Novel assemblages in a rapidly changing climate: the legacy of exotic species

Novel climates, no-analog communities, and ecological surprises

John W Williams[1*] and Stephen T Jackson[2]

No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future. The well documented no-analog plant communities of late-glacial North America are closely linked to "novel" climates also lacking modern analogs, characterized by high seasonality of temperature. In climate simulations for the Intergovernmental Panel on Climate Change A2 and B1 emission scenarios, novel climates arise by 2100 AD, primarily in tropical and subtropical regions. These future novel climates are warmer than any present climates globally, with spatially variable shifts in precipitation, and increase the risk of species reshuffling into future no-analog communities and other ecological surprises. Most ecological models are at least partially parameterized from modern observations and so may fail to accurately predict ecological responses to these novel climates. There is an urgent need to test the robustness of ecological models to climate conditions outside modern experience.

Front Ecol Environ 2007; 5(9): 475–482, doi:10.1890/070037

How do you study an ecosystem no ecologist has ever seen? This is a problem for both paleoecologists and global-change ecologists, who seek to understand ecological systems for time periods outside the realm of modern observations. One group looks to the past and the other to the future, but both use our understanding of extant ecosystems and processes as a common starting point for scientific inference. This is familiar to paleoecologists as the principle of uniformitarianism (ie "the present is the key to the past"), whereby understanding modern processes aids interpretation of fossil records. Similarly, global-change ecologists apply a forward-projected form of uniformitarianism, using models based on present-day ecological patterns and processes to forecast ecological responses to future change. Thus, both paleoecology and global-change ecology are inextricably rooted in the current, and research into long-term ecological dynamics, past or future, is heavily conditioned by our current observations and personal experience.

The further our explorations carry us from the present, the murkier our vision becomes. This is not just because fossil archives become sparser as we look deeper into the past, nor because the chains of future contingency become increasingly long. Rather, *the further we move from the present, the more it becomes an inadequate model for past and future system behavior.* The current state of the Earth system, and its constituent ecosystems, is just one of many possible states, and both past and future system states may differ fundamentally from the present. The more that environments, past or future, differ from the present, the more our understanding of ecological patterns and processes will be incomplete and the less accurately will our models predict key ecological phenomena such as species distributions, community composition, species interactions, and biogeochemical-process rates.

Here, we focus on "no-analog" plant communities (Panel 1), their relationship to climate, and the challenges they pose to predictive ecological models. We briefly summarize a niche-based, conceptual framework explaining how no-analog communities arise (Jackson and Overpeck 2000). We discuss past no-analog communities, using the well documented late-glacial communities as a detailed case study (Jackson and Williams 2004), and argue that these communities were shaped by environmental conditions also without modern counterpart (Williams et al. 2001). We then turn to the future, identifying regions of the world at risk of developing future novel climates (Williams et al. 2007). Finally, we discuss the implications for global-change ecology, including the risk of future novel ecosystems (Hobbs et al. 2006) and the challenges posed for ecological forecasting.

In a nutshell:

- Many past ecological communities were compositionally unlike modern communities
- The formation and dissolution of these past "no-analog" communities appear to be climatically driven and linked to climates that are also without modern analogs
- If anthropogenic greenhouse-gas emissions continue unabated, many future climates will probably lack modern analogs, with tropical regions at greatest risk
- Regions over much of the globe are likely to develop novel communities and other ecological surprises in a future greenhouse world

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John Morton and Matt Bowser
Kenai National Wildlife Refuge

What's an exotic invasive species in a rapidly warming climate?

Future Forests If global temperatures rise, can forests still flourish in their current ranges? Some scientists think not, so British Columbia—with assistance from the U.S. Forest Service—is now testing the climate tolerance of 15 common and commercially valuable tree species in non-native habitats. The aim: to identify ones that can be moved into areas expected to be more hospitable in the future.

Called assisted migration, the controversial approach presumes "evolution can't keep up with the rate of climate change, so it needs some help," says project head Greg O'Neill. Detractors of the increas-

Lodgepole Pine

Elodea

Spread of the Dandelion Weevil

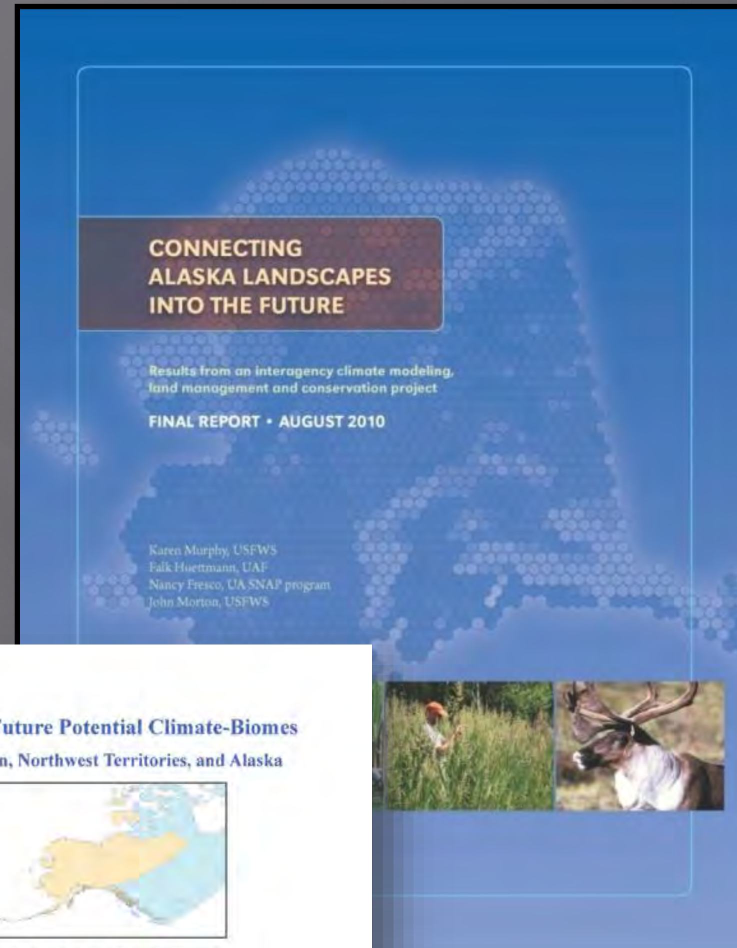
T. ceratophorum
(native) 2017

T. eythrospermum
(non-native) 2016

T. officinale
(non-native) ~1944

Glocianus punctiger
(non-native) ~ 2000

Interagency effort to pioneer assessment of climate change effects on biome and species distributions using climate envelope models

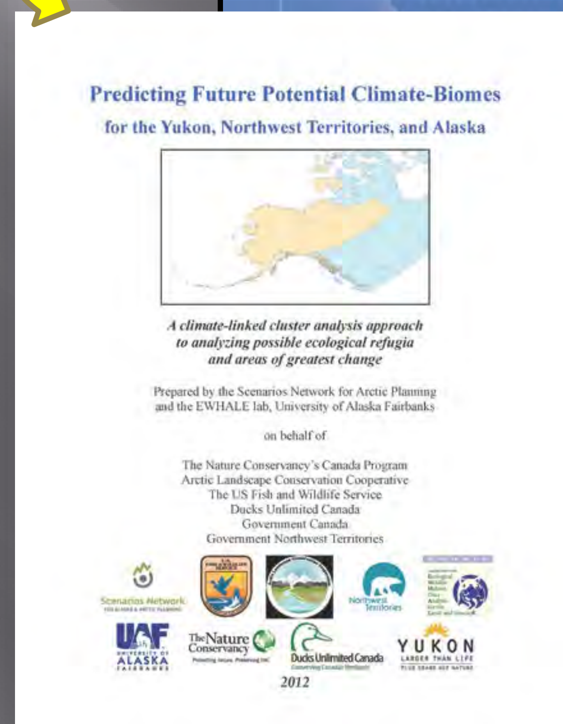


CONNECTING
ALASKA LANDSCAPES
INTO THE FUTURE

Results from an interagency climate modeling, land management and conservation project

FINAL REPORT • AUGUST 2010

Karen Murphy, USFWS
Falk Huettmann, UAF
Nancy Fresco, UA SNAP program
John Morton, USFWS



Predicting Future Potential Climate-Biomes
for the Yukon, Northwest Territories, and Alaska

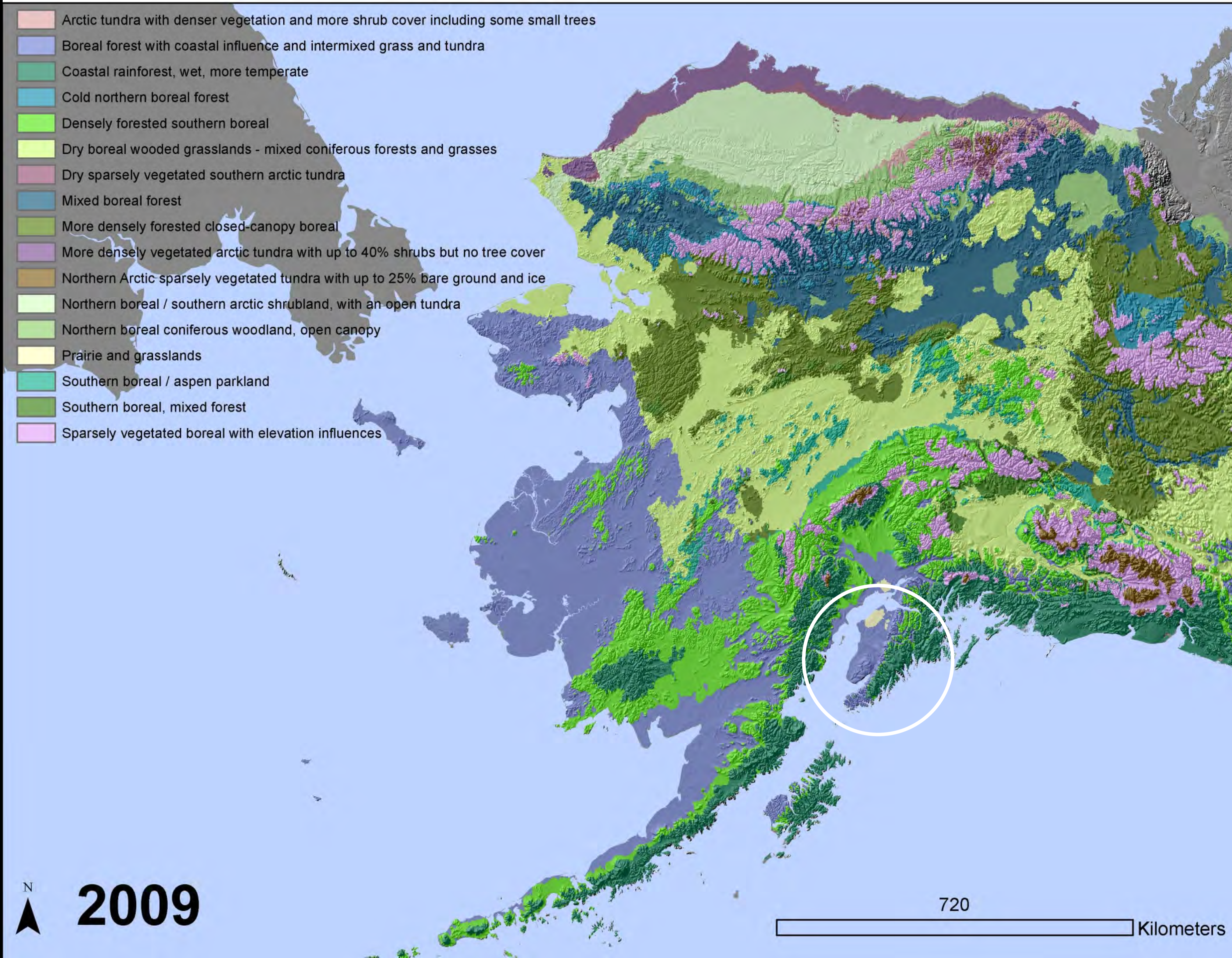
A climate-linked cluster analysis approach to analyzing possible ecological refugia and areas of greatest change

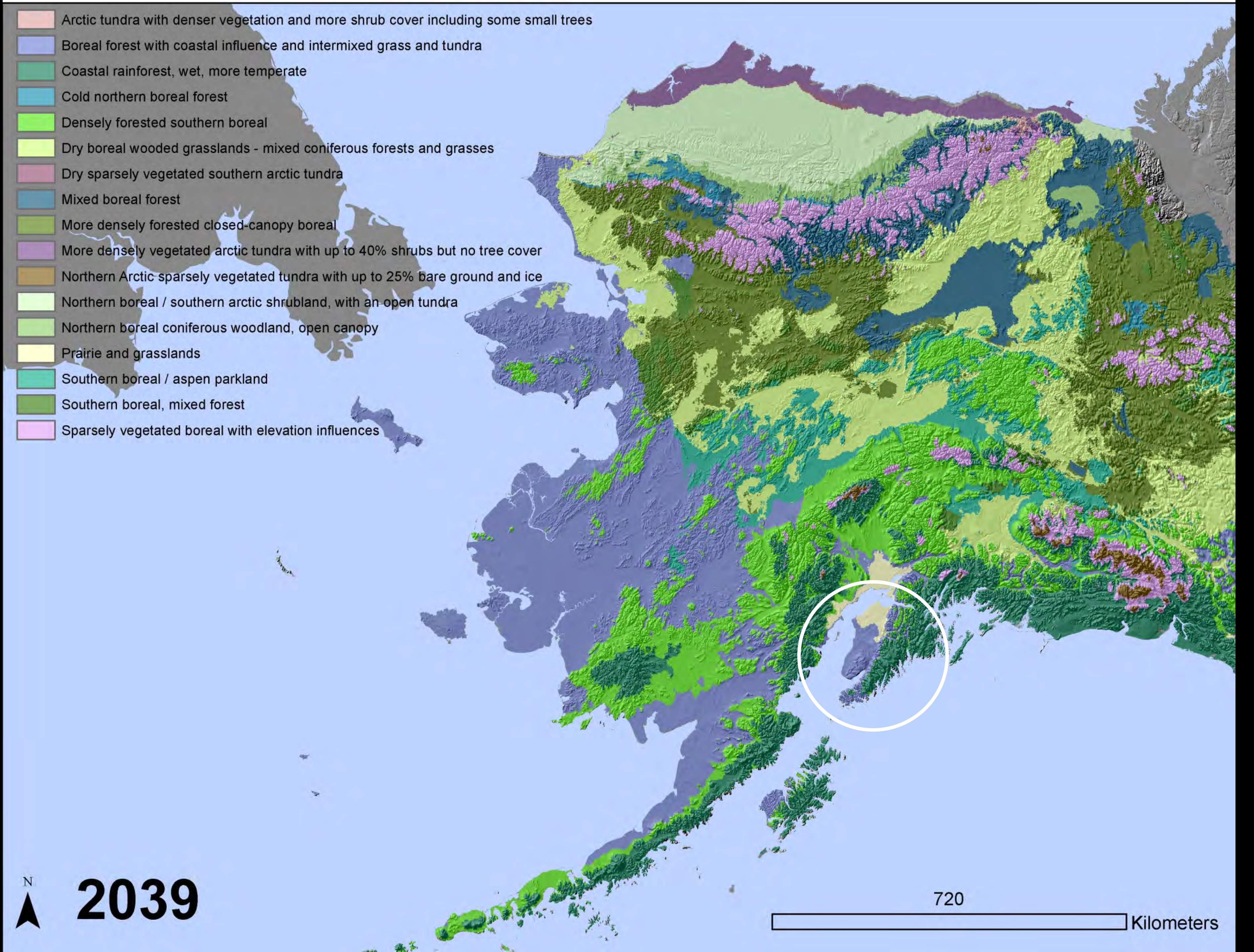
Prepared by the Scenarios Network for Arctic Planning and the EWHALE lab, University of Alaska Fairbanks

on behalf of

The Nature Conservancy's Canada Program
Arctic Landscape Conservation Cooperative
The US Fish and Wildlife Service
Ducks Unlimited Canada
Government Canada
Government Northwest Territories

2012


Arctic tundra with denser vegetation and more shrub cover including some small trees
Boreal forest with coastal influence and intermixed grass and tundra
Coastal rainforest, wet, more temperate
Cold northern boreal forest
Densely forested southern boreal
Dry boreal wooded grasslands - mixed coniferous forests and grasses
Dry sparsely vegetated southern arctic tundra
Mixed boreal forest
More densely forested closed-canopy boreal
More densely vegetated arctic tundra with up to 40% shrubs but no tree cover
Northern Arctic sparsely vegetated tundra with up to 25% bare ground and ice
Northern boreal / southern arctic shrubland, with an open tundra
Northern boreal coniferous woodland, open canopy
Prairie and grasslands
Southern boreal / aspen parkland
Southern boreal, mixed forest
Sparsely vegetated boreal with elevation influences
N
2009
720
Kilometers



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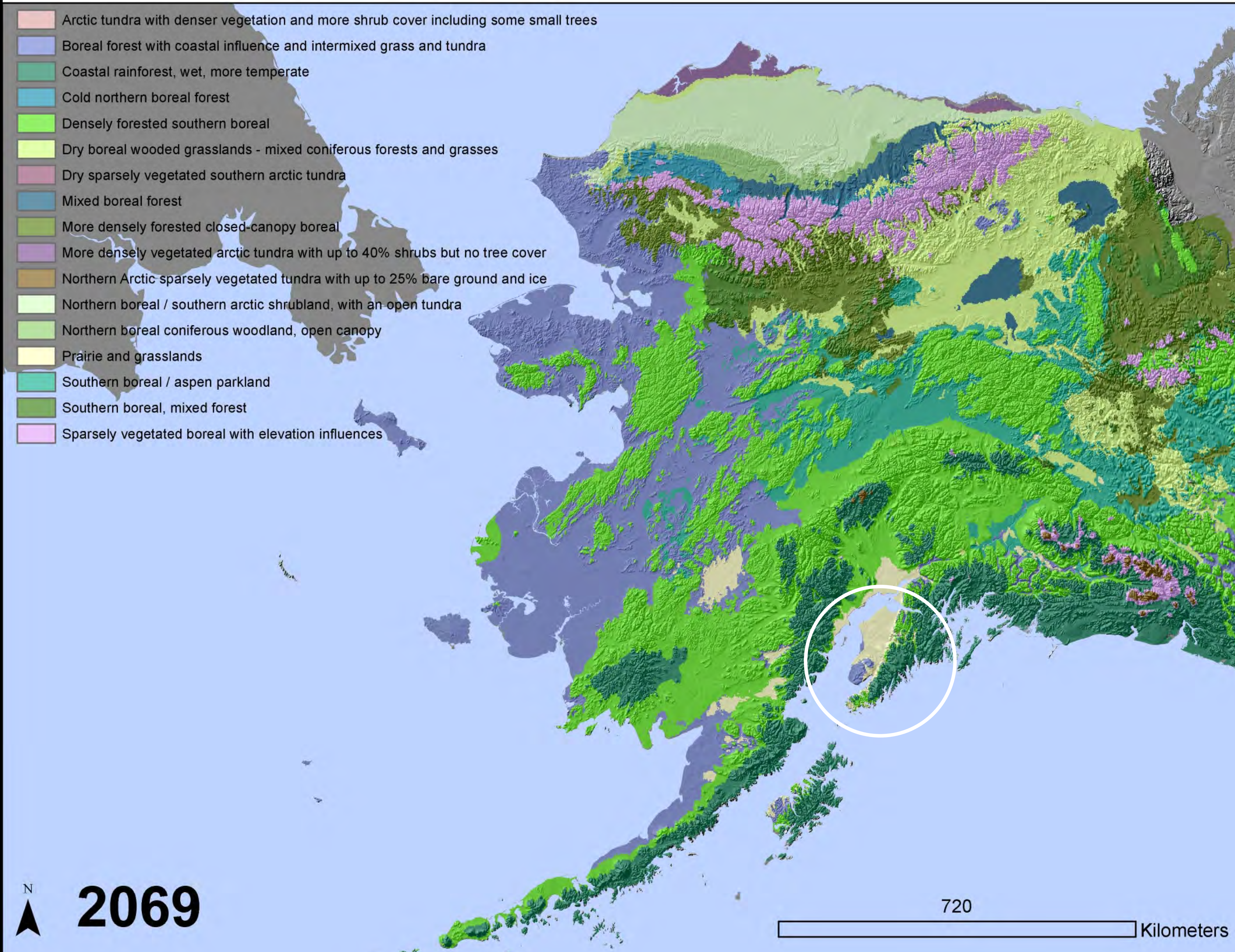
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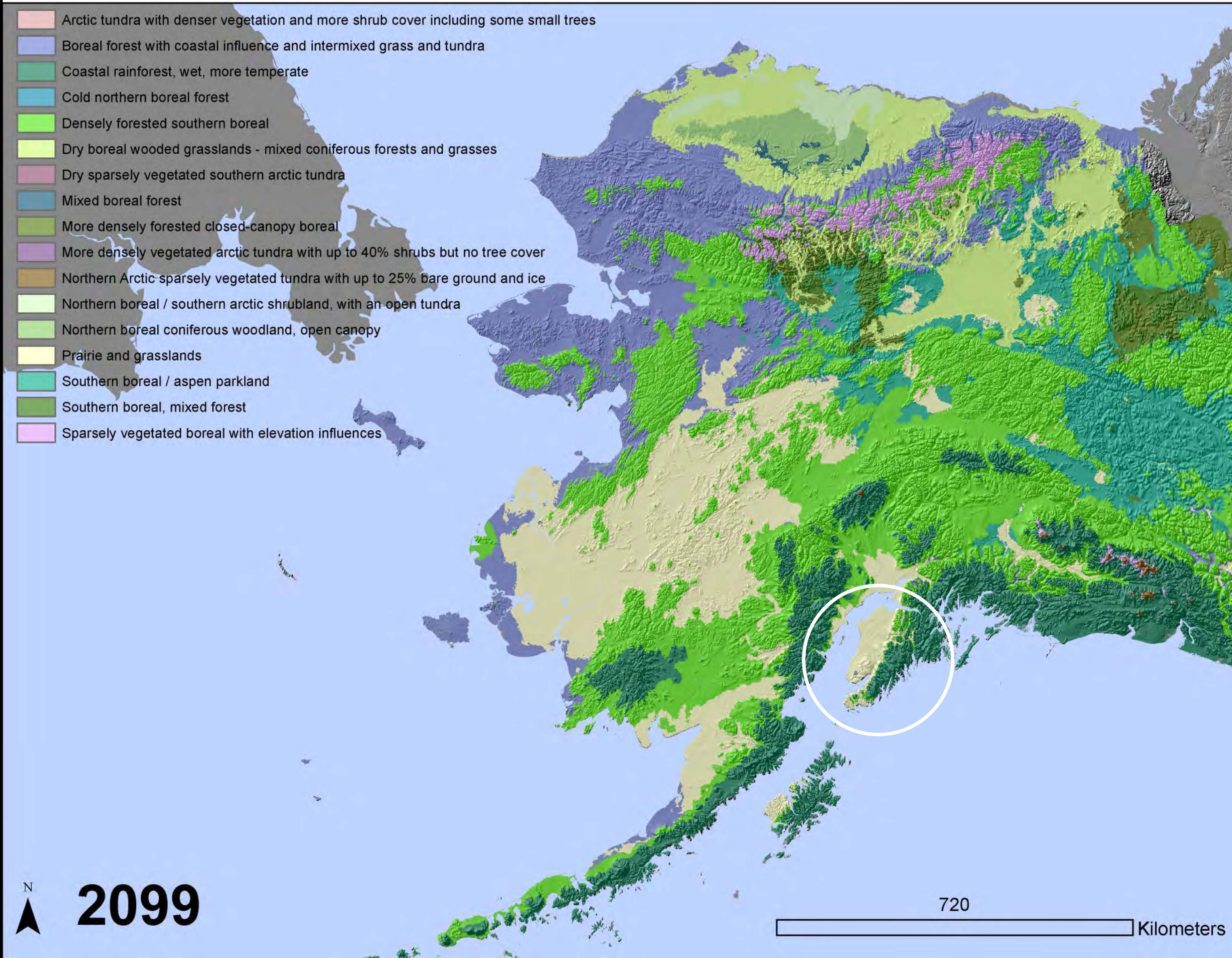
N
2069
720
Kilometers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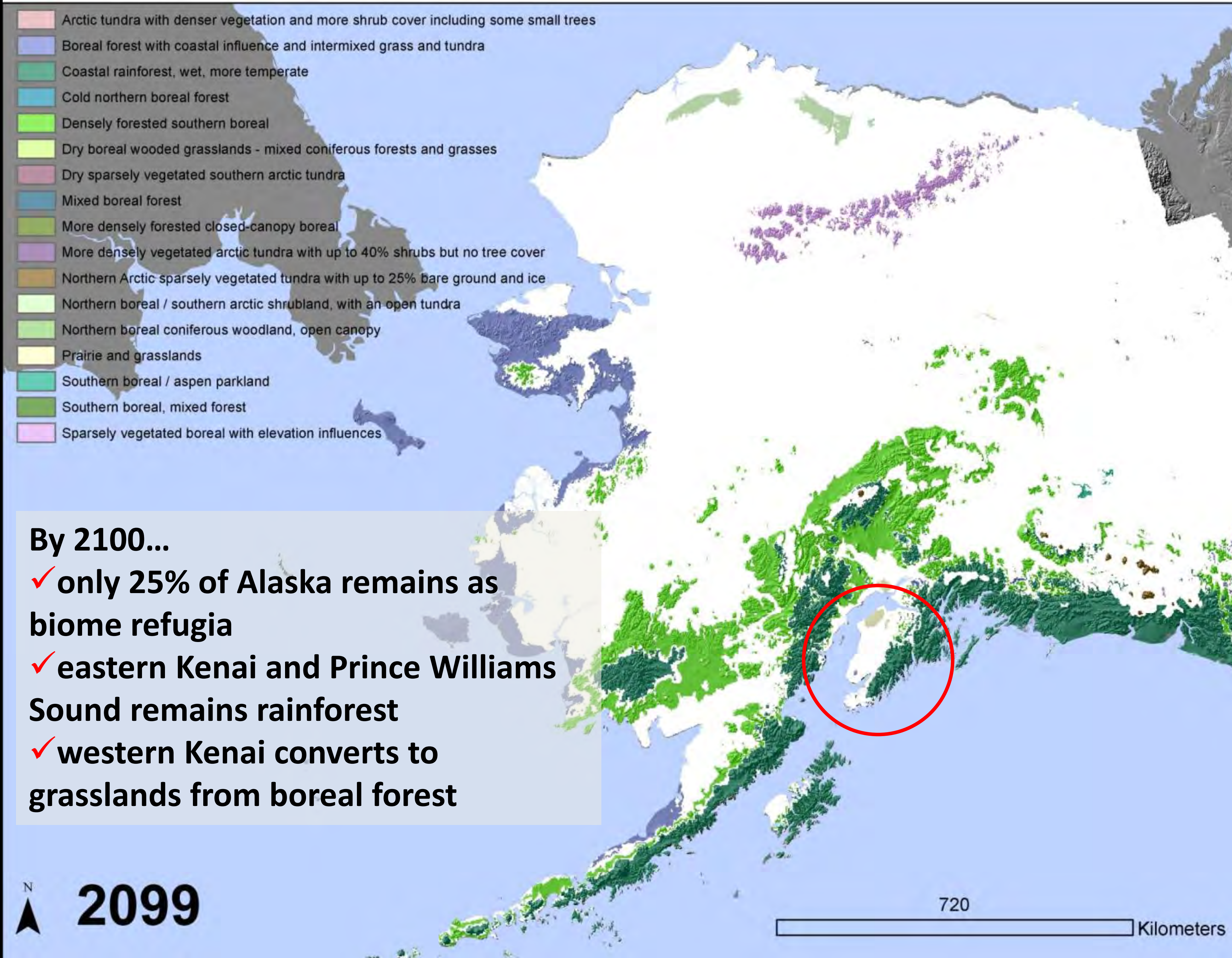
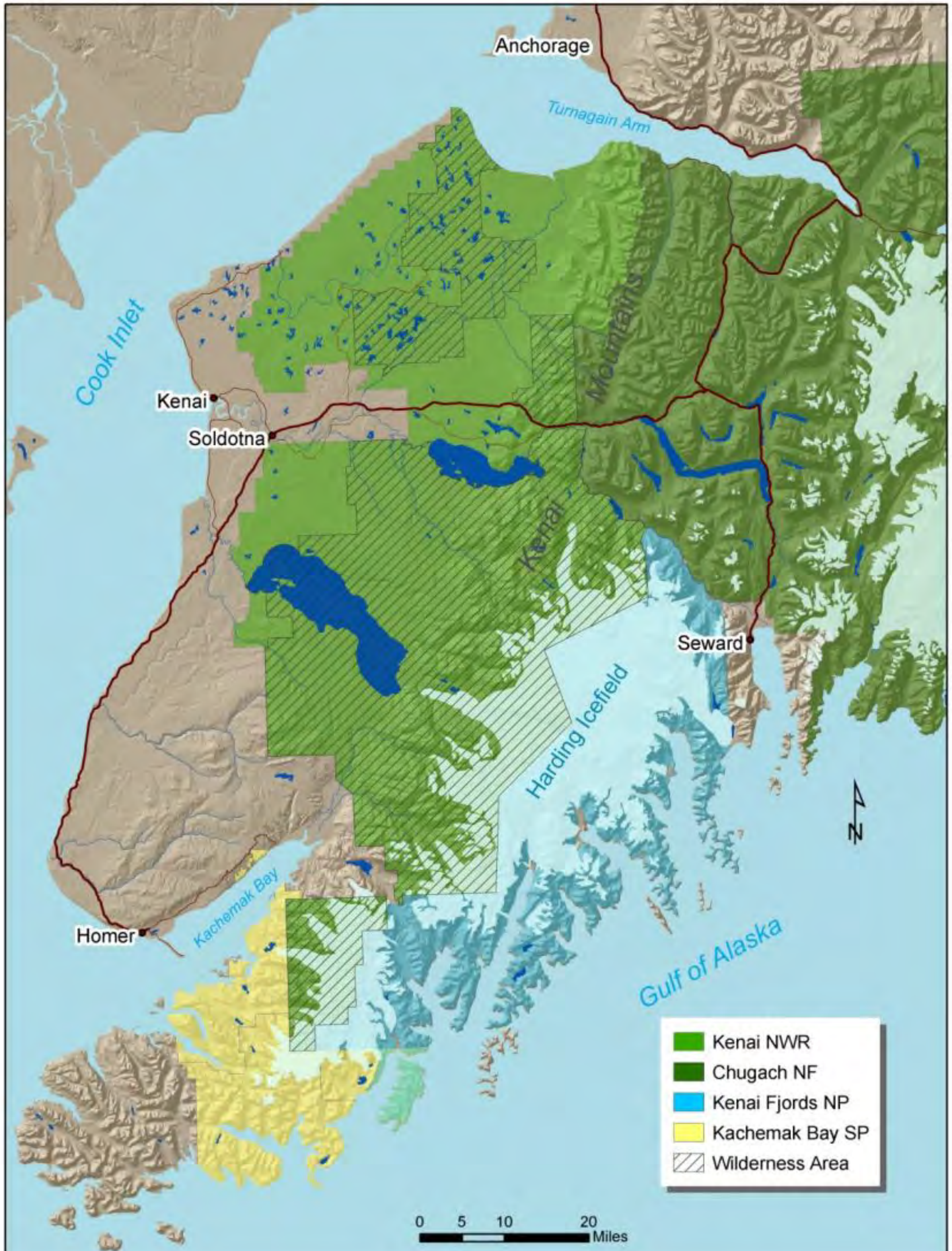
N
2099
720
Kilometers



By 2100…

- ✓ **only 25% of Alaska remains as biome refugia**
- ✓ **eastern Kenai and Prince Williams Sound remains rainforest**
- ✓ **western Kenai converts to grasslands from boreal forest**



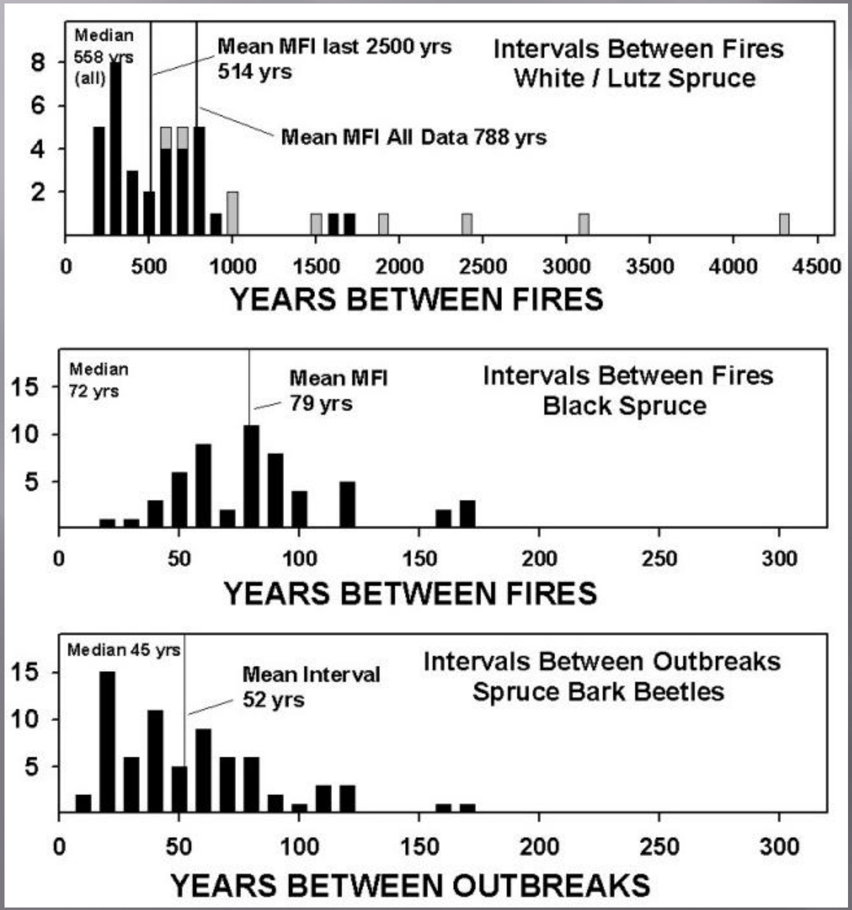
- ✓ Alaska is warming at 2X Lower 48 rate
- ✓ Climate warming effects are not masked by other human-caused drivers of change
- ✓ Kenai Peninsula may be best studied locale in AK outside of high arctic

Kenai's landscape has changed dramatically in last 50 years in response to warming and drying

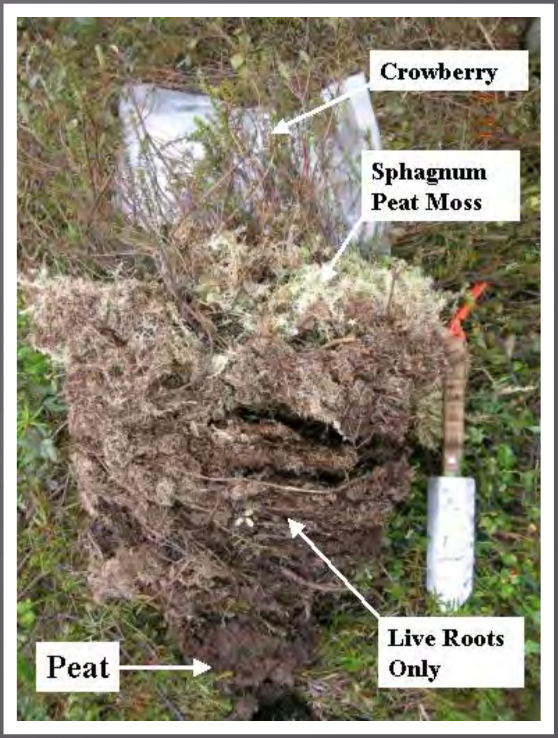
- – available water (60% loss since 1968)
- – wetlands (6 – 11% per decade)
- – glaciers (11% surface area, 21 m elevation)
- \+ treeline (10 m per decade, 2.8 m•y^{-1})
- \+ SB beetle outbreaks (triggered by 2 consecutive warm summers)

Adageirsdottir et al. 1998; Berg et al. 2006; Berg et al. 2009; Dial et al. 2007, 2016; Klein et al. 2005; Rice 1987

Official fire season is now April 1 instead of May 1



Woody shrub encroachment into 8000 year old Spagnum peatlands

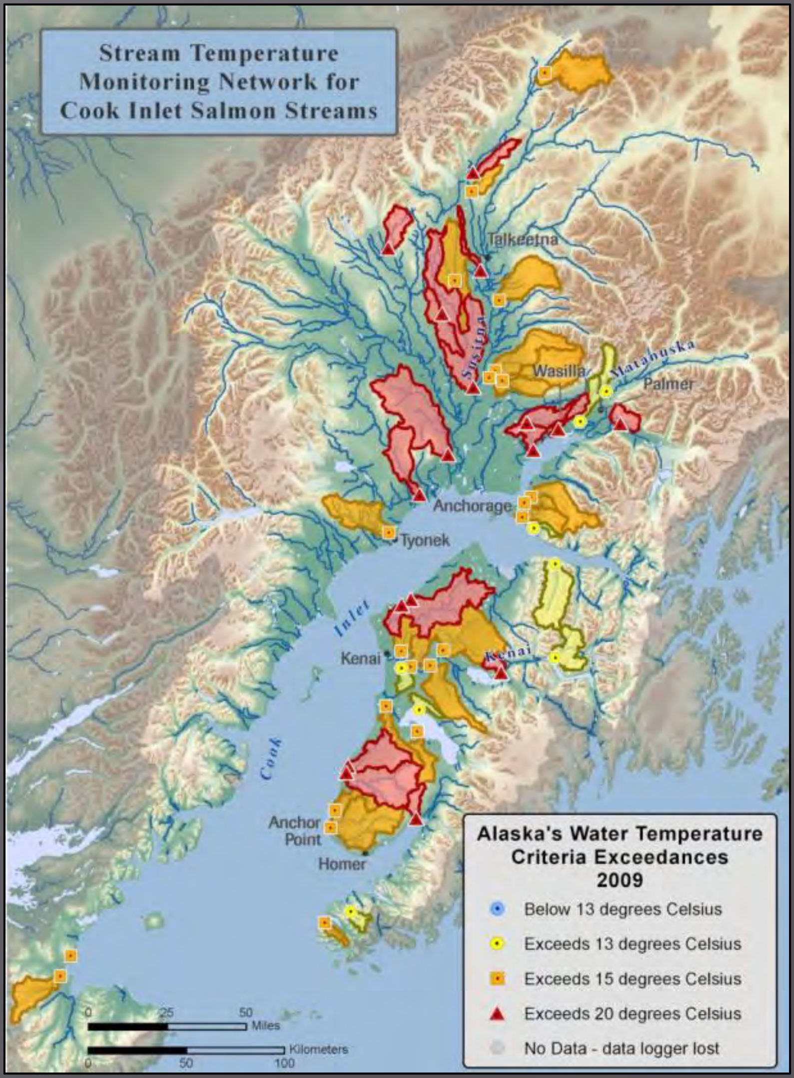


Berg et al. 2009

Salmon in 47 of 48 non-glacial streams experience thermal stress in July

These maximum temperatures shall not be exceeded:

- egg & fry incubation = 13°C
- spawning areas = 13°C
- migration routes = 15°C
- rearing areas = 15°C
- and may not exceed 20°C at any time

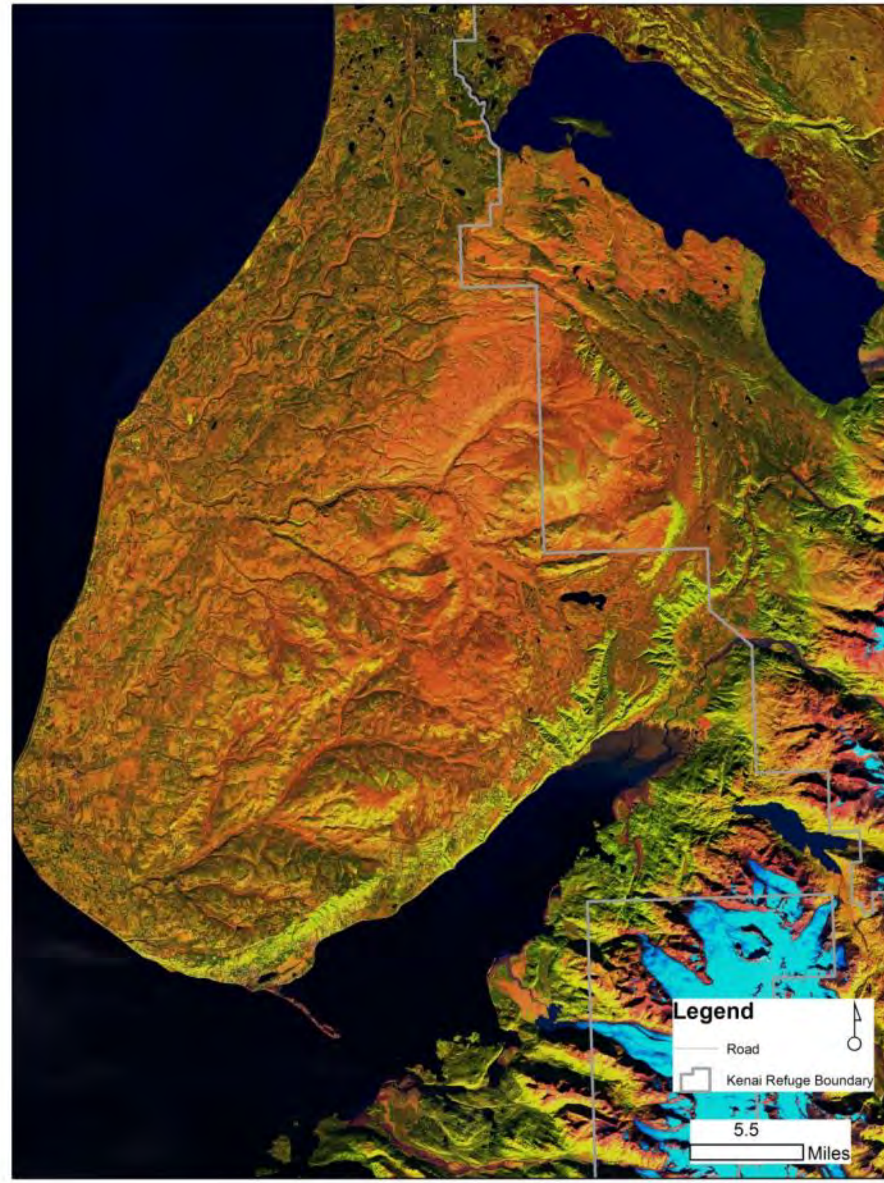


Mauger 2011

Conversion of white/Lutz spruce forests to Calamagrostis savannah

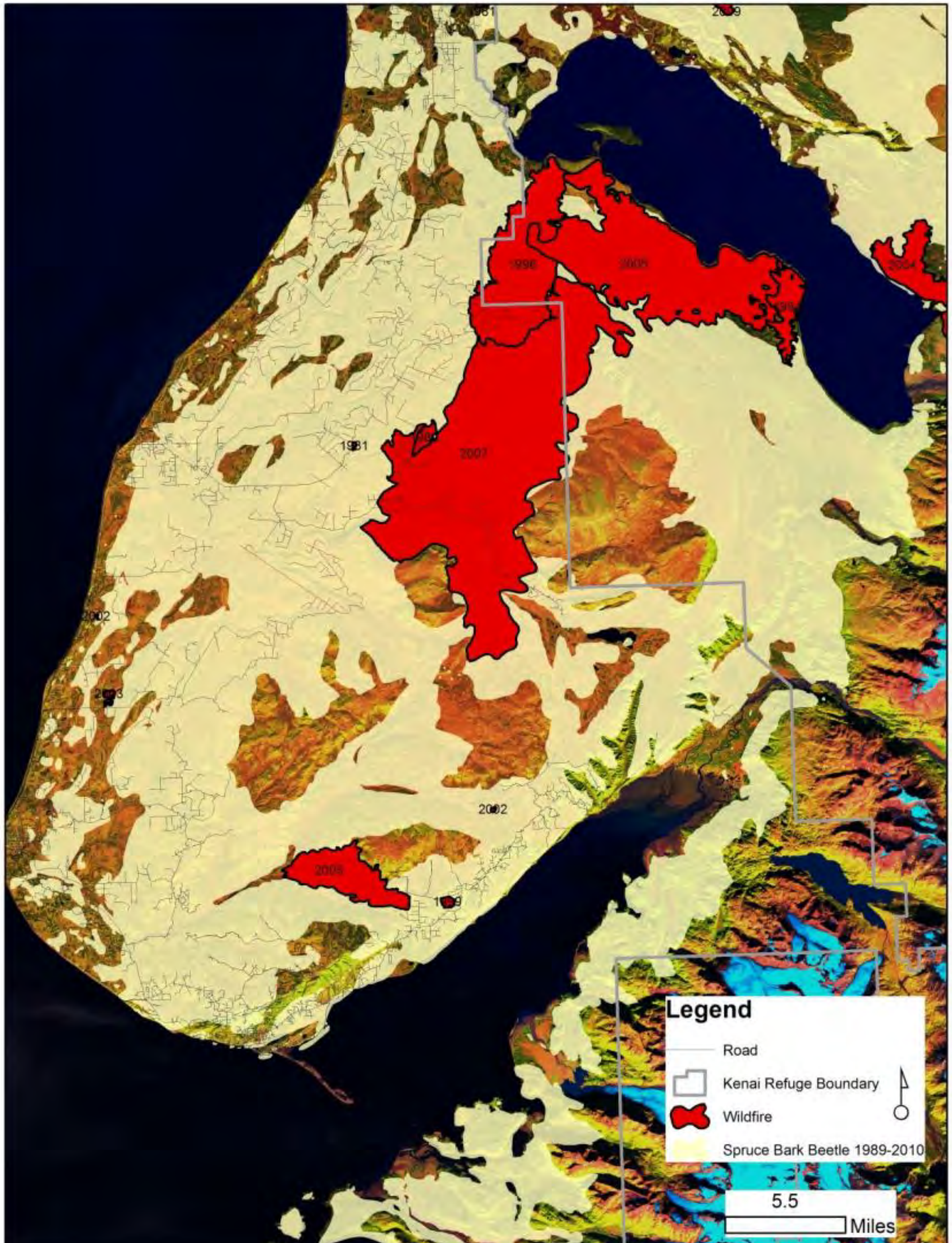
Boucher and Mead 2006, Bowser et al. 2017

SEPT 1985



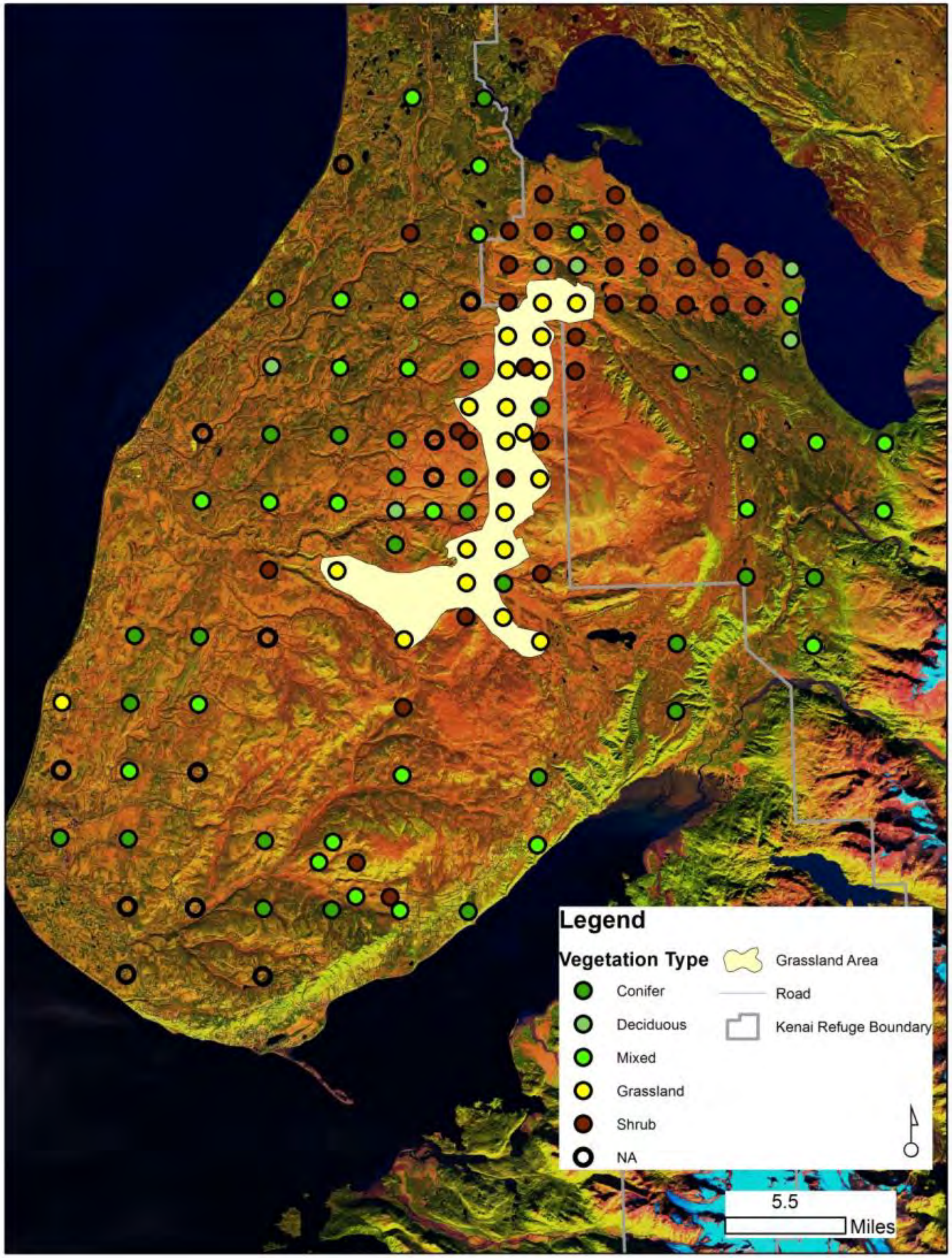
SEPT 2014

Spruce Bark Beetle Mortality (1989-2010)



Wildfires (1994–2007)

1994 Windy Point
1996 Crooked Creek
2005 Glacier Creek
2005 Fox Creek
2005 Tracy Avenue
2007 Caribou Hills

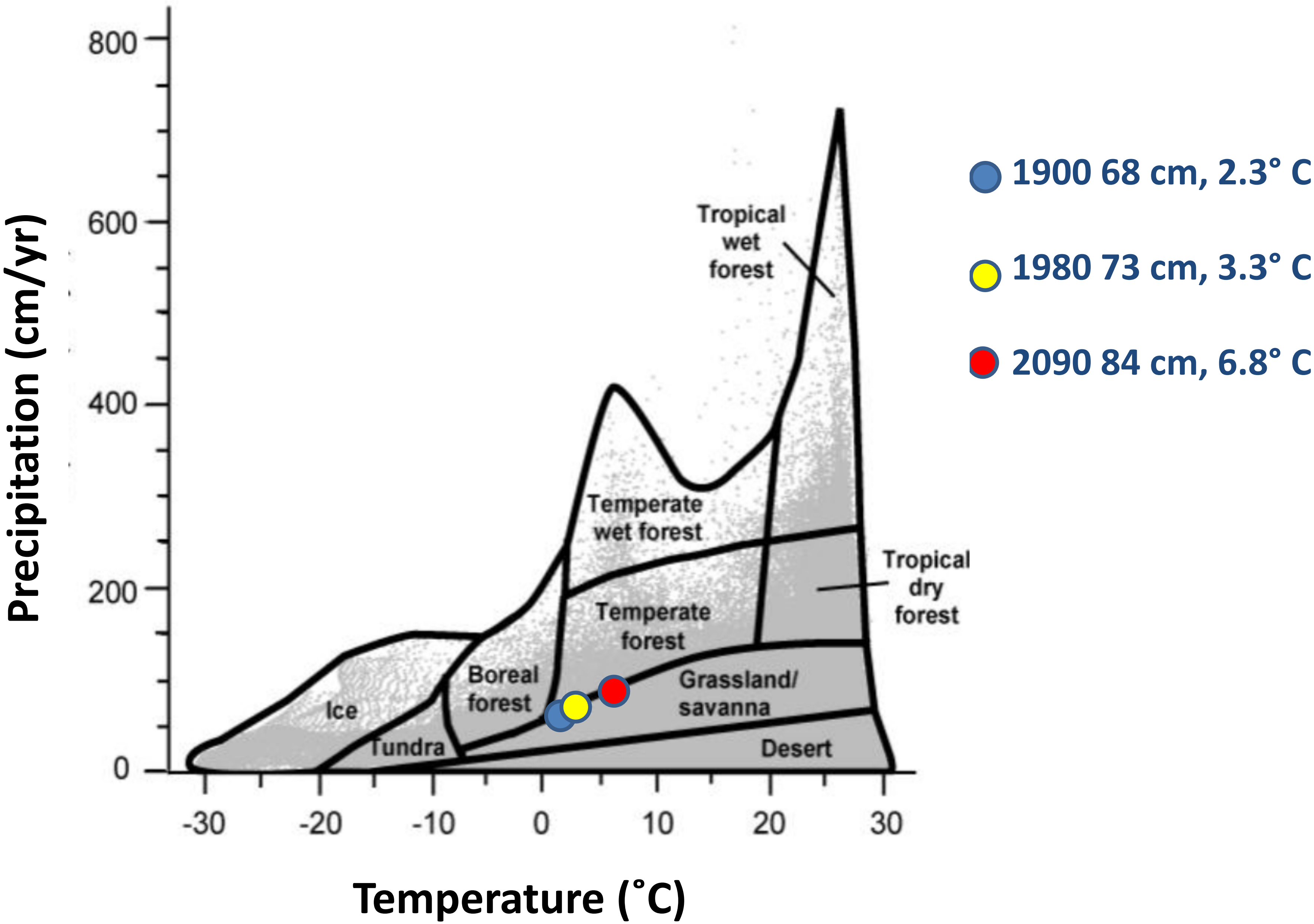


40,000-acre contiguous grassland polygon in 2015

2002 imagery

- Forest 55%
- Other 40%
- Herbaceous 5%


2015/07/19

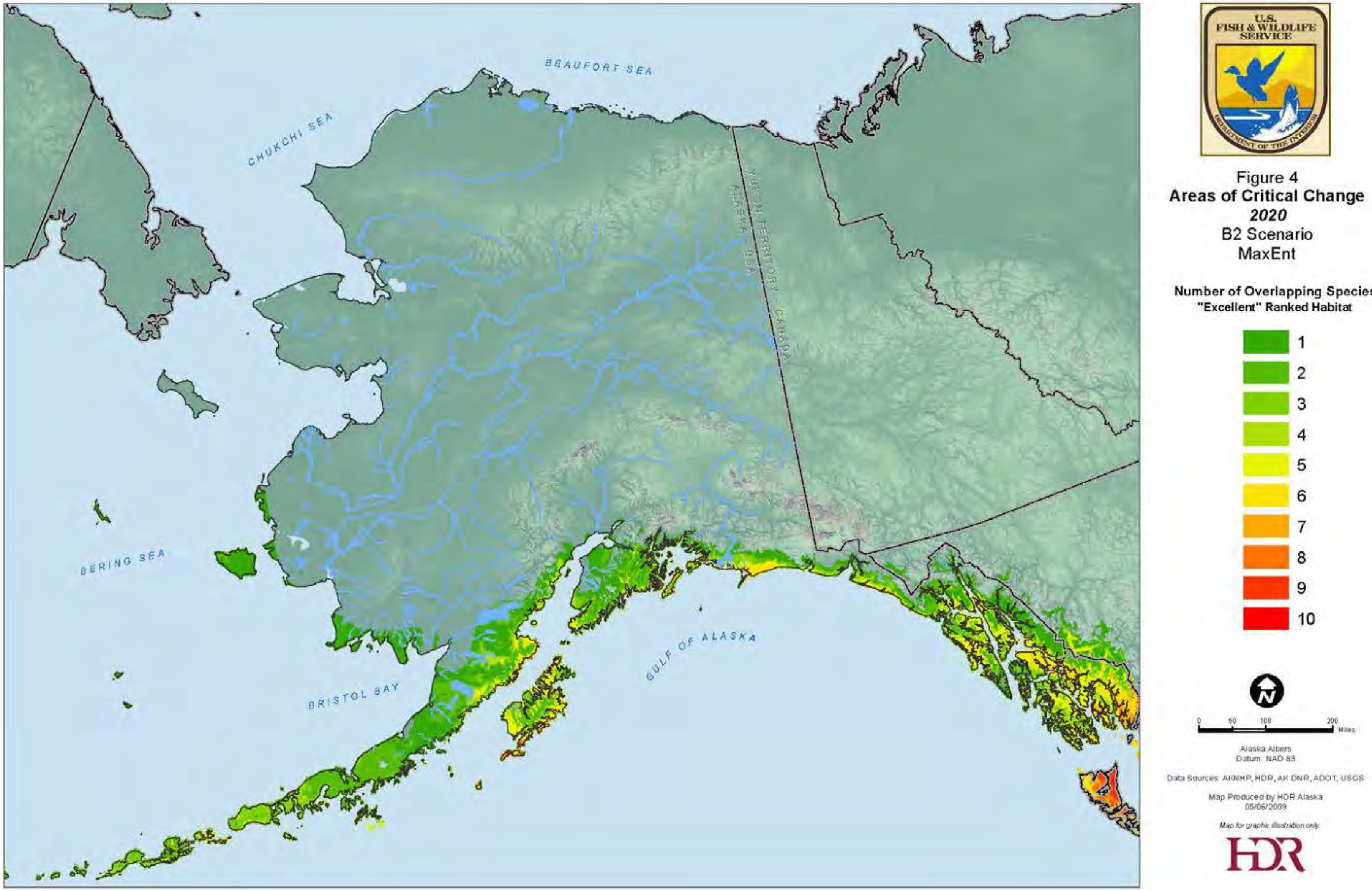


Staudinger et al. 2012. Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment.

Current climate (2000)

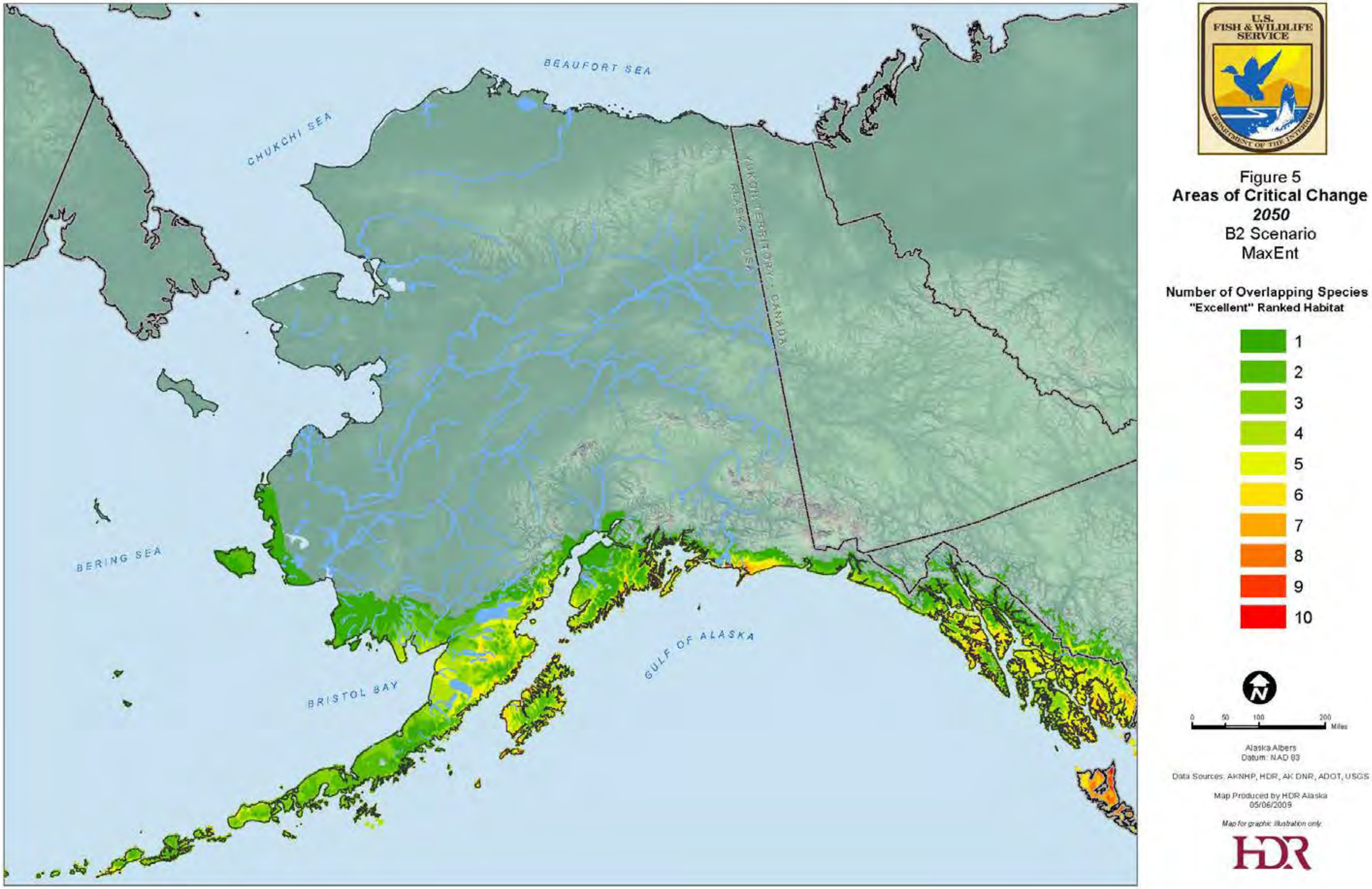
https://www.fws.gov/alaska/fisheries/invasive/reports.htm

2020



https://www.fws.gov/alaska/fisheries/invasive/reports.htm

2050



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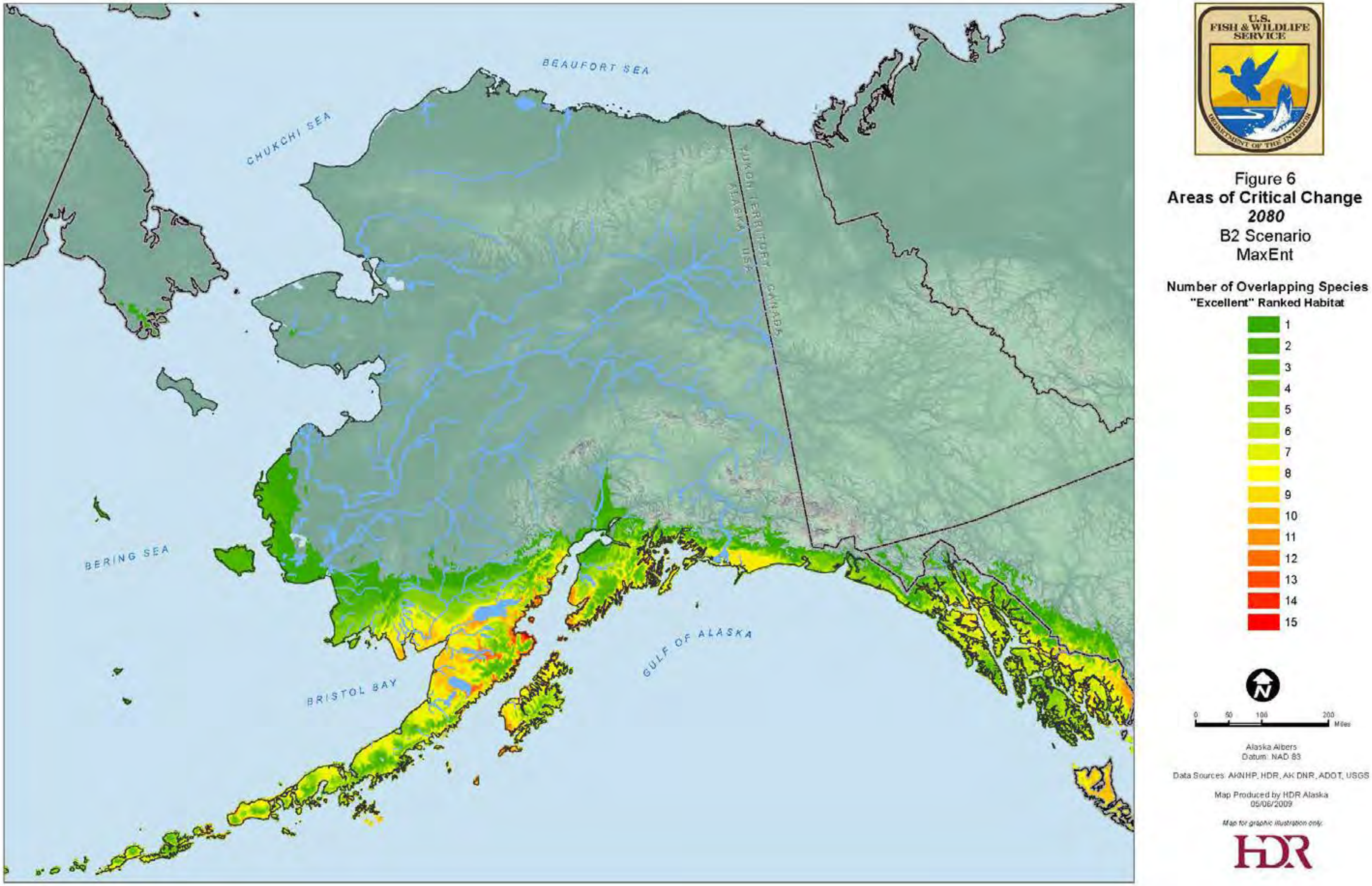
2080



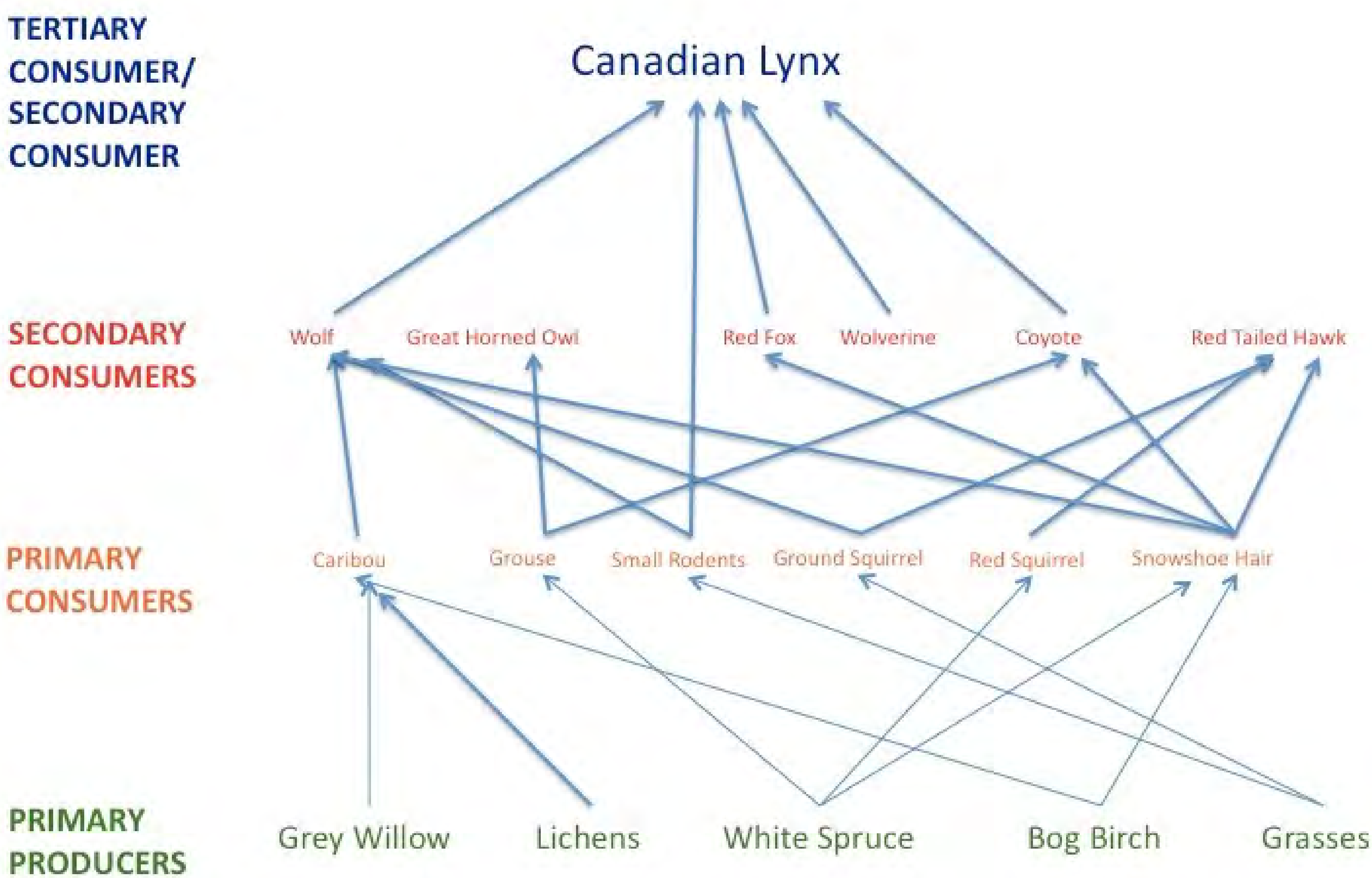
https://www.fws.gov/alaska/fisheries/invasive/reports.htm



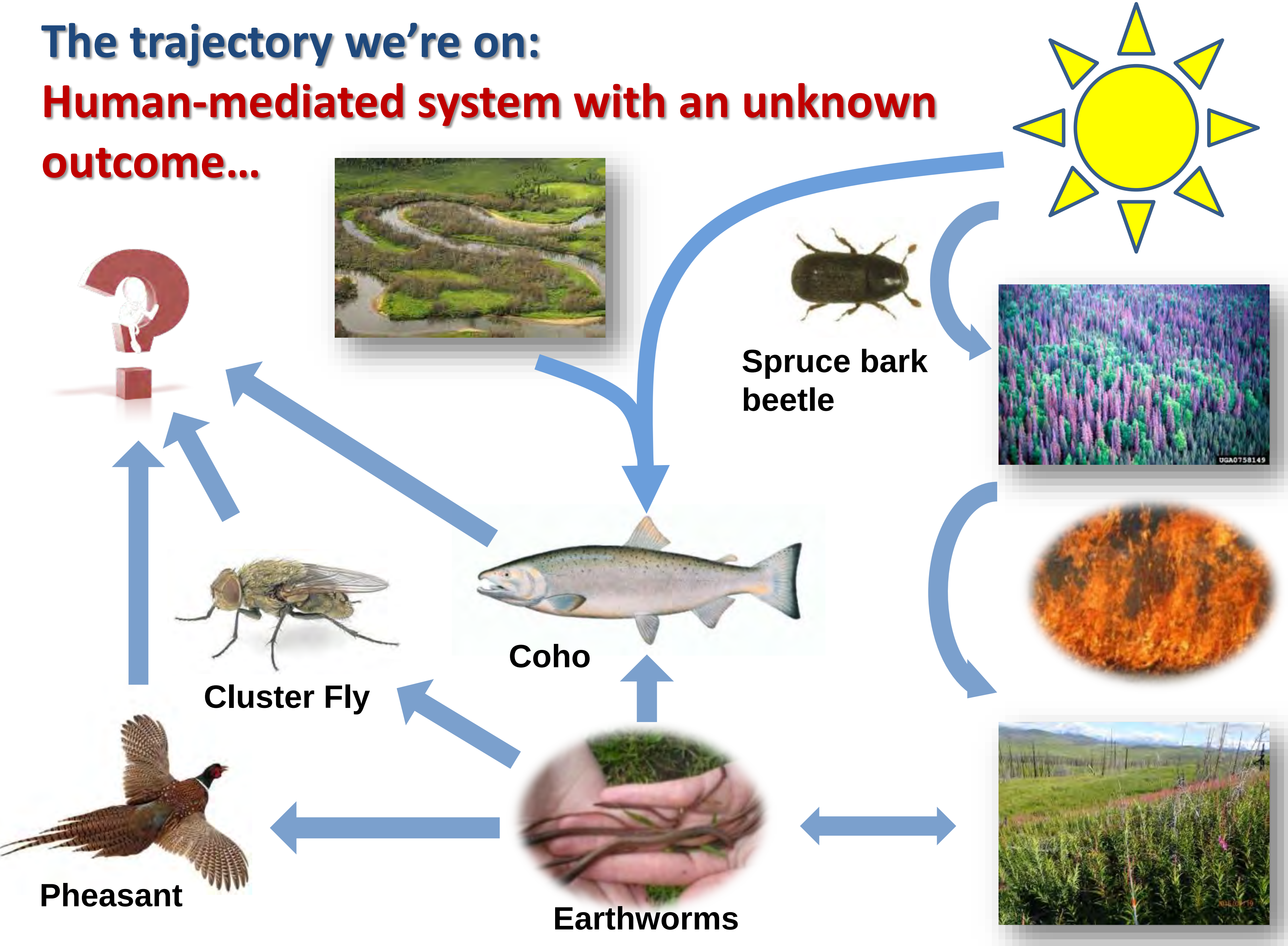
> 138 exotic species of flora (108) and fauna (30) occur on the Kenai Peninsula and are poised to fill novel assemblages



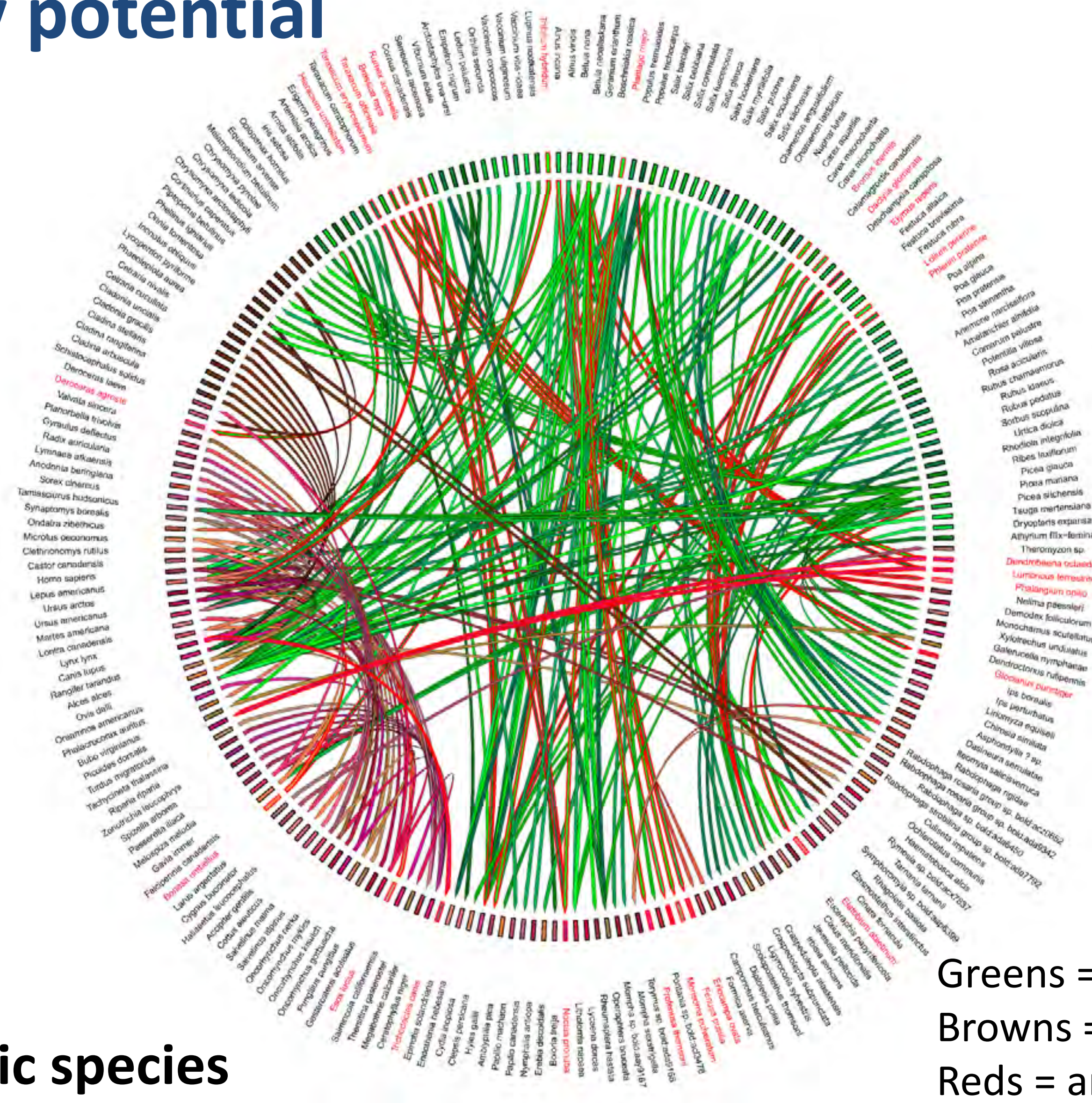
The boreal system as we're taught…



The trajectory we're on:
Human-mediated system with an unknown outcome…



Our management choices affect evolutionary potential



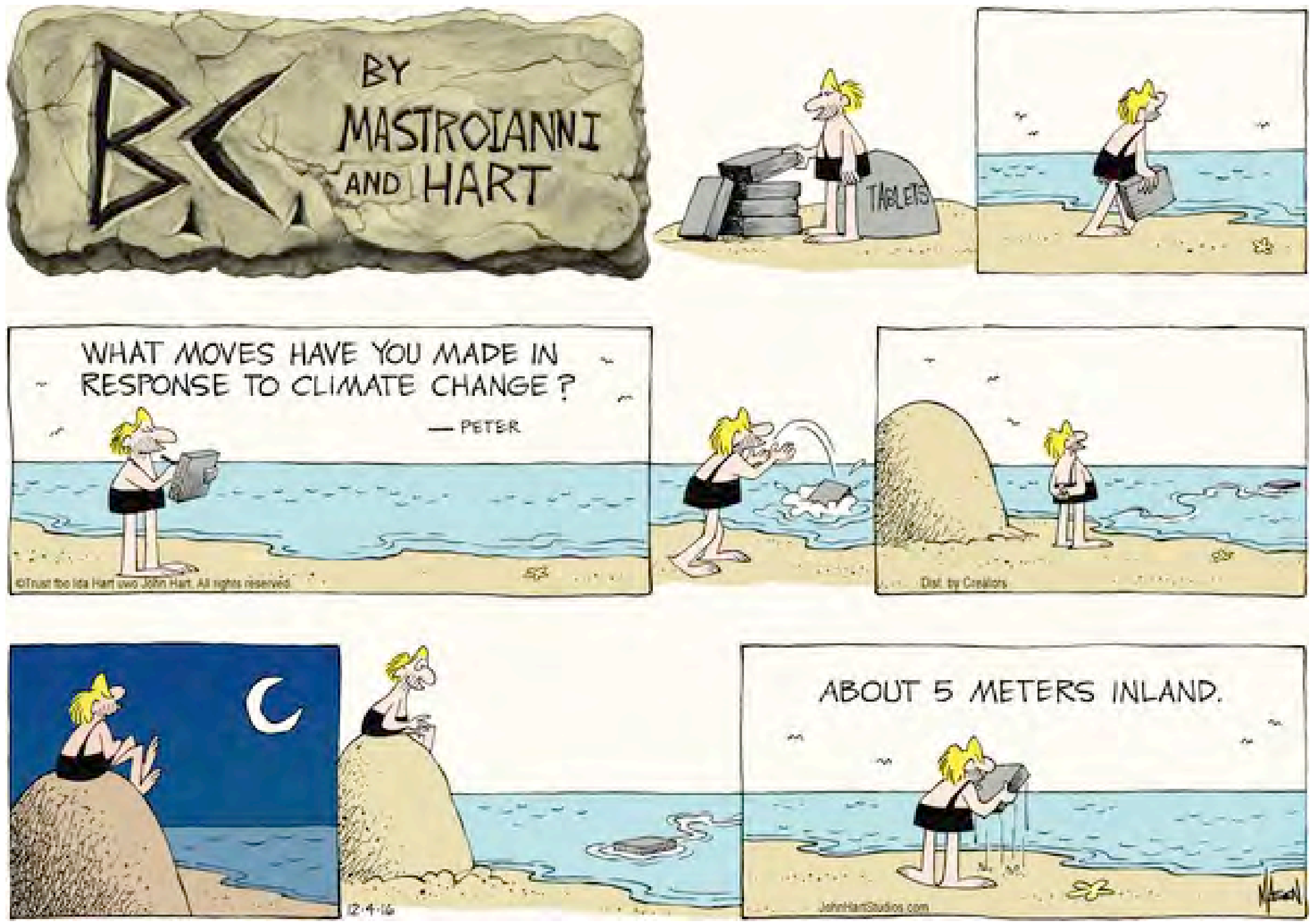
Greens = plants
Browns = fungi
Reds = animals

272 trophic links:
5 involve 2 exotics
31 involve one exotic species

We need a sophisticated perspective on managing exotic species…

- ✓ Alaska is already responding to a warming climate and forecasted to continue doing so
- ✓ Novel assemblages ≠ simple re-shuffling of native biota
- ✓ Many exotic species already introduced and more enroute
- ✓ Focus on novel species (but scale dependent)
- ✓ Be circumspect about invasive species rankings
- ✓ When in doubt, kill it!

Questions????


B.C.
BY MASTROIANNI AND HART
TABLETS
WHAT MOVES HAVE YOU MADE IN RESPONSE TO CLIMATE CHANGE?
— PETER
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12-4-16
ABOUT 5 METERS INLAND.
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