, the literature shows that marked ecosystem change has been occurring in recent decades, particularly with regard to decreases in terricolous lichen ground cover and biomass. These changes are attributed to disturbance by caribou and reindeer and to warming climate, which in turn affects fire and plant growth (Joly et al. 2009). Tundra fires, when coupled with ongoing climate change, can trigger new successional pathways, thus facilitating the invasion of tundra by shrubs (Jones et al. 2013).

Since lichens are the primary winter food source for caribou herds in Alaska, decreases in lichen cover or a shift from lichens to shrubs may have repercussions for subsistence users. This relationship is further explored in the Terrestrial Coarse- and Fine-Filter Sections D-1 and D-2.

Forest

For forested areas, which make up the preponderance of the YKL region, shorter fire cycles are likely to alter the relative proportions of early-succession vs. late-succession vegetation. In general, this is likely to mean that shrubby (e.g., alder and willow) and herbaceous early-succession vegetation and hardwoods (e.g., birch, cottonwood, and aspen) are likely to become relatively more prevalent, while old stands of black spruce and white spruce may become less common.

Such changes would be likely to increase the proportion of the landscape that serves as habitat for wildlife species such as moose that depend on early-succession vegetation. These relationships are discussed more extensively in the Terrestrial Coarse- and Fine-Filter Sections D-1 and D-2.

Limitations and Data Gaps

ALFRESCO is not suited to fine-scale analysis at either a temporal or spatial level, due to the stochastic nature of its outputs. Thus, interpretation should be considered more broadly, in terms of trends over time, rather than in terms of specific fire behavior at particular sites. Given that data were not available regarding fire severity, either in the historical data or via model outputs, we could not analyze the impacts of this important factor, except via literature review.

Difficulties in calibrating the ALFRESCO model to the strict standards insisted upon by the modeling team meant that model outputs were limited to forested areas, and did not include potential tundra fires.

Because the ALFRESCO model is not directly linked to either the climate/vegetation (cliomes) model or the permafrost model used in this assessment, feedback between vegetation, fire, and soil thermal dynamics could be considered only qualitatively, not quantitatively.

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3. Soil Thermal Dynamics (Permafrost)

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Summary

Section B-3. *Soil Thermal Dynamics (Permafrost)* provides the detailed descriptions, methods, datasets, results, and limitations for the assessments of changes in permafrost.

3.1. Introduction

This portion of the Technical Supplement addresses permafrost as a change agent on the YKL landscape, and is primarily concerned with assessing how soil thermal dynamics may change over time. As such, it links directly to the Climate Change section of the Technical Supplement; climate modeling methods described there are not repeated here. Given that human effects on climate are global rather than proximal, for the purposes of this project permafrost is considered a non-anthropogenic CA.

This section describes landscape-level model outputs, including the data, methods, and analysis involved in this modeling. It touches briefly on feedbacks between permafrost and other CAs (fire and climate). Additional information on these feedbacks can be found in the applicable sections. This section also provides an overview of potential impacts to conservation elements. Further information on these interactions can be found in Section D. Conservation Elements.

The Role of Permafrost

Permafrost can be simultaneously considered a conservation element and change agent. Loss of permafrost can have profound effects on ecological systems as well as on human uses and economic endeavors. Permafrost presence and absence cannot be directly assessed except by measurements (e.g., soil cores); modeling of soil thermal dynamics, however, can help estimate the state of permafrost across larger areas.

Assessments of soil thermal dynamics include estimates, based on models that use multiple input datasets, of existing and projected active layer thickness and mean annual ground temperature at 1 m depth, both at 1 km grid cell resolution. Based on these modeling efforts, it is possible to perform a broadly regional assessment of areas in which permafrost thaw may occur, and areas in which thaw is less likely.

Based on this permafrost modeling, broadly regional assessment of the potential effects of these changes on hydrology is also possible. Such models can also be used to estimate the influence of permafrost thaw and associated hydrologic change on terrestrial habitats, with qualitative discussion of potential impacts, particularly with reference to hydrologic change.

Similarly, influence on aquatic habitats can be estimated, including qualitative discussion of potential impacts, particularly with reference to hydrologic change. However, such assessments do not include specific predictions at the pixel level of permafrost thaw or associated hydrologic change, impacts on terrestrial habitats, or influence on aquatic habitats.

Historical and Current Conditions

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.

3.2. Methods

The main components of the permafrost model are represented in the general ecosystem conceptual model. As shown in Figure B-30, 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, as described below.

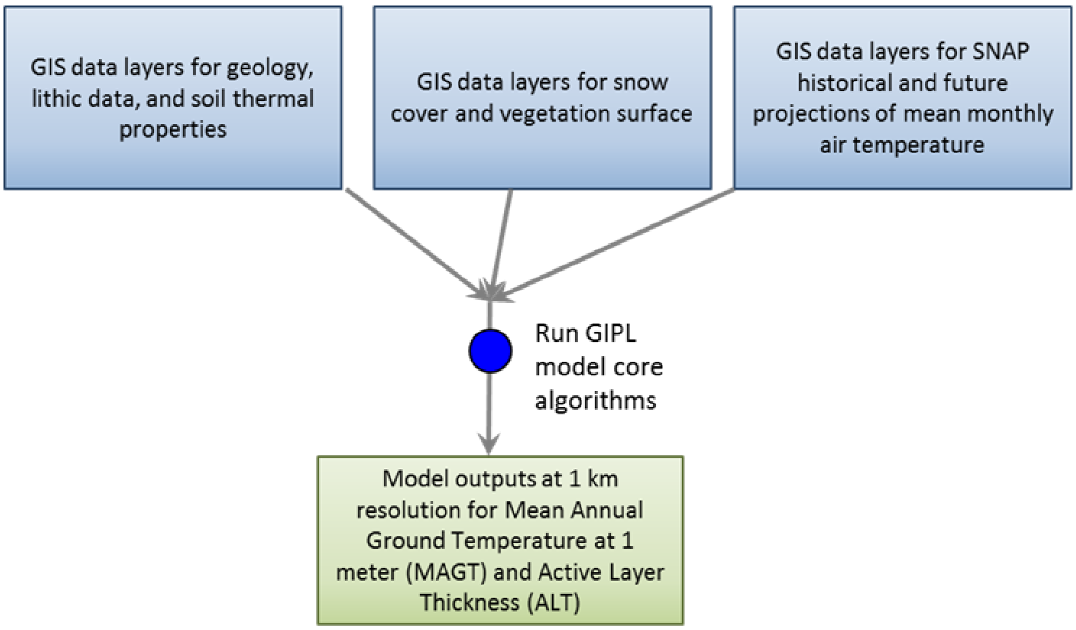

Figure B-30. Process Model of Permafrost Modeling Techniques.

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 (MAGT) at one meter depth, and the active layer thickness (ALT).

MAGT is a relatively straightforward metric, since temperatures below freezing represent permafrost and those above freezing indicate unfrozen ground. However, it should be noted that extensive deeper permafrost may still occur in areas projected to be thawed at one meter. Such deep permafrost has smaller impacts on vegetation and draining than shallow permafrost.

ALT is a more complex metric, in that it represents two different outputs: the depth of seasonal (summer) thaw, for areas with permafrost at one meter depth, and the maximum depth of seasonal (winter) freezing, for areas that are free of permafrost. In other words, for areas without shallow permafrost (ground perpetually frozen at one meter) how deeply does frost penetrate by the end of each winter? And for areas with shallow permafrost, how deeply does the thaw penetrate by the end of each summer? Since these two datasets are mutually exclusive, they can be shown on a single map. Both have strong implications for what plant species can thrive in a given area.

Together, these properties (MAGT and ALT) delineate the presence and local extent of permafrost. The model is ground-truthed and validated using cores from around the state.

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 1 km. Outputs provide a general approximation of areas likely to undergo some degree of thaw and associated hydrologic changes.

Table B-13. Source datasets for the analysis of permafrost as a CA in the YKL REA.

Dataset Name	Data Source
GIPL model outputs for mean annual ground temperature at one meter depth (MAGT) based on GIPL core model and SNAP monthly temperature projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP/GIPL
GIPL model outputs for active layer thickness (ALT) based on GIPL core model and SNAP monthly temperature projections, CMIP3/AR4, A2 emissions scenario, 5-model average, 771m resolution, decadal means, 2010s, 2020s, 2050s, 2060s.	SNAP/GIPL

3.3. Results

In general, results show loss of permafrost across the YKL, with areas of discontinuous permafrost becoming more completely thawed, and colder permafrost becoming discontinuous. These changes can be expected to vary at a fine spatial scale, but associated changes to hydrology and vegetation may occur more broadly.

Current and Future Soil Thermal Dynamics

MQ 16	What are the current soil thermal regime dynamics?
MQ 17	Based on the predictions of the best available climate models and soil temperature models, how will soil thermal regimes change in the future?

Mean Annual Ground Temperature

Projected changes in MAGT between the current decade and future decades out to the 2060s are shown in Figure B-31. Areas shown in blue on these maps represent regions with relatively continuous cold permafrost, and areas shown in orange have very little permafrost. The greatest degree of change can be expected in the zones that lie between these two extremes, where a great deal of discontinuous permafrost is expected to thaw in the next fifty years.

In areas where much of the permafrost has already been lost, future change is likely to be less than in areas that currently retain permafrost, but which are close to that temperature threshold. This includes much of the central portion of the YKL area.

Changes in hydrology, drainage, and vegetation associated with MAGT are discussed in Section D, concerning pertinent Coarse- and Fine-Filter CEs.

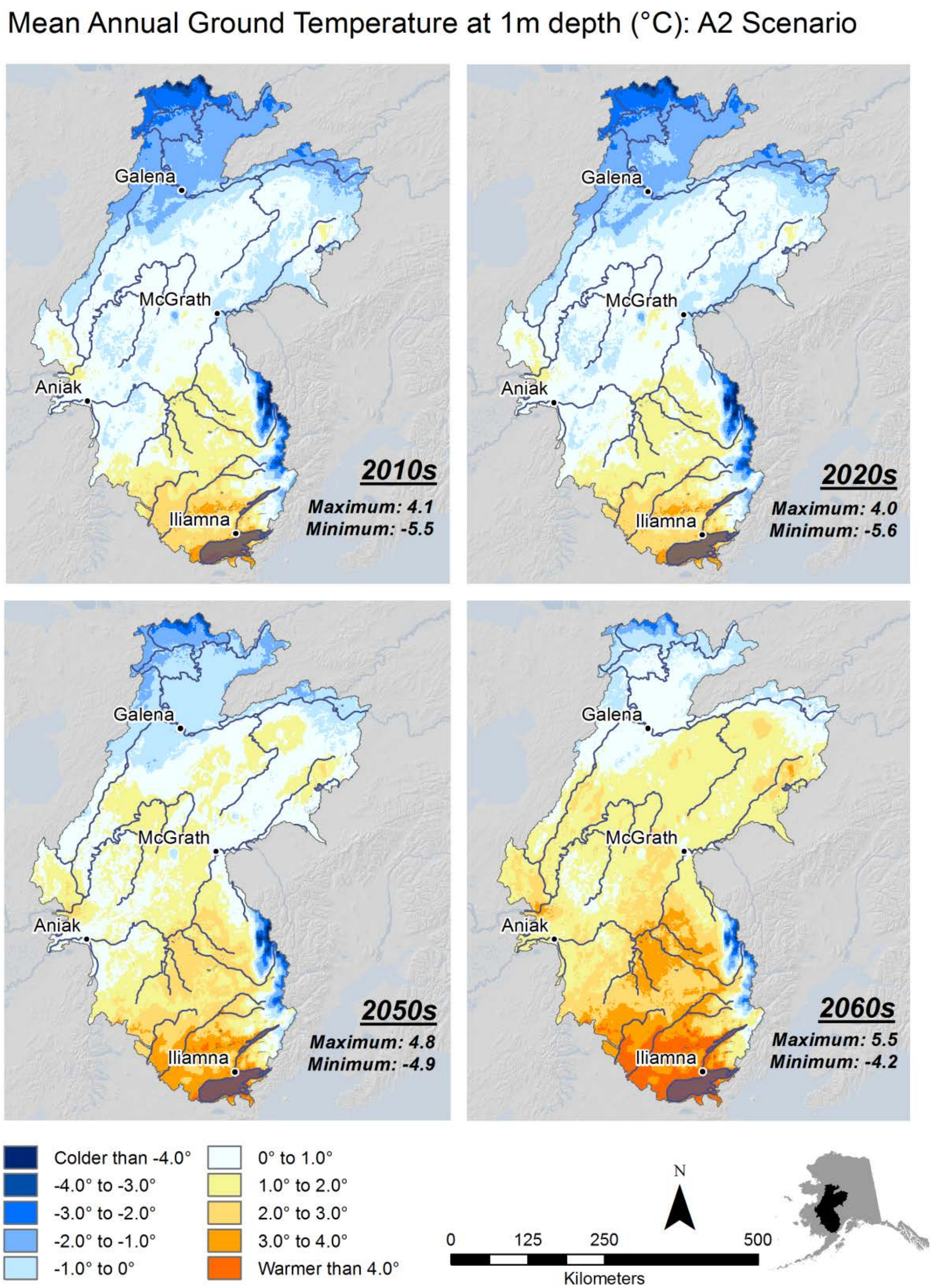

Figure B-31. MAGT projections based on SNAP climate inputs into the GIPL permafrost model. Significant thaw is projected across much of the REA.

Active Layer Thickness

Active layer thickness is expected to increase in areas dominated by permafrost (orange areas to the north), while the depth of seasonal freezing is expected to be less in non-permafrost areas (Figure B-32).

Active layer thickness is correlated closely with vegetation; even slight changes in active layer thickness can trigger threshold shifts from tundra to shrubland or from shrubland to forest, based on minimum rooting depths of the species in question. Thus, the projected changes in ALT may affect dominant vegetation, as well as the wildlife species that depend on this vegetation for forage or cover.

Active layer thickness is also a strong predictor of hydrologic dynamics, with regard to water availability, stream flow, and formation or drainage of wetlands. Deeper active layers are generally associated with greater drainage and drier surface conditions, but outcomes are highly site-specific. Thus, as permafrost thaws, water availability may become greater in some micro-sites and less in others.

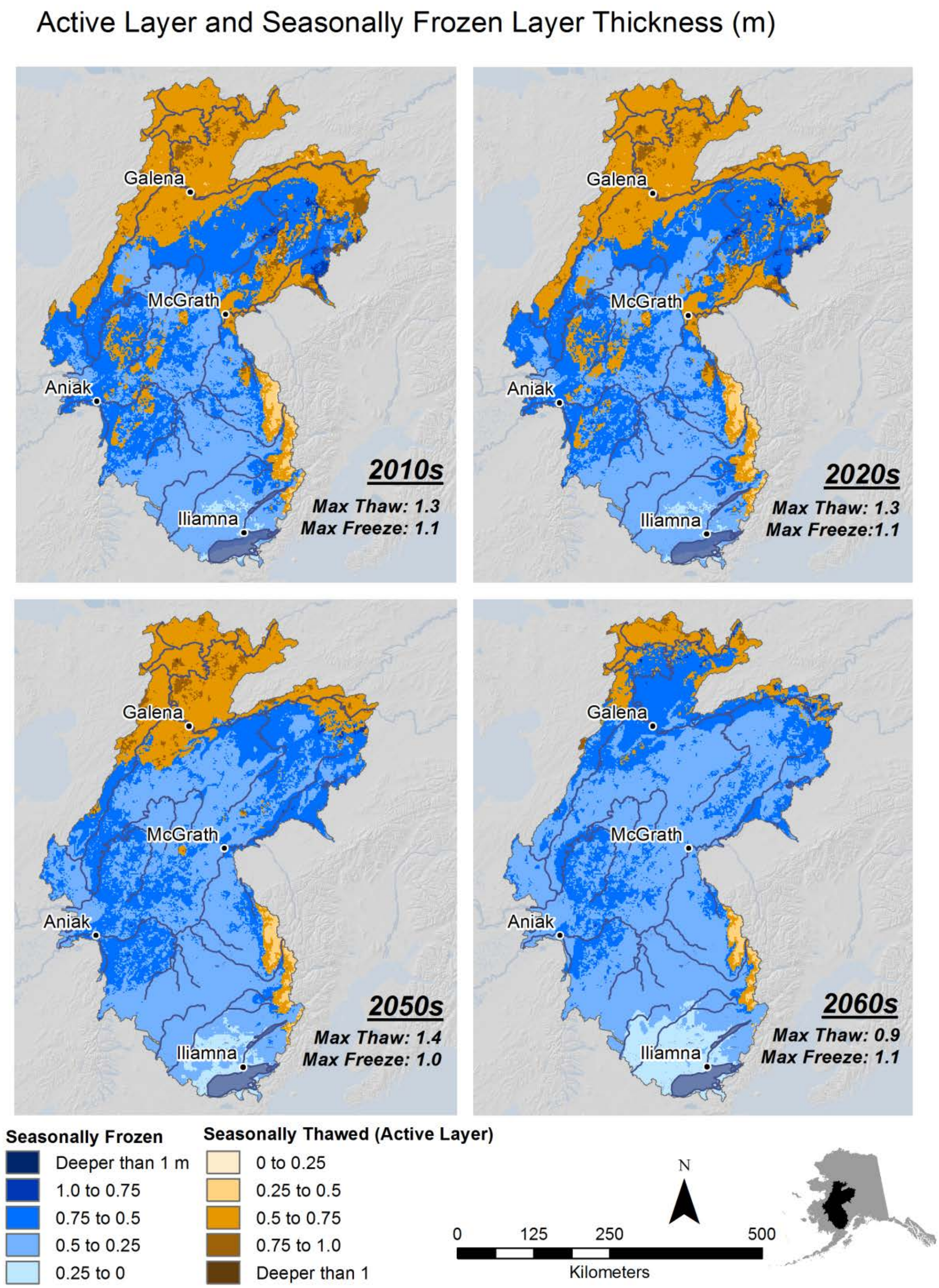

Figure B-32. Projected active layer thickness and depth of seasonal thaw. Projections indicate that in areas lacking permafrost at 1m depth, winter depth of freeze is likely to become shallower, while in permafrost areas, summer thaw will become deeper.

Applications

Permafrost thaw has been shown to lead to fundamental changes in vegetation, water storage and flow paths (Jorgensen et al. 2013). Around lakes and other water bodies, permafrost thaw has been shown to alter ecosystem dynamics. Retrogressive thaw slumping represents an important stressor to the biological communities of lakes, typically reducing nutrient availability (Thienpont et al. 2013). In upland areas, permafrost thaw may increase drainage to the point of creating drought stress for white spruce and other water-limited species.

Although permafrost models are not directly linked with fire and vegetation models used in this study, the literature suggests that interaction between these variables may result in tree line advance in areas with increasing ALT and drought risk in areas where drainage increases; such changes may accompany a shift from coniferous forests to deciduous forests. Some researchers question whether species migration will be able to keep pace with climate change (Garamvoelgyi and Hufnagel 2013).

Limitations and Data Gaps

The outputs of permafrost modeling and mapping are imperfect, despite being based on the best available data layers. Uncertainty is present at multiple levels, stemming from the inherent uncertainties of climate modeling (discussed in the applicable section of this report) and the uncertainty associated with linking climate to soil thermal dynamics.

The feedbacks between permafrost thaw and vegetation change are not always clearly understood. Moreover, these threshold dynamics are complicated by feedbacks between fire, vegetation, and climate. Permafrost can thaw very rapidly following fire, especially if the organic layer is consumed, but, stochastic models cannot predict the exact timing, location, or intensity of fires.

The joint SNAP/GIPL model represents, at best, data for climate, soils, insulating vegetation and other key variables at 1 km resolution. Discontinuous permafrost can vary at scales much finer than this, due to variable slope and aspect, drainage patterns, and numerous other factors. Managers should keep these fine-scale dynamics in mind when making management decisions that take into account changing soil thermal dynamics.

3.4. Soil Thermal Regimes and Communities

MQ 18	Where are predicted changes in soil thermal regimes associated with communities and transportation routes?

Overlaying permafrost modeling outputs with communities and transportation routes, as shown in Figure B-33, allowed us to assess where areas of permafrost retreat may impact human habitation and use. In general, this change is likely to be more pronounced to the north and east, in the regions surrounding Huslia, Nulato, Kaltag, Galena, and Port Alsworth. Other areas to the south and west are less likely to see major shifts because permafrost is already thawed, or predominantly thawed.

Although small pockets of frozen ground may continue to thaw in warmer parts of the YKL area, the greatest impacts to human infrastructure such as roads and communities is likely to occur in areas where drainage patterns are altered by the shift from a permafrost-dominated landscape to a landscape no longer dominated by permafrost.

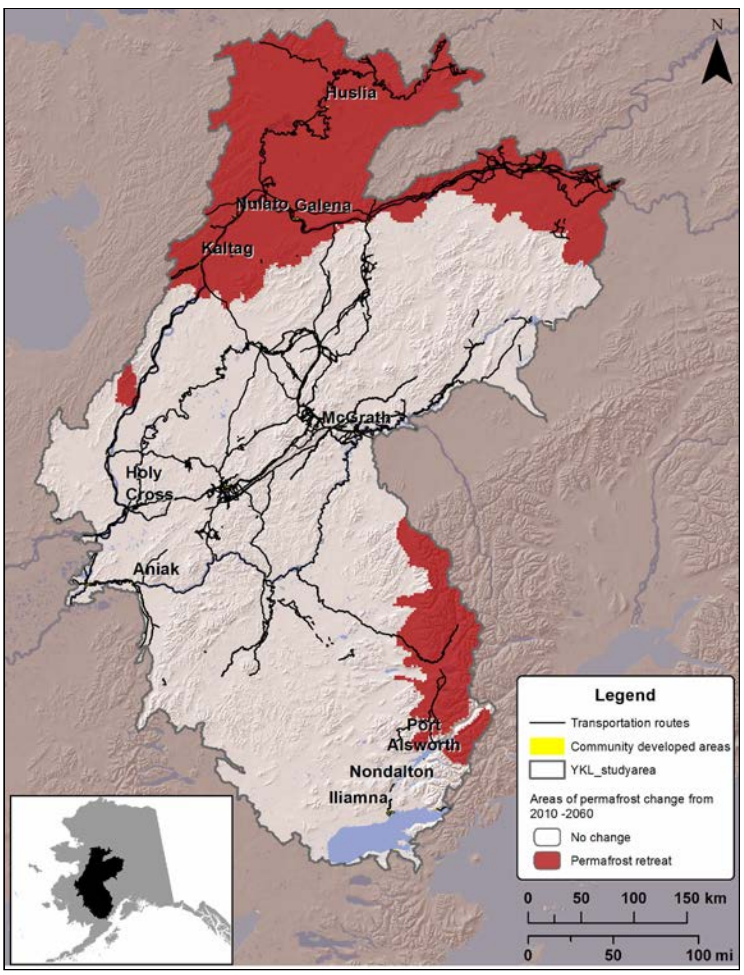

Figure B-33. Overlap of communities and transportation routes (existing or potential) with predicted areas of permafrost retreat between 2010-2060.

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4. Invasive Species

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Summary

Section B-4. *Invasive Species* provides the detailed descriptions, methods, datasets, results, and limitations for the assessments of non-native plants, non-native animals, and forest pest outbreaks.

4.1. Introduction

This portion of the Technical Supplement addresses invasive species and forest pests as a change agent on the YKL landscape. Invasive species are defined as non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human health (see Executive Order 13112); nationally invasive species are recognized to be a major concern for resource management (Pimentel 2005, USDA 2013). In Alaska and the circumpolar North, invasive species are not known to have caused the degree of damage observed at lower latitudes (Carlson and Shephard 2007, Sanderson 2012, Lassuy and Lewis 2013). However, increasing examples of ecological and economic harm are recognized in the state (Croll et al. 2005, Carlson et al. 2008, Spellman & Wurtz 2010, Nawrocki et al. 2012, Schwörer 2012), and while most non-native species populations are currently small and geographically restricted they may become more problematic with future changes in land-use and climate (Carlson and Shephard 2007).

Core-REA and invasive species MQs are concentrated into three theme areas: 1) the current state of invasive species in the YKL and identification of areas and resources which are most at risk, 2) the predicted state of invasive species in the YKL, and 3) the likely vectors of invasive species in the YKL.

This section describes the current status of non-native species and landscape-level model outputs, including the data sources, methods, and analysis involved in this modeling. Invasion vulnerability was assessed in the context of current, near-term (2025), and long-term (2060). Invasive species data were derived from Alaska Exotic Plant Information Clearinghouse Database (AKEPIC 2013); anthropogenic data were garnered from diverse sources and summarized by the Institute for Social and Economic Research; climate data were produced by the Scenarios Network for Alaska and Arctic Planning. We briefly discuss relationships between non-native plant establishment, climate, and development. Invasive species management questions are addressed herein. Potential impacts to conservation elements are summarized here, but additional discussion can be found in sections devoted to each CE.

4.2. Methods

Current Status of Invasive Species

While much of the YKL region has not been surveyed for invasive species, it is clear that numerous populations of non-native plants are well established; information on invasive animals and pathogens in the region are not available. Here we summarize data on non-native plant species in the region and describe a vulnerability assessment for invasion under current and future conditions.

For non-native plants we downloaded the AKEPIC database in November 2012 (see http://aknhp.uaa.alaska.edu/botany/akepic/ for updated data). Current status of invasive species was evaluated by overlaying the YKL boundary with the spatially explicit AKEPIC data and extracting all relevant records. Figure B-34 displays an overview of methods and approach.

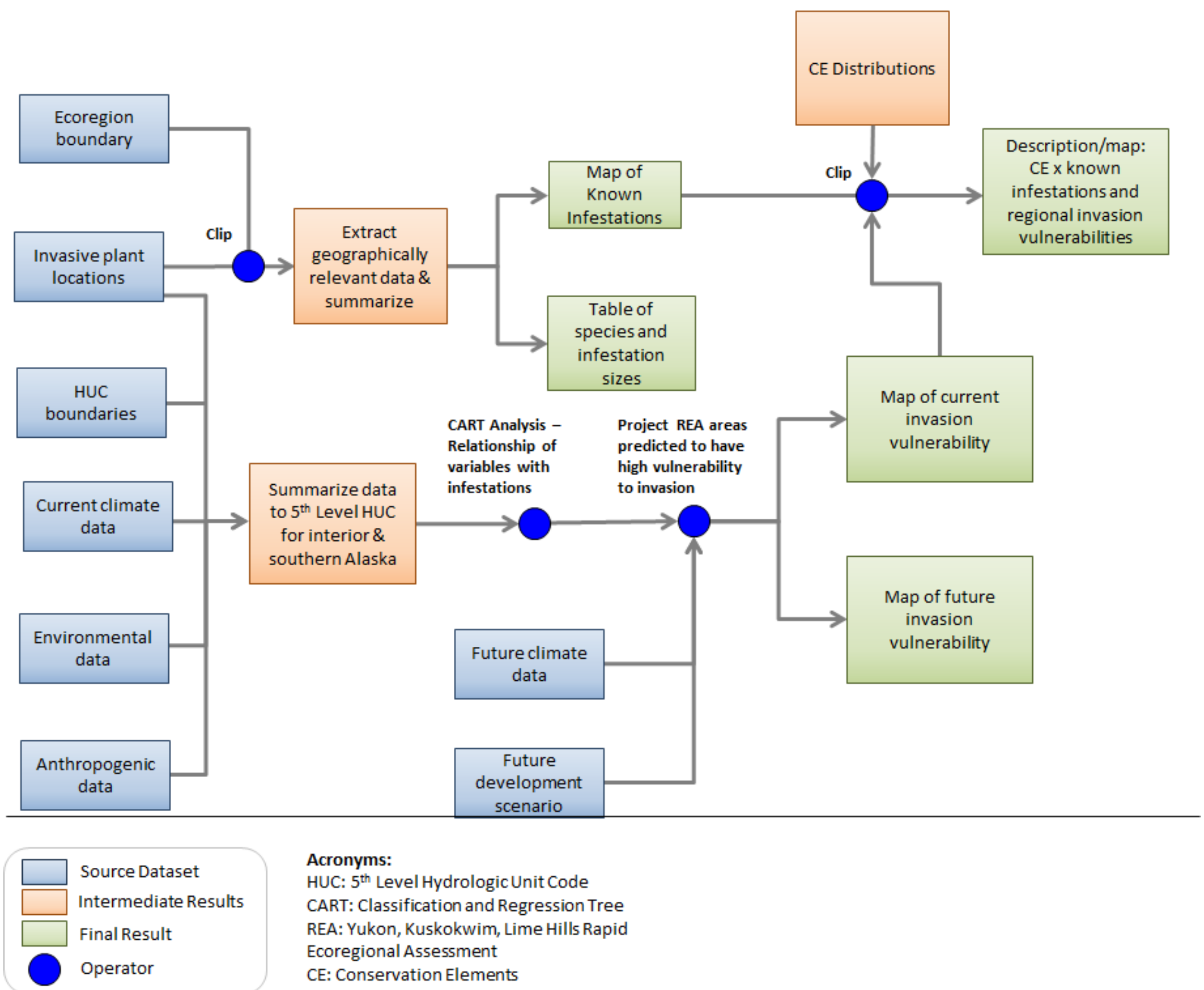

Figure B-34. Process model of invasive species current and predicted future condition methodology.

Infestation Vulnerability

Survey intensity for non-native plant infestations in the YKL is not strong or consistent across the region; we therefore developed an analytical model to identify areas that are perceived to be currently vulnerable to invasion by non-native plant species. This analysis is intended to supplement the empirical data, identify areas in which future surveys may be directed, and to evaluate the potential change in vulnerability in the future. The analytical approach used here (variance partitioning via classification tree and random forest) facilitates the evaluation of a large number of variables that may have non-linear relationships and complex interactions and has been used elsewhere to understand patterns of plant invasion vulnerabilities (see De'ath and Fabricius 2000, Cutler et al. 2007).

The basic approach taken here is as follows:

1. determine the climate, habitat, and anthropogenic variables that are associated with watersheds having weed problems in Interior Alaska based on the AKEPIC dataset;
2. determine which watersheds in the YKL have those climate, habitat, and anthropogenic variables associated weed problems;
3. determine which watersheds in the YKL are projected to have those future climate, habitat, and anthropogenic variables associated with weed problems

More specifically, watersheds with weed problems are defined by having a species likely to cause management concerns (i.e., invasiveness rank of 60 or greater, see Carlson et al. 2008 and Nawrocki et al. 2012) and at least ten non-native species present. These watersheds (5th level HUC, 10-digit) are termed "infested". These criteria separate watersheds into those with only a small number of species that are typically associated with disturbed substrates such as roadsides, and those watersheds that have potentially problematic species and high numbers of non-native species, which are also highly correlated with greater numbers and areas of infestations.

The invasion vulnerability model was first developed for the broad region between the Alaska and Brooks ranges. Model development for this broad region allows for much greater resolution of the relationship among variables. Additionally, it encompasses climate, anthropogenic, and infestation conditions beyond those present in the YKL, but these conditions may occur within the YKL region in the future. A total of 311 10-digit HUCs that were surveyed for non-native plants were included in the broad analysis.

The relationship of the HUC infested/not infested classification was then compared with 19 climate, habitat, and anthropogenic variables in classification tree and random forest analysis. The climate variables included: mean annual temperature and precipitation, mean January temperature and precipitation, mean July temperature and precipitation, mean growing season length, mean freeze date, and mean date of thaw (Table B-14). The habitat variables included: area of permafrost, mean elevation, and river length. Anthropogenic variables included: human population size, length of roads, permanent trails, winter trails, hiking trails, and uncategorized trails, and date of establishment of oldest community. (This approach does not explicitly incorporate vectors of non-native species, but rather identifies landscape-level conditions that are associated with infested watersheds. However some variables, such as road density and human population size, are likely to be strongly correlated with non-native species vectors – see Section 4.4 for more discussion of vectors). Threshold predictor values derived from the classification tree model for the broad region were then used to delineate invasion vulnerabilities within the YKL in GIS. Last, known infestations were overlaid on the modeled infestation vulnerability map to qualitatively compare outputs.

We modeled near-term (2025) and long-term (2060) invasion vulnerabilities using the classification tree approach described above. Invasion vulnerability thresholds from the current classification tree model were maintained; however we used projected future climate and anthropogenic conditions to identify areas vulnerable to invasion for the YKL region.

Current, near-term, and long-term invasion vulnerability outputs are incorporated into the Landscape Condition Model and are overlaid with relevant CE distributions (see Sections C and D).

Table B-14. Source datasets for analysis of Invasive Species.

Dataset Name	Data source
Alaska Exotic Plants Information Clearinghouse (AKEPIC): non-native plant species, location, infestation size, associated vegetation community	AKNHP, UAA
Climate Data: mean annual temperature and precipitation, mean January temperature and precipitation, mean July temperature and precipitation, mean growing season length, mean freeze date, and mean date of thaw for current, 2010s-2020s, and 2060s	SNAP, UAF
Anthropogenic GIS: human population size, length of roads, permanent trails, winter trails, hiking trails, and uncategorized trails, and date of establishment of oldest community	ISER, UAA

4.3. Results

Current Distribution of Non-native Plants

MQ 25	What is the current distribution and area (percent of land with infestations) of introduced and invasive species in the YKL?

A total of 41 non-native vascular plant species were documented out of nearly 600 infestation records, encompassing a total of 273 acres (Table B-15). This accounts for 0.0000048% of the YKL land area. Infestations in the AKEPIC database refer to a population of single species of non-native plant at a particular location; when multiple species are present at a single location more than one infestation is recorded in AKEPIC. More recent surveys (March 2014 AKEPIC) have revealed two additional species (*Alopecurus pratensis* and *Melilotus officinalis*) and an additional 120 infestations of previously documented species – changes in numbers of infestations over this time period more likely represent a greater number of surveys conducted rather than an expansion of populations. Figure B-35 displays the spatial distribution and density of known infestations in the YKL study area.

Table B-15. Non-native vascular plant species present, total area infested and number of infestations by each species in the YKL region, and Invasiveness Rank (see Carlson et al. 2008 for discussion of ranking criteria.)

Species	Total Infested Acres	Number of Infestations	Invasiveness Rank
Amaranthus retroflexus (redroot amaranth)	0.078	1	45
Bromus inermis (smooth brome)	1.090	6	62
Campanula rapunculoides (rampion bellflower)	0.500	1	64
Capsella bursa-pastoris (shepherd’s purse)	0.101	6	40
Caragana arborescens (Siberian peashrub)	0.101	2	74
Cerastium fontanum ssp. *vulgare* (common mouse-ear chickweed)	2.010	4	36
Chenopodium album (lambsquarters)	38.600	57	37
Crepis tectorum (narrowleaf hawksbeard)	38.020	105	56
Descurainia sophia (herb Sophia)	0.023	5	41
Elymus repens (quackgrass)	2.850	6	59
Euphrasia nemorosa (common eyebright)	0.020	2	42
Fallopia convolvulus (black bindweed)	0.020	2	50
Galeopsis bifida (splitlip hempnettle)	5.801	14	50
Galeopsis tetrahit (brittlestem hempnettle)	0.500	1	50
Hordeum jubatum (foxtail barley)	20.840	48	63
Hordeum vulgare (common barley)	1.500	2	39
Leontodon autumnalis (fall dandelion)	0.100	1	51
Lepidium densiflorum (common pepperweed)	0.001	1	25
Leucanthemum vulgare (oxeye daisy)	1.220	6	61
Linaria vulgaris (butter and eggs)	0.840	8	69

Species	**Total Infested Acres**	**Number of Infestations**	**Invasiveness Rank**
Lolium multiflorum (Italian ryegrass)	0.500	1	41
Lolium perenne (perennial ryegrass)	1.000	2	62
Matricaria discoidea (disc mayweed)	45.840	66	32
Melilotus albus (white sweetclover)	0.011	2	81
Phleum pratense (timothy)	0.078	1	54
Plantago major (common plantain)	35.380	67	44
Poa annua (annual bluegrass)	1.502	5	46
Poa pratensis ssp. *irrigata* or *Poa pratensis* ssp. *pratensis* (Kentucky bluegrass)	0.612	5	52
Polygonum aviculare (prostrate knotweed)	12.420	31	45
Prunus padus (European bird cherry)	0.011	2	74
Prunus virginiana (Chokecherry)	1.500	2	74
Rumex acetosella (common sheep sorrel)	0.281	3	51
Rumex crispus (curly dock)	0.010	1	48
Stellaria media (common chickweed)	15.810	34	42
Taraxacum officinale (common dandelion)	30.150	56	58
Trifolium hybridum (alsike clover)	3.110	7	57
Trifolium pratense (red clover)	1.500	2	53
Trifolium repens (white clover)	11.690	25	59
Tripleurospermum inodorum (scentless false mayweed)	0.210	3	48
Vicia cracca ssp. *cracca* (bird vetch)	0.100	1	73
Viola tricolor (johnny jumpup)	0.010	1	34

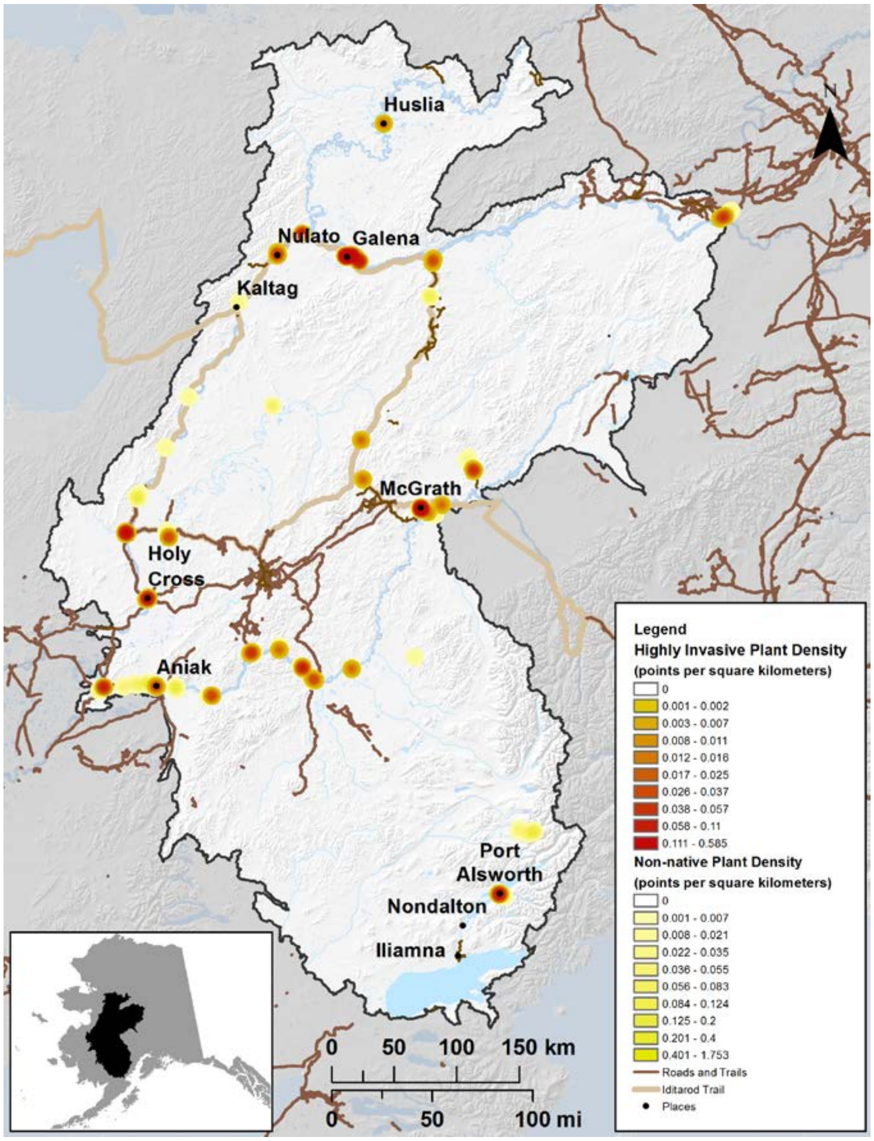

Figure B-35. Distribution of non-native plant infestations in the YKL REA region (yellow to red circles). Orange to red colors represent a gradient in density of species considered to be moderately to highly invasive (ranks > 60). Roads and trails are shown as brown lines and are shown outside the YKL REA region since they represent likely vectors and habitat (see Sect 4.4).

The species with the greatest perceived ecological risk are *Caragana arborescens, Melilotus albus*, *M. officinalis*, *Prunus padus*, *P. virginiana*, *Vicia cracca*, and *Linaria vulgaris*. Fortunately, these species are currently known from only a few locations and within larger communities such as McGrath, Galena, and Aniak (Figure B-36). The most commonly occurring species are the disturbance specialists: *Chenopodium album*, *Crepis tectorum*, *Matricaria discoidea, Plantago major*, and *Taraxacum officinale*. With the exception of *Taraxacum officinale*, these species typically require continued ground disturbance to persist in Alaska and are unlikely to establish in large numbers in natural areas outside of active floodplains.

Figure B-36. Planted invasive shrub, *Caragana arborescens* in McGrath.

In summary, while survey intensity is low in this region, non-native plants do appear to be very limited in their spatial distribution on the landscape. Further because of relatively low densities of invasive plants, it is unlikely they are currently causing significant disruptions to ecological processes. Non-native plants are largely restricted to areas of human habitation and ground disturbance. Some species that are perceived to be more ecologically damaging are present in small numbers in the YKL in population centers. Impacts of currently established or potentially occurring invasive species on Coarse- and Fine-Filters are discussed in those sections (D-1 to D-4).

Current and Future Infestation Vulnerability

MQ 26	Which areas are most likely to be susceptible to infestation by invasive plant species currently?
MQ 27	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?

Classification tree analysis of interior Alaska invasion vulnerability produced a model with moderate explanatory power (misclassification rate = 18.6%; Figure B-37). The resulting five categories were defined as “High Infestation Vulnerability,” “Potentially High Infestation Vulnerability,” “Moderate Infestation Vulnerability,” “Potentially Low Infestation Vulnerability,” and “Low Infestation Vulnerability,” based on the proportion of infested HUCs to the total number of HUCs, as well as the uncertainty associated with sample size (categories with less than 20 HUCs were qualified with the word “potentially”). The variables that best describe the variance (and thus defined our categories) were road density, mean thaw date, river length, and population size.

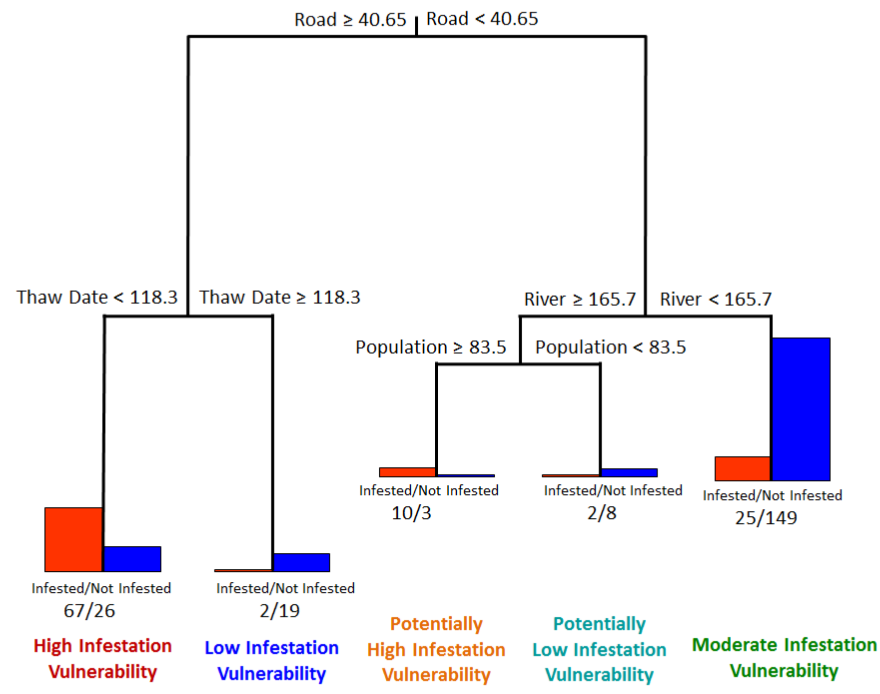

Figure B-37. Classification tree for non-native plant infestations in 5th-level HUCs for interior Alaska. At each node predictor thresholds are indicated. The terminal nodes display the number of infested (red bars) and not infested HUCs (blue bars). Colored labels below the terminal nodes indicate levels of infestation vulnerability, used in characterizing regions within the YKL. Thus, the far left terminal node defined as "High Infestation Vulnerability" illustrates that 72% of HUCs in Interior Alaska with road densities ≥ 40.65 m/km^2 and mean thaw dates prior to the Julian date of 118.3 (April 28) are correctly classified as infested.

Probability of a HUC being infested followed a threshold response for anthropogenic variables, with probabilities increasing dramatically with even modest amounts of human activity. Climate and habitat variables had more diverse relationships with probability of infestation. In general, HUCs with warmer summers, earlier thaw dates, lower elevations, and greater river length had higher probabilities of being infested.

Potential current and projected future infestation vulnerabilities based on the classification tree model are shown in Figure B-38. HUCs predicted to have low infestation vulnerabilities do not have any records of known non-native plant infestations, and only three of the HUCs that were predicted to have moderate to high infestation did not have records of known non-native plant infestations. Additionally there is a strong association of known infestations with modeled moderate to high vulnerabilities, indicating the classification tree results correspond to empirical data in the region and are therefore useful for near- and long-term scenarios. It should be stressed that the characterization of vulnerability at the 5th-level HUC is very coarse for plant invasion and it is likely that only a fraction of the HUC is in fact vulnerable to non-native plant establishment. Infestations are typically localized to areas on or adjacent to the human footprint in the state (Bella 2011; Flagstad 2010), but there are increasing cases of plants moving into natural areas (Carlson and Shephard 2007).

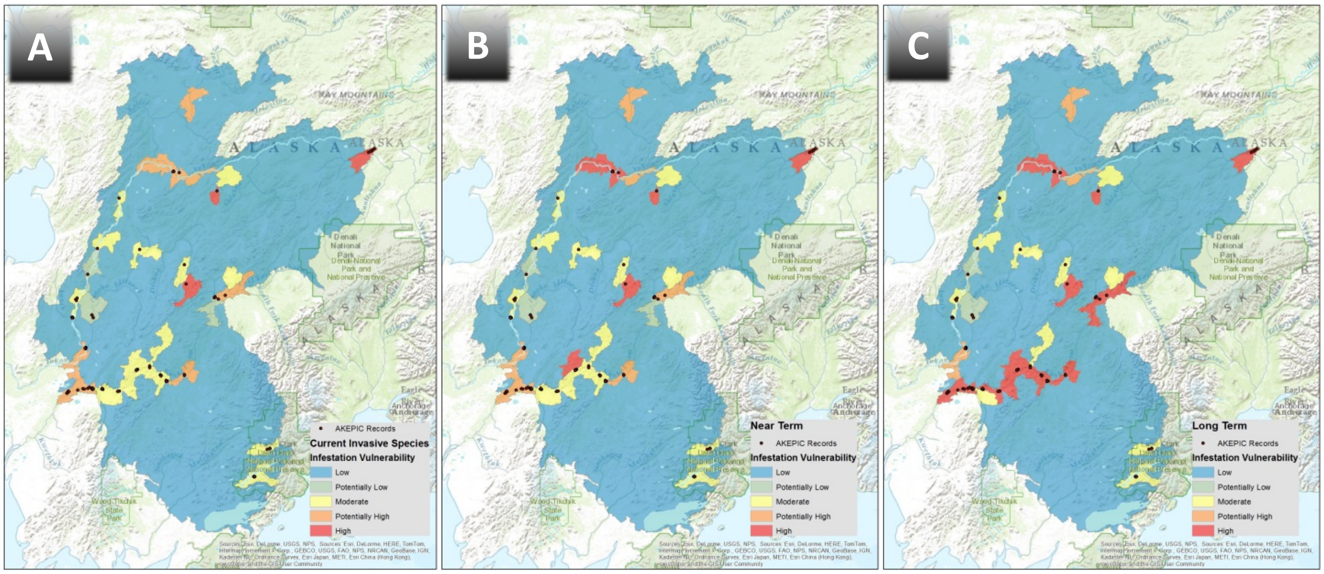

Figure B-38. Modeled infestation vulnerability on 5th-Level HUCs in the YKL for current (a), near-term (b), and long-term (c). HUCs with low predicted vulnerabilities are show in blue, potentially low in green, moderate in yellow, potentially high in orange, and high in red. Known non-native plant infestations are shown as black points.

Areas predicted to be of highest current vulnerabilities were around Ophir, Ruby to Poorman, and Tanana and have high road densities associated with mining activities. The regions associated with the highest population centers such as McGrath, Galena, and Aniak were predicted to have high infestation probabilities as well, but with lower confidence. The HUC harboring the village of Huslia is predicted to have potentially high infestation vulnerability; no records of non-native plant infestations were known from the region at the time of our initial data download, however more recent surveys have been conducted in that community and recorded seven non-native plant species. Projected infestation vulnerabilities tended to be high along the Yukon and Kuskokwim river corridors, particularly at population centers.

With increasing temperatures, earlier thaw dates, and potential increases in road density in the future, HUCS along the Kuskokwim River may transition from moderate vulnerabilities to high vulnerabilities by 2060. Vulnerabilities are not predicted to change for the remainder of the YKL area.

Our modeling results are complementary to species-specific predictive modeling approaches by others (Bella 2009, Murphy et al. 2010, Harkness et al. 2012, Jarnevich et al. in press). Results from these studies suggest that this region has lower invasion vulnerabilities relative to more temperate regions of the state. However, a significant portion of the YKL study area is anticipated to harbor suitable habitat for a number of invasive plant species, particularly toward the end of the century. The plants with the largest area of predicted suitable habitat in the YKL include: *Bromus tectorum*, *Caragana arborescens Euphorbia esula*, *Galeopsis* spp., *Hieracium* spp., and *Leucanthemum vulgare* (Bella 2009), *Melilotus albus* and *Hieracium aurantiacum* (Harkness et al. 2012). The area within the YKL with the greatest overlap in habitat suitability of the invasive species modeled by Bella (2009) is the region around Illiamna to Port Alsworth. Most of the YKL study area is predicted to be of high habitat suitability for *M. albus* and suitable habitat for *H. aurantiacum* is projected to spread from the southern and western margins of the YKL to the north and east by 2060 (Harkness 2012). While the previous modeling approaches do not focus specifically on the YKL and most do not incorporate both climate and anthropogenic variables, all suggest increasing suitability for invasive plant species establishment.

Vulnerability Summary

Overall, we anticipate that invasive plant establishment will be geographically restricted under near- and long-term scenarios and that most CEs will not be strongly impacted by this CA. Our analysis indicated that human population size and road density are the most important drivers of plant invasion at this scale. Areas most likely to develop problems are those around towns and villages, many of which currently have small infestations of ecologically damaging species. Invasive species movement is discussed in Section 5 below. Our analysis indicated that climate (growing season length and summer temperatures) is of secondary importance and the warmer areas of the study area have greater probability of invasive plant establishment.

Large floodplains are the CE that is most susceptible to invasive plant species impacts now and in the future (see Section D-1.9). Once invasive plant populations establish in river systems they will likely expand downstream rapidly. Deciduous forests may see increases in establishment of invasive plants, particularly along forest edges, openings, and adjacent to human activity. It is difficult to anticipate the potential impacts of invasive plant establishment on the Terrestrial and Aquatic Fine-Filter CEs; however moose forage quality could be affected by invasive plant establishment along floodplains and forests (see Spellman and Wurtz 2011, Woodford et al. 2011, UAF Extension Service 2013, and Section D-2); additionally trumpeter swan and pike habitat could be affected if *Elodea* or *Phalaris arundinacea* establishes in the YKL region.

Limitations and Data Gaps

Survey data on non-native species are lacking for many regions of the state, including the YKL. Additionally, surveys are concentrated in areas associated with population centers. Thus, interpretation of current infestations is based on only a small area of the YKL being surveyed for non-native plants. We are not aware of surveys for invasive animals and pathogens in this region.

The spatial bias in survey intensity towards areas in and adjacent to human habitation is likely to inflate the importance of roads and population centers in the classification tree analysis. However, the few surveys that have been conducted in more remote areas of the state suggest that non-native species are indeed very uncommon outside of roadways and population centers.

Future infestation vulnerabilities are based on scenarios of climate change and development that are inherently uncertain (see Section B-1) and caution should be exercised in interpretation of those outputs. Other disturbances such as herbivorous insect outbreaks and wildfires are expected to increase the probability of non-native plant invasion; however, we are unable to incorporate these factors in a meaningful spatial context. Areas subjected to wildfire in remote areas of the interior rarely have non-native plants present (Greenstein and Heitz 2013). We suggest disturbances within regions known to harbor infestations or predicted to harbor infestations are more likely to experience expansions of existing populations.

The analysis of infestation vulnerability is restricted to a scale coarser than the area we are likely to see invaded on the landscape. For example, a 5th-Level HUC with “high infestation vulnerability” is likely to have weed infestations present only in a small portion of the HUC.

4.4. Invasive Species Vectors

MQ 28	What are the likely vectors for new infestations or spread of existing infestations?

Current management approaches to invasive species are increasingly recognizing the importance of identifying the routes in which unwanted non-native species arrive in new areas (Conn et al. 2008, Hulme 2009). Understanding the vectors for invasive species movement facilitates the recognition of areas that are most likely to have incipient populations and implement management policies to limit the probability of invasive species establishment.

Methods

To address this MQ, which is outside the scope of the core REA analysis, we rely on a review of current patterns of non-native plant establishment in the YKL area and elsewhere in interior Alaska (AKEPIC 2012). Additionally we reviewed the literature to present an overview of the state of knowledge regarding vectors of invasive species.

Results

The ecologic and economic damage caused by invasive species requires three events: transportation of propagules, establishment of incipient populations, and subsequent increase in biomass. Invasive species will not become a problem if one of these three events does not occur, and increasing interest is being place on managing pathways and nodes of invasion (Conn, et al. 2008; Davies and Johnson 2011; Mack 2003; Ruiz and Carlton 2003). The pathways that invasive species use to reach new areas are in fact often predictable (Mack 2003). Understanding likely transportation routes is particularly critical in areas that currently have low levels of non-native species establishment, such as the YKL region. Monitoring likely vectors and interception of propagules and incipient populations is likely to be one of the most cost-effective approaches to invasive species management (Conn, et al. 2008).

Non-native species may enter a new region via six principal pathways; these pathways include: release, escape, contaminant, stowaway, corridor, and unaided (Hulme, et al. 2008). These six pathways result from movements associated with the importation of commodities, on transport vectors such as vehicles, or natural spread from adjacent regions where the species has more recently established (Hulme, et al. 2008). Non-native species that are transported via commodities may enter the new region through intentional release or unintentionally through escape and as a contaminant. Stowaways are associated with transport vectors, but are independent of the particular commodities transported and are more generally associated with such elements as cargo and ballast water. The corridor pathway is the result of transport infrastructure and vehicles in the movement of non-native species. The spread of non-native species via natural dispersal mechanisms from adjacent regions where it established is described by the unaided pathway. Vertebrates are most likely introduced into a new area through intentional release, invertebrates and microbes as contaminants, and plants by escape and intentional release (Hulme, et al. 2008). Overall, the vast majority of non-native species introduced to new areas globally are brought intentionally (Dodet and Collet 2012) and in some groups of organisms such as woody trees approximately 99% are intentionally cultivated and released (Reichard and Hamilton 1997).

Pathways of invasive species closely follow the movements of humans. Movements of humans and goods are closely tied to levels of commerce and thus the rates of invasive species importation across all groups of organisms (Hulme 2009). Both the volume and rate at which goods are shipped has increased dramatically in recent decades facilitating in the movement of pest species (Hulme 2009).

Airports at regional hubs, as well as ports along the Yukon and Kuskokwim Rivers are undoubtedly the primary entry points for most non-native species in the region. Once established at these ports of entry, roads represent likely corridors for invasive species to further spread within and between communities due to transportation of goods, vehicles, and people, or indirectly through population expansion on the disturbed and connected habitats (see Hulme 2009). Additionally, incipient populations may spread using natural dispersal mechanisms after reaching reproductive maturity. For example, the spread of the invasive ornamental tree *Prunus padus* from urban areas into semi-natural parklands in the Anchorage area appears to largely be mediated by waxwings, thrushes, and other passerines that are often observed eating fruits and seeds (Flagstad et al. in prep.).

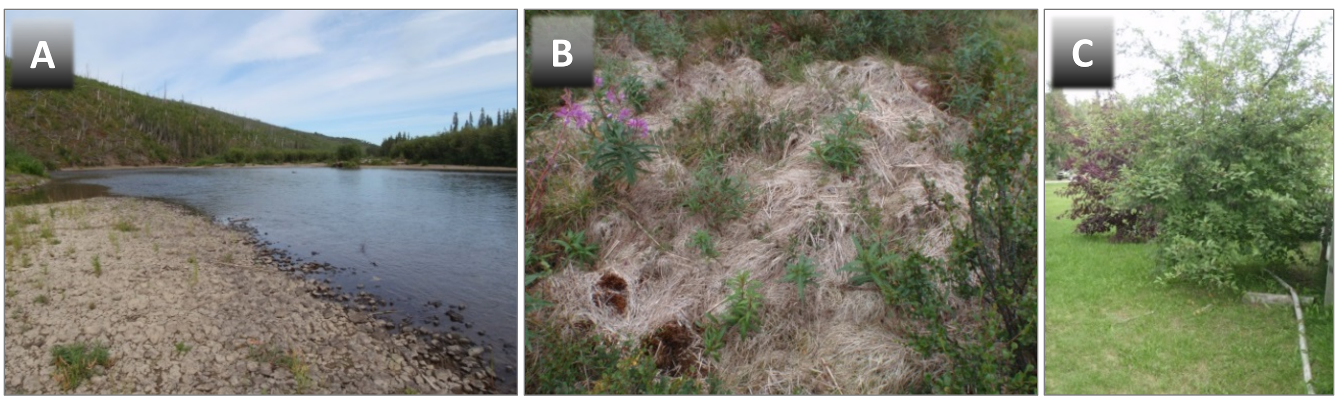

Figure B-39. Innoko River Iditarod Crossing (a) – non-native plant species *(Plantago major, Hordeum jubatum, Poa pratensis* ssp. *pratensis*, and *Taraxacum officinale* ssp. *officinale*) are established at low abundance at this relatively remote site. Discarded straw adjacent to a BLM shelter cabin (b), presumably the vector for *Hordeum jubatum* populations introduced at the site. Invasive ornamental trees (c) planted adjacent to a mixed deciduous forest in McGrath (see Flagstad and Cortés-Burns 2010 for discussion).

Patterns of known infestations of non-native plants follow this assumption of patterns of spread. Only 14 of the 594 documented infestations within the YKL and immediately adjacent to the boundary are located outside of villages or road corridors. The infestations found outside of population centers were located along the Iditarod Trail, the Innoko FWS Field Camp, Kuskokwim River sand bars between Aniak and Kalskag, and historic cabin sites in Lake Clark National Park and Preserve (AKEPIC 2012). Species associated with these infestations were the most widespread and disturbance-associated species in the state. While we are not able to distinguish how survey intensity influences the numbers of infestations, the number of infestations and the identity of the species found gives a general sense of patterns of establishment and spread. The larger communities in the region such as McGrath, Aniak, Anvik, Galena, and Holy Cross typically have larger numbers of infestations (nearly 100 recorded in McGrath) and often had populations of more invasive species such *Melilotus albus* and *Prunus padus* and escaped agricultural grasses. Smaller villages (e.g., Napaimute) typically had a subset of the less invasive, more widespread, and disturbance-associates that are known from the larger communities.

Non-native plants in the region include a mix of intentionally planted ornamentals and groundcover species, as well as numerous gravel/fill contaminants (Figure B-39). Intentionally planted ornamentals in the region include such species as *Prunus padus, Prunus virginianus, Caragana arborescens*, *Leucanthemum vulgare*, and *Linaria vulgaris*. The three species: *Bromus inermis*, *Poa pratensis* ssp. *irrigata*, and *Trifolium hybridum* are commonly planted turf or groundcover species and were likely introduced intentionally to the region. These three species are likely also spread from contaminated fill and vehicles.

While most invasive species are likely to enter this and other regions through intentional means as in most regions, a substantial proportion of non-native plants are imported as contaminants on other products. Pathways of non-native plant introduction have been studied in Alaska as contaminants in three types of commodities: from container-grown ornamentals, hay and straw, and crop and grass seed (Conn 2012; Conn, et al. 2008; Conn, et al. 2010). All of these commodities harbored substantial numbers of weed species. For example, hay and straw bales contained on average 585 weed seeds/kg and 3,844 weed seeds/kg were found in crop seed. Even seeds that had been identified as certified “weed free” often had considerable numbers of contaminant seeds.

These pathways outlined in Conn et al. (2008b), Conn et al. (2010), and Conn (2012) represent an important vector for Alaska, but are likely of lower concern in the YKL region. Large-scale agriculture is not present in this region and importation of crop seed is likely minimal. Also, the high cost of importing goods from regional centers such as Anchorage and Fairbanks is likely to impose some limits the volume of ornamental plants brought into communities, particularly of larger woody species. Last, while use of hay and straw for livestock is likely minimal in the YKL, use of straw for sled dog bedding is common. Surveys along the Iditarod Sled Dog Trail indicate that a number of non-native and native problem weeds are being transported in dog bedding; although the presence of exposed mineral soil and proximity to population centers appeared to be a more important factor than the presence of straw alone (Flagstad and Cortes-Burns 2009).

The footwear of travelers is known to be a pathway of introduction of viable non-native seeds. The average traveler to the Arctic archipelago of Svalbard transports 3.9 non-native plant seeds on their footwear, with more than 40% of individuals transporting at least one non-native species (Ware et al. 2012). More than 25% of the seeds germinated in simulated arctic conditions (Ware et al. 2012). Similar levels of transport have been recorded from visitors to Antarctica (Lee and Chown 2009). Grasses represent the largest percentage of introduced seeds in these contexts. Thus regional hubs and popular backcountry recreation areas in the YKL are the most likely sites of introduction from this vector.

Aquatic invasive species are currently not known from the region, but could pose significant risks to the ecology and economy if they did become established. Pathways for aquatic invasives, as in terrestrial invasives, typically are due to intentional introductions as well as contaminants on or in vessels (Hulme, et al. 2008). The highly invasive waterweed *Elodea* appears to have been dumped from aquariums in multiple locations in Anchorage, Kenai, and Fairbanks (USFWS 2013). Recent surveys for quagga (*Dreissenia* spp.) and New Zealand mud snails (*Potamopyrgus antipodarum*) have not revealed populations in Alaska, but these species have spread dramatically across North America in recent years, even extending into British Columbia (Bogan 2011). The movement of trailered personal watercraft is the primary mode of long distance transport for these invasive mussels and for many invasive aquatic plants as well. Again the remote geography of the YKL region is likely to limit the probabilities that viable aquatic invasive species are transported into the region by watercraft. A more likely vector in the YKL is floatplanes and on non-resident sport anglers and hunters. Invasive species are more likely to remain viable through air transport that is of shorter duration. If invasive species become established through these pathways it presents the additional problem of not becoming obvious at population centers first, and therefore may go undetected until the invasive occupies a large area. We are not familiar with any data on invasive species on floatplanes or of invasive species moved on anglers and hunters in Alaska.

Applications

The map of known non-native plant infestations provides managers with baseline information on distribution and density of non-native species within the YKL study area. Additionally the current and future vulnerability maps and discussion should assist managers in evaluating the risk of invasive species relative to other factors on regional resources of concern. These products should also be useful in identifying areas in which surveys may be directed, areas vulnerable to invasion in the future, and identifying high priority locations for weed management activities. Last, the literature review of invasive species vectors, coupled with the invasion vulnerability analysis should be useful in the development of management strategies to minimize the risk of new introductions.

Limitations and Data Gaps

While some effort is in place to document, control and/or eradicate invasive species in the state (e.g., USFWS, ADF&G, USFS, BLM, and AKNHP), little research has been specifically directed towards movements of invasive species in rural Alaska. The degree to which climate and existing habitats in the YKL may act as a barrier to non-native species establishment and spread are also poorly known.

4.5. Current Distribution of Forest Pest Outbreaks

MQ 29	What is the current distribution of forest pest outbreaks in the ecoregion?

Insects and diseases cause significant alterations to native plant communities in Alaska. Dominant tree and shrub species across Alaska are subject to damage, defoliation, and mortality due to a variety of disease agents (wood decay and canker fungi, root disease, etc.) and native insects (bark beetles and woodborers, sawflies, leaf miners, etc.). Large-scale defoliation and mortality of dominant boreal forest communities can result in cascading effects on plant communities and wildlife and can even alter salmon spawning habitats (Fricker et al. 2006; Tremblay et al. 2011). Additionally, insect and disease impacts are closely associated with climate. For example, seasonally above normal temperatures are responsible for outbreaks of leaf miners and spruce beetles that can result in increased wildfire activity. Thus, interactions between climate change, fire, and insects and disease are likely to influence the distribution of CEs in the future.

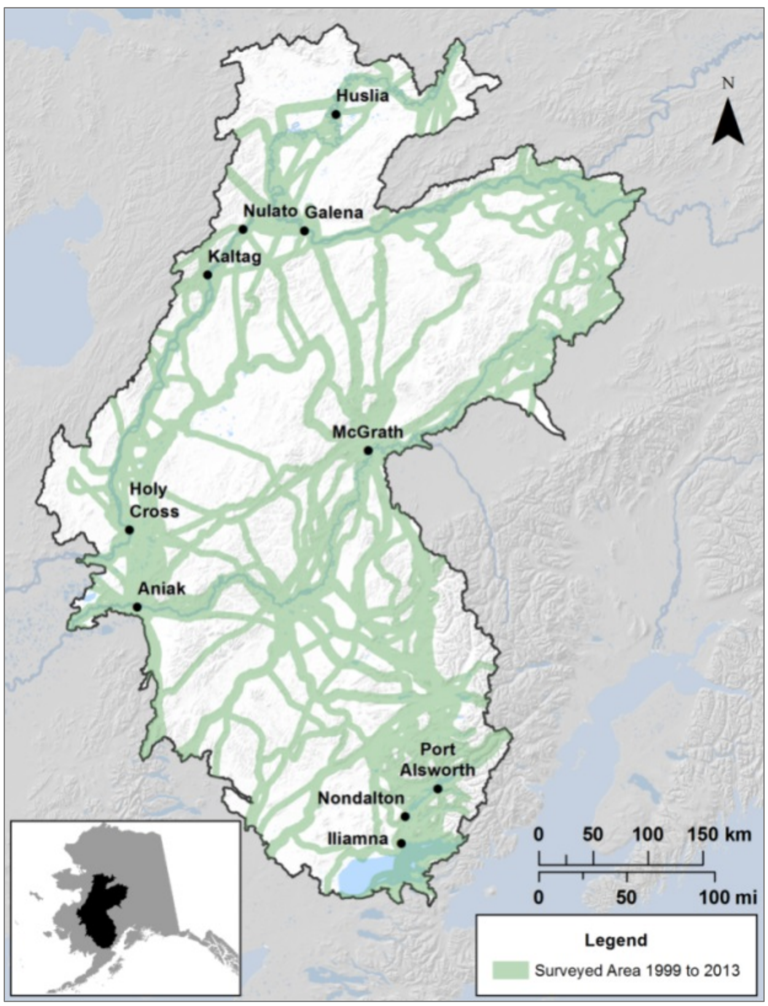

Figure B-40. Total area surveyed along flight paths for forest damage surveys from 1999 to 2013.

The United States Department of Agriculture (USDA) conducts annual forest damage aerial surveys using fixed-wing aircraft along predetermined routes across Alaska's forests, with up to 25% of the total forested area surveyed each year. Insect damage within one to two miles on either side of the flight path is recorded by drawing polygons onto 1:250,000 scale USGS topographic maps or a digital elevation model (DEM) (FS-R10-FHP 2012, 2013). Damage observed has been attributed with severity in three categories: high, moderate, and low. From 1999 to 2013, the period for which survey flight lines are available, approximately 105,545 km^2, or 46% of the study area, was surveyed (Figure B-40).

Methods

Insect and disease outbreaks from 1989 to 2013 were identified within the YKL study area by merging the available Region 10 aerial forest damage survey datasets (Table B-16) and removing polygons for forest damage caused by agents other than insects or diseases (i.e. abiotic agents such as fire, flooding, and wind throw). The 1989 to 1996 aerial forest damage survey datasets were merged into a single dataset. The 1997 to 2012 IDS_shapes feature class was joined to the IDS_attrib table. The attribute tables for the 1989 to 1996, 1997 to 2012, and 2013 datasets were standardized. All three datasets were merged to create a single 1989 to 2013 aerial forest damage survey dataset, and this was clipped to the YKL study area boundary. All polygons damaged by the following agents were removed from the final dataset: flooding-high water, none (pockets of no damage within damaged areas), fire, mud-land slide, wind-tornado/hurricane, and winter injury (Figure B-41).

Because data collected in any single year represents 25% or less of the study area, grouping the data into cumulative multiple year assemblages provides greater spatial coverage of the study area and more meaningful insights into trends. For this reason, we present data related to forest damage in two time intervals: historic, which includes the 25 year period from 1989 to 2013, and current, which includes the 5 year period from 2009 to 2013. The cumulative historic data provide a baseline from which to assess current and future trends in insect and disease related damage. The cumulative current data provide an approximation of the current status of insects and disease and, when compared to the historical data, current trends.

Table B-16. Source datasets for current distribution of forest pest outbreaks.

Dataset Name	Data source
Region 10 Aerial Forest Damage Survey 1989 – 1996 (datasets separated by year)	Forest Health Monitoring Clearinghouse
Region 10 Aerial Forest Damage Survey 1997 – 2012 (datasets integrated)	Forest Health Protection Insect & Disease Detection Survey Data Explorer (IDS Explorer)
Region 10 Aerial Forest Damage Survey 2013	Tom Heutte, Aerial Survey Coordinator, Forest Health Protection, State and Private Forestry, Region 10, USDA Forest Service

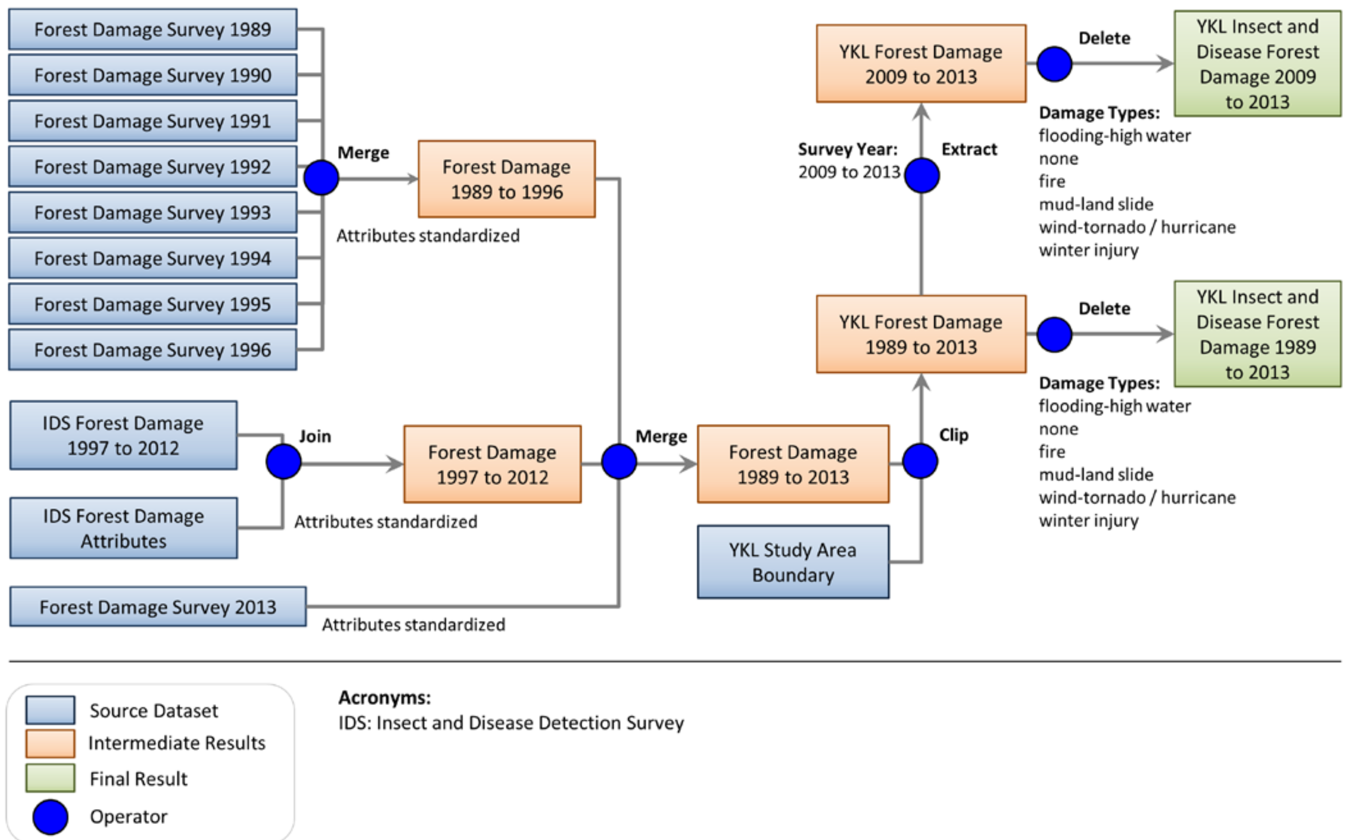

Figure B-41. Process model for current distribution of insects and disease.

Results

Areas damaged by insect and disease agents within the past 25 years are concentrated along the primary riparian corridors, where the larger and more continuous forested habitats occur in the region. Much of the damage observed has occurred along the Yukon, Koyukuk, and Kuskokwim rivers (Figure B-42). White spruce and black spruce have been the most susceptible trees to mortality from insect and disease agents, and spruce beetles were the most significant threat to forested areas. The defoliation of tamarack, quaking aspen, and willow has also been significant over the past 25 years (Table B-17). The top five most widespread insect and disease agents in the study area from 1989 to 2013 (spruce beetle, larch sawfly, spruce budworm, aspen leaf miner, and willow leaf blotch miner) account for over 70% of insect and disease related forest damage in the region (Table B-18).

The defoliation of birch, which was uncommon in the 1990s and early 2000s, has become problematic within the past 5 years, caused largely by birch leaf roller. Birch defoliation in the past 5 years has been concentrated near McGrath, Holy Cross, and Aniak, and in the southeastern portion of the study area around Port Alsworth and Nondalton. Tamarack defoliation and mortality caused by larch sawfly and eastern larch beetle have both declined to nearly undetectable (by aerial survey) levels recently, with very little activity of either agent observed within the past 5 years. Similarly, spruce defoliation caused by spruce budworm has declined drastically. For a comparison of historic and current insect and disease damage to the distribution of Terrestrial Coarse-Filter CEs, please refer to Section D-1.10.

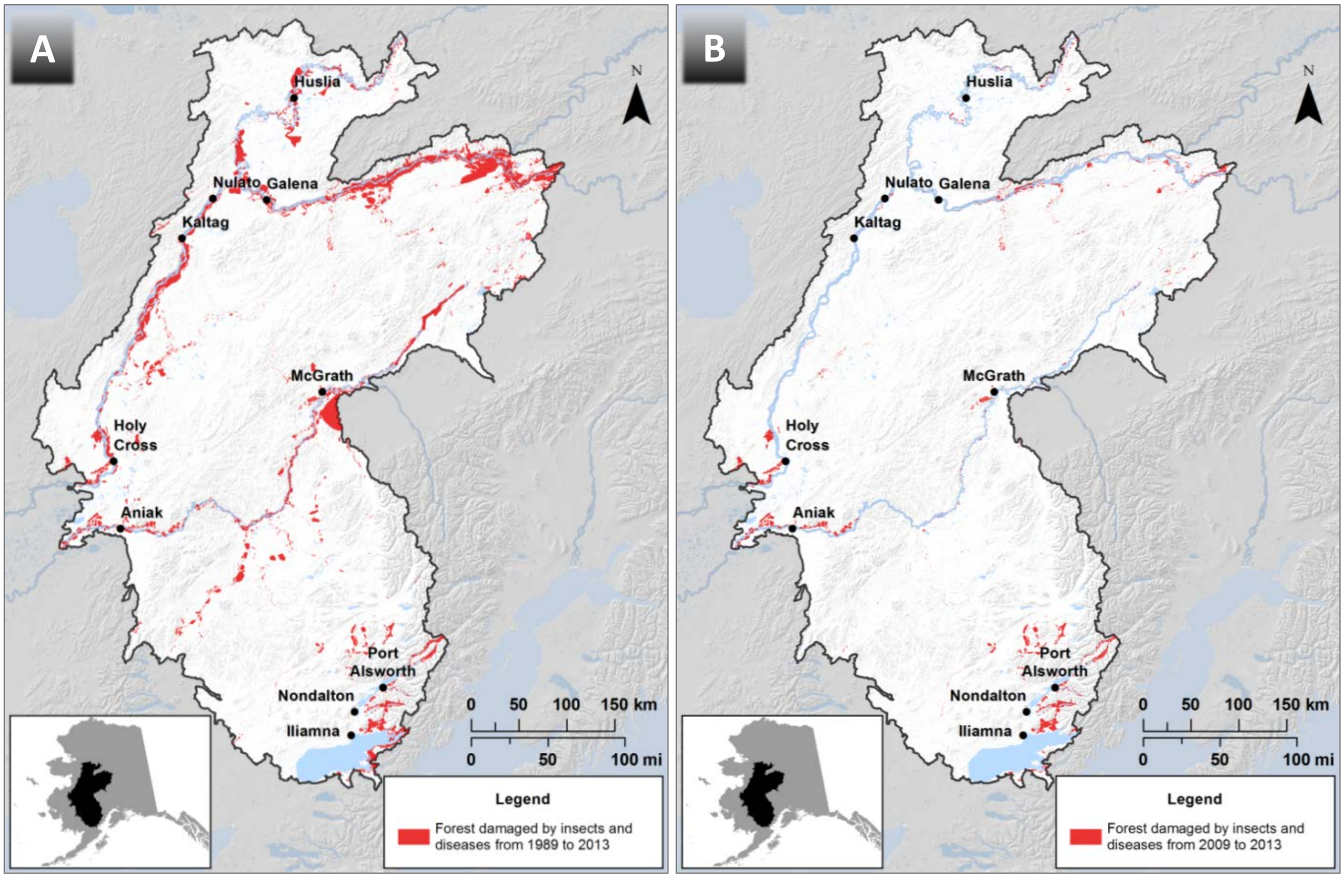

Figure B-42. Cumulative forested areas damaged by insect and disease agents from 1989 to 2013 (a) and from 2009 to 2013 (b).

Table B-17. Forest damage summarized by host and damage type within the YKL study area for the 25 year period from 1989 to 2013 and for the 5 year period from 2009 to 2013. Total damaged area represents the area of damage for one or more hosts. Because multiple hosts may have been damaged within the same area, this value is less than the sum of the columns.

Host and Damage Type	Area (km^2)	
	1989 to 2013	2009 to 2013
white spruce or black spruce mortality	2,461	510
tamarack defoliation	1,945	0.5
white spruce or black spruce defoliation	1,820	28
quaking aspen defoliation	1,545	419
willow defoliation	1,490	216
birch defoliation	1,193	1,127
general defoliation	589	98
general mortality	562	--
black cottonwood or balsam poplar defoliation	162	39
tamarack mortality	99	0.4
white spruce or black spruce discoloration	87	2
alder mortality	83	83
alder defoliation	71	48
softwoods defoliation	6	0.5
dwarf birch defoliation	2	2
general discoloration	2	--
willow mortality	2	2
western hemlock defoliation	0.02	0.02
Total Damaged Area	10,734	2,466

Table B-18. Forest damage summarized by causal agent within the YKL study area for the 25 year period from 1989 to 2013 and for the 5 year period from 2009 to 2013. Total damaged area represents the area damaged by one or more agents. Because multiple agents may affect the same area, this value is less than the sum of the columns.

Causal Agent	Scientific Name	Area (km^2)	
		1989 to 2013	2009 to 2013
spruce beetle	*Dendroctonus rufipennis*	2,455	459
general insect/disease damage	causal agent not identified	2,038	519
larch sawfly	*Pristiphora erichsonii*	1,946	0.5
spruce budworm	*Choristoneura fumiferana*	1,818	27
aspen leaf miner	*Phyllocnistis populiella*	1,426	375
willow leaf blotch miner	*Micrurapteryx salicifoliella*	746	289
birch leaf roller	*Epinotia solandriana*	691	688
northern spruce engraver beetle	*Ips perturbatus*	369	52
eastern larch beetle	*Dendroctonus simplex*	219	0.4
large aspen tortrix	*Choristoneura conflictana*	143	61
spruce needle rust	*Chrysomyxa ledicola*	85	0.2
spear-marked black moth	*Rheumaptera hastata*	68	60
birch aphid	*Euceraphis betulae*	12	12
cottonwood leaf miner	*Phyllonorycter nipigon*	10	--
cankers (general)	many causal agents	9	9
spruce broom rust	*Chrysomyxa arctostaphyli*	3	2
birch leaf miners	*Profenusa thomsoni* *Heterarthus nemoratus* *Fenusa pumila*	0.5	0.5
hemlock sawfly	*Neodiprion tsugae*	0.02	0.02
Total Damaged Area		10,734	2,466

In both the past 25 years and the past 5 years, spruce beetles have been the cause of the most tree mortality of any insect or disease agent in the YKL study area. Historically, mortality of white spruce or black spruce caused by spruce beetle has occurred along major riparian corridors throughout the study area and in the southeastern portion of the study area (Figure B-43). Mortality of white spruce or black spruce has been greatest, at 31% of the total spruce beetle damaged area, in the white spruce or black spruce-deciduous (open-closed) coarse-scale vegetation class from the Boggs et al. 2012 land cover map (Table B-19). However, white spruce or black spruce mortality is not limited to the white spruce or black spruce coarse-scale vegetation classes because mortality occurs in some vegetation communities in which neither white spruce nor black spruce are dominant, although the severity of spruce beetle damage in such areas is likely lower than in damaged areas dominated by spruce.

In the past 5 years, spruce beetle activity has been concentrated in the southeastern portion of the study area around Iliamna, Nondalton, and Port Alsworth. The widespread damage apparent from the previous 20 years has declined spatially and current outbreaks have not occurred along the major riparian corridors of the northern and central portions of the study area. Although spruce beetles continue to be problematic, spruce beetle activity in the southeastern portion of the study area has been declining in both area and intensity in recent years (FS-R10-FHP 2012, 2013). Mortality of white spruce or black spruce remains greatest in the white spruce or black spruce-deciduous (open-closed) coarse-scale vegetation class, at 21% of the total spruce beetle damaged area. Although currently spruce beetle damage is predominantly restricted to the southeastern portion of the study area, the current distribution of damage does not indicate that future outbreaks in other portions of the study area are unlikely because outbreaks appear to be largely stochastic.

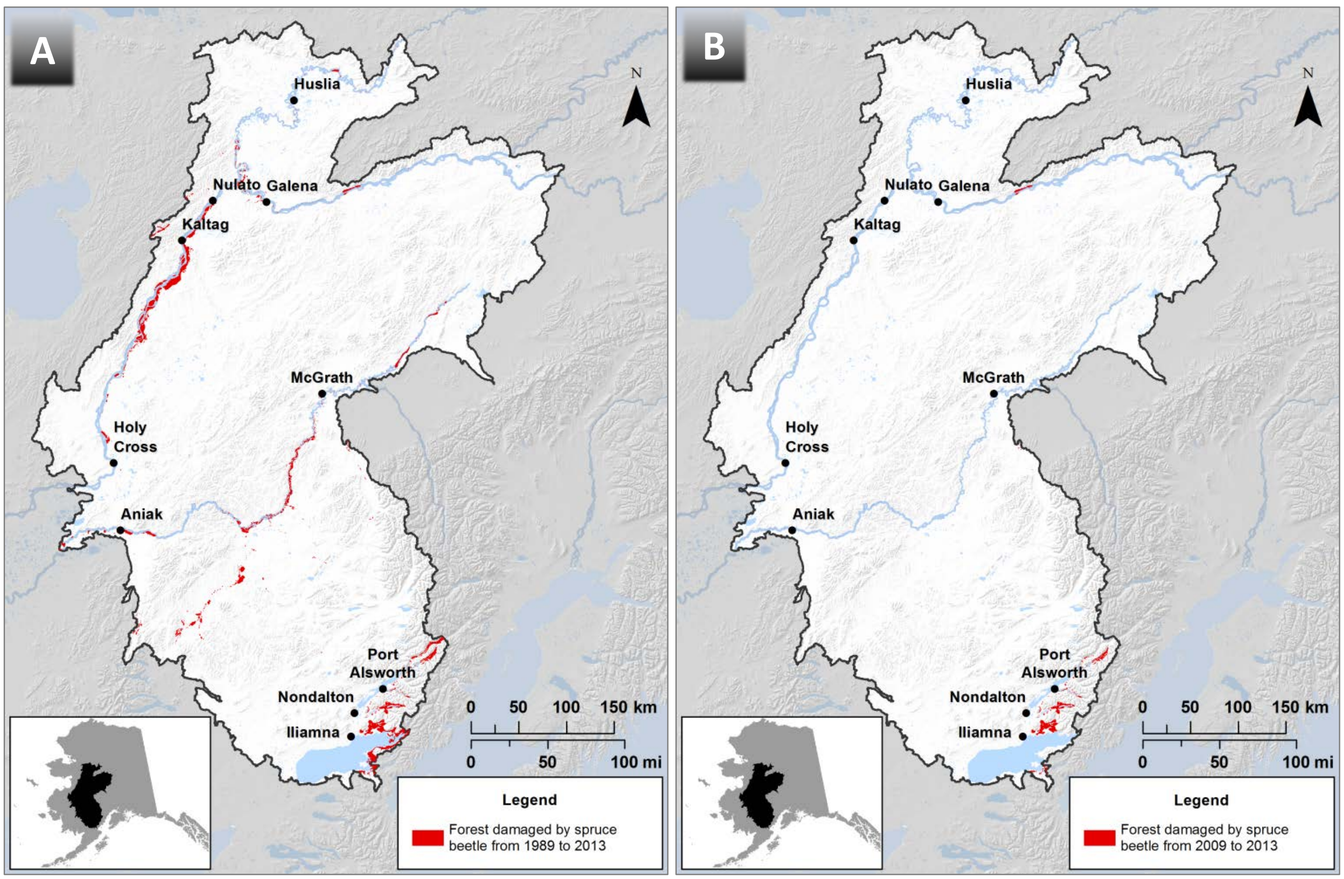

Figure B-43. Cumulative areas of white spruce or black spruce mortality caused by spruce beetle outbreaks from 1989 to 2013 (a) and 2009 to 2013 (b).

Table B-19. Five coarse-scale land cover classes (Boggs et al. 2012) most affected (by area) by spruce beetle inflicted mortality of white spruce or black spruce within the YKL study area for the 25 year period from 1989 to 2013 and for the 5 year period from 2009 to 2013.

Land Cover Class (Coarse)	Area (km^2)	
	1989 to 2013	2009 to 2013
white spruce or black spruce-deciduous (open-closed)	769	97
deciduous forest (open-closed)	412	90
white spruce or black spruce (open-closed)	313	42
tall shrub (open-closed)	307	75
white spruce or black spruce (woodland)	147	30
Total Damaged Area	2,455	459

Limitations and Data Gaps

Surveys have concentrated along riparian corridors in the past, leaving areas far from major rivers under-sampled. Smaller forest patches and mixed shrub and forest habitats are also likely under sampled. Some areas are surveyed annually while others are rarely or have never been surveyed. Additionally, no more than 25% of the forested area is surveyed during a single year, so data from any single year provides an incomplete synopsis of trends in the status of insect and disease agents (FS-R10-FHP 2012, 2013).

Forest damage is determined by aerial detection surveys during which an observer sketches observed damage areas onto a map. Time, money, and the interpretation of the observer all influence the data collected and the areas mapped. Many of the observations are not ground-truthed because of the limitations of time and money. Some insect and disease agents are not readily detectable by aerial survey. However, aerial detection surveys currently provide the most efficient and effective method to monitor forest health in Alaska (FS-R10-FHP 2012, 2013).

While the area and intensity of defoliating insects and diseases are highly stochastic, insect and disease agents are important forces structuring the regional ecology; additionally, outbreaks are likely to increase in frequency with climate warming (see Soja et al. 2007). Insect outbreaks and disease are likely to impact Coarse- and Fine-Filter CEs, as well as increasing the probability of invasive plant species establishment. Without directed research on the topic, however, we refrain from speculating on the nature of these impacts.

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5. Anthropogenic Agents

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Summary

Section B-5. *Anthropogenic Agents* describes the methods, datasets, results, and limitations for the assessments of the changes in social and economic conditions in communities; the changes in the human footprint; and the available Traditional Ecological Knowledge for the YKL region.

5.1. Introduction

This section describes the current extent of anthropogenic factors in the YKL region, and attempts to assess potential change in these factors in the future. Anthropogenic factors include several human activities ranging from heavy industrial activities such as mining, to livelihood activities such as subsistence. Owing to the breadth of such factors, this section is necessarily limited to major factors, guided by the MQs.

Assessment of the extent of anthropogenic activities required an extensive process of discovery, collection, and cleaning of data on various social and economic indicators from multiple data sources, and mapping and analyzing the various types of activities in the region. This section also identifies various data sources used in the analysis, and identifies various limitations to availability and accessibility of required data.

The project requires the results be reported at the 5th-level Hydrologic Unit Code (HUC). Social and economic data are available by political and administrative jurisdictions and do not correspond to HUCs. Where possible and meaningful, data were aggregated to the 5th-level HUC. To better accommodate the needs of the project and the limitations of available data, we grouped communities into three regions based on dominant watersheds.

Human activity in the region dates back to at least 9000 BC (McKennan 1981). Current land ownership and land use patterns reflect the recent history of land settlement in the region following the Alaska Native Claims Settlement Act (ANCSA) in 1971. Future land use is not expected to change significantly in this region.

Thirty-three isolated communities, trails, historic mining activity (mostly around the community of Flat, and along the corridor southeast of Galena between Ruby and McGrath), and current mining activities comprise the current human footprint. Land status in the region represents a checkerboard pattern of land ownership.

5.2. Methods

We identified current and future human footprints in the region by using several data layers. Table B-20 lists the datasets that were included in computing the human footprint in the region. While data on locations of communities, recent mining activities, transportation and communication infrastructure, energy infrastructure, and land claims were available, spatial data for timber harvests and recreational use are either non-existent or unavailable. All sources were cropped to the YKL region boundary. A combined human footprint map was used to generate the Landscape Condition Model (see Section C). This was produced by overlaying all individual layers described below.

Table B-20. Source datasets for analysis of current and future human footprints.

Dataset Name	Data Source
Community Footprints	Digitized from aerial and satellite imagery
General Land Status - October 2013 - All Attributes - Clipped to 1:63,360 Coastline	ADNR Information Resources Management
Iditarod trail	ADNR Information Resources Management
Alaska DNR RS2477 Trails	ADNR Information Resources Management
Alaska Roads 1:63,360	ADNR Information Resources Management
Alaska Resource Data File (ARDF)	U.S. Geological Survey (USGS)
Federal Mining Claims in Alaska	BLM
Alaska DNR State Mining Claims	ADNR Information Resources Management
Alaska DNR State Prospecting Sites	ADNR Information Resources Management
Renewable energy infrastructure	Alaska Energy Authority (AEA)
Contaminated sites program database	Alaska Department of Environmental Conservation (ADEC)

Community Footprints

The community footprints for the YKL REA were produced by digitally tracing the built areas from satellite imagery. This was done to represent the actual footprint more accurately that would have been possible from the U.S. Census Bureau’s Topologically Integrated Geographic Encoding and Referencing (TIGER) files. TIGER files are geospatial files with information on several political and administrative units. These shapefiles include polygon boundaries of geographic areas and features, linear features including roads and hydrography, and point features. The communities in Alaska were released as a polygon shapefile, with each community’s boundary identified. However, there were two major concerns with this file:

i. Community boundary polygons represent the legal boundaries and not the actual developed areas. The actual developed area for all communities in YKL region is much smaller than the legal boundaries. Moreover in many instances, boundaries as identified in TIGER files are not legal boundaries recognized under state law. Therefore, these polygon boundaries are not accurate representations of existing communities, and over-represent the actual community footprint.

ii. Many of the maps produced for this project show community-level social and demographic information. For better representation in such maps, a point file was used instead of a polygon file to identify communities. Generation of a point file from a polygon file is done by locating the point at the center of gravity of the polygon. Given the large polygons in the community TIGER file, centers of gravity are often well outside the actual community footprints.

As a result, Census TIGER files were not used in identifying community footprints. Instead, each community's footprint was digitized from satellite imagery. Communities in YKL region are small and their footprint is concentrated in a small area with some activities scattered around the central location. Population in each community is low and activity beyond identified footprint boundaries is minimal such as isolated fish camps or hunting camps. Since the region is devoid of any major roads connecting communities, impact due to transportation is minimal.

Transportation Infrastructure

Transportation network in the region includes airstrips, few paved or gravel roads within communities, and a network of trails that connect communities. All communities are located along rivers and rivers are major transportation routes. Transportation data files were all obtained from the Alaska Department of Natural Resources (ADNR). Alaska trails from Revised Statute (RS) 2477 of the Mining Act of 1866 are rights-of-way for the construction of highways over public lands, not reserved for public uses. The act granted public right-of-way across unreserved federal land to guarantee access as land transferred to state or private ownership. Rights-of-way were created and granted under RS 2477 until its repeal in 1976. The combined dataset used for this project does not include subsistence access trails on Native land.

Renewable Energy Infrastructure

Renewable energy infrastructure includes several types of energy production installations: wind, hydro, thermal, and biomass. Through multiple waves over the last decade, Renewable Energy Alaska Project (REAP) funded, or is considering funding, several of these installations. All renewable energy sites are small scale. With the exception of the Tazimina hydroelectric plant, energy infrastructure sites are within community footprints.

ARDF Mining Dataset

Data on mining activities in the region were obtained from the Alaska Resource Data File (ARDF), a compilation of mining activity maintained by the United States Geological Service (USGS). It is a subset of the National Mineral Resource Data System (MRDS), "a collection of reports describing metallic and non-metallic mineral resources throughout the world" (United States Geological Service, 2014). All mines, prospects, and mineral occurrences are recorded with descriptions, types of minerals and ores, last reported date, current status of the site, and location.

The following process was followed to prepare the ARDF mining dataset to be included in the human footprint:

1. Main data file had quadrangle codes, and quadrangle code descriptions were given in another file (http://ardf.wr.usgs.gov/explain.pdf). The quadrangle code descriptions have been added in the main dataset.
2. There is considerable uncertainty in several key fields in the dataset.

a. ‘Site status’ had the following values: 'active,' 'active?,' 'inactive,' 'inactive?,' 'probably inactive,' 'not determined,' 'undetermined.' These were recoded and defined as follows:
    i. Active (some work was reported at the time of last report date) - 'active', 'active?'
    ii. Inactive (no work was reported at the time of last report date)– 'inactive' 'inactive?,' 'probably inactive'
    iii. 'undetermined' (no information was available) – 'undetermined', 'not determined,' 'undetermined' and blank cells
b. ‘Site type’ refers generally to the current status or potential for the site to yield a mineral. Three distinct values seem to be valid – 'mine', 'occurrence', and 'prospect'. This classification of reporting mineral occurrences is not congruent with the industry standard set by the Society for Mining, Metallurgy & Exploration Inc. (SME), or other international organizations. No certain definitions could be obtained from USGS. This field had the following recorded values: 'mine', 'mine?', 'mines', 'mine (?)', 'occurrence', 'occurrence(?)', 'occurrence?', 'occurrences', 'prospect', 'prospect(?)','prospect?', 'prospects(?)', ‘prospect', 'mine', and ‘mine and prospect’. These were recoded and defined as follows:
    i. Mine (where a mineral was or is being extracted) – 'mine', 'mine?', 'mines', 'mine (?)'
    ii. Occurrences (a location where a useful mineral or material is or was found) – 'occurrence', 'occurrence(?)', 'occurrence?', 'occurrences'
    iii. Prospect – (prospect is any occurrence that has been developed to determine the extent of mineralization) – 'prospect', 'prospect(?)', 'prospect?', 'prospects(?)', 'prospect; mine', and 'mine and prospect'.
c. Commodities or minerals at each site were recorded in two separate columns – 'commodities-main', and 'commodities-other':
    i. 'Commodities-main' is the main mineral resource that was, is or is expected to be mined at the site. Multiple commodities (up to 21) were listed in this column for many sites.
    ii. 'Commodities-other' are ancillary minerals that may be extracted depending on the technological and economic feasibility. There was more than one commodity listed in this column.
d. 'Deposit model' field contained a brief description of the deposit. These descriptions indicated if a particular site was a placer gold mining site. If the site listed gold in the 'commodities-main' field, these sites were marked as placer gold mining sites, whether in the past, present, or in the future.
e. 'Production' field recorded any production activity at each site as of the last reported date. A variety of values were used. They were all recoded into the following options:
    i. 'No' – 'No', 'None',
    ii. 'Yes' – 'Small'; 'Yes', 'Large', 'Yes', 'medium', 'Yes, small', 'Yes, Very small', 'Yes: small', 'Yes: large', 'Yes, medium', 'Yes, small?', 'Yes: unknown', 'Yes?'.
    iii. ‘Undetermined’ – 'Undet.', 'Undetermined', 'Unknown')
f. 'Last report date' is the only date field in the dataset. This field reports the date of last update on any activity at each site. Date of last update on each site varies, and not all sites are updated annually or periodically.

The ARDF file is not updated in a systematic way (R. Wilson 2013). Data contained in the ARDF are largely a result of voluntary reporting and collection efforts. MQ #53 asked for the recent mine sites, and so only the data with last report date between 2001 and 2012 have been considered in the final data set. There were only 4 prospects that had a report date prior to 2001, all last updated on May 4, 1999.

Because reports in the ARDF file are out of date, we used information from other reports, data on contaminated sites, and Internet searches to produce a more complete description of mining areas.

5.3. Results

Thirty-three small communities are located in the region. Their total footprint is 65 km^2, accounting for roughly 0.03% of the YKL area. Figure B-44 shows the locations of all communities. Broadly, these communities can be thought of as three regions based on major watersheds. Galena in the northwestern part of the YKL, McGrath on the northeast, Aniak in the southwest, and Iliamna in the southeast part of the region serve as transportation and service hubs for surrounding communities.

Current Human Footprint

Current human footprint in the region is a combination of several anthropogenic uses including community locations, transportation networks, mining, and recreation. This section explains the extent of these activities independently of each other. A combined human footprint was generated to compute the landscape condition (Section C).

MQ 42	Where is the current human footprint in the region?

Community Locations and Current Transportation Networks

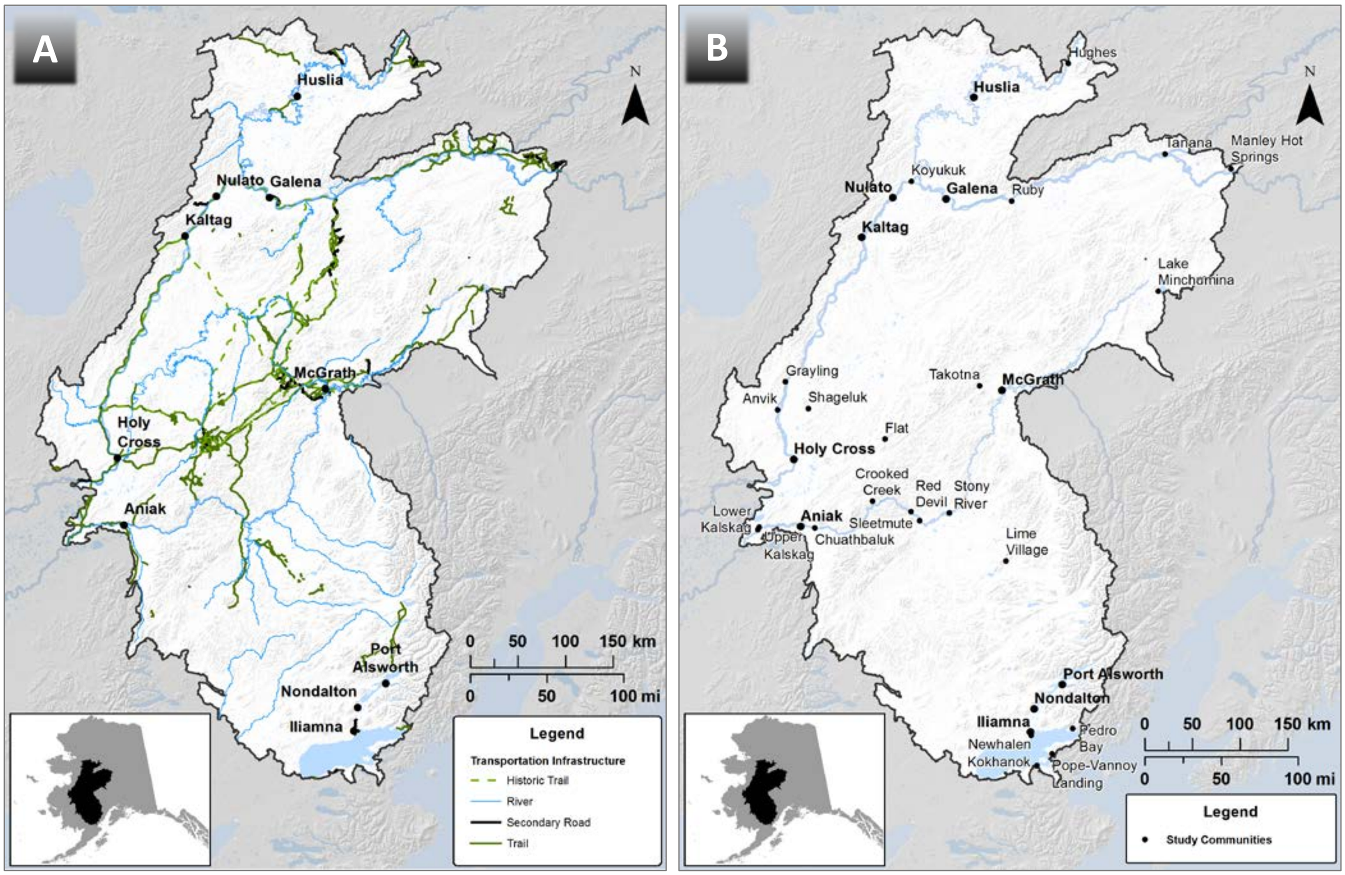


Figure B-44. Current community locations (a) and transportation networks (b) in the YKL region.

The region has four hub communities: Aniak, Galena, McGrath, and Iliamna. Several smaller communities are located closer to these hub communities along major river corridors or around Lake Iliamna. The largest community, Aniak is home to just over 500 people. Owing to small populations, footprints of communities, including all houses, public buildings, and transportation networks within each community are minimal.

Commuter (scheduled) and air taxi (unscheduled) services provide the only year-round transportation in and out of the region. Each community has an airstrip with flights to and from the closest hub community. The four hub communities are served from Anchorage. Only two (Galena and Aniak) have more than 10,000 enplanements per year (FAA 2013). Air travel between communities served by each hub is relatively easy but expensive. However, hub-to-hub air travel is cumbersome since it requires travel through Anchorage.

The transportation network includes trails, secondary roads, and rivers. None of the communities are connected by paved roads. However, many trails exist in the region. Some trails are more often used than others. Table B-21 shows the lengths of trails/secondary roads and rivers in the region. Secondary roads shown in the map are old roads/trails, built prior to statehood through the efforts of the Board of Road Commissioners for Alaska. These roads, between McGrath and Takotna, and north to the Yukon River were built in the 1920s to facilitate transportation between the Yukon River and the Takotna Valley. The Takotna Valley was an active mining area and the mines needed a portage to the Yukon River. These roads are minimally used in current times, but remnants remain (Stirling, 1986).

Table B-21. Types of transportation routes and their lengths in km.

Transportation route type	Length (km)
National Historic Trail	2450
Secondary Road	718
Trail	5009
River	12978
Unknown	26

The Iditarod National Historic Trail runs through this region, and several trails connecting the old Flat mining district with the surrounding area are still used occasionally. Most of the trails are used for access to subsistence resources in the lands surrounding the communities during summer months. Some of these trails cross water bodies and can be used only in the winter months when the rivers and lakes are frozen. Snow machines and all-terrain vehicles (ATV) are used in the winter months. ATVs are also used in the summer months on land, and small boats are used on rivers. Boat travel is between May and mid-October, beginning after spring break-up. Break up is earlier on the Kuskokwim than the Yukon (YK Transportation plan 2002). The Kuskowkwim River also serves as an ice road during the winter and is plowed from Bethel to Aniak.

Land Status and Land Claims

MQ 43	What is current land status in the region?
MQ 44	Where are unsettled land claims?

The State of Alaska is the largest landholder in the YKL region (Table B-22). Through various acts of US Congress, the state was entitled to land selections. Approximately 447,582 km^2, or 96.3% of the state entitlement, was already selected in the entire state. This selection includes 149,976 km^2 of land that was tentatively approved for selection (Bradner, 2013). Approximately 115,417.78 km^2 of this selected land lies within the YKL region and is managed by Alaska's Department of Natural Resources. These selections were to provide necessary resources for the state's development, and to convey control over the state's internal affairs from the federal government. These selections were based on the principles of encouraging development and settlement, development of natural resources, and development of recreational uses of land (Alaska Department of Natural Resources, 2000). Other than isolated mining activities, no major use of the state selected land is witnessed in the YKL region at this time.

Table B-22. Land status and ownership in the YKL region.

Owner/Management Agency	Area (km^2)
Bureau of Land Management	35,572.58
USFWS	39,937.80
Military	169.56
NPS	9,290.04
State Patent or TA	100,331.62
State Select	15,086.17
Native Patent or IC	27,494.35
Native Select	2,958.54
Private	31.10

In addition to the State Patent or Temporarily Approved (TA) selection, State of Alaska also selected lands that are yet to be approved by the federal government. This land is awaiting approval and is not yet conveyed either through a patent or temporary approval. Approximately 15,086.17 km^2 of land is marked as state selected lands in the YKL region, not all of which may be eventually conveyed under the authorizing legislation. While the state files a claim and the land is marked as "state select", the land is closed for federal mining claims but the state of Alaska accepts mining claims on this land. However, there is considerable risk associated with such a claim since the federal government may restrict such claims or may not eventually convey the selected land to the state. (Alaska Department of Natural Resources, 2014).

Similar to the state selection, Alaska Native corporations were entitled to land selections through the Alaska Native Claims Settlement Act of 1971. A total of 27,494.35 km^2 of land is either conveyed or in interim conveyance (IC), and another 2,958.54 km^2 of land was selected but yet to be conveyed. Recipients of conveyances under ANCSA are a mixture of regional and local Alaska Native corporations, and the majority of this land will be private landholdings of Alaska Native corporations. A small portion of this land will be conveyed as a landbase for communities. These conveyances for community lands (up to 1200 acres) will first be transferred from local Alaska Native corporations to the state, in trust for a future municipal body to be incorporated under state law. Upon incorporation of such a municipal entity, these conveyed trust lands will be conveyed to the local municipal entity. Such lands are selected by each community through an extensive public process involving members of that community and other stakeholders in the lands around that community. Most communities in the YKL region did not complete their land selections.

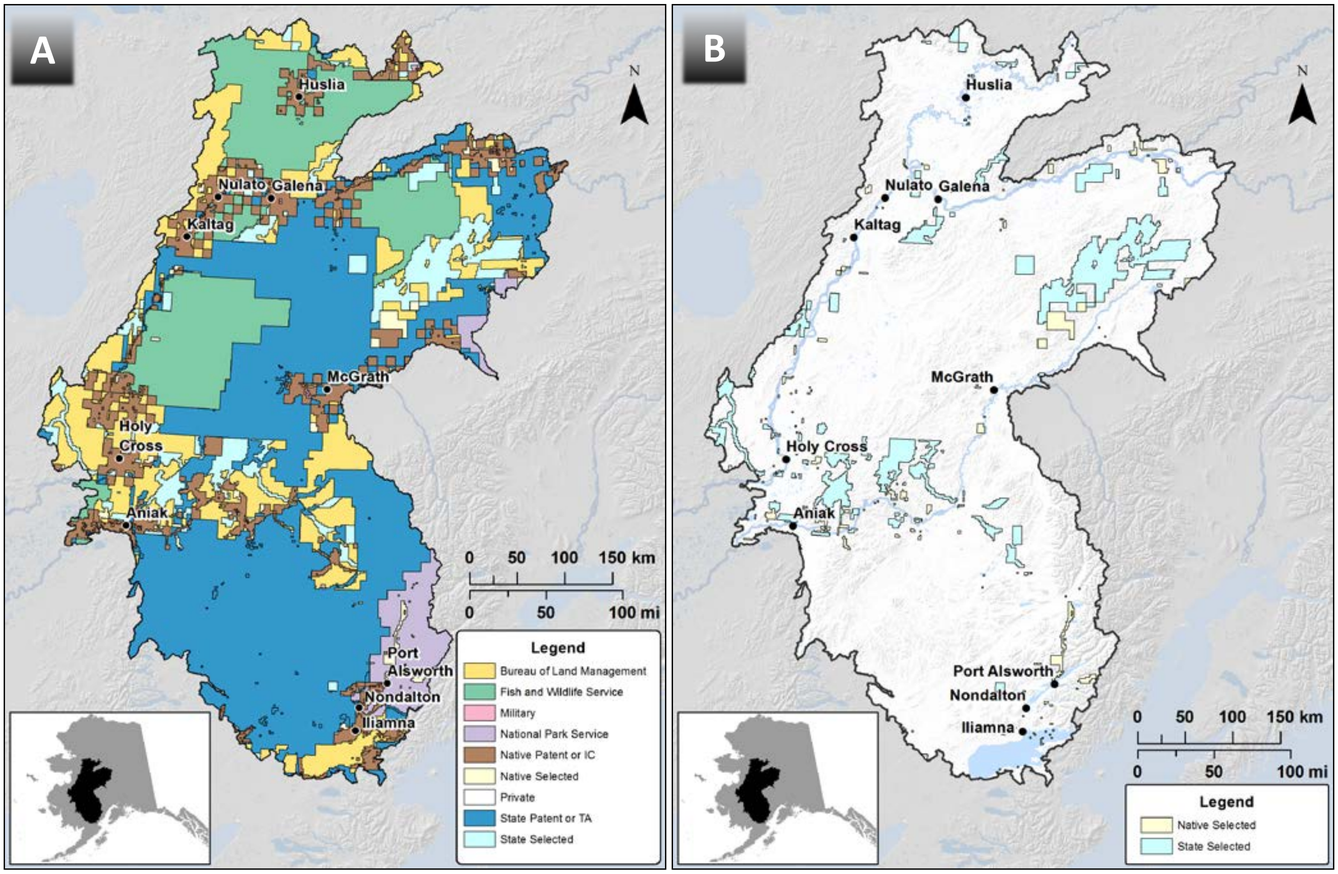


Figure B-45. Land status (left) and unsettled land claims (right) in the YKL region.

Lands that were selected and conveyed to Native corporations, and through them to the communities, appear to form a checkered pattern. The left panel in Figure B-45 shows all lands within YKL region, by ownership or management status. The right panel in Figure B-45 shows the lands that are selected by either the state or the Native corporations for consideration to be conveyed. These lands (18,044.71 km^2) are currently owned by the federal government and are not included in the areas listed as managed by any of the federal agencies or military in Figure B-45 and Table B-22.

Recent Mining Activity

Data for mining activity in the region is obtained from the Alaska Resource Data File (ARDF) compiled by the United States Geological Service (USGS). As described in the previous section, ARDF data has several imitations. The activity for each mine location is as current as the 'last reported date'. Activity last reported at some of the locations is quite dated. However, the last reported date may not accurately reflect the possible latest activity. The status of any location is noted variously as 'active', 'inactive', or 'undetermined'. Since mining activity is not reported consistently, reliability of ARDF is questionable. Despite this, ARDF is considered the most comprehensive source of information on recent mining activity in Alaska.

The left panel in Figure B-46 shows all 150 placer gold mines in the YKL region as identified in Alaska Resource Data File. The majority (102) of these operations are listed as inactive, while the status of a few is undetermined or unknown. Most of the placer gold mines are located along a corridor from Flat to McGrath and north to the

Yukon River, part of the Innoko-Iditarod mining district. Out of a total of 17 hard rock mines in the dataset (right panel in Figure B-46), ten are inactive, five are active, and two are undetermined.

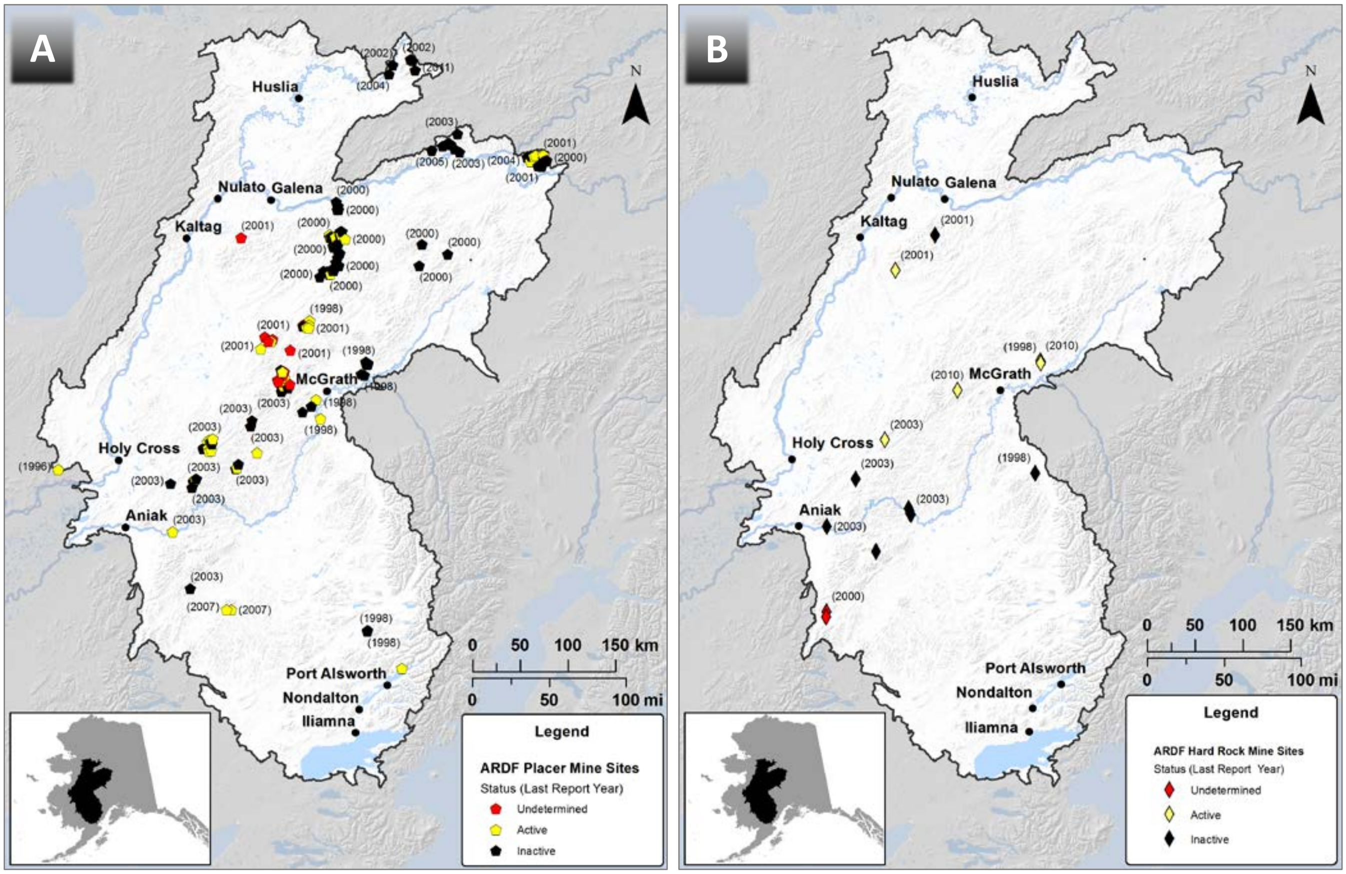


Figure B-46. Current and past mining activities in the YKL region – placer mines (a) and hard rock mines (b) . Mining claim dates are included in parentheses. ARDF refers to Alaska Resource Data File.

Mining Claims

A mining claim gives the owner certain immediate property rights to already discovered deposits (Alaska DNR 2006). Claims can either be 40 acres or 160 acres, and may remain "active" for any length of time in return for set fees and devoid of violating legal restrictions. In cases where other resources are affected, claims are converted to upland mining. As part of the claim process, before locatable minerals can actually be mined, a mining permit application (APMA or plan of operation and reclamation plan) must be filed and approved. A reclamation bond is required for disturbance areas larger than five acres. Prospecting sites are for acquiring potential "locatable" mineral rights (base and precious metals) that have not been discovered yet (BLM 2013).

Current mining claims in the YKL region are mostly on state-owned land. A total of 9,316 km^2 of state land, including the Donlin and Pebble mining claims, are currently active. A relatively insignificant amount of 25 km^2 active claims are located on federal lands. A small area (152 km^2) within the region is marked as prospects. Figure B-47 shows the location and extent of claims and prospects listed in the ARDF dataset.

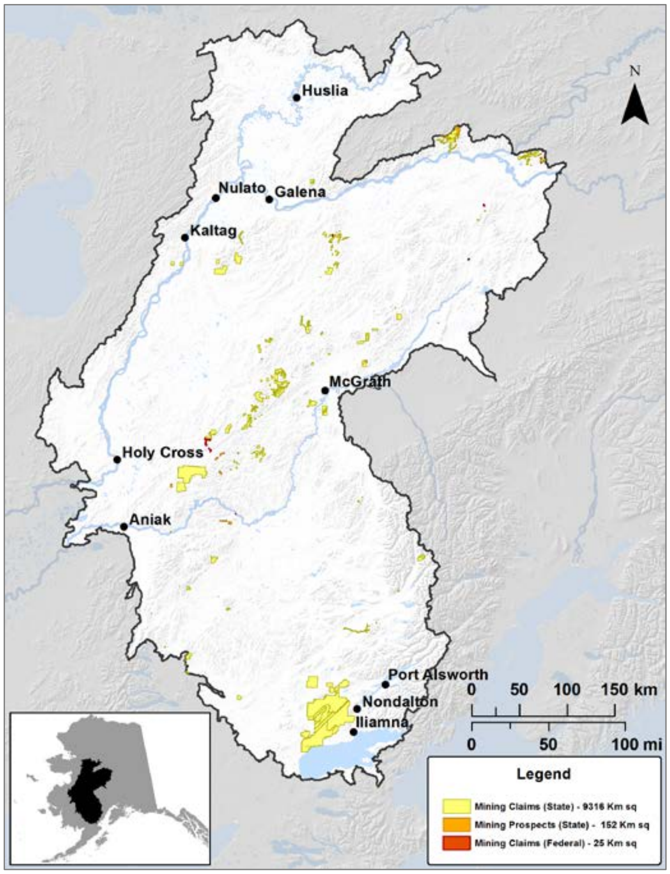


Figure B-47. Current mining claims in the YKL region.

Existing Energy Sites

With the exception of a hydroelectric plant near Iliamna, all energy infrastructure is within community boundaries. The region is characterized by isolated power grids, as is the case in most remote rural Alaska. Diesel generators are the main source of power. Some communities such as Sleetmute have multiple generators and distribution networks due to geographical barriers within the community. Other communities have interties that need one source for those communities. A total of 33 diesel-fuel power generators (Figure B-48) exist in the region as reported by the Alaska Energy Authority. In addition, there are alternative energy sites in the region.

Renewable energy projects vary in size. The largest project is the Tazimina hydro-electric plant near Iliamna. It is a run-of-the-river hydroelectric project producing 824 kW of electricity, meeting the power needs of the three small communities of Iliamna, Nondalton, and Newhalen. Run-of-the-river projects divert a portion of the river through turbines to make power before returning the water downstream (AEA 2014). In contrast, the solar energy project in Kaltag, is a 9.6 kW photovoltaic panel system built on a storage container that offsets some of the fuel consumption of the powerhouse. Management of a renewable energy installation in remote rural Alaska involves multiple challenges. Both the technical and managerial skills are in short supply in rural communities. The solar project in Lime village is an example of difficulties maintaining and operating alternative energy facilities, especially in places with small and decreasing populations. The solar project operated for one month in 2003 (AEA 2014).

The Alaska Renewable Energy Fund through its six rounds of funding has assisted communities across the state in identifying, developing, and utilizing alternative sources of energy. Communities in the YKL region received funding for and are currently operating seven such sources of energy. Figure B-48 also shows the alternative energy projects funded by AEA currently in operation in the region. These installations are in various stages of development. Many of the biomass projects are completed. The wind power installations are in their final stages of testing.

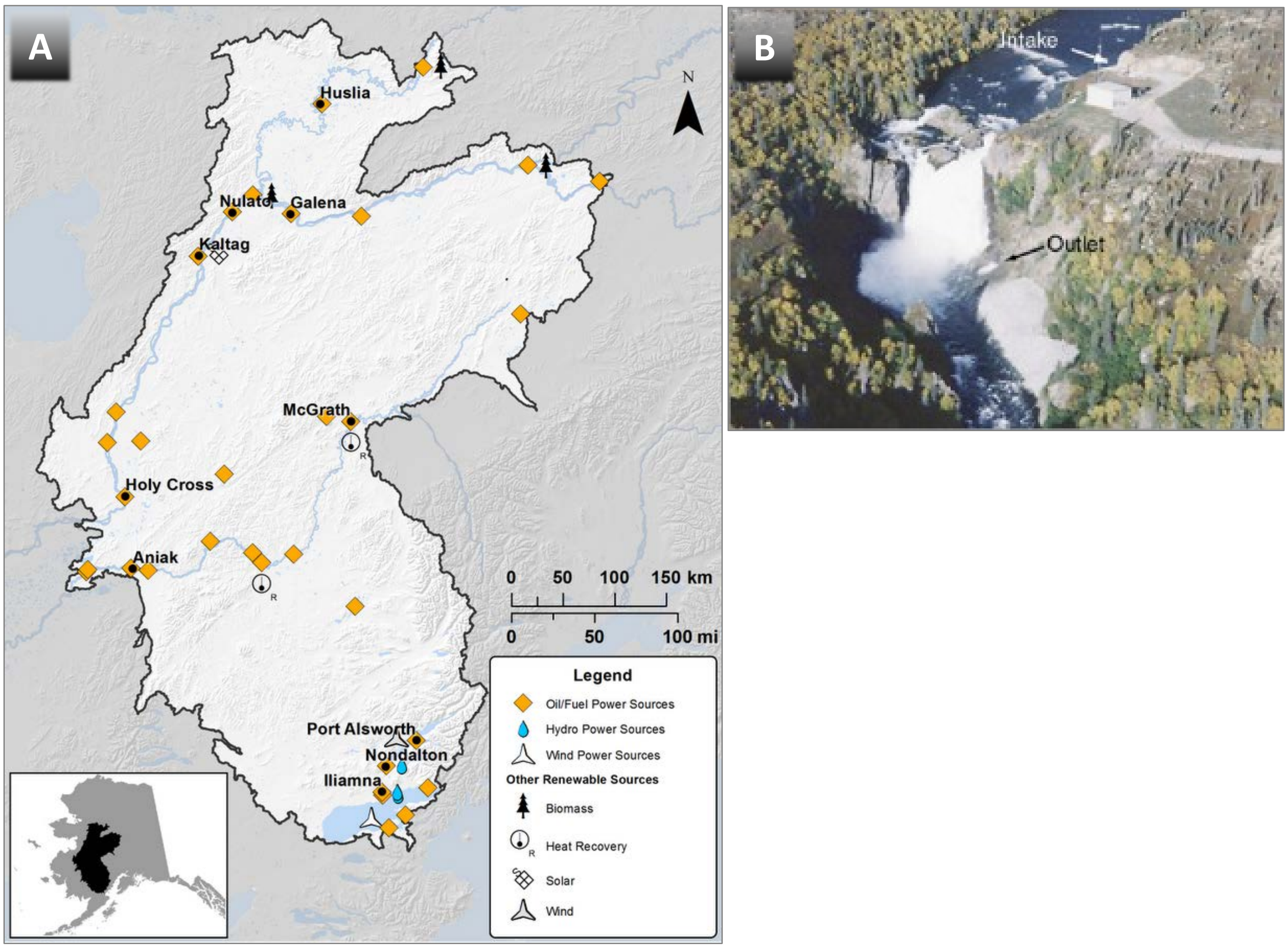


Figure B-48. Existing energy production facilities in the YKL study area (a); Tazimina Hydro-Electric Plant (b).

Future Transportation and Communications Infrastructure

MQ 48	Where is planned transportation/communication infrastructure to be located?

Several ground transportation options were suggested over the years, to increase the economic viability of the region, and to improve connectivity within and beyond the region. It has been discussed several times over the last few decades to connect villages on the Yukon and Kuskokwim rivers to fuel and other supplies in Fairbanks, to reduce the cost of living in remote communities, and reduce associated out-migration (State of Alaska DOT 2014). Four different projects are in various stages of development in the region.

1. *The road from Manley Hot Springs to Tanana*: A one-lane, 26-mile pioneer road with frequent turnouts (Brehmer 2014) will connect Tanana to Fairbanks and the State's road/rail system. It will also expand access to mineral resources in the Manley region (State of Alaska DOT 2014). The project is permitted and construction will begin in August 2014 (Friedman 2014). Tanana residents have been harvesting timber from state land cleared for the right-of-way for use as firewood and in the wood-fired boilers that heat several public buildings (Brehmer 2014). However, this road will not immediately reduce fuel costs because it is not wide enough for fuel trucks (Friedman 2014).
2. *The Yukon Kuskokwim Energy Freight Corridor*: This project connects the Yukon and Kuskokwim rivers at their closest point near Kalskag. It was initiated by the regional non-profit corporation, the Association of Village Council Presidents (AVCP). Barges will carry fuel and freight from Fairbanks down the Yukon River, then cargo will be moved overland by truck to Kalskag, and again by barge to other villages on the Kuskokwim. The road is expected to expand market size, improve the reliability of fuel and freight movement, and lower costs (AVCP 2014). In FY12 this project received $460,000 from the State of Alaska. In FY13, this project received $3,000,000 from the State of Alaska. In FY15 it received $600,000 of a $6 million request. The estimated cost of the design phase through right of way acquisition is $13.2 million (State of Alaska DOT 2014).
3. *Ruby to McGrath Road*: This project connects Ruby on the Yukon River to McGrath on the Kuskokwim River and beyond to Donlin Creek (Yukon Kuskokwim Transportation plan 2002),
4. *Road to Nome*: Four alternative routes were proposed for a road from Fairbanks to Nome. The least preferred alternative passes through the northern part of the YKL region (Dowl HKM 2010). However, the state has no long-term plan to build a road to Nome with an estimated cost of $3 billion (Forgey 2013).

Figure B-49 shows two possible scenarios: a near-term and a hypothetical long-term scenario. The hypothetical scenario features a road along the Kuskokwim River, which (based on construction of a natural gas pipeline crossing the Kuskokwim and nearly parallel to the river for the last part of the pipeline closer to the proposed mine) is a distant possibility.

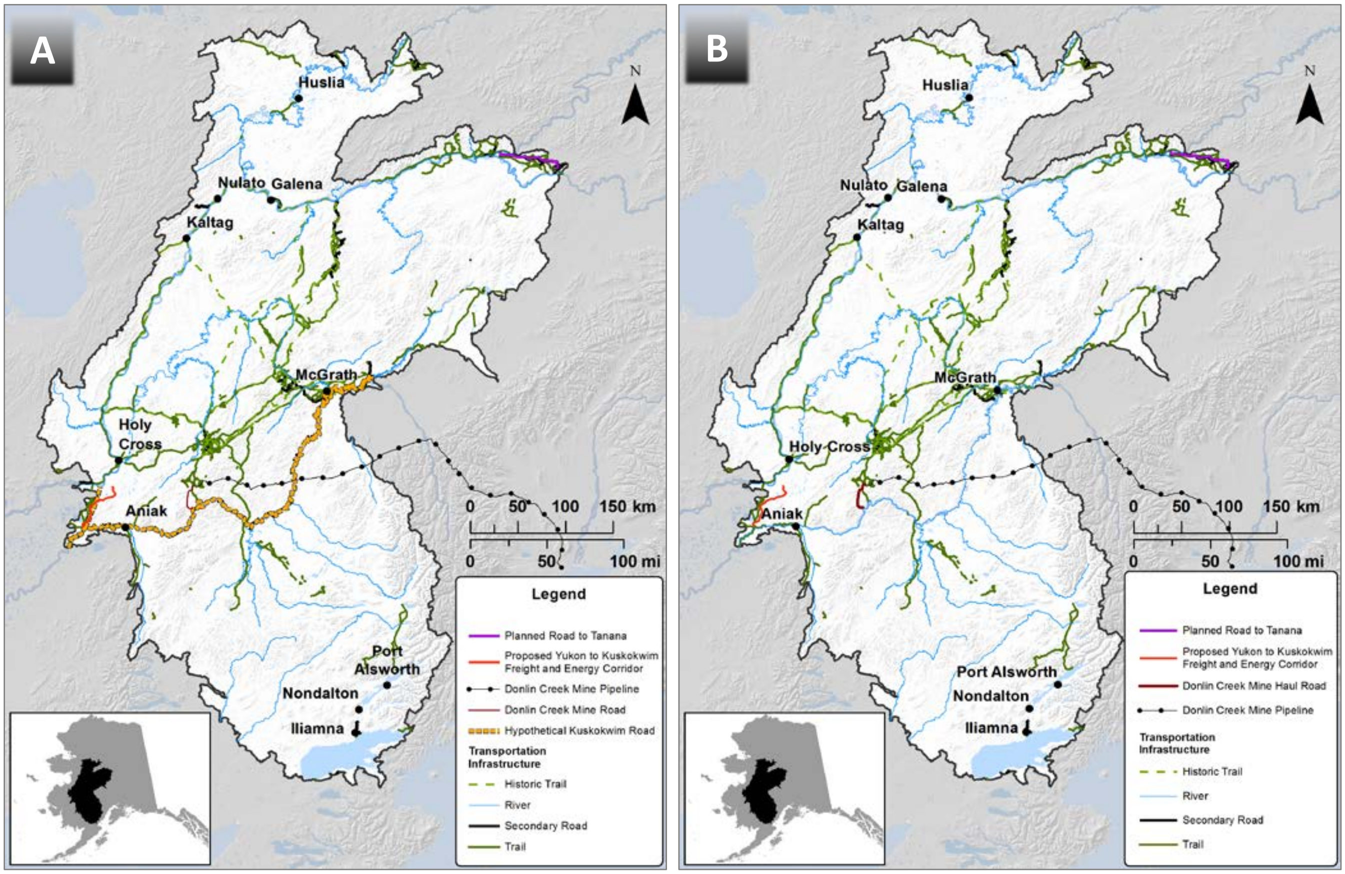


Figure B-49. Near-term future (a) and long-term future (b) transportation scenarios in the YKL region.

Future Mining Activity

MQ 46	Where are areas of energy and resource extraction currently and likely to occur in the future?

There are no major large scale energy projects in the region, nor are any being planned to our knowledge.

In addition to mining activities described in the previous section, exploration activities are underway on two major open-pit mines: Donlin Creek (gold) and Pebble (copper). These mines are expected to be two of the largest mining operations in the world. Figure B-47 shows claims and prospects on state and federal lands in the region. Both Donlin Creek (northeast of Aniak) and Pebble (west and north of Iliamna) hold claims on large portions of land. Donlin Creek Mine is progressing through the permitting process and will be a few years before actual mining operations begin (US Army Corps of Engineers 2013). The US Army Corps of Engineers is preparing the Environmental Impact Statement to analyze the impacts of permitting the mine. The proposed mine would have a total footprint of approximately 16,300 acres. Several assessments and feasibility studies over the last sixteen years indicate a potential small diameter (14 inch) 313 mile gas pipeline from the west side of Cook Inlet to the mine across the Alaska Range, as the potential source of power for the mine. The mine will also include a five acre barge landing downriver from Crooked Creek on the Kuskokwim River, a 30 mile access road from the barge landing to the mine site, and a 5,000-foot airstrip at the mine site (US Army Corps of Engineers 2013).

While Donlin Creek is proceeding at a steady pace, the Pebble prospect is delayed due to various reasons. After much debate on the merits, potential positive and negative impacts of the mine on the environment and population in the region, the Environmental Protection Agency (EPA) conducted an assessment of these potential impacts (United States Environmental Protection Agency 2014). This process halted any permitting by the U.S. Army Corps of Engineers. Permits are essential for the mining activities to proceed further. The assessment, released in January 2014, was the basis for EPA's decision to initiate a process under the Clean Water Act of 1972 to "identify appropriate options to protect the world's largest sockeye salmon fishery in Bristol Bay, Alaska from potential destructive impacts of the proposed Pebble Mine" (United States Environmental Protection Agency 2014). While attempts at pursuing the prospect are still underway, actual development of the prospect is delayed due to the slew of political, legal, and social challenges of such a development in the Bristol Bay area.

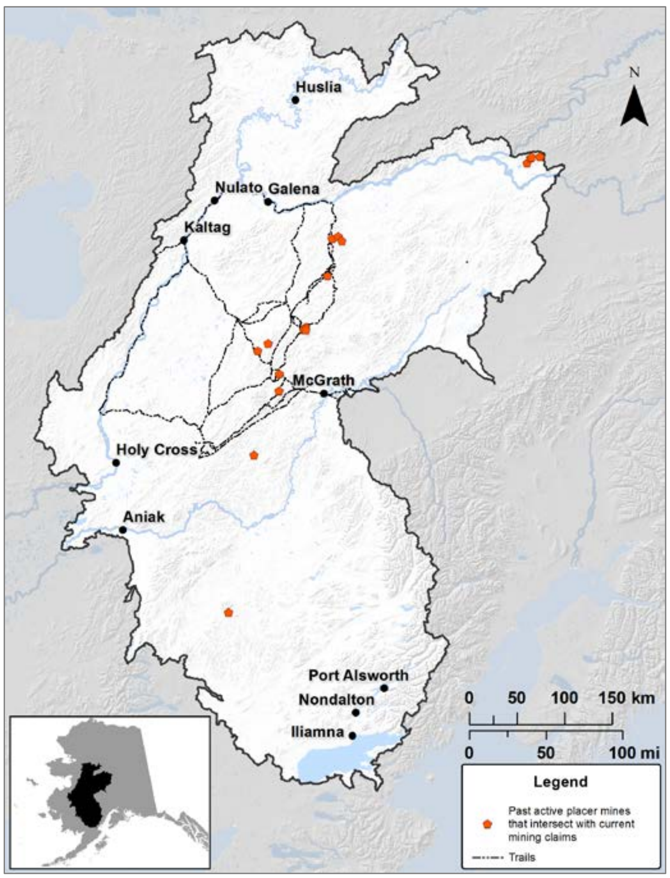


Figure B-50. Placer mining potential in YKL region.

Beyond Donlin Creek, the location and size of future large-scale hard rock mining is difficult to predict. Development depends on the availability and accessibility of minerals, economic feasibility of mining, and environmental impacts. However, placer mining may be predicted with the data available. Figure B-50 shows the potential placer mining locations in the YKL region. Because of the small scale of placer mines, the map depicts areas of mining activity rather than individual mines. These locations are identified based on the last reported activity in the ARDF database, and an active mining claim. Those locations that were reported as being active in the year 2000 or later were identified from the ARDF dataset. These 'active' mines that fell within the boundaries of an active mining claim were identified as potential placer mines in the future. The majority of the potential locations for placer mining are located along the corridor southeast of Galena between the Yukon River and McGrath (Ruby to Ophir).

Future Alternative and Renewable Energy Sites

MQ 47	Where are planned sites for alternative/renewable energy?

Figure B-51 shows alternative/renewable energy projects that have been funded by AEA and proposed projects that were not funded. Funded projects are in various stages of development from permitting to completed-but-yet-to-be-commissioned. It is relatively quicker to construct and commission a biomass project of the scale funded in this region. Many of the biomass plants are functional.

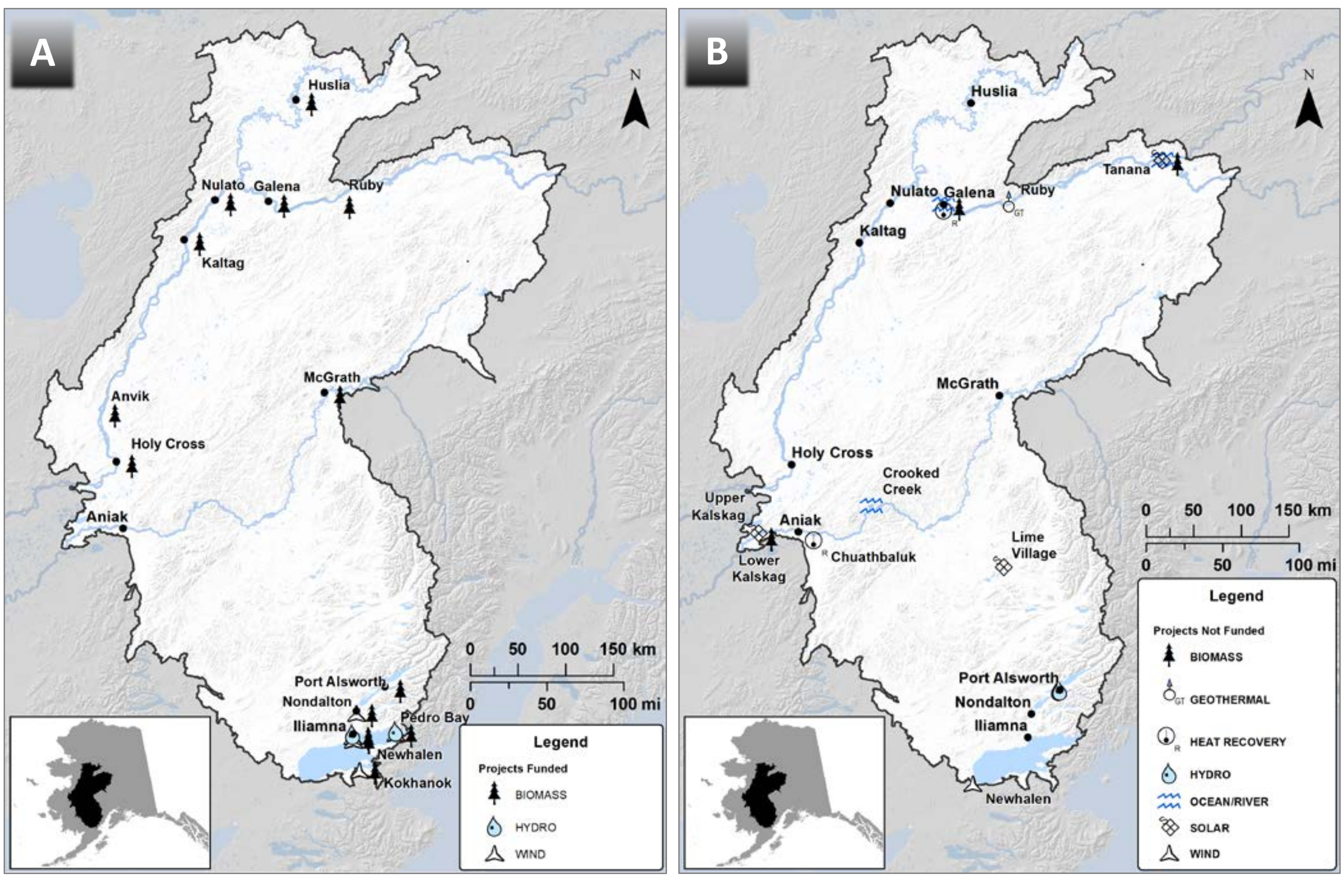


Figure B-51. AEA funded (a) and unfunded (b) renewable/alternative energy production facilities as of 2014.

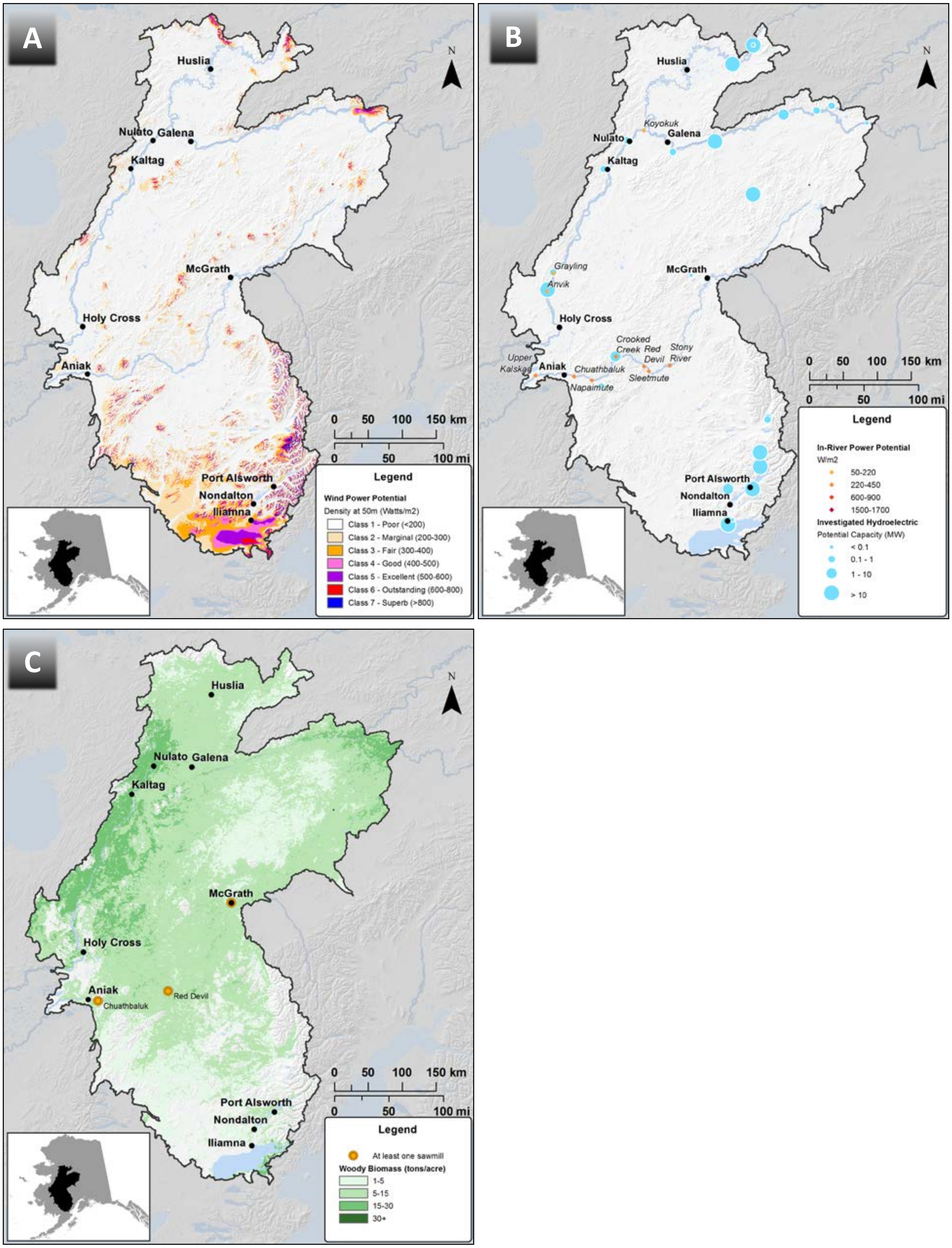


Figure B-52. Areas of potential sources of alternative/renewable energy resources in the YKL region: wind (a), hydro (b), and biomass (c) resources.

Figure B-52 shows the potential areas of alternative sources of energy from wind, hydro, and biomass. Wind can be a prominent source of energy in the southeast part of the region. While hydroelectric potential seems to be a viable source of energy, only one project is proposed in the area. Wood has traditionally been used for fuel and modern technologies are allowing communities in the region to maximize the utility of this traditional source of energy.

Timber Harvests

Out of Alaska's 127 million acres of forested land, 12 million acres is timberland – defined as "unreserved forest land productive enough to be able to produce 20 cubic feet of industrial-sized roundwood per acre per year" (Halbrook, et al. 2009). Timber harvests are defined as "the total volume of wood removed from a forest site from both growing stock and non-growing stock sources for the purposes of conversion to products or direct use by consumers" (Brackley, Haynes, & Alexander, 2009, p. 2). Despite the importance of timber harvest and sales data for effective forest management, such data were sparsely available, even at a state level, until 2009. Only the southeast region of the state had a complete forest inventory.

Although Alaska's timber and forest products industry has a long history, the majority of the harvest and sale at a commercially viable scale happens in the southern and southeast regions of the state, home to the two largest National Forests – the Tongass and Chugach. Timber harvest in the state of Alaska declined by 67% between 1990 and 2004. (Brackley, Rojas, & Haynes, Timber products output and timber harvests in Alaska: Projects for 2005-25, 2006).

Of the five regions identified in the 2009 report by Halbrook et. al., the YKL region includes forest and timber land from both Western and Interior regions. Two active and one inactive saw mill were identified within the YKL boundary. Due to the high fuel costs, recent efforts to reduce energy costs resulted in the establishment of several small dry-kiln facilities. The timber harvest data for this region, as reported in the 2009 report, was minimal compared to the rest of the regions, and was combined with data from the south-central region for confidentiality reasons. Comprehensive data on timber harvests is not available for this region.

A series of studies from the late 1960s to early 1980s generally concluded that no viable timber industry is possible in the Kuskokwim Valley (Sampson, et al. 1988). The 1988 Kuskokwim Area Plan, the most recent for the area, prepared by the Alaska Department of Natural Resources, Division of Mining, Land and Water, reported "approximately 570,000 acres of state-owned land with high or moderate potential for timber harvest" (Alaska Department of Natural Resources, 1988).

The only commercial timber harvesting operation along the Kuskokwim River is the Napaimute timber harvest. Wood is harvested for fuel and sold to downriver communities (Native Village of Napaimute 2013). The 2010 harvest totaled 120 cords of firewood. The harvest rose to 1,000 cords in 2012 when the company brought in heavy equipment for the harvest. The operation moved from Napaimute to Kalskag in 2013. The 2013 harvest was about 300 cords of firewood. The operation moved because of high expenses. Napaimute has no permanent population so employees were brought in and housed. Because there is no air service to Napaimute, workers traveled to Aniak by boat or snow machine for parts and supplies. Even with a resident work force and air service, operations in Kalskag also face difficulties. Wood quality is lower than in Napaimute, and access to timber is limited. Although Native Corporation land is available, BLM land is too far from the river, and small state owned parcels do not have enough timber (Napaimute News 2013).

Limitations and Data Gaps

The land status map is accurate in a broad sense but not for detailed planning. Native lands are over-represented on the map because land status is mapped only to the nearest square mile and Native lands are given priority for display at this level. Further, conveyance is on-going so land status is changing.

The USGS ARDF file has several limitations. None of the mining activities as recorded in the database are required to be reported, nor USGS a mandated agency to track and report these activities. Data are not collected in a systematic way, nor are there checks on the accuracy of data. We used information from literature and internet searches to provide more information about mines in the ARDF data set and found that nearly all mines had closed.

The contaminated sites database, which we used to update the mines data, contains only point locations of sites. Polygons are not provided because the size of the site changes as cleanup progresses. For example, the area can increase following discovery and during initial assessments and then can decrease during the cleanup.

The Tiger Census Places footprints tend to be larger than the actual built environment because they include all municipal incorporated lands. Therefore the development impact of communities may be over-estimated.

The Alaska DNR RS2477 Trails dataset includes trails/right of ways that were created to access state and private inholdings on federal land. It does not include trails to subsistence areas or camps, nor winter snow machine trails.

5.4. Current Socio-economic Conditions

MQ 30	What are current socio-economic conditions in YKL communities?

Thirty-three small communities, with populations ranging from 13 people to around 500, are scattered over a large area within the region[1]. Owing to small populations, sample sizes for indicator values are often too small, and thus may not be accessible for confidentiality reasons.

Table B-23. Communities in the YKL region divided into three regions based on proximity to a major river basin.

Yukon Communities	Kuskokwim Communities	Iliamna Communities
Anvik	Aniak	Iliamna
Flat	Chuathbaluk	Kokhanok
Galena	Crooked Creek	Newhalen
Grayling	Lake Minchumina	Nondalton
Holy Cross	Lime Village	Pedro Bay
Hughes	Lower Kalskag	Pope-Vannoy Landing
Huslia	McGrath	Port Alsworth
Kaltag	Red Devil	
Koyukuk	Sleetmute	
Manley Hot Springs	Stony River	
Nulato	Takotna	
Ruby	Upper Kalskag	
Shageluk		
Tanana		

Methods

Small populations are difficult to model. MQs are addressed with a synthesis of literature and data reviews and summaries, and individual personal communications. Data include commonly used, publicly available sources, such as US Census and ADF&G subsistence harvest surveys, as well as survey data that are not publicly available. Most of the literature used in this study is unpublished reports, such as ADF&G community harvest studies, newspaper articles, and reports from individual research grants.

We used statistical models for population projection, and combined results from three statistical models: ARIMA, Decomposition, and time trend forecast. All models analyze and forecast equally spaced univariate time series data, each using a slightly different algorithm.

[1] A few communities straddle the border of REA regions and are counted in more than one region. Seven communities in YKL are also in the Seward Peninsula-Nulato Hills-Kotzbue Lowlands (SNK) region.

A comprehensive index of various indicators was attempted to describe the socioeconomic conditions of the region. Such an index would allow relative comparisons between the region and other similar regions in the state. The Arctic Social Indicators (ASI) Report (Larsen, Vilhjalms, Schweitzer, Petrov, & Fondahl, 2013) identified a list of indicators organized into six domains of life in the Arctic. Domains were identified through extensive interviews across the circumpolar north to reflect the life circumstances of the region. The seven domains are: health, population and demographics, material well-being, education, cultural wellbeing, closeness to nature, and fate control. Several indicators identified are relevant to multiple domains. We reorganized the list of indicators identified to represent these overlaps. Figure B-53 shows the reorganized list of ASI domains and indicators, and intersections between domains.

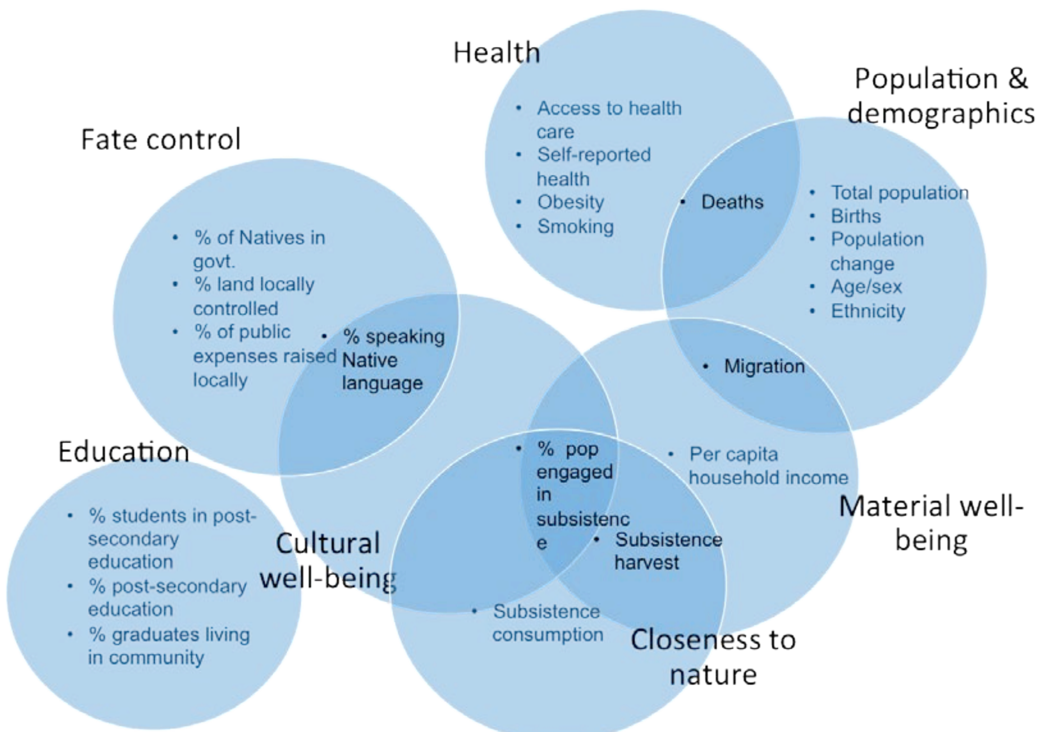


Figure B-53. Arctic Social Indicators (ASI) organized into seven domains.

Data from the U.S. Census are available every 10 years. Since 2000, the decennial census collects only demographic information (age, sex, and race/ethnicity of household members). Starting with Census 2000, the Census Bureau eliminated the long form, which contained questions about income, occupation, education, migration, language use, and disabilities. The census long form was replaced by the American Community Survey (ACS) which is used to collect long form equivalent information every year. However, in Alaska, the community level sample size for the ACS is too small to provide reliable data. To compensate, data are pooled over a 3-year period. However, error ranges on the estimates are often larger than the estimates.

The Alaska Fuel Price Projections are developed for the Alaska Energy Authority (AEA) for the purpose of estimating the potential benefits and costs of renewable energy projects. Project developers submit applications to AEA for grants awarded under the Alaska Renewable Energy Fund (REF) program process. These fuel price projections are used to evaluate the economic feasibility of project applications; economic feasibility is only one of many factors of the project evaluation process. In addition to their use for the REF review, the Institute of

Social and Economic Research (ISER), University of Alaska Anchorage (UAA) uses the projections for other economic research and energy project evaluations.

Table B-24. Source datasets for analysis of community socio-economic conditions.

Dataset Name	Data Source
Demographic information – population, gender, race (1990-2010)	U.S. Census Bureau, AKDOLWD
Status of distressed communities 2012	Denali Commission
Fuel prices (1990-2010)	AEA/ ISER
School enrollment data (2000-2014)	NCES
Alaska Game Management Units (GMUs)	ADF&G
Alaska harvest statistics	ADF&G
Alaska sport fish harvest	ADF&G
Lake Clark visitor data	National Park Service (NPS)
Alaska visitor statistics	McDowell group

Data on most of the indicators identified by the ASI Report are not available at the community level. The report acknowledges the lack of data on several identified indicators and encourages jurisdictions across the circumpolar north to collect data on all these indicators. For the purposes of this project, we retained the domains as a conceptual framework and identified proxies for indicators, for which local level data were available. We planned to construct an index that yields a simple way to capture the social and economic conditions of the region.

Table B-25 identifies all domains and indicators suggested by the ASI Report, whether or not data are available, and suggested proxy variables. The ASI report suggested a single variable per domain that would best represent each of the seven domains; these variables include such statistics as infant mortality rate for the health domain, net migration rate for population/demography domain, per capita income for material well-being, ratio of students successfully completing post-secondary education for the education domain, and language retention for the cultural well-being domain. Data for several variables are not systematically collected in Alaska. We identified proxy variables for few others.

Table B-25. Indicators identified in ASI report. Key variables that according to the ASI report best represent the domain are indicated with an asterisk.

Domain	Variables suggested by Nordic Council	Community level data availability	Used
Health	Access to health care	Unavailable	N
	Self-assessed health		
	Smoking rate		
	Obesity rate	Community level data are confidential.	
	Child mortality rate	Community level data are confidential.	
	Infant mortality rate*		
	Suicide rate		
Population/ Demography	Total population	AK DOLWD and U.S. Census	Y
	Population growth or decline rates and projections	Calculated	Y
	Number of births	Annual community level data are not available. We assumed that these rates do not vary significantly among communities.	N
	Age/sex/ethnicity composition of the population including age and sex ratios		
	Birth rates		
	Mortality rates		
	Infant or child mortality rates		
	Net migration*		
	Number of death		
Material Well-being	Per capita household income *	ACS 2006-2010 moving average *Proxy variable:* Per capita income (past 12 months) for total population and for AIAN. (ACS 2006-2010) Alaska Department of Labor estimates of annual per capita earnings by community.	Y
	Per capita gross domestic product	GDP data for Alaska is available at US Government Federal Reserve	Y
	Unemployment rate	AKDOLWD – ALARI provides unemployment insurance claimants by community	
	Poverty rate	Community level data are not available.	
	Subsistence harvest per person	ADF&G subsistence harvest data are not collected every year in every community, nor for every species in every year. However, they are available for nearly all of the YKL communities.	
	Net migration rate	Community level data are not available. State and census area level are available.	

Domain	Variables suggested by Nordic Council	Community level data availability	Used
	A composite index that takes into account three sectors: Per capita household income, Net migration rate, Subsistence harvest	Lacking complete data	
Education	Proportion of students pursuing post-secondary education	*Proxy variable:* Proportion of students pursuing secondary education (AK DEED; NCES)	Y
	Ratio of students successfully completing post-secondary education *	*Proxy variable:* Ratio of students successfully completing secondary education (AK DEED; NCES)	Y
	Proportion of graduates who are still in their own community (or have returned to it) 10 years later	Unavailable	N
Cultural Well-being	Cultural autonomy	Unavailable	N
	Do laws and policies recognize institutions that exist to advocate for cultural autonomy or national minority populations?		
	Do institutions representing national minority cultures exist?		
	What is the proportion of such institutions to minority peoples, e.g. are all peoples represented through such organizations?		
	Are resources available to such institutions?		
	Are funding policies in place and how well-resourced are they?		
	Language retention* (e.g. what percentage of a population speaks its ancestral language?)	*Proxy variable* : Multiple variables from community level language data from US Census.	Y

Domain	Variables suggested by Nordic Council	Community level data availability	Used
	Belonging (e.g. what percentage of people are engaged in recreational or subsistence activities?)	ADF&G subsistence harvest data report the number of people attempting to harvest, successfully harvesting, and using each species. However, data are not available for all communities.	N
	A composite index that takes into account above three sectors	To be computed but data unavailable	N
Closeness to Nature	Harvest of country foods*	Partial subsistence data available from ADF&G	Y
	Consumption of country foods*	Partial subsistence data available from ADF&G	
	Number of people or households engaged in the traditional economy	ADF&G subsistence harvest data report the number of people attempting to harvest, successfully harvesting, and using each species. However, data are not available for all communities.	Y
Fate Control	Percentage of indigenous members in governing bodies (municipal, community, regional) relative to the percentage of the indigenous people in the total population	*Proxy variable:* native corporations' earnings	Y
	Percentage of surface lands legally controlled by the inhabitants through public governments, Native corporations, and communities*	Acres of land owned by native corporations	
	Percentage of public expenses within the region (regional government, municipal taxes, community sales taxes) raised locally	*Proxy variable:* Municipal taxation, State of Alaska from DCCED, Alaska Taxable	Y
	Percentage of individuals who speak a mother tongue (whether Native or not) in relation to the percentage of individuals reporting corresponding ethnicity	U.S. Census collects the data that shows how many people speak only English in the community	Y

*Key variables to use as indicators – According to authors of the Arctic Social Indicator report.

Because many of the domains share indicators, for example, subsistence is a component of three domains. We used available data in a principal components analysis in an attempt to identify similar but mutually exclusive domains. The number of observations (communities) was too small and with little variation among them. When data for YKL communities were combined with data for other rural communities in Alaska, the results were similar in that there was little variation among YKL communities.

Distressed Communities

To describe socio-economic conditions, we adopted the Denali Commission categorization of communities as distressed or non-distressed (Denali Commission, 2012)[2]. Distressed communities meet at least two of the three criteria: (1) Average market income in 2011 less than $16,120 (half-time employment at $7.75 minimum wage); (2) More than 70% of residents 16 and over earned less than $16,120; and (3) Less than 30% of residents 16 and over worked all four quarters of 2011. More than half of all communities in the REA are distressed. The status of each community in the YKL region is shown in Table B-26.

Table B-26. Distressed status of communities in the YKL region (Denali Commission, 2012).

Community	Distressed Status	Average market earnings in 2011	Percentage of residents 16 and over that earned less than $16,120.00 in 2011	Percentage of labor force employed all four quarters of 2011
Yukon River Communities				
Anvik	N	$ 17,114	60.7	54.1
Flat	*	*	*	*
Galena	N	$ 24,488	52.6	45.6
Grayling	Y	$ 6,588	82.9	28.8
Holy Cross	N	$ 13,004	65.7	37.9
Hughes	N	$ 10,692	66.2	46.5
Huslia	Y	$ 11,130	74.1	36.0
Kaltag	Y	$ 12,939	73.9	32.6
Koyukuk	Y	$ 13,450	75.7	36.5
Manley Hot Springs	N	$ 18,560	64.9	30.9
Nulato	Y	$ 10,388	75.0	28.2
Ruby	N	$ 16,408	67.6	38.8
Shageluk	Y	$ 8,231	84.3	35.3
Tanana	N	$ 17,523	60.9	37.5
Kuskokwim River Communities				
Aniak	N	$ 20,479	59.9	41.4
Chuathbaluk	Y	$ 8,932	74.7	31.6
Crooked Creek	Y	$ 11,188	74.3	25.7
Lake Minchumina	Y	*	84.6	15.4
Lime Village	Y	$ 9,391	73.7	36.8
Lower Kalskag	Y	$ 7,888	82.7	36.6
McGrath	N	$ 19,856	62.0	36.0

[2] Most recent designation of distressed communities was in 2012.

Community	Distressed Status	Average market earnings in 2011	Percentage of residents 16 and over that earned less than $16,120.00 in 2011	Percentage of labor force employed all four quarters of 2011
Red Devil	Y	$ 2,428	100	15
Sleetmute	Y	$ 9,060	81.0	33.3
Stony River	Y	$ 12,058	74.1	40.7
Takotna	N	$ 17,619	71.0	32.3
Upper Kalskag	Y	$ 10,957	72.4	34.5
Lake Iliamna Communities				
Iliamna	N	$ 27,358	48.9	42.4
Kokhanok	*	*	*	*
Newhalen	N	$ 26,167	58.9	42.9
Nondalton	Y	$ 12,550	72.5	32.4
Pedro Bay	N	$ 23,732	63.3	40.0
Pope-Vannoy Landing	Y	*	100	0
Port Alsworth	N	$ 16,933	66.3	30.8

* Data unavailable

Results

According to the 2010 US Census, over 5,000 people live in the region. Approximately 76% of the population is Alaska Native. Populations of most communities, and the region as a whole, declined between 2000 and 2010 (U.S. Census Bureau, 2010). Figure B-54 shows the locations of all communities in the region. The Yukon sub-region is the most populous, with 2,413 people in 14 communities, followed by the Kuskokwim sub-region (1,819 people in 12 communities) and the Iliamna sub-region (840 people in seven communities) (U.S. Census Bureau, 2010).

Table B-27 shows the total population of each community, organized by three regions in 2000 and 2010. During that period, the study area's population declined by 12.3% (709 people). Nearly all communities in both Yukon and Kuskokwim regions lost population. While Yukon River region declined by 18% (526 people) and Kuskokwim River region declined by 10% (204 people), Lake Iliamna region gained 3% (21 people) during the same time period.

Table B-27 shows the gender ratios by community for 2000 and 2010. There is considerable variation both among and within communities. Notable are Kaltag and Kokhanok. The gender ratio (ratio of the number of men to women) is indicative of several things: "The balance of the sexes in a population reflects the sex ratio at birth, inequalities in mortality between the sexes, and difference in composition due to migration" (Dyson, 2012, p. 444). The gender ratio of young adults can be considered a key social indicator. In small rural communities, it is usually the combined result of higher death rates for men, due to accidental deaths, suicides, and homicides, as well as out-migration. In the YKL region in 2010, among 20 to 24 year olds, men outnumbered women in many communities by 2 to 1, and in one community by 6 to 1. Research on migration in other areas of rural Alaska shows that more females are leaving and more males are returning (Martin 2010). Hamilton and Seyfrit (1994) coined the term 'female flight' to describe disproportionate migration. Men are more likely to stay in rural communities and cite subsistence hunting and fishing as the main reason. But for men who remain, there are fewer suitable partners and younger girls often receive inappropriate attention (Hamilton and Seyfrit 1994). Of men and women who move away, more men return. Fewer women return because they are more like to marry or find jobs outside of rural Alaska (Hamilton and Seyfrit 1994, Martin 2010). In addition, dropout rates at urban Alaska universities are higher for men than women (Martin 2010). Gender imbalance resulting from female out-migration can have broad effects on communities. Some describe out-migration is a possible measure of a weakened community level subsistence network (James Magdanz ADF&G, pers. comm., June 2004).

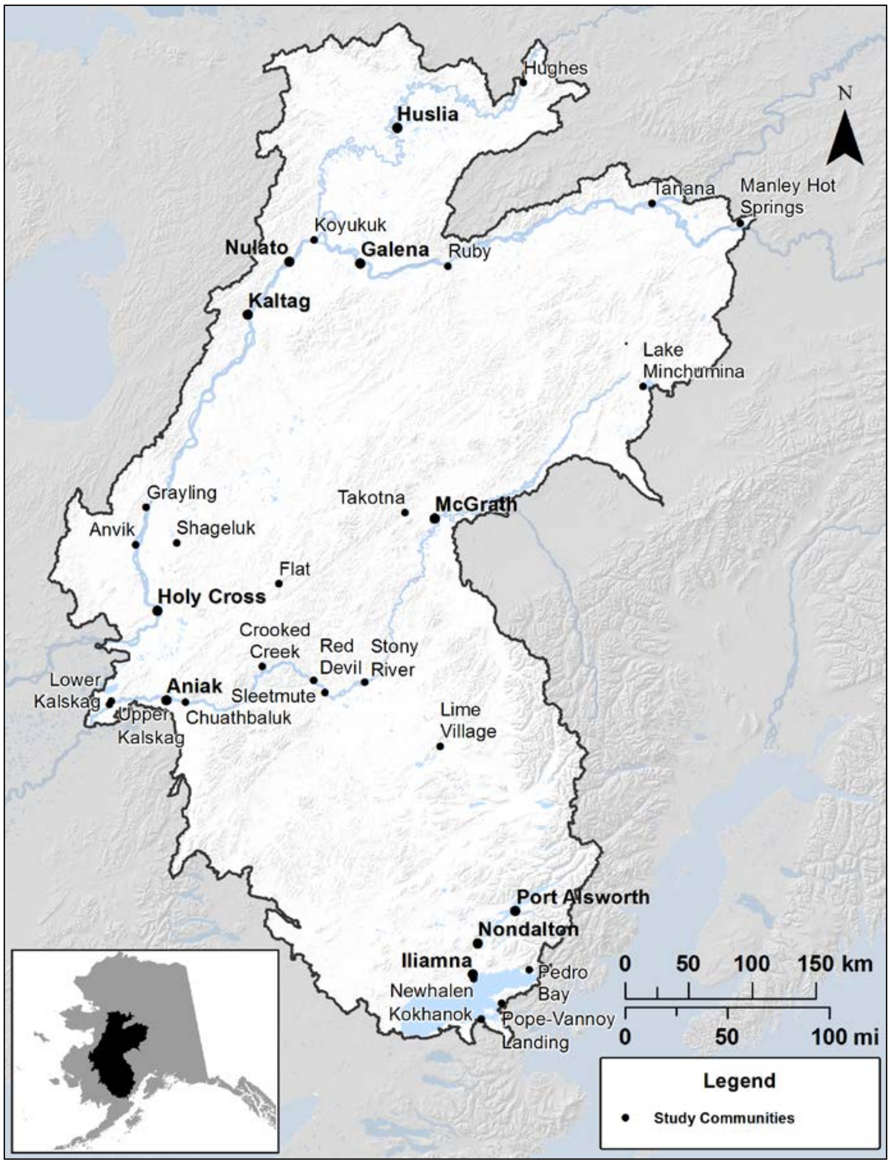


Figure B-54. Locations of communities in the YKL region.

Table B-27. Total population, gender ratio, and change in gender ratio between 2000 and 2010 for each community in the YKL region.

Community Name	2000				2010				A-B
	Population			Gender Ratio (A)	Population			Gender Ratio (B)	
	Total	Male	Female		Total	Male	Female		
Yukon River Region	**2939**	**1580**	**1359**	**1.16**	**2413**	**1276**	**1137**	**1.12**	**0.04**
Anvik city	104	57	47	1.21	85	46	39	1.18	0.03
Flat	4	2	2	*	0	0	0	*	*
Galena city	675	370	305	1.21	470	241	229	1.05	0.16
Grayling city	194	97	97	1	194	99	95	1.04	-0.04
Holy Cross city	227	131	96	1.36	178	92	86	1.07	0.29
Hughes city	78	41	37	1.11	77	38	39	0.97	0.13
Huslia city	293	154	139	1.11	275	136	139	0.98	0.13
Kaltag city	230	131	99	1.32	190	116	74	1.57	-0.24
Koyukuk city	101	50	51	0.98	96	49	47	1.04	-0.06
Manley Hot Springs	72	40	32	1.25	89	49	40	1.22	0.02
Nulato city	336	166	170	0.97	264	144	120	1.2	-0.22
Ruby city	188	99	89	1.11	166	93	73	1.27	-0.16
Shageluk city	129	67	62	1.08	83	42	41	1.02	0.06
Tanana city	308	175	133	1.31	246	131	115	1.14	0.18
Kuskokwim Region	**2023**	**1043**	**980**	**1.06**	**1819**	**941**	**878**	**1.07**	**-0.01**
Aniak city	572	298	274	1.09	501	262	239	1.1	-0.01
Chuathbaluk city	119	57	62	0.92	118	57	61	0.93	-0.02
Crooked Creek	137	73	64	1.14	105	58	47	1.23	-0.09
Lake Minchumina	6	4	2	*	13	6	7	*	*
Lime Village	32	17	15	*	29	13	16	*	*
Lower Kalskag city	267	131	136	0.96	282	137	145	0.94	0.02
McGrath city	401	205	196	1.05	346	180	166	1.08	-0.04
Red Devil	48	26	22	*	23	12	11	*	*
Sleetmute	100	58	42	1.38	86	48	38	1.26	0.12
Stony River	61	33	28	1.17	54	31	23	1.35	-0.17
Takotna	50	24	26	*	52	29	23	1.26	*

Community Name	2000				2010				A-B
	Population			Gender Ratio (A)	Population			Gender Ratio (B)	
	Total	Male	Female		Total	Male	Female		
Upper Kalskag city	230	117	113	1.03	210	108	102	1.06	-0.02
Lake Iliamna Region	**819**	**433**	**386**	1.12	**840**	**414**	**426**	**0.97**	0.15
Iliamna	102	54	48	1.12	109	51	58	0.88	0.25
Kokhanok	174	102	72	1.42	170	80	90	0.89	0.53
Newhalen	160	80	80	1	190	92	98	0.94	0.06
Nondalton	221	121	100	1.21	164	80	84	0.95	0.26
Pedro Bay	50	22	28	*	42	19	23	*	*
Pope-Vannoy Landing	8	6	2	*	6	5	1	*	*
Port Alsworth	104	48	56	0.85	159	87	72	1.21	0.35

* Values were not calculated for communities with population less than 50.

Figure B-55 shows age and gender distributions for the YKL region and sub-regions. Comparing 2000 to 2010 shows that the total population has declined and the age distribution has changed: the number of people ages 65 and older has increased (by 18%).

Approximately 75% of the population in the region is Alaska Native. The Yukon communities have a higher percentage of Alaska Natives compared to the other two groups. Figure B-56 shows the population of white, Alaska Native or American Indian (AIAN), and other races as a percentage of the total population of each region for 1990, 2000, and 2010. Note that a new race category was added starting with the 2000 census: 'two or more races'. Many Alaska Natives identify as 'Two or more races' so the AIAN category after 1990 includes some or all of the 'Other' as well. Total population is shown in parenthesis on the horizontal axis. More than 80% of the population in Yukon sub-region of communities is Alaska Native and has been increasing over the last three decades while the total population fluctuated to a high of 2,939 in 2000 and low of 2,413 in 2010. In the Kuskokwim group of communities, the total population has been steadily declining but the percentage of Alaska Natives held constant at about 70%. In the Lake Iliamna communities, the total population has been steadily increasing while the Alaska Native population fluctuated to a high of almost 70% in 2000, but decreased to almost 60% in 2010, similar to the proportion in 1990.

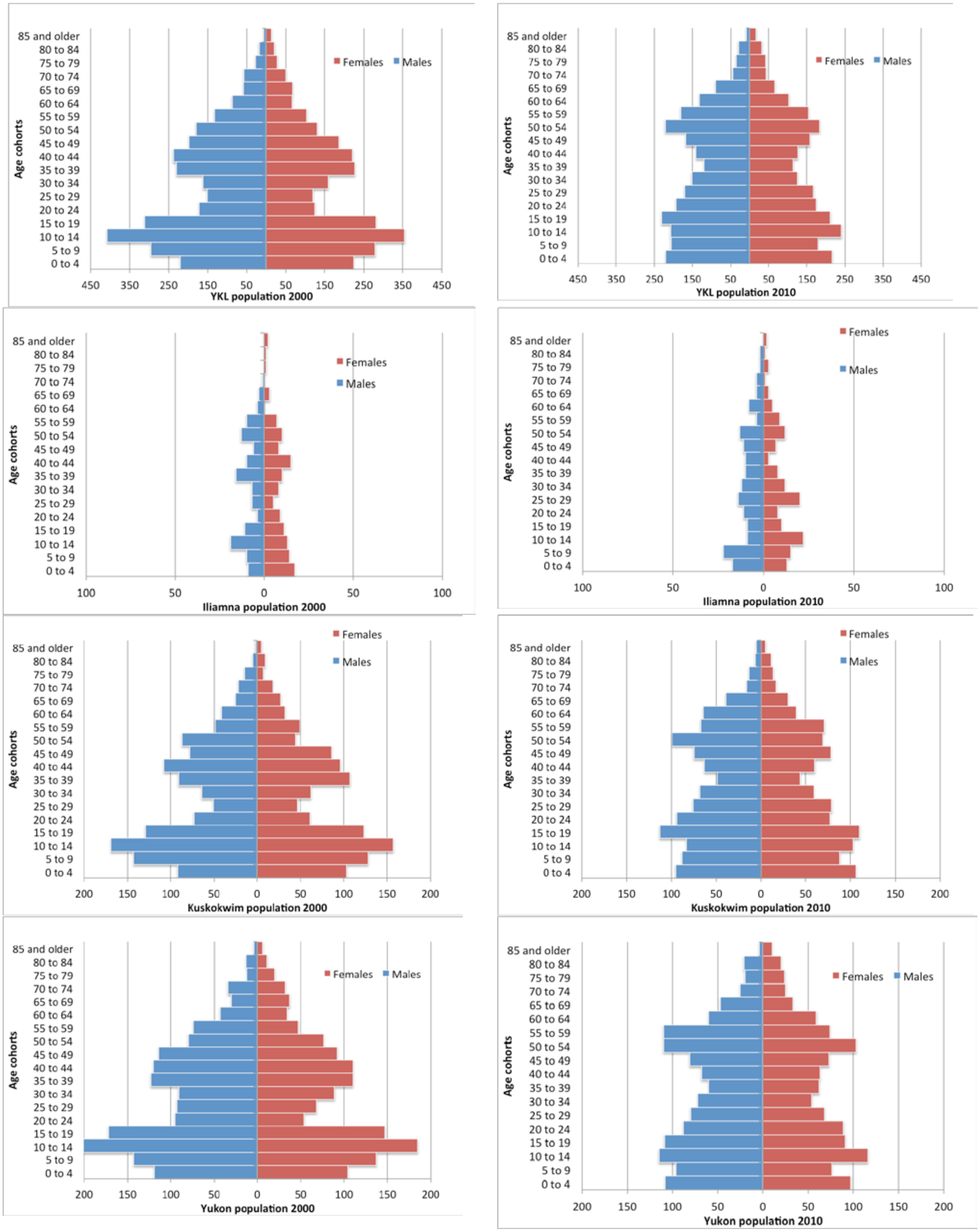


Figure B-55. Population pyramids for the YKL region as a whole and the three sub-regions.

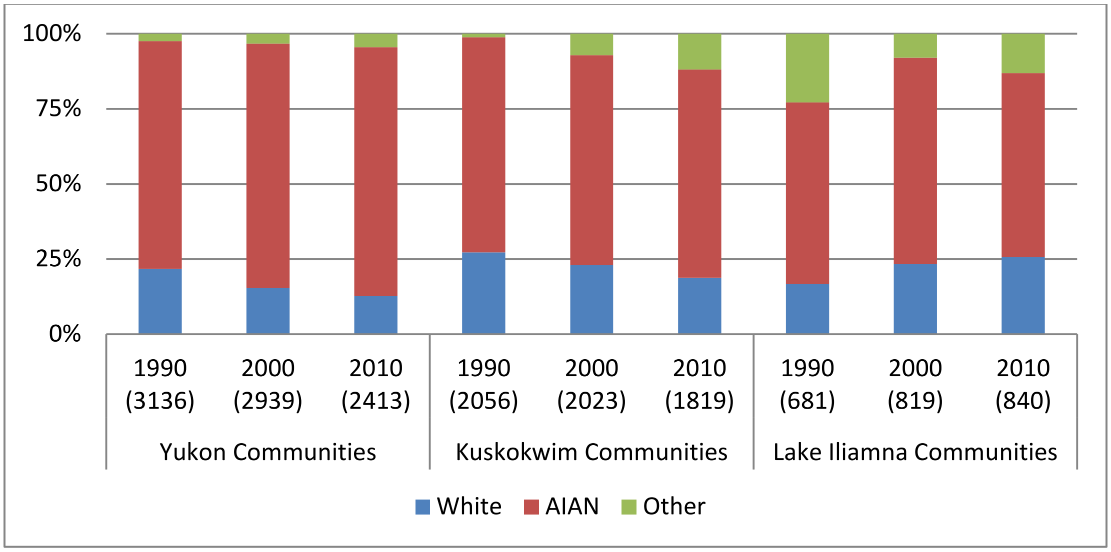


Figure B-56. Percentage of population by race for all three groups of communities in the YKL region for 1990, 2000, and 2010. Total population is given in parentheses.

Cost of Living

The cost of living in remote rural Alaskan communities is generally much higher than in urban Alaska. In general, since 1985, communities outside Alaska's rail belt and off the Alaska road system have seen greater increases in living costs relative to Anchorage (McDowell 2008). Heating and gasoline cost more than twice as much as in urban Alaska. Rising fuel prices have triggered increases in the price of store bought foods and other goods and transportation in and out of villages. In turn, high food costs mean that people tend to rely more on subsistence foods. The situation has become even more difficult because rising fuel prices also make subsistence more expensive. In addition, there is some evidence that the high cost of living leads to increased out-migration threatening viability of very small communities.

Energy Prices

The energy picture in rural Alaska can be understood as constituted of three key components – electricity, heating, and transportation. Alaska had 2,197 mW of installed capacity for electricity generation and approximately 6.6 million mW-hours of electricity were generated. While a majority (58%) of the state's electricity is generated with natural gas, almost all of this was consumed in the rail belt region. Most communities in the western and interior parts of the state rely primarily on electricity generated with diesel fuel (Fay, Villalobos Melendez, & West, 2013). These communities had the most expensive electricity in 2011. Most remote rural communities are eligible for the Power Cost Equalization (PCE) program instituted by the state to offset the high fuel prices in these communities. The program pays 95% of residential electricity cost. However, the program has not been fully funded by the Legislature in 15 out of its 25 years of existence, and electricity rates in rural Alaska with PCE are still higher than in urban Alaska (Fay and Villalobos-Melendez 2012). In addition, PCE increases the vulnerability of rural households to changes in state spending.

Heating houses and other buildings is a necessity in Alaska. Communities across the state rely on a variety of fuel sources for heating: natural gas, diesel, electricity, wood, or other sources such as geothermal energy. Saylor and Haley (2007) report 79% of the houses in remote rural Alaska are heated using diesel fuel. Between 2000 and 2005, cost of diesel for home heating increased by 83% in these remote rural communities.

Transportation consumes both gasoline and diesel. In addition to commuting between villages, transportation to and from subsistence areas is extremely important to sustain the cultural lifestyle of residents of the region. In a survey of 54 households in Norton Sound, a similar remote region of the state, Schwoerer (2013) reports that each household travels 774 miles on snow machines, 416 miles on boats, and 172 miles on all-terrain vehicles (ATVs), on an average per year, one-way to access subsistence resources. These households consume approximately 1,291 gallons of gasoline per year. In addition, they also consume 886 gallons of diesel oil and 4 cords of wood per year for various other purposes.

There has been a recent dramatic increase in fuel prices throughout Alaska. Looking only at changes from 2000 through 2006, Saylor and Haley (2008) used census data to document that total utility costs – including heat, electricity, water, and sewer – paid by residents of remote Alaska communities[3] increased from a median value of 6.6% of total income to 9.9% of total income. By comparison, the median amount spent by Anchorage households increased from 2.6% to 3.1% of household income during this same period.

Fay et al. (2008) identified five definitive components of the delivered price of fuel in Alaska communities: world price of crude oil, refining costs, transportation cost, storage and distribution cost, and taxes. A sixth component "other" was also identified to capture the gap between the final price and the sum of the other five. Crude oil and refining costs were constant across all sample communities in the study. Transportation had the largest variance. Among the sample communities, Lime Village (the only community that is part of the YKL region) had the highest transportation costs and thus, the highest fuel costs. Climate change could affects fuel prices as warmer temperatures lead to later freeze-up, leaving riverbanks unprotected from winter storm surges (Arctic Climate Impact Assessment 2004). Erosion makes rivers wider and shallower and more difficult for tugboats and barges to navigate. Communities sometimes offload fuel from barges onto small boats to bring it in. If barges cannot reach communities, or communities that are not located on a river (such as Lime Village), fuel is flown in. This is the most expensive option. However, most communities in the region are members of Alaska Village Electric Cooperative (AVEC). AVEC has lowered fuel costs by reducing the cost to transport fuel. The cooperative purchased two tugs and barges and now delivers fuel to its member communities at a lower cost than before. Costs are lower because the co-op has been able to reduce transportation costs compared to fuel transportation companies (Andrews 2013).

Figure B-57 shows the change in price of a gallon of diesel. Prices are inflation adjusted 2013 US dollars. The figure shows the change over the 1991-2000 and 2000-2010 decades. The prices decreased moderately in almost all communities across the region except for Iliamna and Kokhanok, both Lake Iliamna communities. However, during the decade of 2001 through 2010, all communities experienced an increase in fuel prices, the majority of them between $0.19 to $0.30 per gallon of diesel. This increase put severe strain on household incomes.

[3] Their use of the "remote" definition was driven by the way census public use micro-data are provided. The census "remote" region is roughly the same as our concept of "rural," but also excludes several census areas and individual places that are on the road system, such as the Valdez-Cordova, Haines, and Skagway-Hoonah-Angoon census areas.

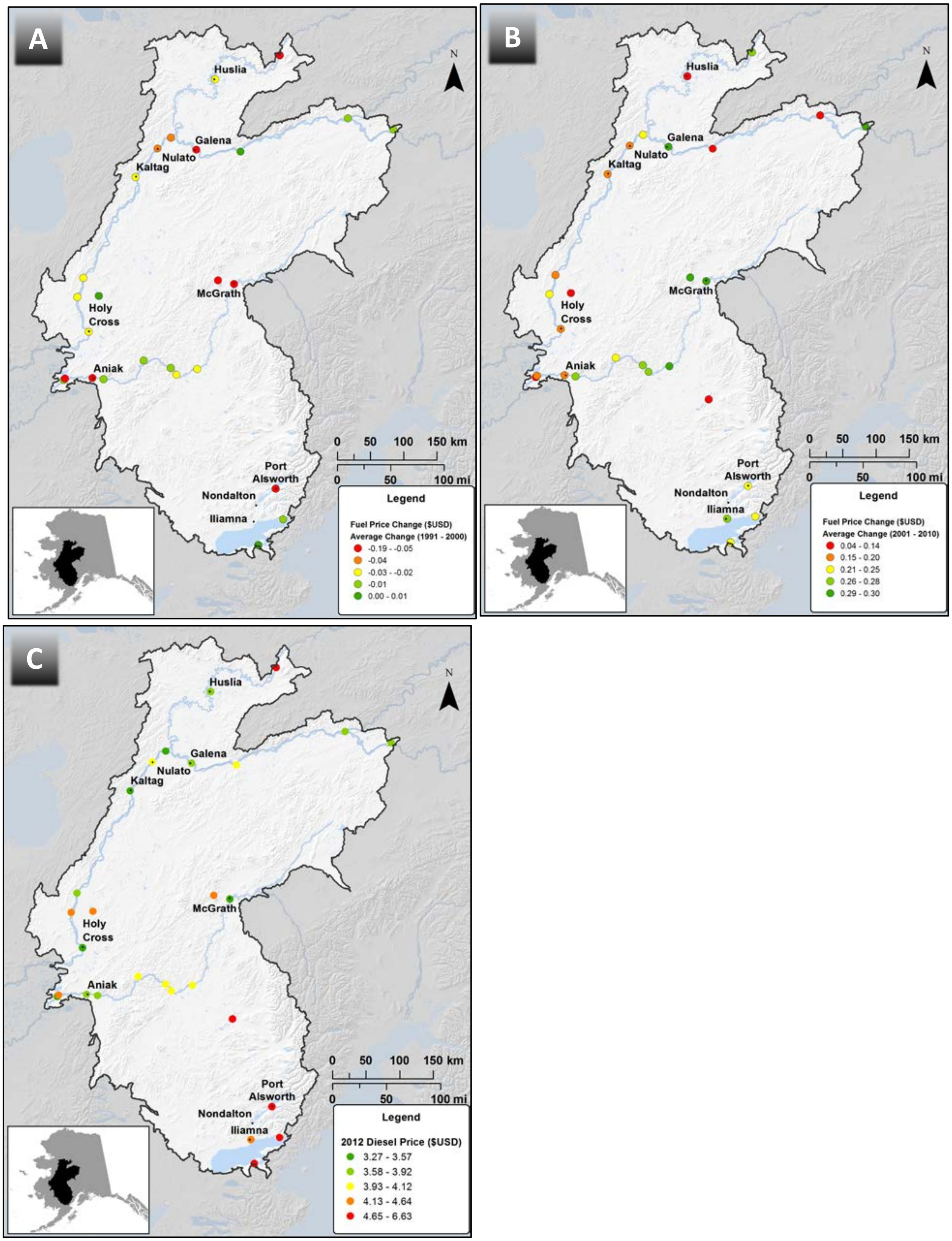


Figure B-57. Change in fuel prices from 1991 through 2000 (a), change in fuel prices from 2001 through 2010 (b), and 2012 diesel cost (c) calculated in 2013 Dollars.

School Closures and Declining Enrollment

In small villages, school closure is the end: "An Alaska village fades when its school dies. That's because families with children often move when the school doors shut, sparking a downward spiral that can cost a village other services, such as regular mail deliveries or air travel" (DeMarban 2012). Schools are typically among the largest employers in remote rural Alaska. When schools close[4], many of the jobs disappear. School closures also disrupt social networks among children and families. Short of closure, declining enrollments affect communities. The Kuspuk School District alone has seen a drop of more than a third in the past 14 years. When enrollment drops, state funding decreases. The district laid off five teachers in 2013, leaving just 30 (Demarban 2013).

Figure B-58 shows total school enrollment by sub-region. Enrollment has been decreasing. Since 2000-01, overall enrollment in the region has dropped by 37%. Five schools have closed. Schools in several other communities are susceptible to closure due to low enrollments.

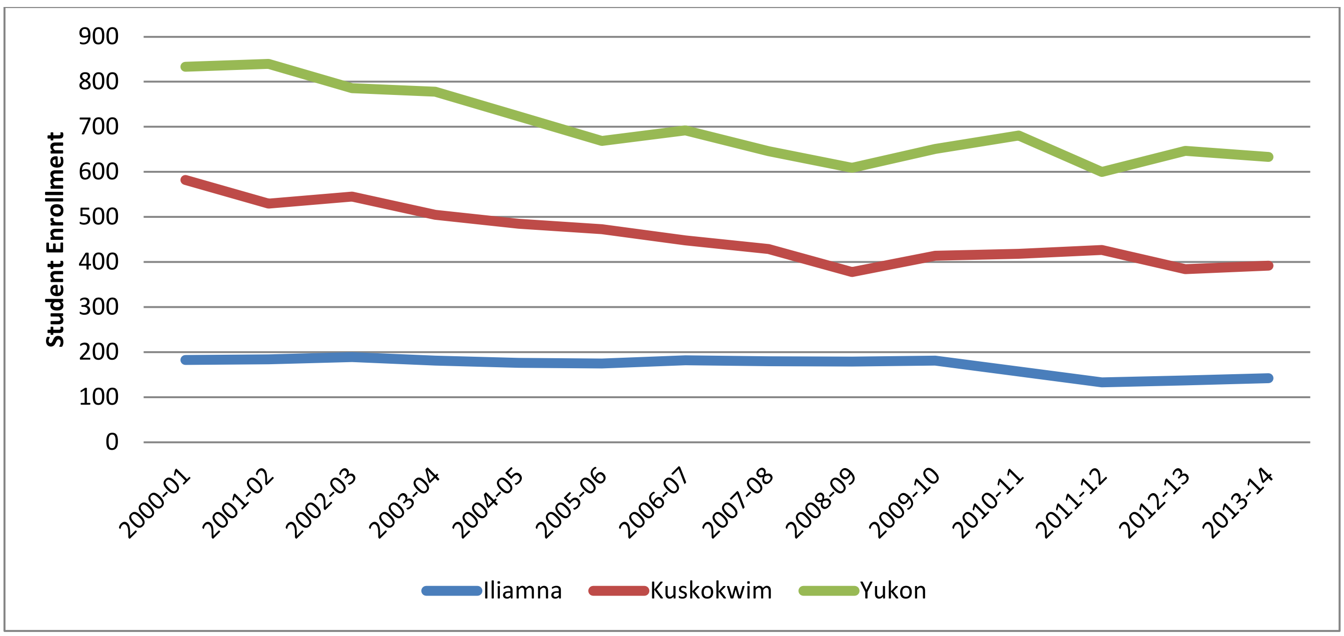


Figure B-58. Total number of students enrolled in schools within each community, aggregated by the three YKL sub-regions, for each academic year from 2000-01 to 2013-14.

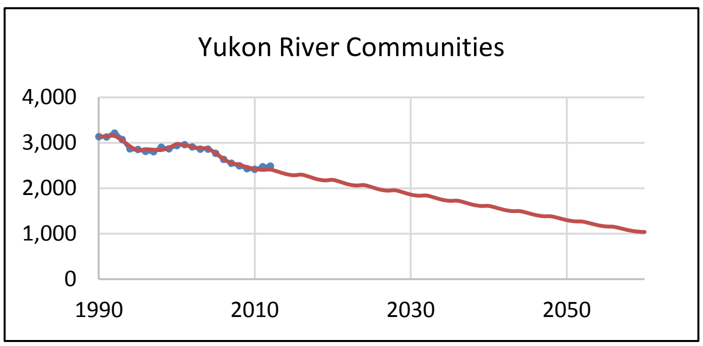
Overall, social and economic conditions show a region in decline. Lack of employment opportunities, high cost of living, and resulting loss of population leading to school closures is a downward spiral. To date, sustainability of most small remote communities in the YKL region depends on state and federal government funding.

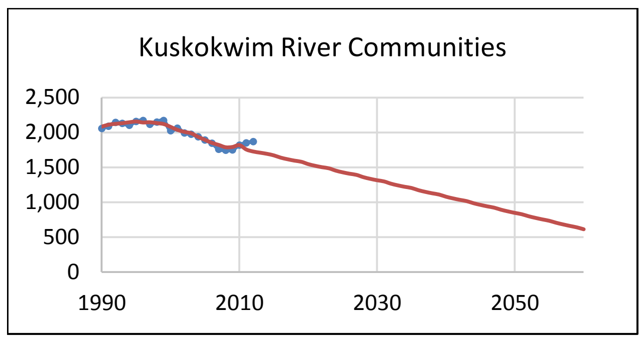
[4] Shutdowns began in 1999, after the legislature passed a law cutting off state funds for schools with nine or fewer students. Four years ago, the legislature passed another law to help ease the burden for districts with such schools. It phases out state support over four years, rather than ending funding abruptly.

5.5. Future Socio-economic Conditions and Development Scenarios

MQ 31	What are the projected socio-economic conditions in the future?
MQ 32	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 33	What are the potential impacts of renewable energy projects on local economies in the region?
MQ 34	How might change in transportation corridors impact communities?

Populations of the Yukon and Kuskokwim river sub-regions have been declining over the last two decades, and the Lake Iliamna sub-region has grown. However, the combined population of Lake Iliamna communities is small and only increased by 21 people from 2000 to 2010. Figure B-59 shows the projected populations for each sub-group. Projections are based on actual population in 1990 and 2000, estimates of population for intervening years. In the absence of any dramatic change in the regional economy, population is expected to decline in both the Yukon and Kuskokwim communities whereas a moderate increase is expected in the Lake Iliamna communities (about 160 people by 2060).





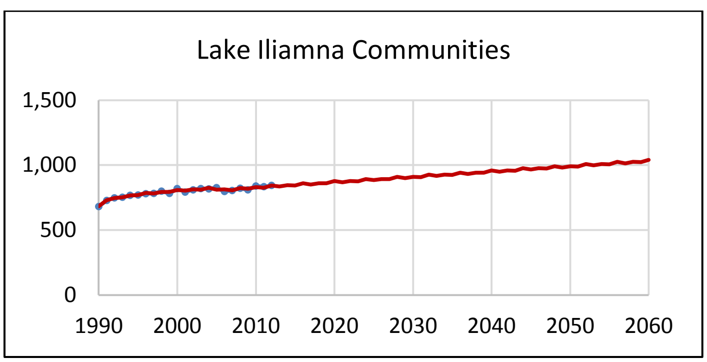


Figure B-59. Population projections for each group of communities in the YKL region.

Small numbers and fewer data points make the projections to 2060 less reliable. In population projections, the base period should be longer than the forecast period. The accuracy of projections increases with population size, and is higher for slow growing places. Communities in the REA meet none of these criteria. They have small populations and are undergoing rapid change. Demographers for the State of Alaska project population by borough/census area rather than by community and use a more complicated method. This method uses birth-death data, income tax returns, and the Permanent Fund Dividend (PFD) registration files. None of these are available to researchers at a community level. Other recent studies show the difficulty in accurately projecting populations, even in the near term. The Yukon-Kuskokwim transportation plan (2002) presents population projections for western Alaska from three sources, all of which use 1990 to 2000 data as a base, and all projected growth.

Future social and economic conditions depend on several factors. Mining developments that can lead to increased wage employment, and transportation infrastructure, which can increase access to the region, reduce the cost of living, and increase access to resource development. Development of alternative energy sources may also have an impact.

Employment is driven internally by population change and local demand for goods and services, or externally driven by projects originating outside the local area. School jobs are an example of internally driven employment. More people mean more children and more schools. Mining projects are an example of externally driven jobs. The number of people hired in the mine is independent of the size of the local population. Because population growth rates are very low (less than 1% per year) and state and federal spending is decreasing, there is not likely to be a significant increase in internally driven jobs. Any change in employment will come from externally driven jobs. Figure B-60 shows potential population change from two development scenarios: No change and Donlin Creek Mine.

Donlin Creek Mine job opportunities are fewer than the available workforce in the region. ARCADIS (2013) estimates 3,000 construction and pre-production jobs. Of these, approximately half are expected to be filled by Alaska residents. An estimated 996 jobs will be created when the mine becomes operational. The socioeconomic impact analysis conducted for the Donlin Gold project assumes that Calista shareholders will make up between 20% and 50% of the proposed Donlin Gold project's operations labor force. Any benefits from the mine will accrue to a much broader shareholder base of Calista Corporation than just those living in YKL region. Most shareholders live in Bethel and western Alaska, or Anchorage. In addition, some Calista shareholders live in other parts of the state and outside Alaska.

Because there are no road connections, Donlin Mine will be an enclave development with fly-in, fly-out workers. Air service from Anchorage to Donlin Mine would allow potential employees to commute from Anchorage. This is similar to Red Dog Mine, which employs about 220 (NANA[5]) shareholders (Haley and Fisher 2012). Not all NANA shareholders who work for Red Dog live in the region. Direct jet service from Anchorage to Red Dog Mine allows workers to commute from the Anchorage/MatSu area. Construction activities related to Red Dog Mine started in 1986 (Dames and Moore 1992), the mine became operational in 1989 and expanded operations in 2001 (Haley and Fisher 2012). The population of the Northwest Arctic borough has increased steadily since 1970 and does not show a sharp increase around the start of Red Dog Mine. Any increases are likely due to employment with Native corporations, government, and school districts, which make up a much larger share of employment. However, Red Dog may have slowed out-migration from the region. Thus, based on a similar situation with Red Dog Mine we conclude that YKL population likely will not increase, but population decline may slow down.

[5] NANA derives from the earlier association name Northwest Arctic Native Association.

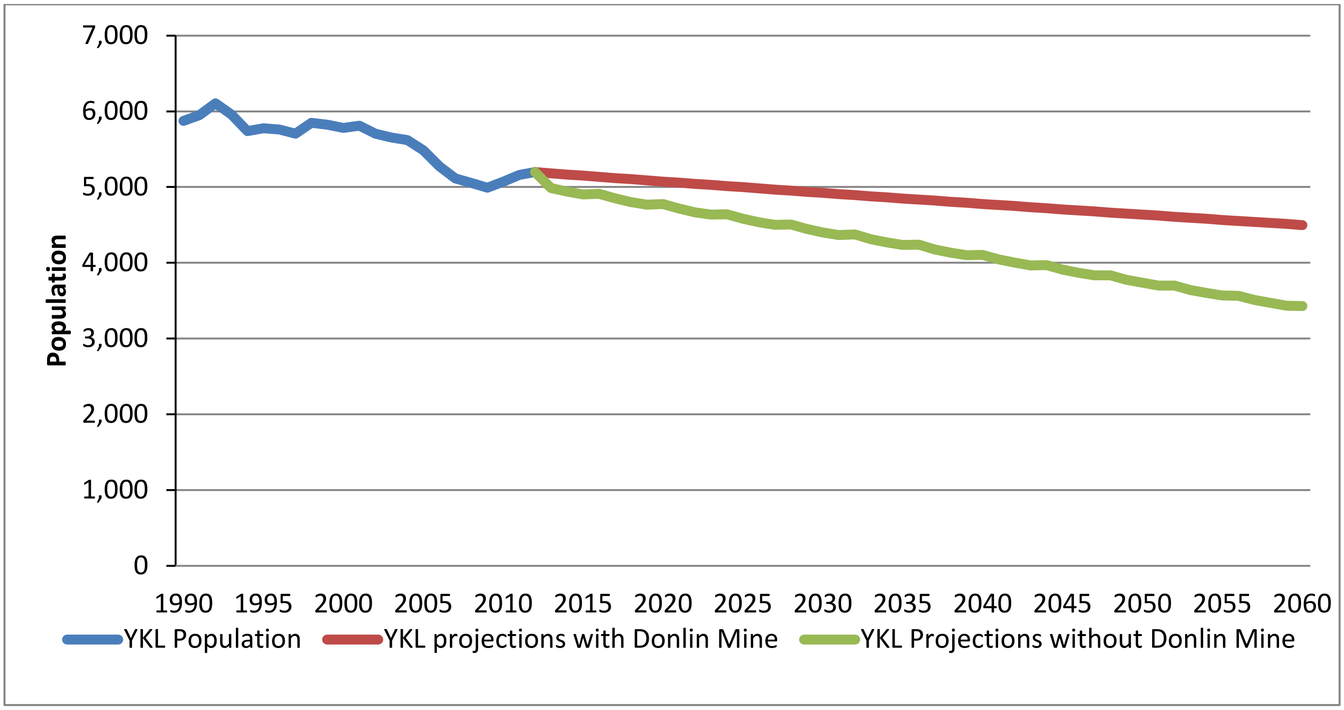


Figure B-60. Potential population growth/decline scenarios based on similar related to Red Dog Mine.

Fuel prices are projected to rise faster than in urban Alaska because of increasing difficulties and costs of getting barges into communities (Szymoniak et al. 2010). Most renewable energy projects can help keep costs down but will not replace diesel generators, at least not in the near future. Except for the hydroelectric plant, renewable energy sources do not reduce the electricity costs for residential customers. Most projects provide heat or electricity for public buildings such as schools and washeterias. Savings from these projects go to the building operators, usually municipalities or schools. If residential fuel costs are lowered because of the use of renewable energy sources and if the community participates in the PCE program, lower electricity costs will be offset by a decrease in the PCE subsidy. In these cases, the state will save money.

5.6. Subsistence Harvest Resources

MQ 35	Where are current subsistence harvest areas?
MQ 36	What do ADF&G harvest data and TEK/LTK show about how harvest amounts, types of fish/animals/plants, and harvest seasons changed in the recent past (including beavers)?

Fishing and hunting are essential parts of local livelihoods. Subsistence forms a substantial part of the household and community economy in the region. A large majority of the population in remote rural Alaska depends substantially on subsistence to supplement their wages (Goldsmith 2008). Subsistence use areas are broadly defined as areas where people hunt, fish, or gather food for household consumption or for cultural significance.

Subsistence foods are a large part of household food consumption. According to the Survey of Living Conditions in the Arctic, subsistence foods make up between half and ¾ of all food consumed by Alaska Native households (Martin 2005). Higher income households are also high subsistence-producing households, and have been termed "super households" (Wolfe et al. 2009). Wolfe et al. (2009) identified what has become known as the "30:70 rule," where 30% of households produce 70% or more of a community's subsistence food. Even though only 30% hunt, nearly everyone reports using subsistence foods, illustrating widespread sharing and role of the hunter as part of a much larger system. Subsistence traditions connect people to each other, the animals, and land over thousands of years. This is especially true of Alaska Natives who are among the only aboriginal groups in the world that have not been displaced from traditional lands (Magdanz, et al. 2010).

Subsistence species vary from community to community and from year to year. Each community has a seasonal round in which one harvest follows another, signals about what to harvest next come from tradition and what people observe during the current harvest.

These areas can only be identified through direct observations or interviews with local residents in communities in the region. The Alaska Department of Fish and Game (ADF&G) conducts annual surveys in communities across the state, inquiring about subsistence harvest amounts and practices. This is the only known and accessible source of data on subsistence use areas. Additional information can be gleaned from various reports on subsistence practices that are available for the region. However, utilizing these reports and the traditional ecological knowledge embedded in these reports was beyond the scope of this project.

It was decided early in the REA process that it is not feasible to use traditional ecological knowledge (TEK) to address MQs. Many reports document subsistence practices, its significance, and several other details on hunting and fishing in the region. However, these reports are not systematically organized in any one central place and assessing and utilizing such a scattered resource to answer specific MQs was determined to be beyond the scope of the project. Thus, MQ 36 was partially addressed. Only trends in harvest amounts and the types of resources harvested were examined. Data were obtained from ADF&G's online Community Subsistence Information System (CSIS) by community and was combined into one single dataset for trend analysis.

Assessing the demand for subsistence resources for larger population could not be accomplished. As with population projections, projecting for future demand requires sufficient data on current and past demand. Such data are either unavailable or not accessible. ADF&G community surveys are the only source for such data. Small populations yield small numbers that are confidential. Moreover, communities are not surveyed every year. Thus, there are large gaps in data, making it impossible to project demand.

Methods

Original spatial data, organized in shapefile format in geodatabases for each community, by CE, were obtained from ADF&G Division of Subsistence. These data were collected as part of the ADF&G annual community subsistence surveys. The shapefiles did not have any attributes or data associated with the spatial information. Each polygon shapefile was converted into 60 m rasters and were processed to match the habitat models for each CE prepared by AKNHP. Raster files for each CE were then added together to create a single raster for each CE. The final raster depicted how subsistence use areas between communities overlapped.

Table B-28. Source datasets related to subsistence harvest in the YKL study area.

Dataset Name	Data Source
Community Subsistence Information System	ADF&G, CSIS
Subsistence harvest areas	ADF&G

Results

A series of maps were computed to show the subsistence use areas for each resource. Figure B-61 shows the subsistence use areas for brown bear, black bear, berries, and waterfowl. Brown bear is mostly hunted in the Lake Iliamna area. Black bears are hunted all along the Kuskokwim River and in the Lake Iliamna area. Although black bears are more predominant, their harvest is low, suggesting the relatively lower preference of the population for black bear compared to other subsistence resources. Berries and plants are a common resource for people in the region. Berries are harvested close to the communities, typically on the tundra on the banks of rivers. Waterfowl, like berries, is abundant in the region, and is hunted through the region along the river corridors.

Figure B-62 shows the subsistence areas for caribou, wolf, moose, ptarmigan. Caribou is mostly hunted in the Lime Hills area. This area of YKL is the primary range for the Mulchatna herd. Wolf is not sought after as a food resource. The State of Alaska manages hunting statewide and some areas of the YKL region are, or may be open to wolf hunting. Moose is the most hunted ungulate in the region. All lowlands in the region are moose habitat. Ptarmigan is mostly hunted along the Kuskokwim River.

Figure B-63 shows the subsistence areas for salmon, northern pike, sheefish, and beaver. Salmon is the most sought-after subsistence resource in the region. Four major species of salmon are found in the region. Similarly, northern pike is fished by all surveyed communities in the region. Sheefish are mostly found in the Kuskokwim and Yukon rivers. Beavers are hunted near a few communities on both the Kuskokwim and Yukon rivers.

As can be seen from these figures, most subsistence harvesting is done close to the communities, along the river corridors. These areas are relatively easier to access and either because of the abundance of these resources in the region or due to the price of fuel and transportation, hunters prefer to stay close to communities and river corridors.

The recent crash in Chinook (king) salmon stocks was a cause for distress among residents of the region. In the Golovin, Anvik, Shageluk, and Holy Cross communities on the lower Yukon River, people increasingly relied on non-salmon fish, following low salmon harvests. However, animal condition, and thus usability varies from place to place, so patterns of substitution vary by location. For example, sheefish are in better condition on the lower Yukon River than on the upper, so are a better substitute for salmon in lower Yukon communities (Brown et al. 2005). Other research shows shifts between similar species. Communities in the northwest Arctic switched from sheep to caribou when caribou migration routes brought them closer (Georgette and Loon 1999).

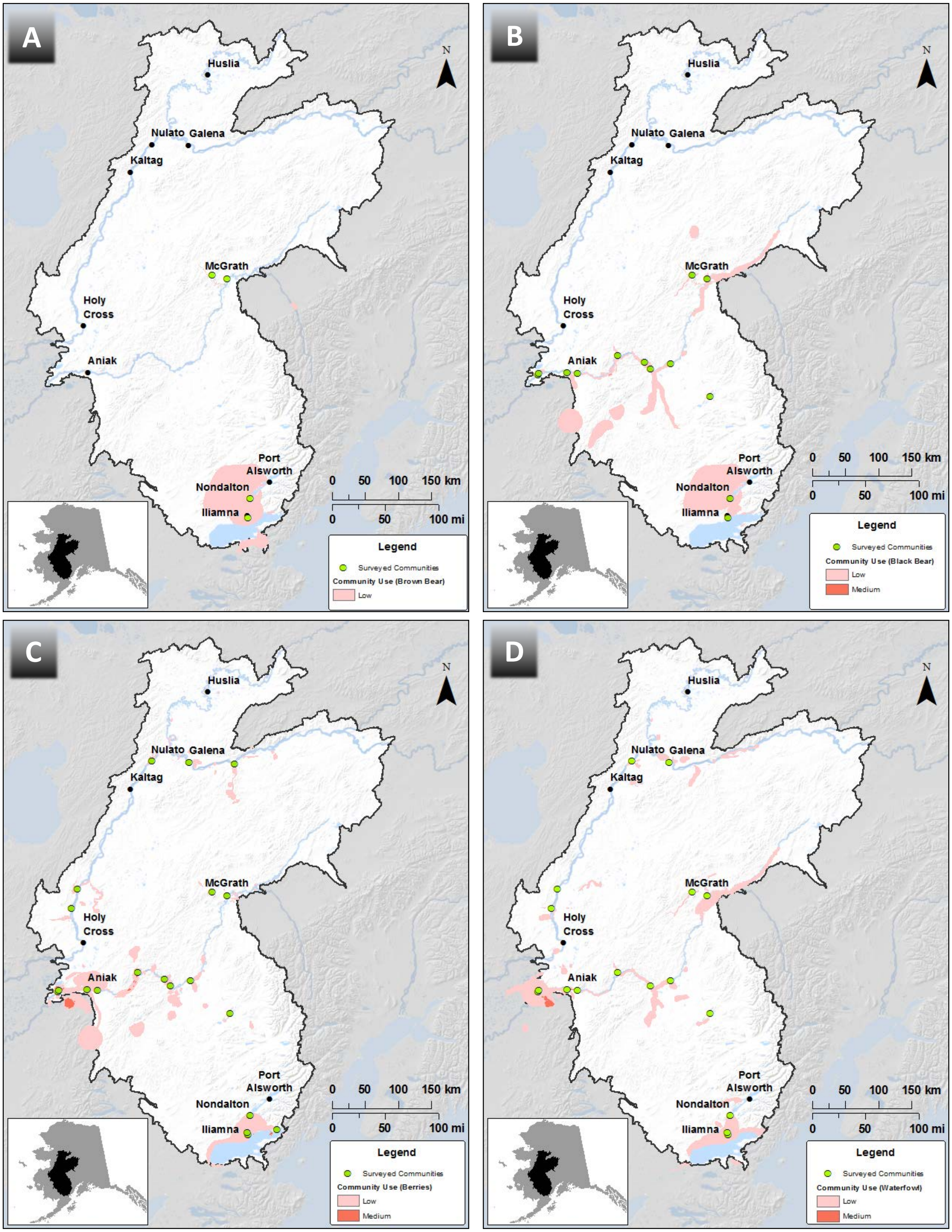


Figure B-61. Subsistence use areas: brown bear (a), black bear (b), berries (c), and waterfowl (d).

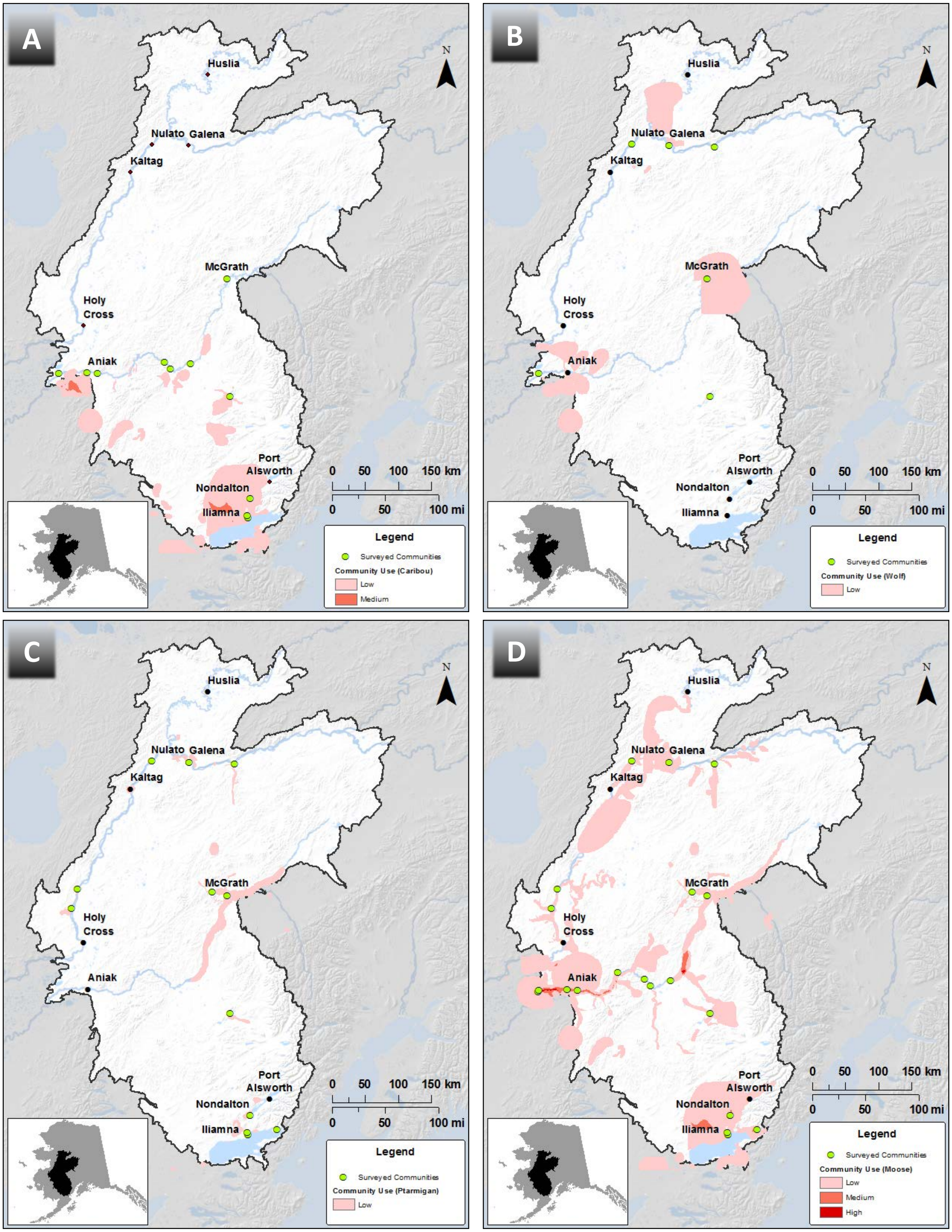


Figure B-62. Subsistence use areas: caribou (a), wolf (b), ptarmigan (c) , and moose (d).

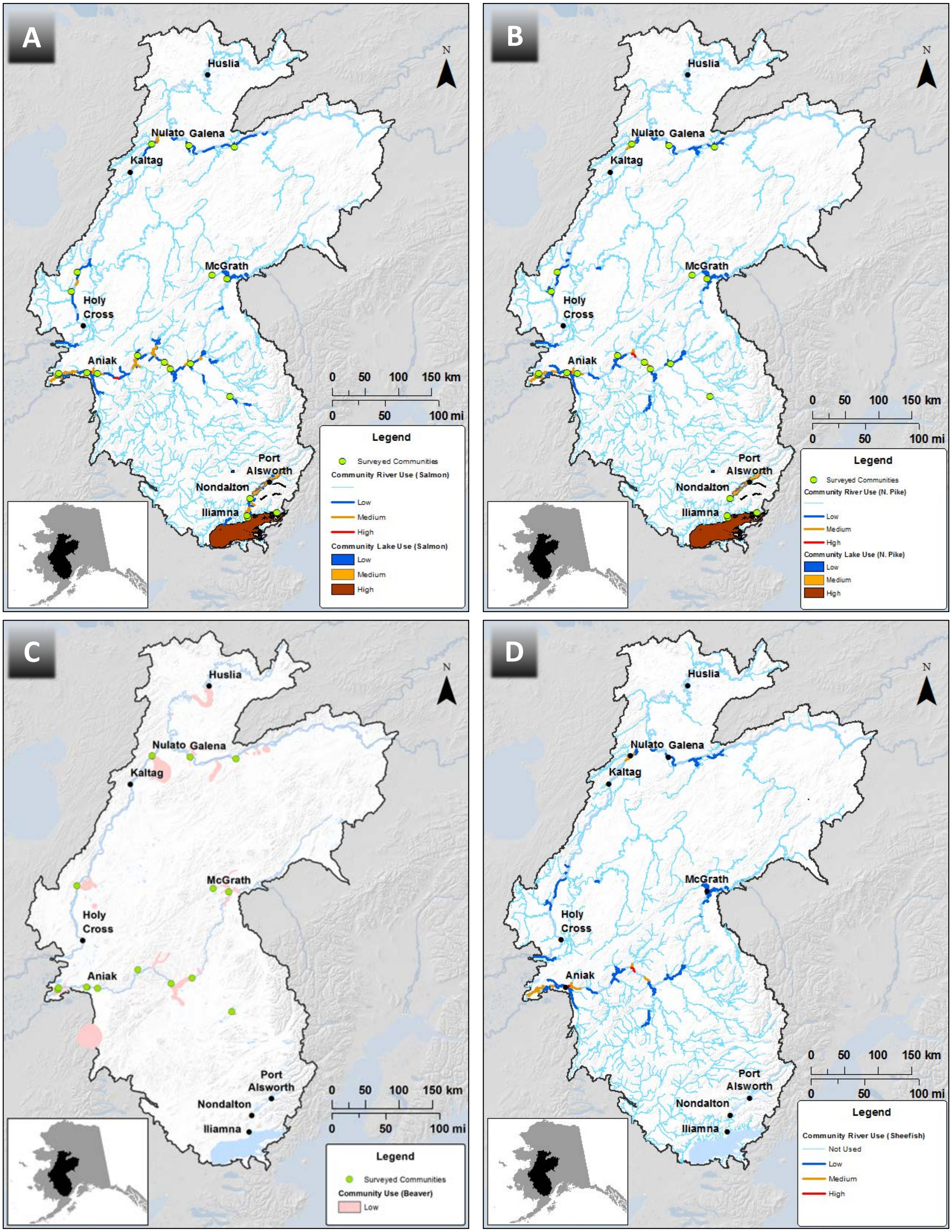


Figure B-63. Subsistence use areas: salmon (a), northern pike (b), beaver (c), and sheefish (d).

Table B-29. Pounds per capita harvested for the top four resources. Data are from the latest survey conducted in each community in the YKL region.

Community	Harvest #1		Harvest #2		Harvest #3		Harvest #4	
	Resource	PPC	Resource	PPC	Resource	PPC	Resource	PPC
2002								
Koyukuk	Whitefish	40	Sheefish	22	Pike	7	Burbot	1
Lake Minchumina	Moose	94	Whitefish	91	Pike	43	Burbot	22
2004								
Pedro Bay	Sockeye Salmon	250	Moose	28	Char	9	Berries	6
2006								
Kaltag	Whitefish	8	Sheefish	6	Pike	5	Grayling	3
2007								
Lime Village	Sockeye Salmon	275	Caribou	159	Chinook Salmon	142	Chum Salmon	107
2008								
Iliamna	Sockeye Salmon	208	Chinook Salmon	15	Chum Salmon	1	Coho Salmon	0
Newhalen	Sockeye Salmon	193	Coho Salmon	3	Chum Salmon	1	Chinook Salmon	0
Nondalton	Sockeye Salmon	280	Chinook Salmon	1	Chum Salmon	0	Coho Salmon	0
Port Alsworth	Sockeye Salmon	82	Chinook Salmon	3	Chum Salmon	1	Coho Salmon	1
2009								
Aniak	Chinook Salmon	67	Chum Salmon	60	Coho Salmon	46	Moose	38
Chuathbaluk	Chinook Salmon	68	Sockeye Salmon	42	Moose	32	Chum Salmon	31
Crooked Creek	Chinook Salmon	69	Chum Salmon	49	Coho Salmon	33	Sheefish	21
Lower Kalskag	Chinook Salmon	64	Moose	32	Chum Salmon	18	Whitefish	16
Red Devil	Sockeye Salmon	46	Sheefish	45	Chinook Salmon	44	Whitefish	39
Sleetmute	Chinook Salmon	109	Sockeye Salmon	66	Chum Salmon	55	Coho Salmon	46
Stony River	Chinook Salmon	147	Sockeye Salmon	102	Whitefish	66	Coho Salmon	60
Upper Kalskag	Chinook Salmon	123	Moose	40	Berries	32	Chum Salmon	25
2010								
Galena	Moose	85	Chum Salmon	64	Chinook Salmon	38	Summer Chum	36
Nulato	Moose	82	Chinook Salmon	73	Chum Salmon	19	Coho Salmon	16

Community	Harvest #1		Harvest #2		Harvest #3		Harvest #4	
	Resource	PPC	Resource	PPC	Resource	PPC	Resource	PPC
2011								
Anvik	Chinook Salmon	140	Moose	90	Chum Salmon	67	Summer Chum	44
Grayling	Chinook Salmon	67	Moose	58	Chum Salmon	43	Summer Chum	30
McGrath	Moose	107	Chinook Salmon	31	Coho Salmon	21	Berries	12
Takotna	Moose	124	Beaver	8	Grouse	8	Black Bear	7

The biggest change to subsistence harvests in the YKL region has been the sharp drop in Chinook salmon. Braund (2012) writes 'Decreases in harvests of major species or overall harvests have implications for quality of life, nutrition, and cultural continuity". He also notes that decreased diversity of harvests means less dietary diversity. Loss of the species means loss of huge parts of culture, because transmission of knowledge about a species ties generations together. Traditions and practices around preparing for harvests, harvesting, and sharing cannot be replaced by substituting species.

Results of other studies can help to understand community responses to shocks in animal populations. Possible household responses to a sharp decline in the availability of subsistence resources is a function of availability of substitutes, cultural preference and norms about how to harvest and what is fit to eat, the cost of equipment and technology, knowledge of animal habitat and behavior, knowledge of how to hunt, and how to navigate terrain and weather, as well as the distance to animals and the cost of fuel and ammunition. Whether people would eat more store bought foods in response to a shortage of subsistence foods depends on food cost and availability, job opportunities, and income. Martin (2010) showed that during the caribou crisis in the mid-1970s, people in Anaktuvuk Pass ate more store bought foods as a response. However, at that time jobs were plentiful, sea mammals were not part of harvest traditions and were hundreds of miles away, and the crisis ended quickly and people returned to caribou.

In a 2003 interview Orville Huntington of Huslia describes why communities do not always harvest new species when they appear:

> *We never used to get beluga in the summer. (I went to the) National Science Foundation, and Alaska Native Science Commission Northwest Alaska regional meeting, and I had to ask them. I said 'What do you guys do with your beluga?' I said, "We're getting beluga up the Koyukuk River now and they're moving my net around. I don't know what to do with them. You guys are telling me you're seeing our beaver, you don't know what to do with them. I can tell you what… I grew up with them, I know what to do with beaver. But I don't know what to do with a beluga whale that's in the Koyukuk River, I really don't."*

Other responses to a shortage could be traveling or moving to a community with access to animals, increased consumption of store bought foods, moving out of the region, increased harvests by communities with access along with increased sharing among communities. Hunting regulations and the degree to which they are enforced will also affect household responses.

A sharp drop in salmon availability is the cause of lower YKL salmon harvests. However, other factors affect subsistence harvests. These include animal health, access to animals, time available to hunt, cost of hunting, and skills. Loss of a subsistence species has effects beyond food supply.

"Climate warming is affecting access of hunters to land mammals. Hunters customarily use rivers as their primarily access routes. Rivers are accessible by boat in the summer and by snow machine in winter but are largely inaccessible during autumn freeze-up and spring breakup. The slow freeze-up of rivers has lengthened the interval of unsafe river ice in autumn, an important season for hunting moose and trapping marten. In addition, wildfires burn shelter cabins" (Kofinas et al. 2010).

"Winters of unusually deep snow, which are projected to become more frequent with climate warming, can create massive mortality of moose, particularly if they are nutritionally stressed. Rain-on-snow events, which are also expected to occur more frequently with climate warming, reduce access by caribou to lichens during winter, creating a critical food stress. These indirect effects of climate change on subsistence resources are currently recognized as important but their future impacts remain highly speculative" (Huntington, Fox, Berkes, & Krupnik, 2005).

Beaver Populations

Increases in the beaver population are a concern in some YKL communities (proccedings, 2012). Figure B-63 shows the current beaver subsistence areas. People reported hunting or trapping beavers on both the Yukon and Kuskokwim rivers. Data from the ADF&G on beaver harvest shows a mixed pattern. Beavers were harvested through the 1980s. Trapping was much more prevalent than it is today and pelts were a major source of income for rural households. From 1985 to 1989, Alaska exported between 10,000 and 15,500 beaver pelts annually (Anderson 1993). Harvests were minimal through mid-2000s and increased in the late 2000s. Data on beaver harvests are obtained from the subsistence surveys, and are only available for some communities in select years because questions about beaver harvests were not included in all surveys and not all communities were surveyed every year. Table B-30 presents beaver harvests in number of animals.

Table B-30. Beaver harvest data from ADF&G community subsistence surveys in the YKL region from 1980-2011.

Community	1980-1991	2002-2011
Aniak		94 (2009)
Anvik	353 (1990)	56 (2011)
Chuathbaluk	158 (1983)	59 (2009)
Crooked Creek		48 (2009)
Galena	314 (1985)	132 (2010)
Grayling	242 (1990)	109 (2011)
Holy Cross	577 (1990)	
Hughes	113 (1982)	
Huslia	275 (1983)	
Iliamna	27 (1983); 25 (1991)	5 (2004)
Lake Minchumina		25 (2002)
Lime Village		41 (2007)
Lower Kalskag		54 (2009)
Manley Hot Springs		34 (2004)
McGrath	10 (1984)	180 (2011)
Newhalen	35 (1983); 78 (1991)	11 (2004)
Nondalton	200 (1980); 251 (1981); 206 (1983)	84 (2004)
Nulato		175 (2010)
Pedro Bay	10 (1982)	0 (2004)
Port Alsworth	2 (1983)	6 (2004)
Red Devil		17 (2009)
Shageluk	31 (1990)	
Sleetmute	277 (1983)	80 (2009)
Stony River		163 (2009)
Takotna		20 (2011)
Tanana	379 (1987)	
Upper Kalskag		54 (2009)

5.7. Population Increase and Subsistence

MQ 37	How could larger community populations affect subsistence resources?

Figure B-64 presents subsistence salmon harvests on the portion of the Yukon river that is within the YKL boundary and total population of communities along the same stretch of the Yukon river. There is no clear relationship between subsistence harvests and total population. Although salmon harvests were highest in the mid-1980s when population was also high, in early 1980s they were at the same as they are currently, although in 1980, almost 30% more people lived in the region.

In another study using ADF&G salmon harvest data to examine the relationship between population growth and subsistence salmon harvests on the Kuskokwim river (Howe and Martin 2010) did not show community population growth to be correlated with subsistence salmon harvests in the same communities. This relationship is counter-intuitive, but indicates that salmon populations are affected by more than human populations.

Partial explanation for the lack of a relationship between community population and salmon harvests may be tied to community demographics. Larger populations often mean more young families, who do less subsistence than other types of households (Magdanz 2005). It could also be due to wage employment because time at work leaves less time for subsistence. Formal and informal rules, land ownerships, and customs, may limit access to fishing areas. If larger populations are in-migrants who are not part of the local tribal group, they may not have access through Native land to reach fishing areas.

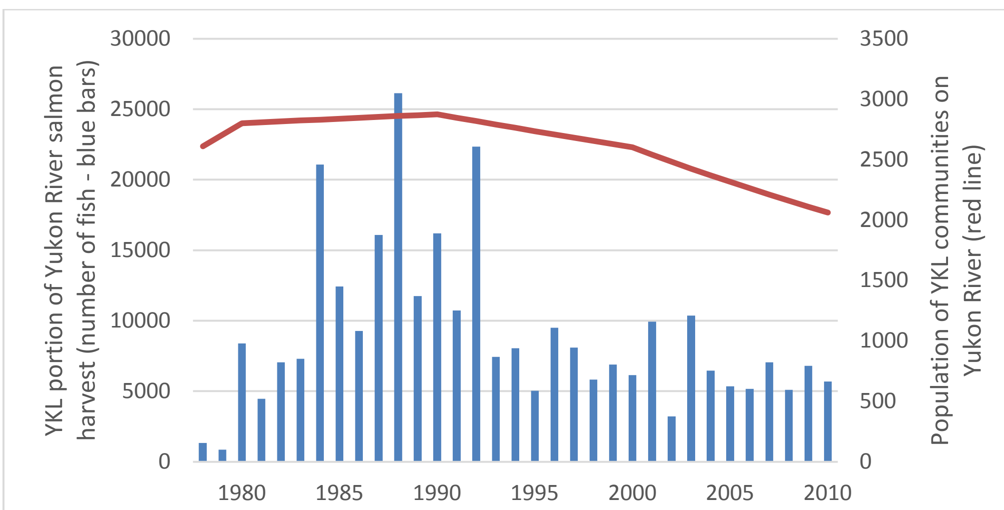


Figure B-64. Subsistence harvest numbers of salmon among Yukon River communities in YKL region; and the total population in those communities.

As evident from the harvest numbers of moose and caribou, the two primary large land mammal species in the region, human population of the region is not directly correlated with the harvest numbers. Harvest amounts of subsistence resources are likely dependent on several factors.

5.8. Commercial Salmon Harvest

MQ 40	What have been the commercial harvest levels of salmon over the past 10 years?
MQ 41	Where are current commercial fish harvest areas?

There are no commercial salmon harvests in the Iliamna area. Commercial salmon harvests are limited to the Yukon and Kuskokwim rivers. Current harvest levels are almost non-existence compared to 30 years ago. Even though this question addresses the past 10 years, it is useful to look a harvest levels over a longer period to understand the importance of salmon harvests for local economies, the relationship between commercial and subsistence harvests.

Table B-31. Source datasets related to commercial salmon harvest in the YKL study area.

Dataset Name	Data Source
Alaska Commercial Salmon Harvests and Exvessel Values	ADF&G

Results

Figure B-65 presents subsistence and commercial salmon harvests on the Yukon River from 1961 through 2011. By including 50 years of harvest data for subsistence and commercial use, the figure shows (1) the peak of salmon harvests in the late 1970's through 1980's, the crash in 2000, and commercial closure in 2001; and (2) the relative shares of subsistence and commercial harvests. In most years, especially the high harvest years, subsistence makes up a small share of total harvests. However, subsistence and commercial fishing are related. Many commercial fishermen are also subsistence harvesters, and for them, commercial fishing provides equipment and cash for other inputs to subsistence activities. Earnings from commercial salmon fishing are positively correlated with subsistence harvests, according to a regression analysis (Howe and Martin 2010). In years where commercial harvests are low, fishermen are less able to afford subsistence fishing.

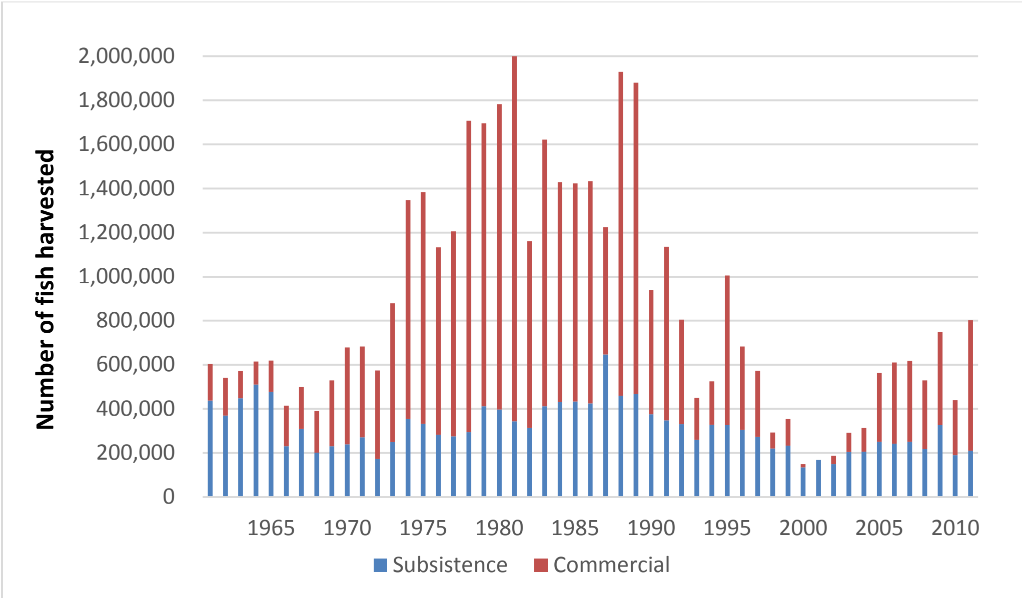


Figure B-65. Number of salmon harvested by subsistence and commercial fishermen on the Yukon river from 1961 through 2011.

5.9. Current and Future Recreation

MQ 45	Where is recreation activity highest?
MQ 49	How might recreational use in the region change over time?

Methods

In the recreational activity section, we use tabular data from unpublished reports to describe statewide trends in tourism. Then we use data from the National Park Service (NPS) and Alaska Department of Fish and Game (ADF&G) to describe recreational use patterns in the region.

Table B-32. Source datasets related to current and future recreation in the YKL study area.

Dataset Name	Data Source
Lake Clark visitor data	National Park Service (NPS)
Alaska visitor statistics	McDowell group

Results

Because of its remote location, few people visit the region for recreational use, and except for the Iditarod, activities are concentrated in the summer. Recreation in the YKL region includes sport hunting, sport fishing, and general outdoor hiking and camping activities (see the next section for a discussion of sport hunting and fishing). This section and the next, show that sport hunting and fishing make up the largest share of recreational use. The Alaska Visitor Statistics Program (AVSP) VI (McDowell Group 2011), reported that 4% of an estimated 1.56 million visitors to the state visited the southwest part of the state[6].

Small planes and floatplanes provide access to the remote recreational areas. However, the use of floatplanes may contribute to the spread of the invasive waterweed *Elodea* (pers. comm. T. Schwoerer 7/9/2014, and see Section B-4).

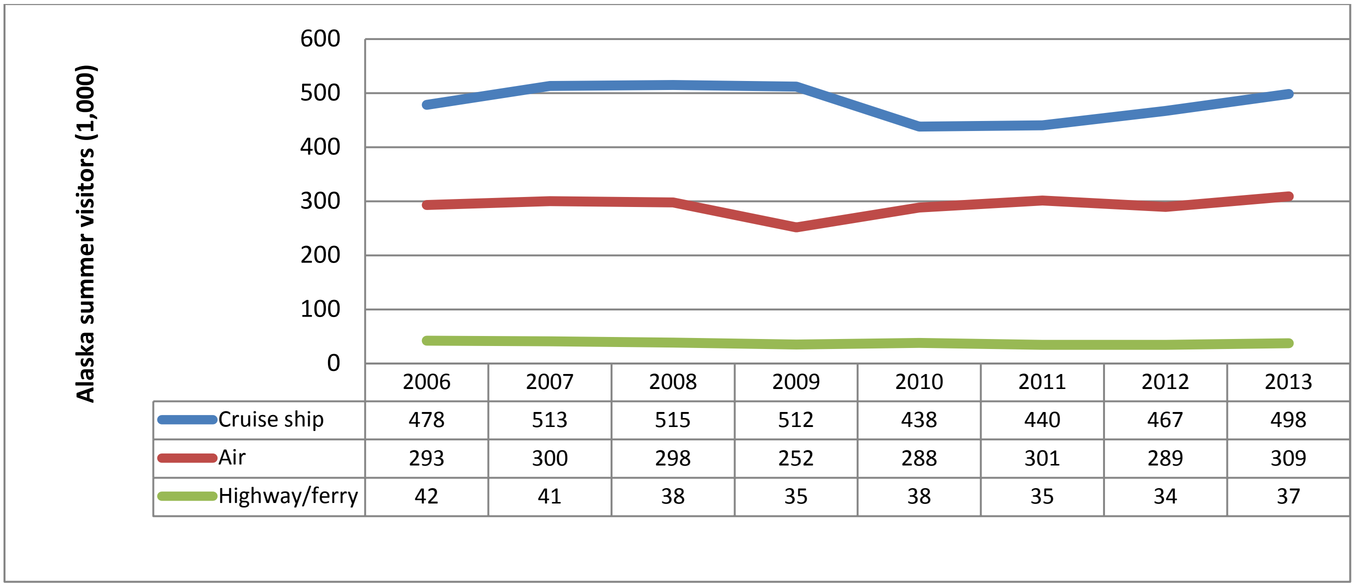
Even though tourism is increasing statewide, and visitors to Lake Clark National Park and Preserve are increasing, recreational use in the YKL is not likely to increase enough to offset the decrease in sport fishing. Increased recreational use of the region could adversely affect local residents access to subsistence resources. Also, to many Alaska Native residents, catch and release fishing is considered offensive, 'We were taught by our elders not to play with our food' (AVCP 2013).

The long-term projection of transportation options in the YKL region includes a possible road along the Kuskokwim River connecting McGrath to Aniak and beyond. There is also a proposed road connecting Holy Cross

[6] AVSP, a periodically commissioned study of Alaska's visitors by Alaska's Department of Commerce, Community, and Economic Development, divides the state into five regions. YKL region is spread between the southwest and interior regions.

on the Yukon and Kalskag on the Kuskokwim. While these roads may increase connectivity and access among different communities and the surrounding areas, the projected decline in population and the lack of increased employment opportunities in the region may keep the current hunting demand unchanged.

Figure B-66 shows total statewide summer visitors statewide from 2006 to 2013. Visitor counts follow national economic trends and are recovering from the drop after 2008.



	2006	2007	2008	2009	2010	2011	2012	2013
Cruise ship	478	513	515	512	438	440	467	498
Air	293	300	298	252	288	301	289	309
Highway/ferry	42	41	38	35	38	35	34	37

Figure B-66. Alaska summer visitor volume 2006-2013.

Four National Wildlife Refuges (NWR) managed by USFWS are either located entirely within or overlap with the boundaries of YKL region (Table B-33). Together they comprise 49,219 km^2. Created in 1903, the National Wildlife Refuge system currently encompasses more than 150 million acres within 556 refuges and 38 wetland management districts. While the national system attracts 45 million visitors annually, data on the visitor statistics are not available for all refuges. The latest effort in assessing visitor characteristics in these refuges (Sexton, Dietsch, Don Carlos, Miller, Koontz, & Solomon, 2013) was a sample survey conducted in 2010/2011. The survey included 53 refuges that had at least 25,000 annual visitors. Two refuges, neither from the YKL region, participated in the survey.

Table B-33. National Wildlife Refuges, National Parks and State Parks within the YKL region.

Name	**Area km^2**	**% of total recreation areas within YKL**	**% of each area within YKL**
Innoko NWR	19,483	32.3%	100%
Koyukuk NWR	18,657	30.9%	100%
Nowitna NWR	8,994	14.9%	100%
Yukon Delta NWR	2,085	3.5%	2.1%
Total	**49,219**		
Lake Clark National Park and Preserve	9,344	15.5%	60.1%
Denali National Park and Preserve	1,730	2.9%	7.2%
Total	**11,074**		
Wood-Tikchik State Park	**123**	0.2%	2.0%
TOTAL	**60,416.30**	**100%**	

The National Park Service manages the two National Parks that overlap with the YKL boundary. More than half of the Lake Clark National Park and Preserve lies within the YKL boundary, in the southeast part of the region. Port Alsworth, Nondalton, and Iliamna serve as major access points to the park. Lake Clark National Park and Preserve is one of the least visited parks in the NPS system. Figure B-67 shows visitors to Lake Clark National Park and Preserve from 1982 through 2013. Note that some of the variation in totals is due to changes in data collection methods. All visitors reported backcountry use and visits were concentrated during the summer. Even though visitation is increasing, the total number of visitors is small. For example, in 2013, visitation was highest in August with about 20 people per day. Less than 10% of the Denali National Park and Preserve is within the YKL boundary and primary access and use areas are outside of the YKL. Although comprehensive visitor statistics are available for Denali National Park, these are not representative of the YKL region. Figure B-68 shows the national recreation areas in the YKL region.

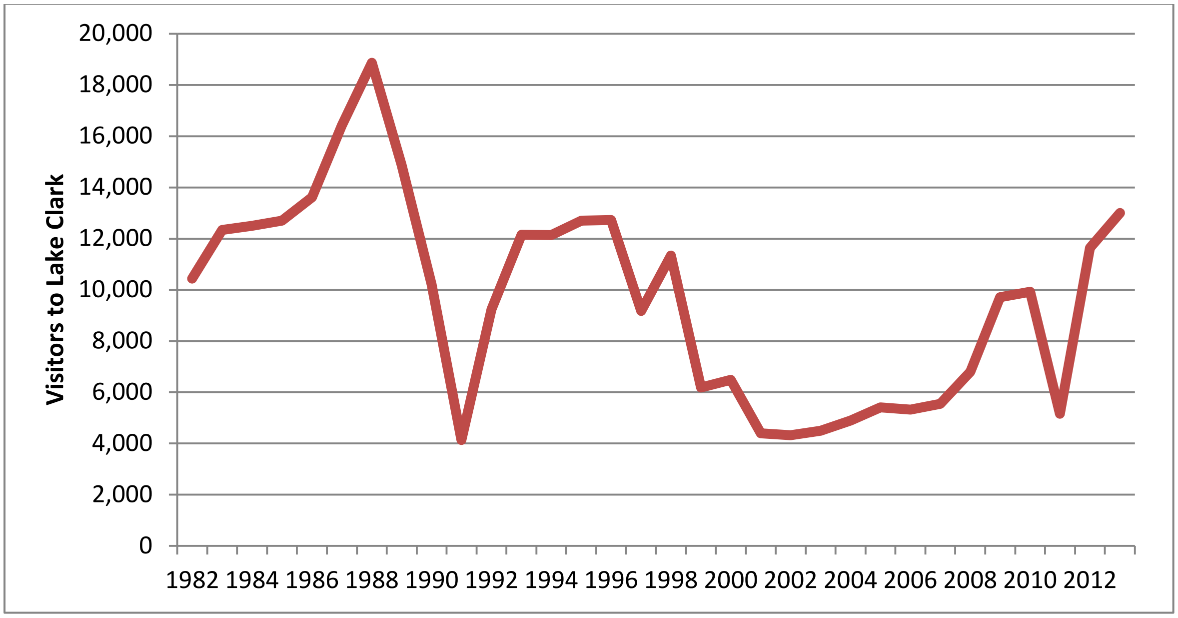


Figure B-67. Annual visitors to Lake Clark Park and Preserve 1982 to 2012 (Source: NPS Visitor Statistics 2014).

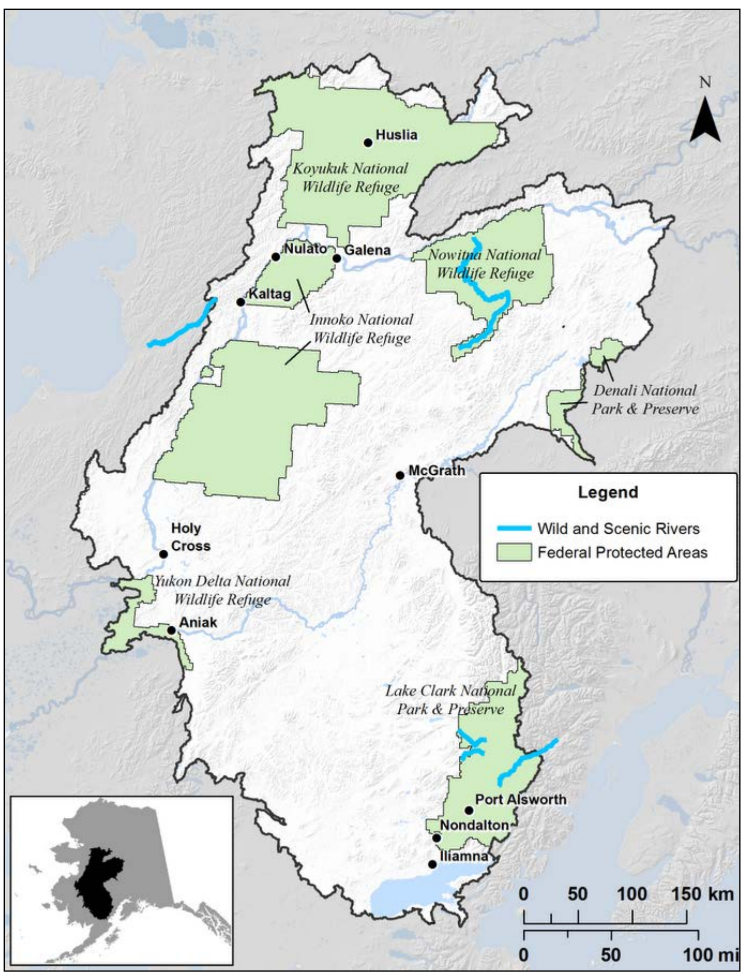


Figure B-68. National Recreation Areas in the YKL study area.

5.10. Sport Hunting and Fishing

MQ 38	What are general (sport) harvest levels of salmon, moose, and caribou in the recent past?
MQ 39	Where are current sport hunt areas?

Methods

Data on sport harvest of caribou and moose are available dating back to 1983 by game management unit (GMU). The YKL region includes ten GMUs. Five other GMUs overlap with the YKL boundary, but the YKL region includes less than 40% of the GMU area. These were not included in this analysis.

The ADF&G Sport Fish Division has conducted a mail survey to estimate sport fishing total harvest (fish kept) since 1977 and total catch (fish kept plus fish released) since 1990. The estimates derived from this survey are available online through this application for study years 1996 through 2012.

Table B-34. Source datasets related to sport hunting and fishing.

Dataset Name	Data Source
Alaska Game Management Units (GMUs)	ADF&G
Alaska harvest statistics	ADF&G
Alaska sport fishing survey	ADF&G

Results

Figure B-69 shows the annual average sport hunting harvest of moose and caribou by GMU within the YKL boundary during the years 2000-2012. The Yukon lowlands (21E, 21D, and 21A) and Lime Hills regions (17B, 19B, and 09B) recorded the highest annual average harvest of moose. This pattern is reflective of the distribution of moose in the region. The long-term (2060) landscape condition forecast predicts the landscape to be highly intact except in the regions around the villages of McGrath and Galena, where it shows a minor decrease in quality of the habitat.

There are seven distinct herds of caribou in the YKL region. The Western Arctic herd's peripheral range extends into the northwest portion of the YKL boundary and thus does not offer many opportunities for hunting. Ranges of both Galena Mountain herd and Wolf Mountain herd are mostly within the YKL boundary and offer some opportunity for hunting. However, both these herds are declining, with very few numbers reported in 2010. Although declining, the Mulchatna herd totaled 30,000 animals in 2010. The Mulchatna herd's primary range is in the Lime Hills area. The annual average sport hunting harvests of caribou by GMUs shown in Figure B-69 reflect the distribution of herds in the YKL region. Caribou harvests are highest in GMU 19B and GMU 09B.

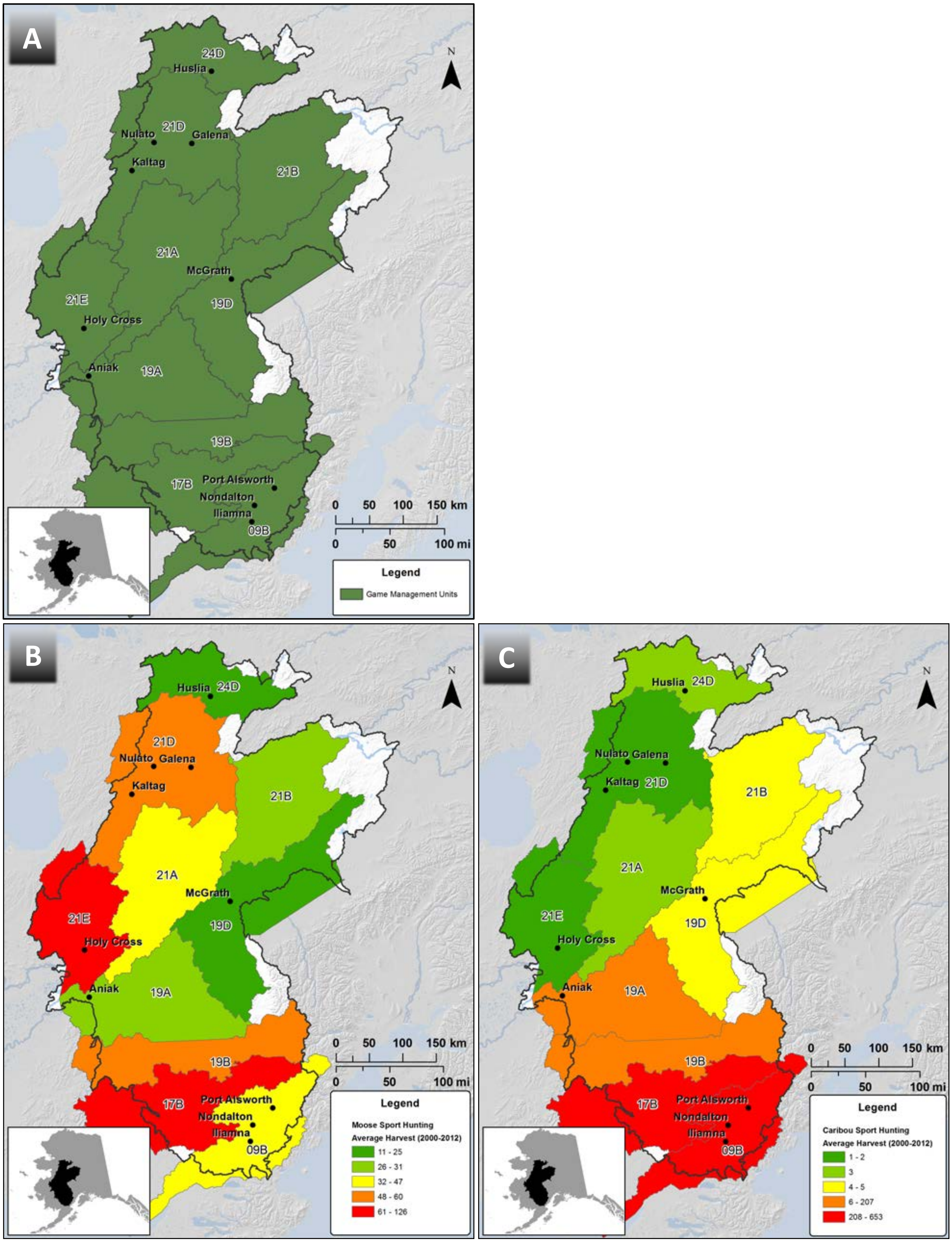


Figure B-69. Game Management Units (a), average sport hunting harvest of moose (b), and average sport hunting harvest of caribou (c) in the YKL study area.

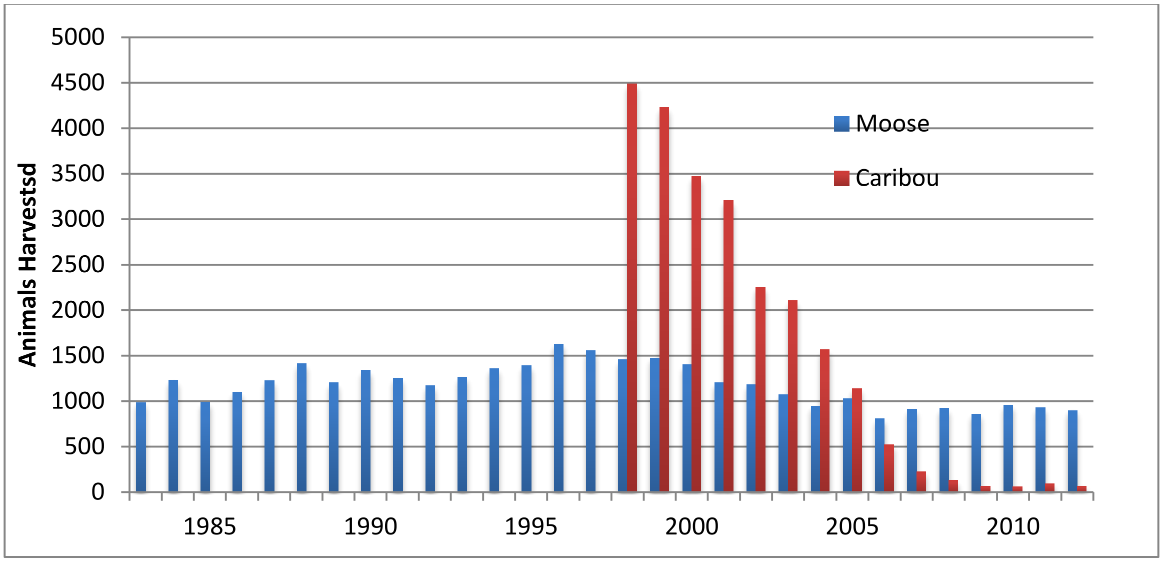
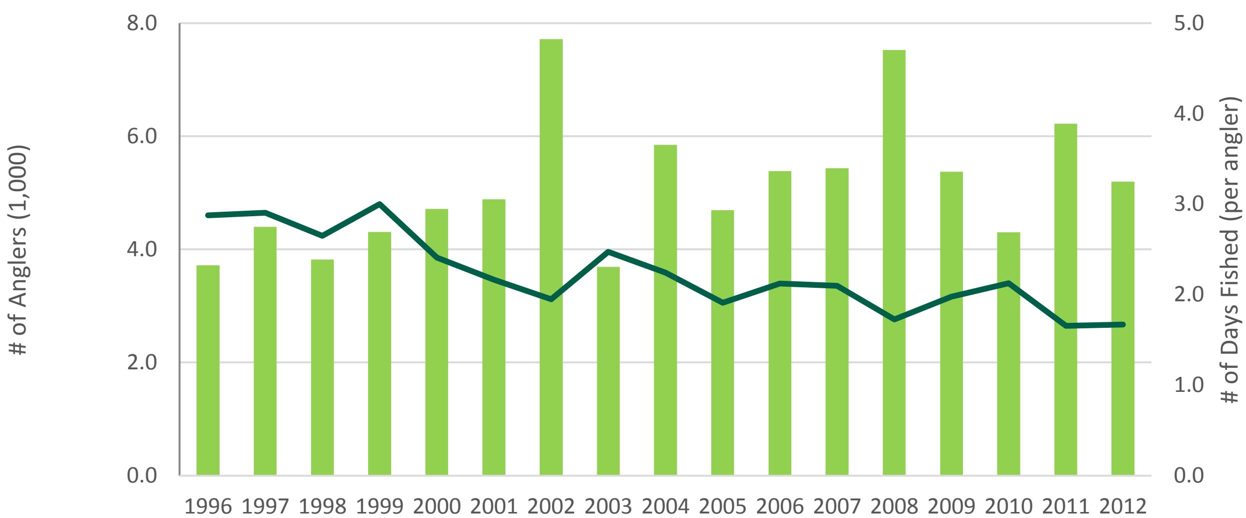


Figure B-70. Number of moose and caribou harvested in the YKL region (1977-2011); Source: ADF&G (2014).

Figure B-71 and Figure B-72 present sport fishing data for the Yukon and Kuskokwim rivers. Comparing the figures shows a sharper decline in the number of anglers on the Yukon River than on the Kuskokwim River. Declines in both regions have negative effects on the Alaska economy and on some local businesses within the REA. Fewer fishermen mean lower spending on equipment, travel, and licenses. It also means fewer jobs for guides and associated businesses (Southwick Associates 2008).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Days Fished	3.0	4.1	4.2	4.4	4.8	5.1	4.6	4.8	4.9	4.2	5.3	5.1	5.2	4.1	4.1	4.8	5.5
Anglers	5.4	6.7	6.7	6.0	4.2	4.1	4.5	5.1	5.2	4.7	4.2	4.2	4.9	4.3	4.8	4.7	4.3

Figure B-71. Sport fishing harvest of salmon on the Kuskokwim River.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Day Fished	2.3	2.7	2.4	2.7	2.9	3.1	4.8	2.3	3.7	2.9	3.4	3.4	4.7	3.4	2.7	3.9	3.2
Anglers	4.6	4.6	4.2	4.8	3.9	3.5	3.1	4.0	3.6	3.1	3.4	3.4	2.8	3.2	3.4	2.6	2.7

Figure B-72. Sport fishing harvest of salmon on the Yukon River.

Limitations and Data Gaps

Data on social and economic indicators in Alaska are limited, and scattered across several federal, state, regional, and local agencies. Identifying, securing, and compiling a reliable and meaningful comprehensive dataset is a considerable challenge. As illustrated in the methods section above, and as identified in Table B-25, data for many indicators identified were minimal or unavailable. An additional challenge is the small sample sizes for key indicators such as birth and death rates. These vital statistics are confidential and only aggregates for large geographies are published. Advanced analyses such as attempted with the socioeconomic index will not yield meaningful results with limited data.

ADF&G collects harvest information from each household in a community (or a random sample of households). Harvests, attempts, and use are reported by species by community, rather than by specific harvest location. In some cases, species reported in a community were not harvested near there. For instance, people will sometimes travel to assist with bowhead whale harvests and report whale harvests from inland communities. Not all species are included in all surveys and only a few communities in the state are surveyed each year. Subsistence harvest survey data are insufficient for modeling. Table B-35 shows communities that have been surveyed by the ADF&G Subsistence Division, years when surveys were conducted, and species groups included in each survey. The table shows that not all communities are surveyed every year, time series data for most communities do not exist, and not all surveys ask about all species. The first issue makes cross sectional comparisons problematic. The second issue makes time series analysis problematic. The third issue introduces complications for both cross sectional and time series analysis. Between 2009 and 2011, comprehensive subsistence harvest surveys have been implemented in many communities as part of the planning for Donlin and Pebble mines. Mapping subsistence use areas was part of this effort. Mapping is not usually part of the surveys. However, these data are already at least three years old. In addition, data collection using household surveys is a lengthy and expensive process. Residents of nearly all rural Alaska communities have participated in tens of surveys, and most report survey fatigue.

Table B-35. ADF&G subsistence harvest surveys.

	Large Land Mammals	Small Land Mammals	Non-Salmon Fish	Salmon	Birds and Eggs	Berries	Vegetation	Plants, Greens and Mushrooms	Marine Invertebrates	Marine Mammals
Aniak										
2001			X							
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Anvik										
1990	X	X	X	X	X	X	X	X		
2002			X							
2003	X	X								
2004	X	X								
2011	X	X	X	X	X	X	X	X	X	X
Chuathbaluk										
1983	X	X		X						

	Large Land Mammals	Small Land Mammals	Non-Salmon Fish	Salmon	Birds and Eggs	Berries	Vegetation	Plants, Greens and Mushrooms	Marine Invertebrates	Marine Mammals
2001			X							
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Crooked Creek										
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Galena										
1985	X	X	X	X	X	X	X	X		
1998	X									
1999	X									
2001	X									
2006			X							
2010	X	X	X	X	X	X	X	X	X	X
Grayling										
1990	X	X	X	X	X	X	X	X		
2002			X							
2003	X	X								
2004	X	X								
2011	X	X	X	X	X	X	X	X	X	X
Holy Cross										
1990	X	X	X	X	X	X	X	X		
2002			X							
2003	X	X								
2004	X	X								
Hughes										
1982	X	X	X	X	X	X	X			
2002			X							
Huslia										
1983	X	X	X	X	X	X	X	X		
1998	X									
1999	X									
2001	X									
2002			X							
Iliamna										
1983	X	X	X	X	X	X	X	X	X	X
1991	X	X	X	X	X	X	X	X	X	X
2001	X									
2003										
2004	X	X	X	X	X	X	X	X	X	X

	Large Land Mammals	Small Land Mammals	Non-Salmon Fish	Salmon	Birds and Eggs	Berries	Vegetation	Plants, Greens and Mushrooms	Marine Invertebrates	Marine Mammals
Kaltag										
1985				X						
1998	X									
1999	X									
2001	X									
2006			X							
Koyukuk										
2002			X							
Lake Minchumina										
2002	X	X	X	X	X	X	X	X	X	
Lime Village										
2007	X	X	X	X	X	X	X	X	X	X
Lower Kalskag										
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Manley Hot Springs										
2004	X	X	X							
McGrath										
1984	X	X	X	X	X	X	X			
2011	X	X	X	X	X	X	X	X	X	X
Newhalen										
1983	X	X	X	X	X	X	X	X	X	X
1991	X	X	X	X	X	X	X	X	X	X
2001	X									
2003										
2004	X	X	X	X	X	X	X	X	X	X
Nondalton										
1973	X	X	X	X	X					
1980	X	X	X	X	X					
1981	X	X	X	X	X					
1983	X	X	X	X	X	X	X	X	X	X
2001	X									
2003										
2004	X	X	X	X	X	X	X	X	X	X
Nulato										
1998	X									
1999	X									
2001	X									
2006			X							
2010	X	X	X	X	X	X	X	X	X	X
Pedro Bay										

	Large Land Mammals	Small Land Mammals	Non-Salmon Fish	Salmon	Birds and Eggs	Berries	Vegetation	Plants, Greens and Mushrooms	Marine Invertebrates	Marine Mammals
1982	X	X	X	X	X	X	X	X	X	X
1996	X	X	X	X	X	X	X	X	X	X
2001	X									
2003										
2004	X	X	X	X	X	X	X	X	X	X
Port Alsworth										
1983	X	X	X	X	X	X	X	X	X	X
2001	X									
2003										
2004	X	X	X	X	X	X	X	X	X	X
Red Devil										
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Shageluk										
1990	X	X	X	X	X	X	X	X		
2002			X							
2003	X	X								
2004	X	X								
Sleetmute										
1983	X	X		X						
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Stony River										
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X
Takotna										
2011	X	X	X	X	X	X	X	X	X	X
Tanana										
1987	X	X	X	X	X	X	X	X		
1998	X									
1999	X									
2006			X							
Upper Kalskag										
2003	X	X								
2004	X	X								
2005	X	X								
2009	X	X	X	X	X	X	X	X	X	X

5.11. Mercury Contamination

MQ 50	Are there areas in the REA that are impacted by mercury contamination?

Mercury has no known metabolic function and is unsafe to living organisms, affecting the central nervous system in humans. Southwest Alaska has several small deposits of mercury owing to its highly mineralized geology. Cinnabar is the most common mercury-rich ore found in the region, with occasional occurrences of liquid mercury. Most deposits are small, concentrated around other mineral deposits. Mercury deposits are not economically viable for mining. Few mines operated in the past but are not in operation at this time. Mercury concentrated around these mineral deposits enters the food chain in the form of organic compounds and concentrates up the food chain.

Results

A 1994 study (U.S. Geological Survey, 1994) reports comparisons of concentrations of mercury in samples of stream sediment, water, and fish collected from locations close to the known deposits and from locations far and upstream from known deposits of mercury. Table B-36 shows comparisons of mercury concentrations in samples of sediment, stream water, and fish in the Kuskokwim basin. Since cinnabar is relatively stable and is insoluble in water, sediments close to the mine sites or deposit sites are expected to have mercury. While the stream waters near mercury deposits, and the edible parts of fish, are high in mercury concentration, contamination is below the threshold set by regulating agencies.

Table B-36. Comparisons of mercury concentrations in samples downstream and upstream from known mercury deposits in the Kuskokwim river basin (U.S. Geological Survey, 1994).

Sample	Near or downstream from mercury deposits	From unmineralized streams
Stream sediment	In excess of 5000 ppm	Less than 1 ppm
Stream waters (Recommended: Below 2.0 ppb – State of Alaska; Below 2.4 ppb – EPA)	As much as 0.75 ppb	Less than 0.1 ppb
Edible portions of fish (Recommended: Below 1.0 ppm – US Food and Drug Administration	0.6 ppm (wet weight)	0.2 ppm

Following the 1994 study, the Bureau of Land Management is leading a study to assess the elevated mercury concentrations in the Kuskokwim. Samples of invertebrates and fish from a 730 mile stretch of the Kuskokwim River and its 17 tributaries between Aniak and Stony River were tested in 2010-2011. An interim report (Matz 2012) from this project reports similar results to the 1994 study.

Figure B-73 shows all known mercury mines and deposit sites in the YKL region. The figure shows the six known mines listed in the Alaska Department of Environmental Conservation (ADEC) Contaminated Sites with Mercury report (Alaska Department of Environmental Conservation 2011). Cinnabar Creek at the headwaters of the Holitna River is the only site listed as having been cleaned. Former mines – Kolmakof, Mountain Top, Red Devil, and Nixon Fork – are all on the Kuskokwim River, directly impacting the river basin. Indian River gold mine camp is the only one identified on the Yukon River. The figure also shows the streams in the Kuskokwim basin that are were or are under a fish consumption advisory from the State of Alaska.

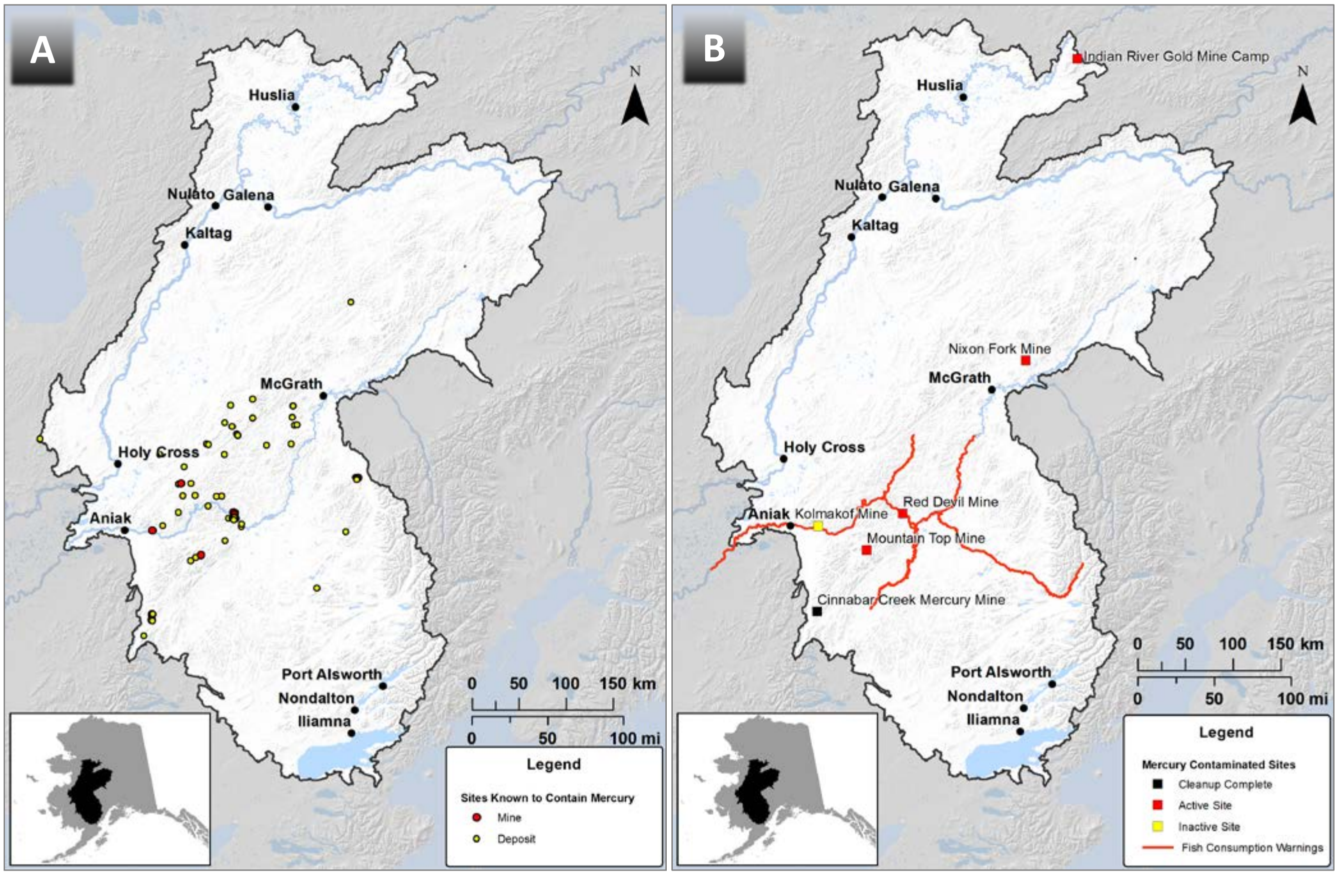


Figure B-73. Mercury contamination: mines and deposits known to contain mercury (a) and rivers with mercury warnings (b).

Figure B-73 shows all the known mines and sites with mercury deposits as reported in the Alaska Resource Data File from the USGS. As reported in several studies (U.S. Geological Survey 1994), the Kuskokwim basin is a highly mineralized, and mercury is found in small deposits in most mineral sites along the river.

5.12. Traditional Ecological Knowledge

MQ-68	*What TEK is available for the region?*

The AMT suggested the use of Traditional Ecological Knowledge (TEK) as an information and data source. After a preliminary review, it was determined that using available TEK is challenging for the following reasons:

- TEK was not clearly defined within the confines of the project. It was not clear what may be considered TEK.
- Clear and consistent sources of TEK could not be identified. Many reports were considered to be TEK. Reports differed widely in topics they covered, methodologies used, intended audience, purpose, etc. The authors are not aware of any assessment of these reports for quality and consistency.
- The extent of availability and coverage was not clear. Since reports were scattered in libraries, online sources, and other unidentified depositories, it was impossible to assess the extent of availability and access to them.

These limitations restricted the potential use of TEK to answer any MQ. In response to these challenges, the AMT agreed to transform all MQs to exclude the potential use of TEK and requested identification and cataloguing of available TEK for the YKL region.

Three distinct products were produced in response to MQ-68: An annotated bibliography of available TEK reports for the region; an MS ACCESS database of the available reports; and this narrative to identify a potential methodology to use available TEK for the assessment.

The purpose of this study is to:

- Review the literature to identify varying definitions of TEK,
- Identify current uses of TEK,
- Identify prevalent methodologies used in collecting and compiling TEK,
- Assess the extent of availability of TEK in the YKL region, and
- Identify a potential method to use TEK for REA purposes.

Introduction

Traditional Ecological Knowledge (TEK) provides a qualitative understanding of ecosystems at temporal and spatial scales. Observations can include the availability of subsistence foods, changes in local environments, mental mapping (description of spatial characteristics), and plant/animal nomenclature. These data can be used to identify research needs, strengthen research design, inform methodologies, explain research results, or provide alternate narratives to those produced using other quantitative and qualitative data. As such, TEK has been discussed/suggested as a valuable tool in resource management strategies worldwide. Apart from a few instances, however, TEK has yet to be utilized broadly in management schemes.

In literature on TEK, there isn't a common understanding of the definition of TEK or how TEK can be used to address 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).

Definitions of TEK include:

> *TEK refers to the knowledge base acquired by indigenous and local peoples over many hundreds of years through direct contact with the environment. It includes an intimate and detailed knowledge of plants, animals, and natural phenomena, the development and use of appropriate technologies for hunting, fishing, trapping, agriculture, and forestry, and a holistic knowledge, or "world view" which parallels the scientific discipline of ecology* (Inglis 1993 p. vi).

Usher refers to TEK as "all types of knowledge about the environment derived from the experience and traditions of a particular group of people" (Usher 2000 p. 185).

> *…traditional ecological knowledge is a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment* (Fikret Berkes, 1999, p. 8).

Usher (2000) and others have discussed the difficulties with inconsistency of definition. Not only are the terms "environmental" and "ecological" frequently interchanged, but there is also a range of terms used synonymously or alongside TEK. In particular, Usher points out the use of these variable terms in Canadian policy requirements, which use numerous terms to describe what may (or may not) be the same concept (Usher 2000, p. 184). These terms include: traditional knowledge (TK), indigenous/aboriginal knowledge (IK/AK), local ecological knowledge (LEK) and local knowledge (LK), among others.

Current Uses

The value of TEK to resource managers and conventional science has been discussed in numerous publications, although few assess the practical application of TEK in such contexts. Nevertheless, there are several arguments in favor of integrating TEK into a management/research paradigm. Bohensky and Maru (2011) list several of these arguments, stating that the integration of TEK and its counterparts:

- Promotes global cultural diversity and engages scientists and locals together in the maintenance of biological diversity, which is intimately tied to the former.
- Fills knowledge gaps and provide vital information
- Reflects "social justice, sovereignty, autonomy, and identity of indigenous peoples".

There is no consensus within the scientific community, on the above or other motivating factors at work in projects involving TEK.

Outside of the YKL region, TEK has been utilized in the United States to differing degrees and with different goals. In the United States, there have been efforts to integrate TEK *and cultural views/foundations/values* in combination with or comparison to other data (monitoring, GIS, etc.) to promote and enact ecological restoration. On the White Mountain Apache Reservation, individual and collective efforts uphold a system of adaptive management based on TEK and supported by quantitative methods. Similarly, some community-based forestry organizations use an integrated ecological stewardship approach that combines local knowledge and conventional data to balance social, ecological and economic goals. This integrated approach involves locals in management, monitoring, and data collection/interpretation.

In other cases, TEK is used to inform research needs, questions, designs, and methodologies. For instance, the USFWS utilized TEK data regarding polar bear habitat, density estimates and population numbers to justify their decision to list the polar bear as a threatened species under the Endangered Species Act, stating that both traditional and contemporary indigenous knowledge recognized climate related changes occurring in the Arctic, and that those changes were (are) negatively impacting polar bears (USFWS 2008). Some national parks (such as Death Valley National Park and the South Unit of Badlands National Park) have taken strides to formalize land co-management strategies which attempt to incorporate traditional use and knowledge in monitoring and management strategies (Haberfeld 2000; National Park & Tribe 2012).

Importantly, TEK has become increasingly recognized as a valuable resource by federal agencies and organizations.[7] Sallenave (1994) for instance, argues for the use of TEK in environmental impact assessment, citing the acknowledged value of TEK as a supplement to scant environmental baseline data, and the capacity of TEK to link ecological and social impacts of past and future projects. In some cases, TEK is gathered for *potential* use in management. The Office of Subsistence Management's Fisheries Resource Monitoring Program (initiated in 2000) funds projects focusing on harvest monitoring and TEK. The goal is to provide information for federal subsistence fisheries management. Recently the EPA established the "EPA-Tribal Science Council." The goals of this council are to develop a better understanding of "tribal traditional lifeways" (TTL), design a framework for including TTL into EPA decision making, provide information on TTL for application to specific environmental problems, and suggest a pathway to preserving traditional life ways that is clear and transparent for the tribes as well as respectful of tribal cultures (Cirone 2005). Several other examples of the employment of TEK in federal agencies in Alaska include:

1. EPA use of collected TEK information as part of permitting processes
2. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEM) has funded projects to collect TEK
3. NOAA maintains a collection of TEK quotations, sound bites, and video about natural marine resources in the Alaska Native Traditional Ecological Knowledge Database
4. BLM has included TEK in EIS literature pertaining to the National Petroleum Reserve-Alaska (NPR-A) and also established, and continues to gather information through the Subsistence Advisory Panel whose members are comprised of residents of North Slope villages

Worldwide trends in the use of TEK have fallen under several themes similar to and different than those already cited in the United States. TEK has been used in combination with or comparison to other data (monitoring, GIS, etc.) for purposes of fisheries management in Lough Neagh, Ireland (McKenna, Quinn, Donnelly, & Cooper 2008); forest preservation and management in Canada, India, and Ecuador (Brooke et al. 1993; Charnley, Fischer, Jones, & Pacific Northwest Research 2008, Dowsley 2009, Herrmann & Torri 2009, Newmaster et al. 2011, Ratner & Holen 2007) and in ecological monitoring in the Arctic Borderlands by the Arctic Borderlands Ecological Co-op (Eamer 2006). In other contexts, TEK has provided baseline data, been useful in climate change research (Viles & Tribal Climate Change Profile Project 2011) and contributes to efforts in species monitoring and/or co-management strategies (Anadon, Gimenez, Ballestar, & Perez 2009; Moller, Berkes, Lyver, &

[7] An entire issue of Practicing Anthropology was dedicated to this theme in 2005. See Traditional Environmental Knowledge in Federal Natural Resource Management Agencies, Jennifer Sepez and Heather Lazrus, eds. *Practicing Anthropology* 27(1).

Kislalioglu, 2004). As mentioned above, TEK can also be instrumental in informing/identifying research needs. It has been used in natural resource management in national parks (Shey-Phoksundo National Park, Himalayas of Nepal); marine habitat studies (northwest coast, British Columbia, Canada); drought monitoring and management (Makuani District, Kenya); and non-timber forest product and forestry management (Indonesian Borneo). On a smaller scale, TEK has been integrated into community-based natural resource management or voluntary use of common pool resources, such as small-scale fisheries and wildlife management.

Of particular value to the current project are attempts to compile cultural information and TEK into databases for use in resource management contexts. Two such projects are the NOAA Fisheries Alaska Native Traditional Environmental Knowledge Database (mentioned above) (Lazrus & Sepez 2005) and the Aurukun Ethnobiology Database Project (Edwards & Heinrich 2006). The former was designed as a resource for employees who write NOAA documents and is continually updated. It contains material compiled into a catalog of quotes and paraphrases from published literature, videos, and pre-existing interviews relevant to the management of natural marine resources. The latter is part of an attempt to gather TEK not only for purposes of ethnobiological study, but also is an effort to preserve traditional knowledge in danger of being lost.

Methods

TEK gathering methods are predominantly qualitative in nature. Primary modes of data collections are: 1) interviews (structured, semi-structured, follow-up, etc.) in which sets of questions or discussion points are posed to individuals or groups; 2) systematic surveys; 3) survey questionnaires; 4) community workshops and roundtable discussions of particular issues; 5) participant observation; and 6) archival research of extant literature (historic documents, ethnographies, reports, recordings, photographs, etc) (Henry P. Huntington 2000, Miraglia, Alaska. Dept. of, & Game.Division of 1998, Ristroph 2012).

The research methods and sampling methods chosen for gathering TEK largely depend on the nature of the inquiry (Miraglia et al., 1998). If the goal of the research is to gain expertise on a particular topic, identification of key informants using judgmental and/or chain referral methods, rather than a sampling methods, is most effective in gaining targeted information (Miraglia et al. 1998, pp. 27-29; Ristroph 2012, pp. 95-99). Key informants are frequently identified through participant observation, word of mouth, or recommendation. Questions used in interviews, questionnaires and surveys can be based upon research questions or issues raised in extant literature. Frequently, initial questions are reworded to reflect participants' worldview. This rephrasing process is an important step as the ways in which researchers and interviewees conceptualize issues and themes are frequently very different. Thus the language used in questions (holistic vs. reductionist, for example) can greatly impact the effectiveness of the interview or questionnaire in gathering pertinent information (Thomson 2000).[8]

Literature and web searches were employed to address the above goals. JSTOR and WorldCat were searched for peer-reviewed journal articles on TEK. In addition, the ADF&G Database was extensively used to identify reports

[8] For an in-depth look at the importance of recognizing/acknowledging the local perspective, see GW Wenzel, "From TEK to IQ: *Inuit Qaujimajatuqangit* and Inuit Cultural Ecology," 2004. This article cites the differences between TEK and *Inuit Qaujimajatuqangit*, which he defines as "a guiding principle within the government of Nunavut [Canada]" He cites the nature of the *Inuit Qaujimajatuqangit* conceptualization of human-animal interaction, which in comparison to TEK (which seeks out 'facts' about animal behavior and ecology) is heavily nuanced.

that may contain relevant TEK. A wider web search was conducted to identify reports that may have been commissioned by other state and federal agencies as part of several major research efforts over the past decades.

Several key words were used in searching for literature. "Traditional ecological knowledge" was used in combination with each community name in the region (Aniak, Anvik, Chuathbaluk, Crooked Creek, Flat, Galena, Grayling, Holy Cross, Hughes, Huslia, Iliamna, Kaltag, Koyukuk, Lake Minchumina, Lime Village, Lower Kalskag, Manley Hot Springs, McGrath, Newhalen, Nondalton, Nulato, Pedro Bay, Pope-Vannoy, Port Alsworth, Red Devil, Ruby, Shageluk, Sleetmute, Stony River, Takotna, and Tanana). Some studies were regional and more generic, and included several communities and often may not be focused on collecting TEK. To capture these studies, the term "Alaska" was also used in combination with "Traditional Ecological Knowledge". The ADF&G Database was searched for keywords including each community name in the region, "Lime Hills", "Yukon Lowlands", and "Kuskokwim Mountains".

After a review of the title and abstract of the top ten hits for each search string, all relevant non-duplicate articles were included. Following a review of each document, the list of citations included in each article was examined to identify any further relevant literature not found through the above web search process. This process produced 54 articles and two books relevant to the region, with an additional 20 articles relevant to the integration of science and TEK. These results primarily focused on subsistence practices, ethnographic descriptions, community observations, and management strategies.

In addition to the above literature search, in-state organizations such as ANTHC, UAF Project Jukebox, and the North Pacific Research Board (NPRB) LTK Program were consulted. Project Jukebox is a collection of recorded interviews on particular topics or (i.e., climate change, community health aides, subsistence) or from particular communities within the region – these sources are available via UAF Project Jukebox. Observations of unusual events were recorded by ANTHC as qualitative data tied to specific latitude and longitude points, including findings from within the region. Below is the list of additional sources with examples of entries available from each:

Of the relevant articles found, a representative selection includes:

1. Alaska Department of Fish and Game Technical Papers, which primarily describe community or region-specific TEK related to defined years and/or particular subsistence species, i.e.:
   - "Traditional Ecological Knowledge and Harvest Survey of Nonsalmon Fish in the Middle Yukon River Region, Alaska, 2005-2008" (Brown, Koster, & Koontz 2010)
   - "Wild resource harvests and uses by residents of Lake Minchumina and Nikolai, Alaska 2001-2002" (Holen, Simeone, & Williams 2006)
2. Articles focused on specific change agents beyond anthropogenic uses, including fire and climate change, i.e.:
   - "Resilience of Athabascan Subsistence Systems to Interior Alaska's Changing Climate" (Kofinas et al. 2010)
   - "The Significance of Context in Community-Based Research: Understanding Discussions about Wildfire in Huslia, Alaska" (Henry P. Huntington et al. 2006)
3. Articles about integrating TEK into an environmental research and management, i.e.:
   - "Traditional Ecological Knowledge in Conservation Research: Problems and Prospects for their Constructive Engagement" (Shackeroff & Campbell 2007)

- "The Politics of TEK: Power and the 'Integration" of Knowledge'" (Nadasdy, 1999)

4. ANTHC Climate Observations, including observations in Lime Village, Nondalton, Pedro Bay, Chuathbaluk, Lower Kalskag, Anvik, Grayling, Galena, Koyukuk, and Huslia http://www.anthc.org/chs/ces/climate/leo/upload/LEO_Observations-2012.pdf
5. The North Pacific Research Board (NPRB) Local and Traditional Knowledge (LTK) program has linked traditional knowledge to harvests by asking about harvests and observations in the same survey. These data are not accessible to the public.
6. UAF Project Jukebox http://jukebox.uaf.edu/site/projects Alaskool.org
    - Orville Huntington interviewed by Bill Schneider with Sidney Stephens in Fairbanks, Alaska on climate change in the Koyukuk Region (Huslia) http://jukebox.uaf.edu/ClimateChange/htm/orvilleh.htm
    - Community Health Aides Program Project Jukebox in Huslia, McGrath, Aniak, and Holy Cross http://jukebox.uaf.edu/CHA/htm/map.htm
    - Holy Cross Community Project Jukebox http://jukebox.uaf.edu/holycross/start.htm
    - Lake Clark National Park Project Jukebox, with interviews from Nondalton http://jukebox.uaf.edu/lakeclark/home.html
    - Raven's Story, wildlife, fish, and subsistence in the Koyukuk and Middle Yukon areas, including Huslia, Galena, Ruby, Kaltag, Hughes, Nulato, and Koyukuk
    - Tanana Tribal Council Jukebox http://jukebox.uaf.edu/TananaJBX/Index.htm

Of the 57 sources noted above for the YKL REA, the majority (20) utilized a combination of the research methods described above. Most frequently this combination of methods included survey, interview, and mapping. Directed interviews of key informants chosen for their expert knowledge on a particular subject were conducted in 14 of the articles. Ten sources, primarily consisting of subsistence harvest reports, relied on surveys alone. Only three articles described the use of group workshops or training, and the remaining ten articles relied on research of extant documents and data, rather than collection of new TEK. The collection of articles can be divided into five categories:

1. Articles about subsistence and/or subsistence resources (7)
2. ADF&G subsistence harvest reports (22)
3. Articles whose primary focus was collection of TEK (15)
4. Ethnographic materials (7)
5. Miscellaneous articles referencing change agents (fire, climate change) (6)

Traditional Ecological Knowledge is often recorded as stories, ethnographies, and bits of wisdom collected during surveys. Thus we find that information about traditional knowledge of a community or region is obtained as a by-product of projects whose primary purpose is not to target TEK. The term "traditional ecological knowledge" is also not a universally understood term, and consequently much TEK is assumed to be classified under other terms, or embedded within other ethnographies or studies without conscious recognition that they contain TEK. As the collection of TEK within the YKL region has not been systematic, or focused on the CEs and CAs specified in this REA, large gaps in TEK are assumed to exist that could only be addressed by extensive interviewing of individuals within the region. Proposals to include TEK in land management strategies would have to accommodate for these gaps.

Applications

Land management typically falls within a western scientific framework which, according to Drew and Henne (2006) clashes with environmental anthropologies (and thus, TEK), forming "linguistic, cultural, and epistemological barriers" to integration. Traditional Ecological Knowledge provides qualitative description of place-specific observations that can both inform the interpretation of data, and provide an alternative narrative to the data. Gilchrist and Mallory (2007) suggest that "the purpose of collecting TEK in a wildlife management context is to seek out and apply any sources of reliable data, including information collected independently from conventional science, to help make more informed wildlife management decisions." Johannes (1993) in his discussion of environmental impact assessments, has suggested that TEK can be used successfully if four key perspectives are included in the research: taxonomic, spatial, temporal, and social. These perspectives will help researchers to identify the significance of land features and species to communities, ascertain important locations on the landscape, utilize observations of animal behavior gathered over long periods of time, and better understand the local perspectives on and relationships to the land.

Bohensky and Maru (2011) argue that there are four critical features of knowledge integration needed to successfully utilize TEK in conjunction with conventional science. First, they suggest that efforts to "integrate" TEK should acknowledge the "originality and core identity" of the source. Secondly the social context of the information should be taken into account. This suggests that not only should the current condition of indigenous peoples (their livelihoods, cultural resilience, etc.) be recognized, but that care be taken to ensure their future survival, as well. Furthermore, the contexts in which TEK is usable/used should be taken into consideration, as it may be more or less valuable as a resource for land management purposes on a case-by-case basis. Third, the testing or verification of TEK, while not unnecessary, should not be undertaken strictly within the framework of conventional scientific method. It is important to remember that just as TEK has cultural context, so too is conventional science culturally bounded. The two sources of information may seem irreconcilable, but the differences may be as much a factor of differing world views as "correct" or "incorrect" data. Finally, Bohensky and Maru suggest that key informants participate in scientific processes and monitoring, thus "bridging" the gap between the values and goals of the scientific and local communities.

TEK and Land Management Decisions in Alaska

Life style of Alaska Native populations in the region and across the state is intricately linked to the land and its resources. Their participation is essential for natural resource management decision-making. As Cornell and Kalt (2003, p. iii) have emphasized, "this is not a matter of consultation, voicing opinions, or perfunctory 'participation.' It instead requires that Native peoples be in the driver’s seat, proposing and adopting concrete institutional, organizational, and managerial solutions that reflect their own diverse preferences, cultures, circumstances, and needs." Participation, especially from people who live in very small remote communities, is challenging. Alaska Natives are overloaded by the number of requests for participation, most are inadequately funded, in some cases public meetings are not the appropriate venue (Gallagher, 1988). A short list of agencies and organizations requesting local participation includes school boards, state and federal wildlife management agencies, species level co-management organizations, local and tribal governments, regional governments, ANCSA for profit and non-profits, village corporations, and visiting research projects. Nevertheless, participation of local communities in monitoring, discussion, mapping, observation, and through collection of new TEK can play a role in land management decisions.

Cruikshank (1998) warns against parsing tradition and local knowledge into data. Some efforts are underway to do just that. The NOAA Fisheries Alaska Native Traditional Environmental Knowledge Database provides a positive outlook for the utility of a TEK database for purposes of making land management decisions. In order to maximize the value of extant TEK resources the database produced for this project should be expanded to include other genres of media (including voice and video recording, and maps). Additionally, the database should not only associate sources of TEK with related CEs and CAs, but should identify or pull out key items of interest. This will make the search process more efficient, as the database in its current configuration only references a source document, but does not guide the researcher to relevant sections or quotations. Although the limitations noted above still apply, especially with regards to intellectual and cultural rights over the information gathered in TEK materials, the ability to have source materials at hand can guide research questions, inform land managers of cultural contexts and guide them towards human sources of TEK for updated/more detailed information.

In Alaska TEK could prove invaluable in terms of providing insights into species abundance and landscape observation. Here observations over many years are in stark contrast to the limited field observations possible within funded studies. As such, TEK has the potential to provide a wealth of data. More importantly, a grasp of the available ethnographic and TEK materials can help to better inform land managers on the ways in which communities interact with the landscape. This information is valuable when making decisions about land use, as regulations could be designed to better reflect the realistic context of life and livelihoods in the YKL region.

Unfortunately the TEK data for the YKL region is somewhat limited and/or sourced in non-TEK publications and grey literature. This means that although the literature can provide some insights, the full benefits of TEK resources cannot be exploited without further research. The current state of literature is, however, a reliable baseline resource with which to conduct preliminary inquiries for land management decisions. To that end the most logical way to incorporate the available TEK into a management toolkit is to create a comprehensive database which includes all of the various types of source material.

Limitations and Data Gaps

Local knowledge is often place-specific and can vary regionally, even community to community, so there may or may not be a "regional" TEK from which to draw (Ghimire, McKey, & Ameeruddy-Thomas 2004). It is not predictive (Krupnik & Jolly 2002). TEK data have been critiqued for being gathered using ill-defined methodologies and research design (Davis & Ruddle 2010). Questions asked during the interview process are rarely linked to testable hypotheses. The information thus gathered uses qualitative, rather than quantitative indicators and may therefore be limited in its application/integration with western scientific methods and strategies (Berkes & Berkes 2009).[9] It is unclear how valuable TEK can be if it is not tested, and the assumption that all TEK is or will be "vitally important" depends on the context of a given project (Gilchrist & Mallory 2007).

Huntington et al. (2006) discusses the importance of context for understanding local and traditional knowledge and the need to be cautious in interpreting information, suggesting that even differences in worldview can affect the ways in which questions about the environment are approached. For example, Athabascans view

[9] Ethnopharmacology has recently emerged as a leading field of research utilizing multiple disciplines. For a useful discussion of the integration of anthropological, biological, and ethnomedical methods, ethics and discussions, see Heinrich et al, 2009.

humans as an integral component of nature in which the respect that people have for nature influences the probability of biophysical outcomes. Conventional science tends to view people as apart from nature with human impacts on ecosystems occurring purely through biophysical mechanisms (Henry P. Huntington et al. 2006). In a similar vein, Kofinas (2002) has described traditional and local knowledge as pertaining to the 'How?' and conventional science the 'Why?'.

Moreover, TEK can change, as people change and can contain spiritual elements that are not part of conventional scientific methods. This can lead to confusion, as the measures by which subjects are observed and discussed do not always mesh easily. This may cause conflict between land managers reliant on conventional science and community members whose land management practices rely upon traditional knowledge. Key informants may be unwilling to share some aspects of traditional knowledge, for reasons of privacy, or even a concern that shared information will be dismissed (Ristroph 2012).

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Data Request Method

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

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

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

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

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

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