Using Genetics to Address Conservation Issues on the Kenai Peninsula

Research Article

Estimation of the Brown Bear Population on the Kenai Peninsula, Alaska

Canadian Journal of Forest Research

OPEN ACCESS | Article

The dynamics of a changing Lutz spruce (*Picea* × *lutzii*) hybrid zone on the Kenai Peninsula, Alaska

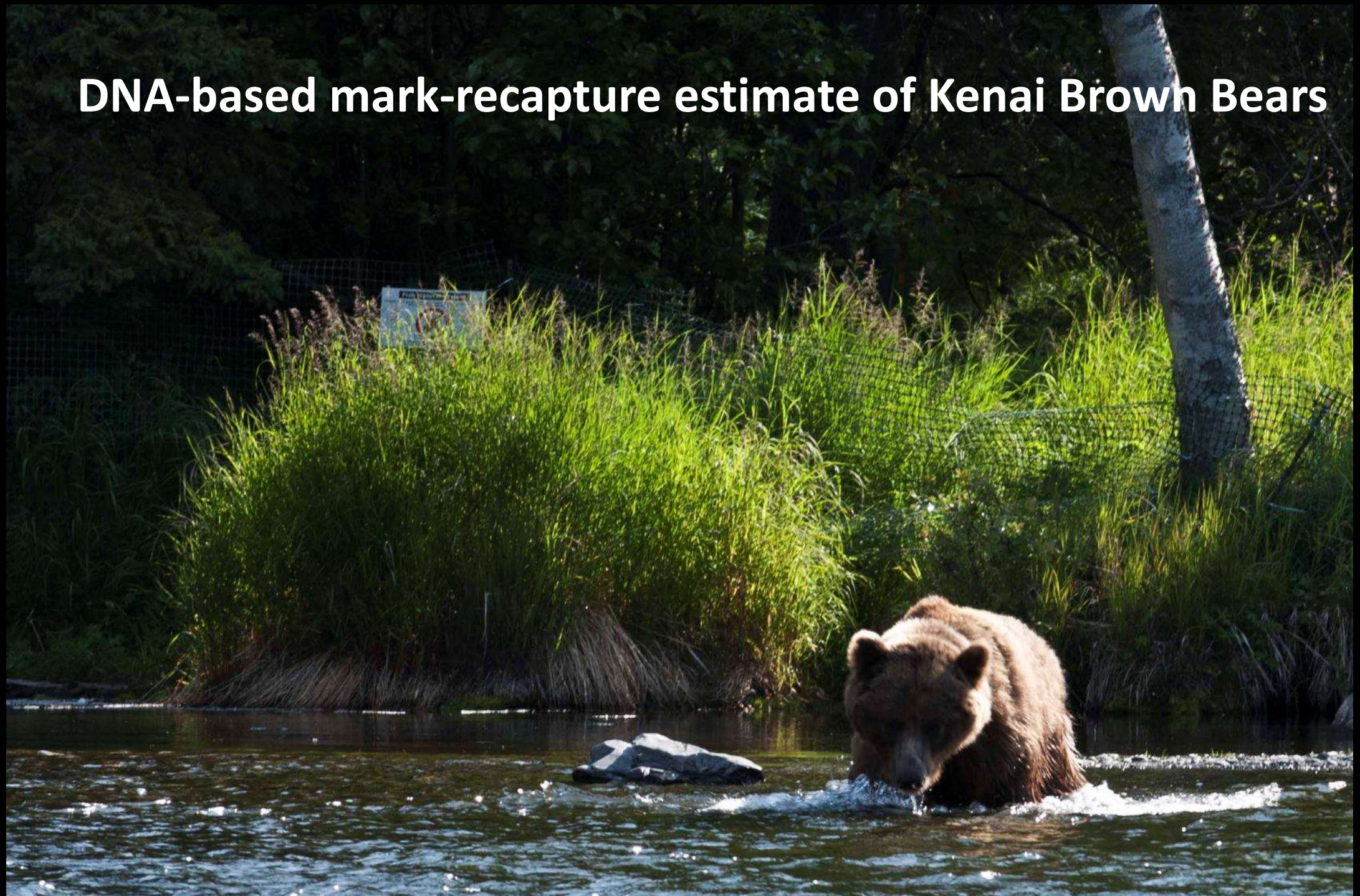
Research Article

Towards conserving natural diversity: A biotic inventory by observations, specimens, DNA barcoding and high-throughput sequencing methods

John Morton, PhD

Brown bear population	Spruce hybridization	Species richness
Hair (DNA)	**Leaves (needles)**	**Organism (any part)**
Marker G10J (species) Multilocus (7) microsatellite markers (individuals) Amelogenin marker (♀♂)	12 microsatellite loci (species) Nad5a (mitochondrial [♀] locus) Trnt-L (chloroplast [♂] locus)	313 bp region of COI (cytochrome c oxidase) gene mitochondrial DNA (mtDNA)

DNA-based mark-recapture estimate of Kenai Brown Bears



Why we estimated the Kenai brown bear population in 2010…

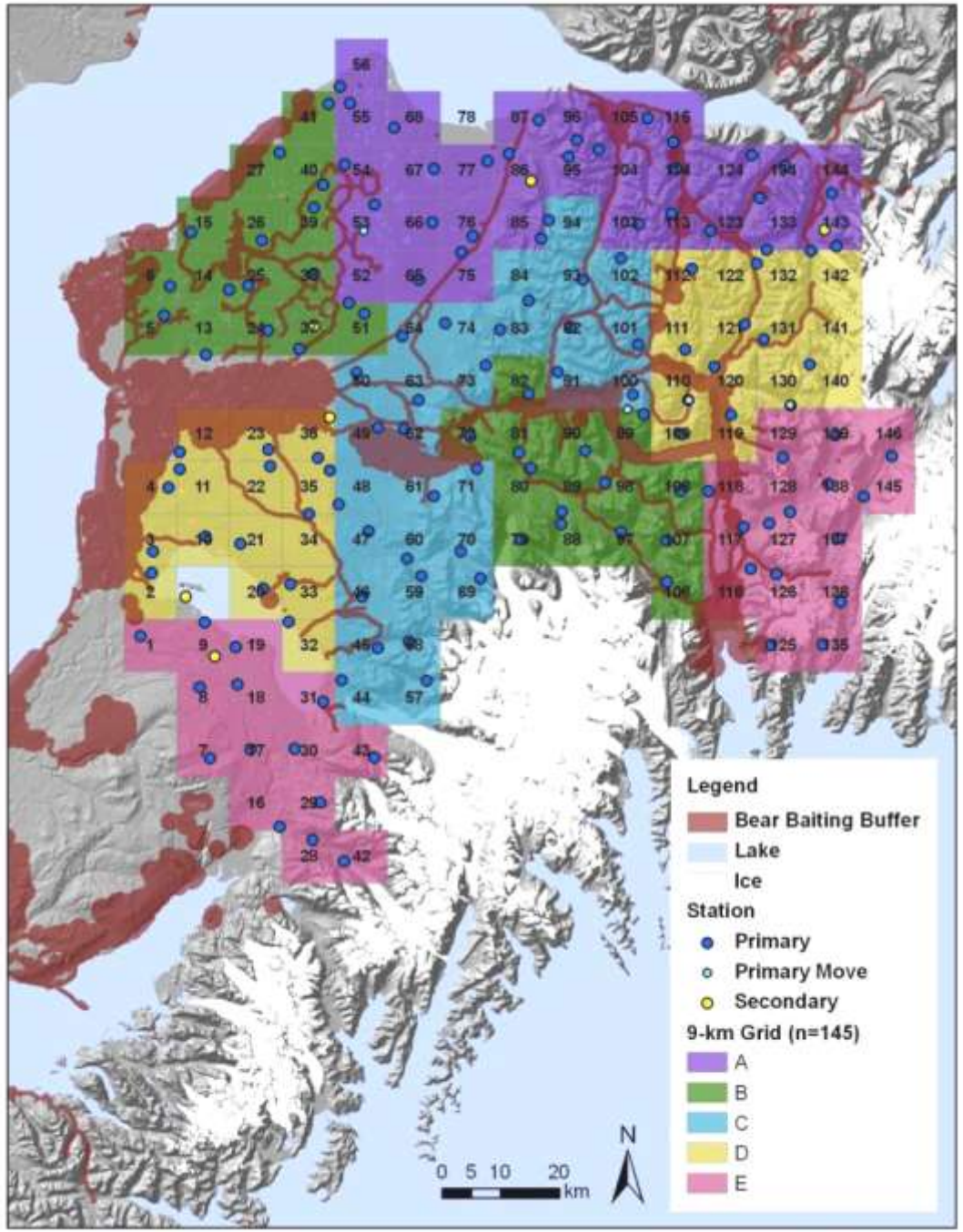
- ✓ Designated *Population of Special Concern* by State of Alaska in 1998 – 2010
- ✓ Genetically less diverse than (and distinct from) adjacent mainland Alaskan brown bears
- ✓ Only estimate of 250-300 brown bears based on multiplying the area of suitable habitat by mean bear density from other AK studies
- ✓ Population trend unknown (λ = 0.9364 – 1.0588)
- ✓ Low yearling survivorship and small proportion of subadult females suggested low recruitment
- ✓ Annual DLPs increased from <1 in 1960s to 5 in 1990s to >20 in 2000s

Simple Lincoln-Petersen Estimator

$$N = MC/R$$

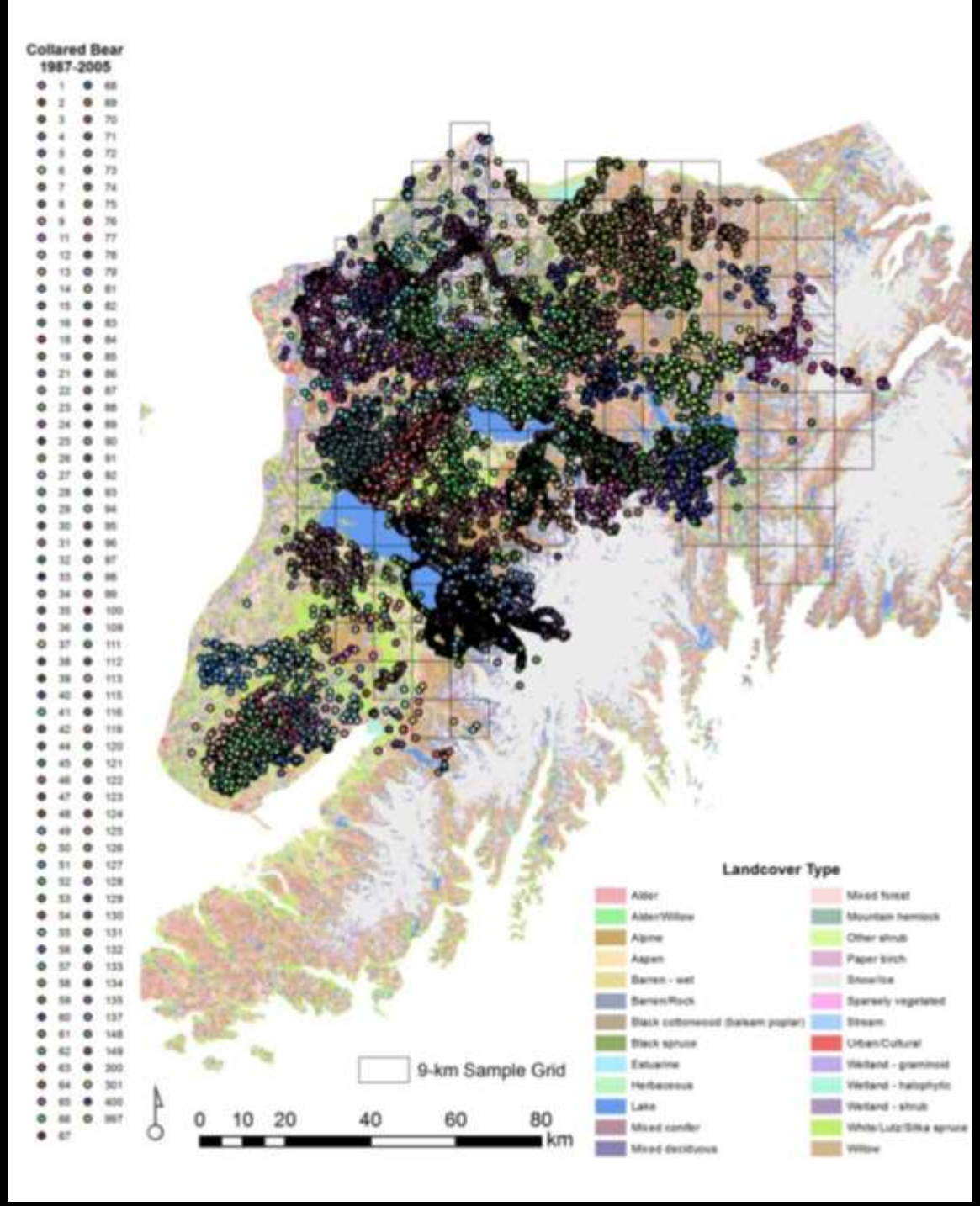
N = Estimate of total population size
M = Total number of animals captured and marked on the first visit
C = Total number of animals captured on the second visit
R = Number of animals captured on the first visit that were then recaptured on the second visit

…estimate is not based on the number of individuals marked (i.e., genotypes) but on their recapture rates



145 primary hair stations subjectively placed within 81-km^2 cells systematically distributed over 11,700 km^2 study area

29 stations sampled daily over five 5-day trap sessions using rotating panel design

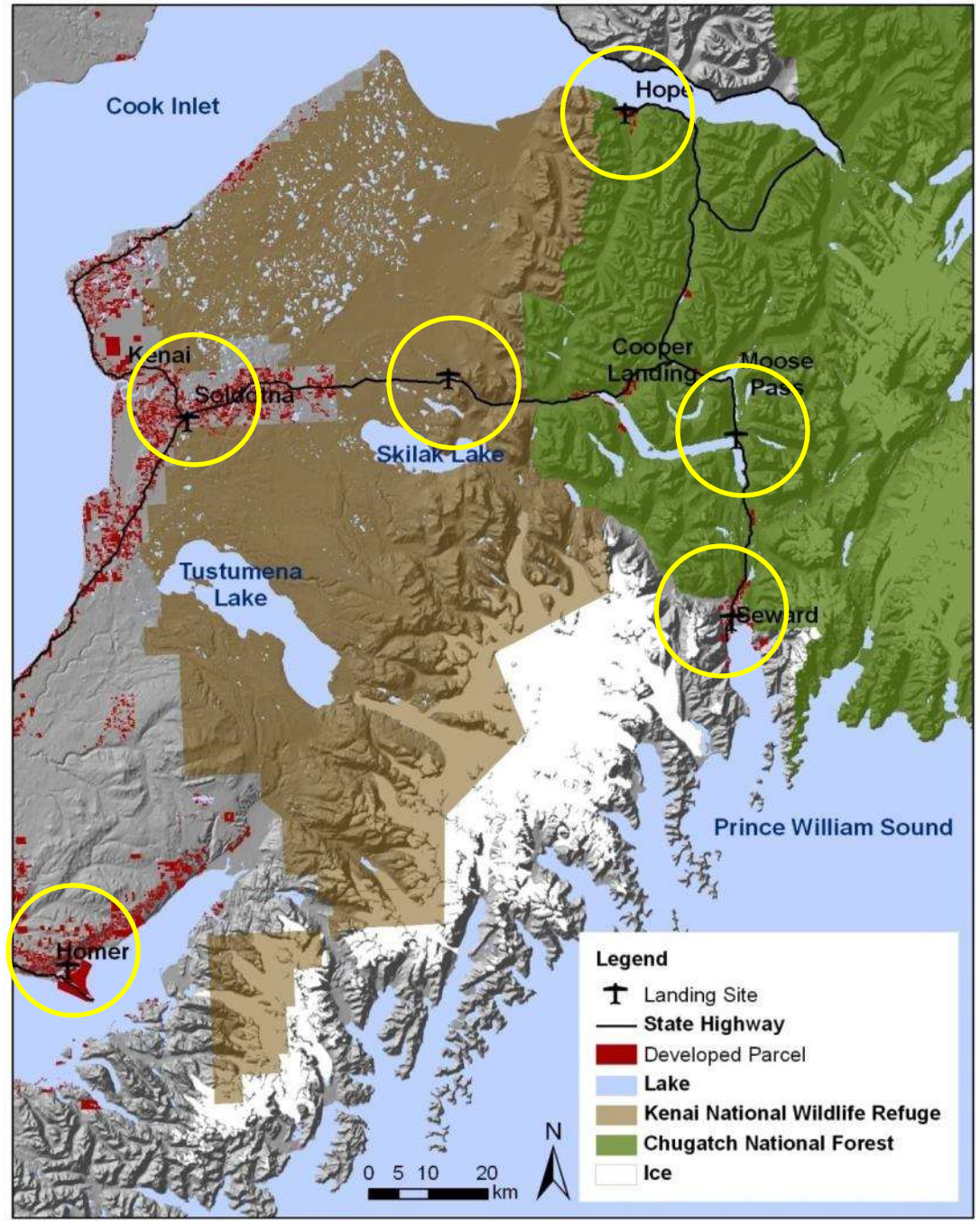


Distribution of 144,024 telemetry locations from 125 female brown bears with GPS and VHF collars (1987-2005)

►87% were on study area

Selection criteria for hair stations

- ✓ adequate space for helicopter access
- ✓ > 400m from trails, cabins, roads
- ✓ riparian/wetland corridors
- ✓ other travel corridors (ridges, shoulders, chutes)
- ✓ OTBE, ensure good spatial separation among sites within a cell



Four sets of 2-person field crews operated out of Moose Pass and Soldotna for 31 consecutive days


N204PA
2000 GAL
1863
FLAMMABLE
NO SMOKING

1MINUTE 07 JUN.19,10 08:00 AM

1MINUTE 07 JUN.19,10 08:01AM

1MINUTE 07 JUN.19,10 08:04 AM

1MINUTE 07 JUN.19,10 08:05 AM


1MINUTE
07
JUN.19,10 08:06 AM

1MINUTE 07 JUN.19,10 08:09 AM

1MINUTE 07 JUN.19,10 08:10 AM

1MINUTE 07 JUN.19,10 08:11AM


Hair station: _____
Barb #_____ Session # _____
Date: June ____, 2010
3 hairs or less? Y / N
Hair Location: Upper strand / Lower strand
unknown
106624
106624


BERNZOMATIC
TS4000

11,175 hair samples (grid) + 91 hair samples (rub tree)

11,266 hair samples

2,671 DNA samples

1,034 brown bear samples

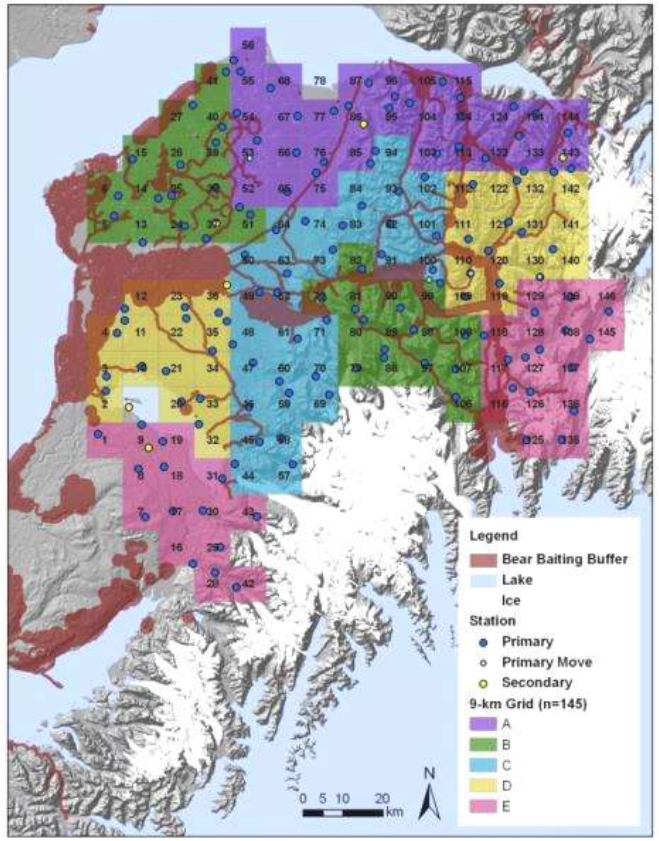
211 unique genotypes

104 males + 99 females (n = 203)

How many brown bears on the Kenai Peninsula in 2010?

428 (353-539) brown bears estimated (all ages) on 11,700 km^2 sample frame

of which 10,200 km^2 is available habitat



≈ 42 bears per 1,000 km^2

≈ 582 bears on the KP (469-719)

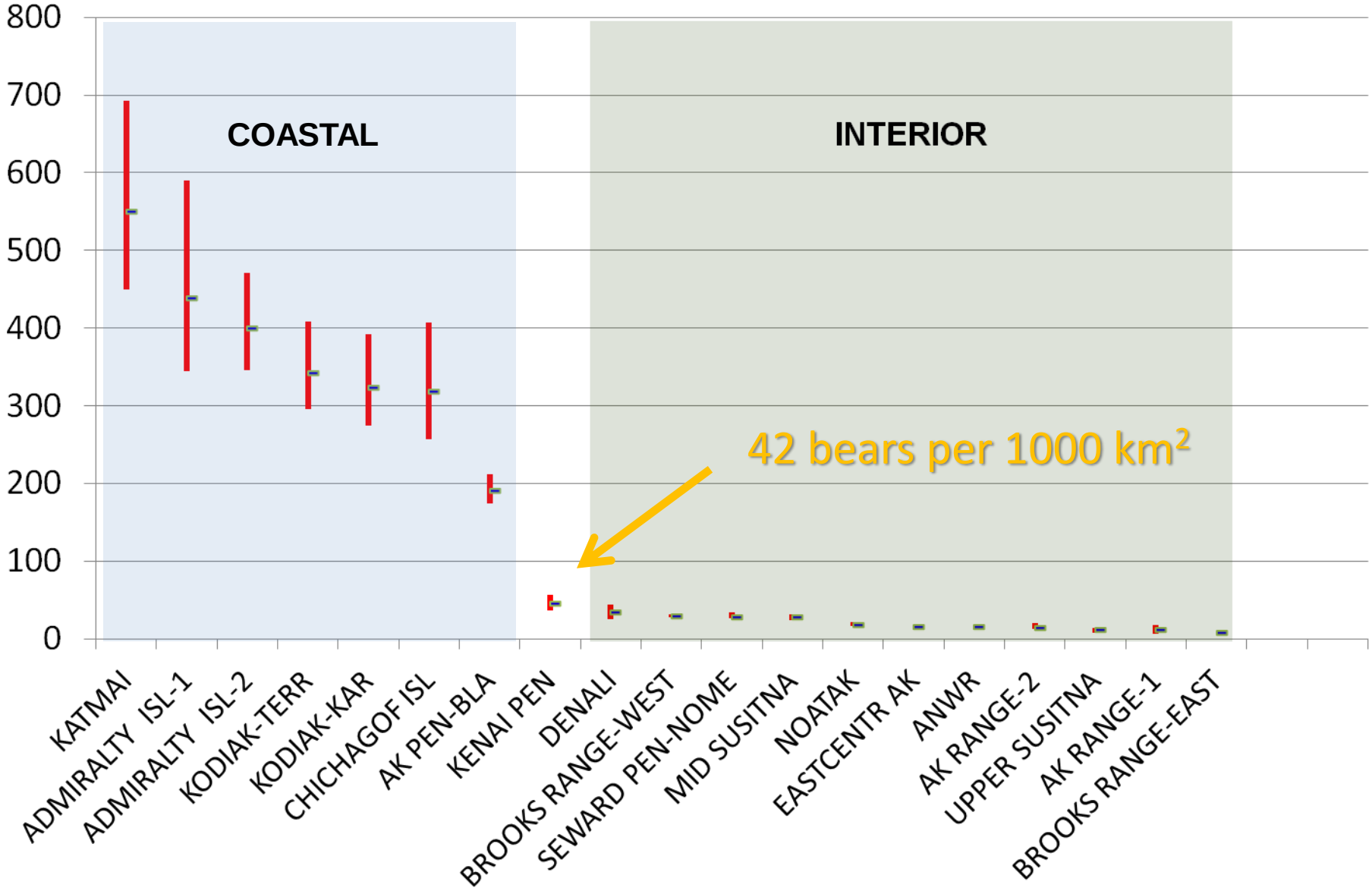
≈ 188 adult females + 188 adult males

≈ 206 dependent young

(Morton et al. 2016)

ALASKA BROWN BEAR DENSITIES (PER 1000 KM^2)

(after Miller et al. 1997)



What are the management implications for Kenai brown bears?

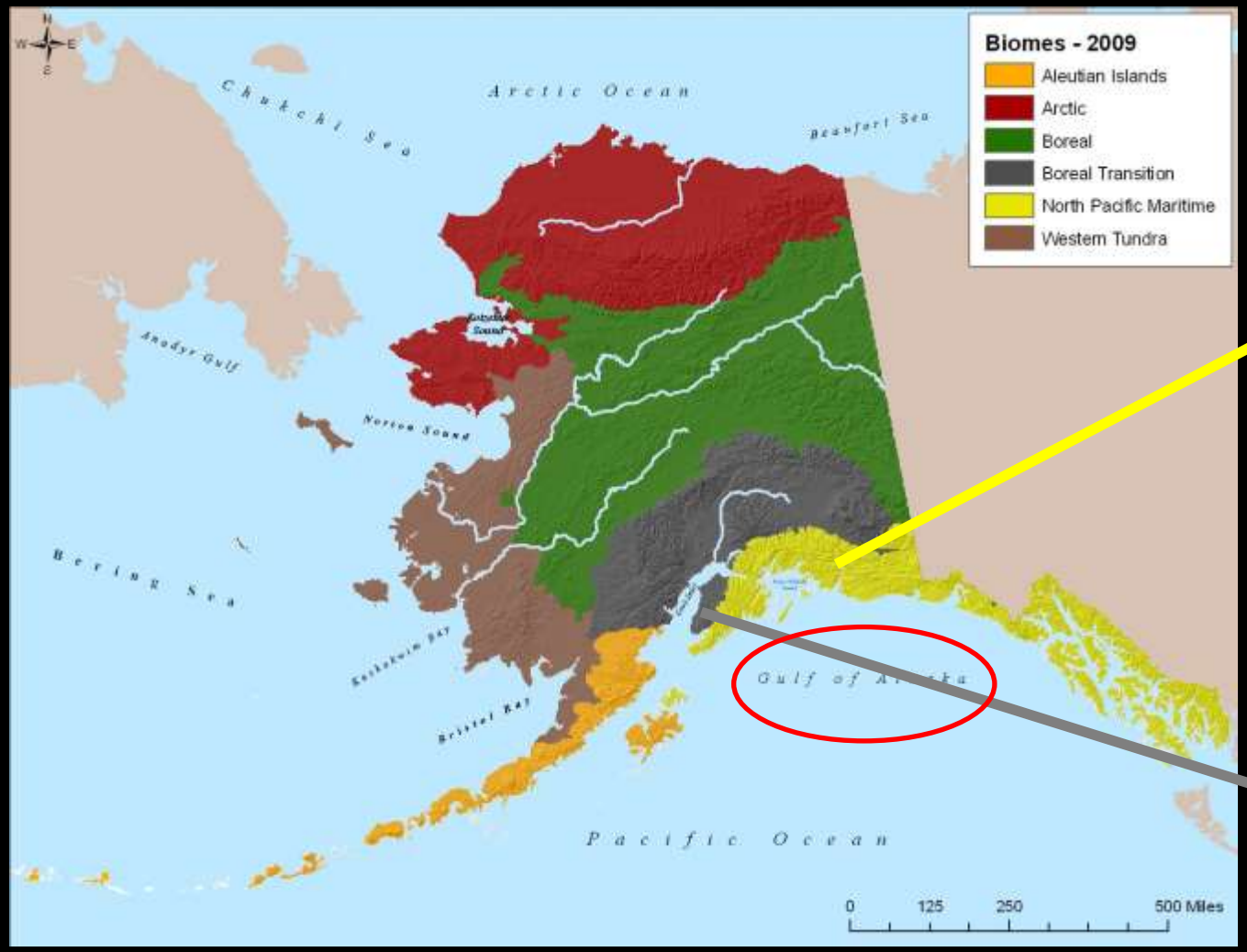
Represents 1st empirically-based estimate of the Kenai brown bear population

Puts human-caused mortality (legal harvest, illegal take, vehicle collisions, agency kills and DLPs) into better demographic context

Helps determine sustainable harvest

Why care about Lutz spruce?

Kenai Peninsula is the nexus of two biomes



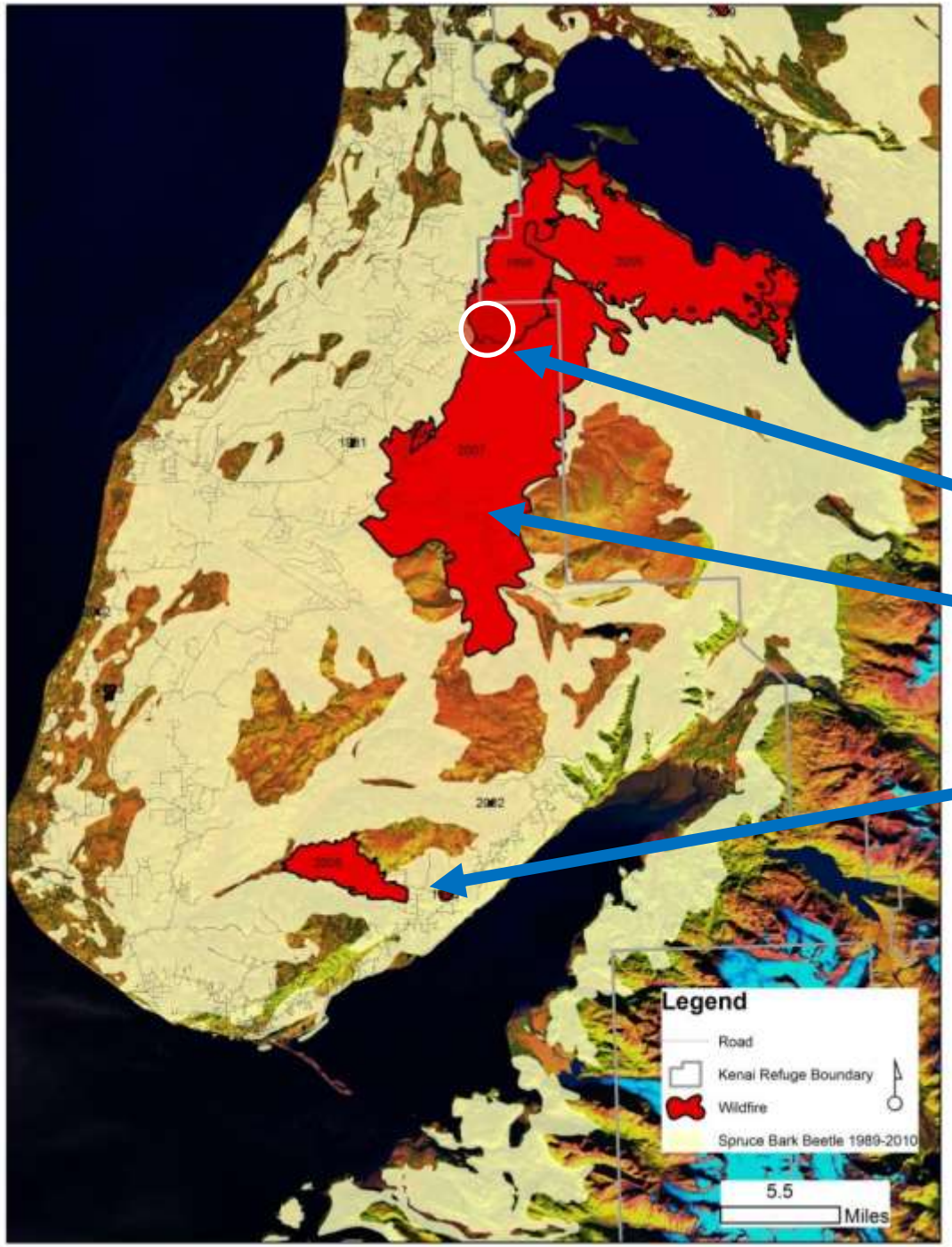
White spruce arrived first
8500 YBP

Sitka spruce arrived later
4000 YBP

White spruce (1)

Lutz spruce (3-4)

Sitka spruce (6-7)



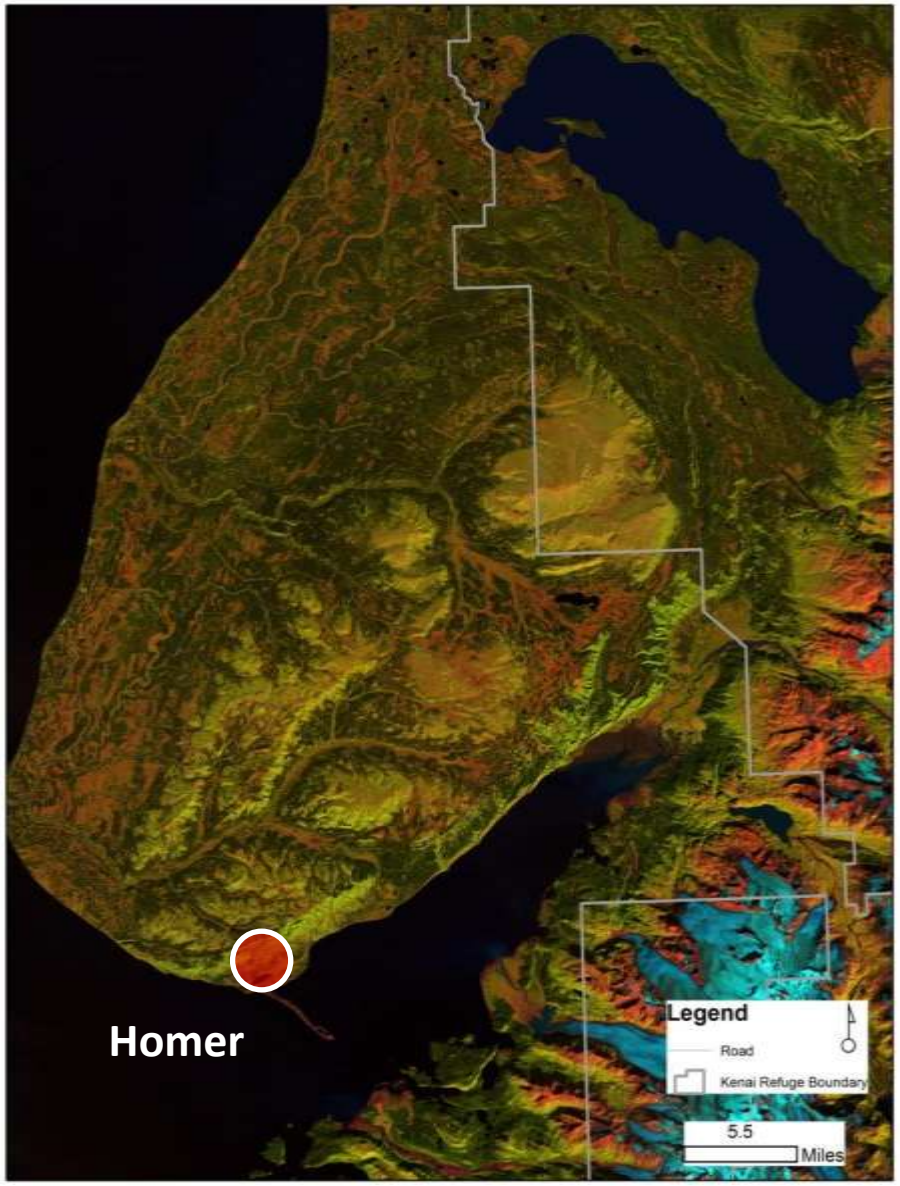
Southwestern Kenai Peninsula was the epicenter of 1990s spruce bark beetle outbreak

2019 Tustumena Lake
2007 Caribou Hills
2005 Tracy Avenue
2005 Fox Creek
2005 Glacier Creek
1996 Crooked Creek
1994 Windy Point

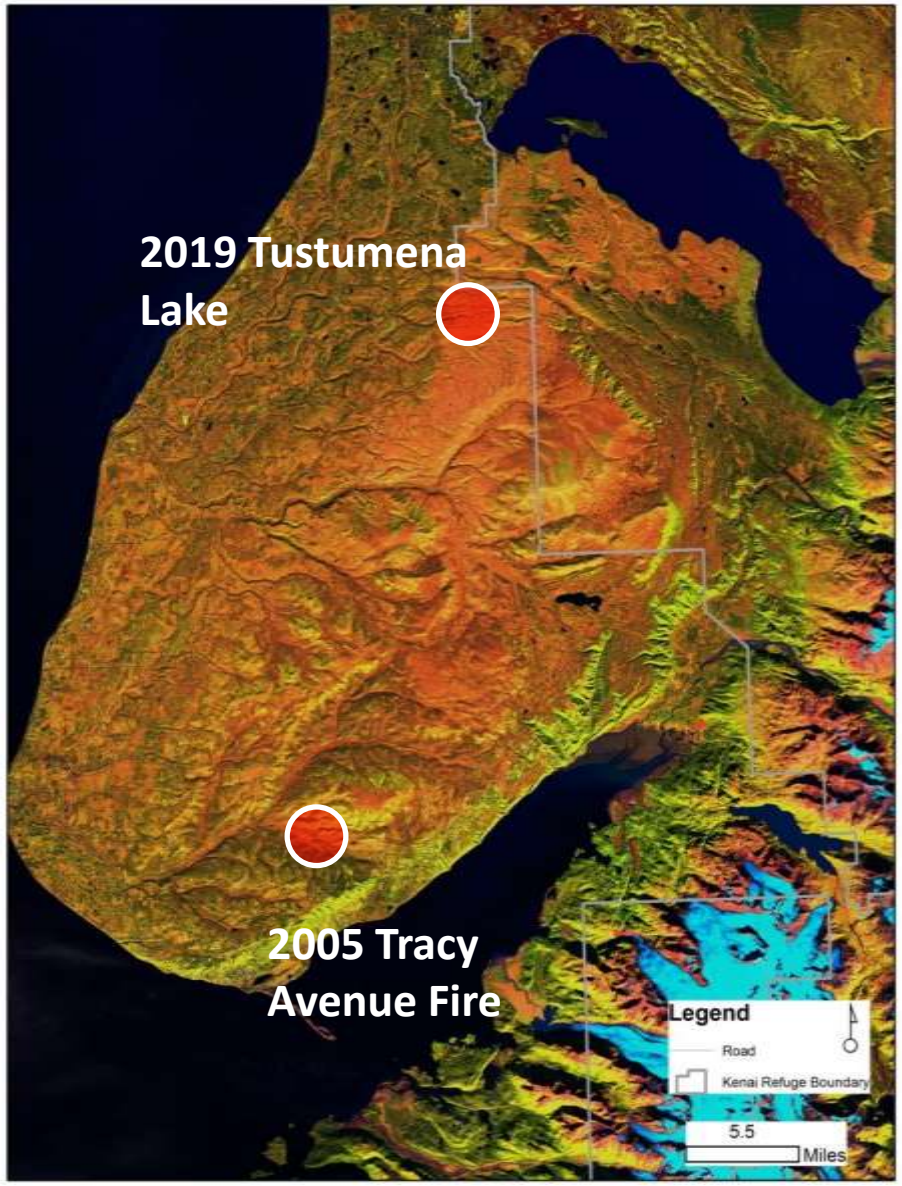
Morton at al. 2023. The dynamics of a changing Lutz spruce (*Picea x Lutzii*) hybrid zone on the Kenai Peninsula, Alaska. Canadian J. Forest Research. 10.1139/cjfr-2022-0212.

First lightning-caused grassland fire in spring on Kenai Peninsula

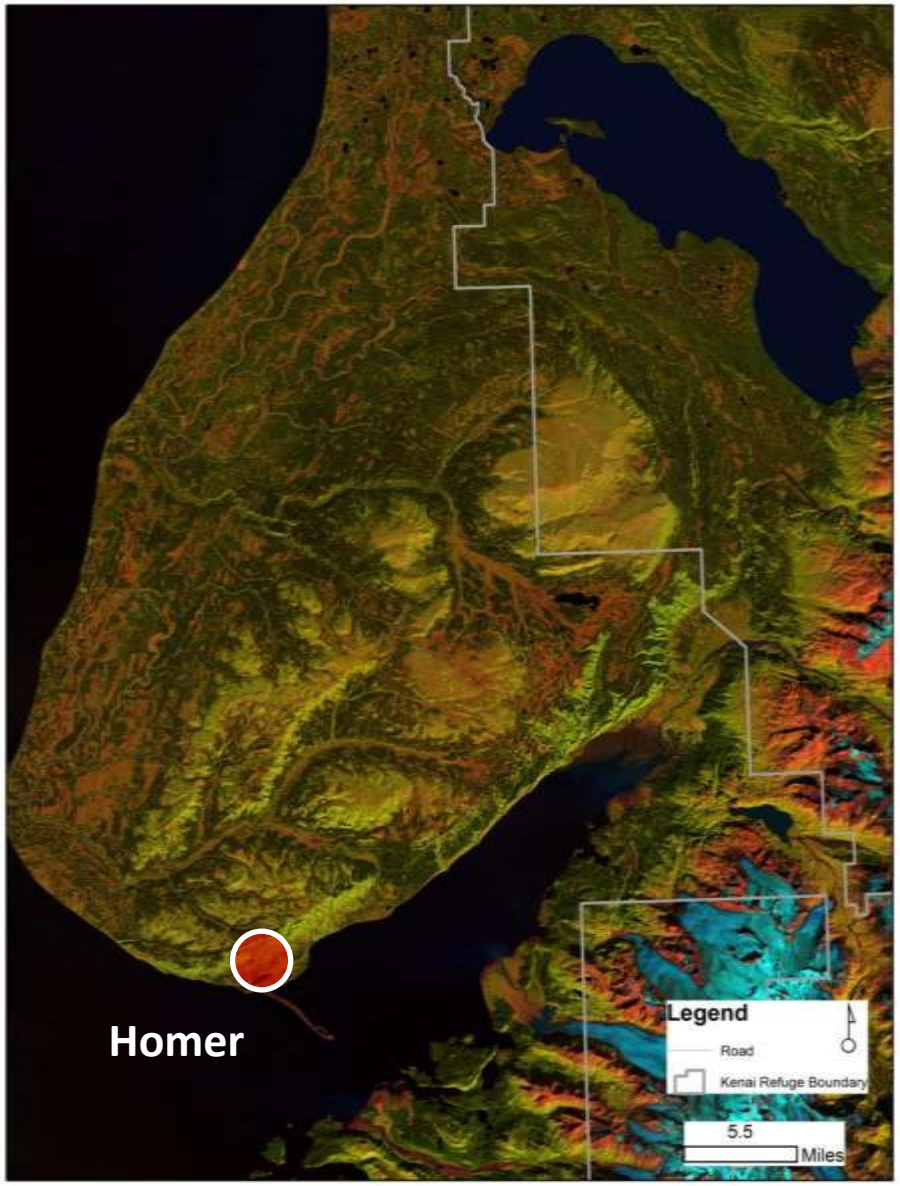
2019 Tustumena Lake Fire



SEPT 1985



SEPT 2014



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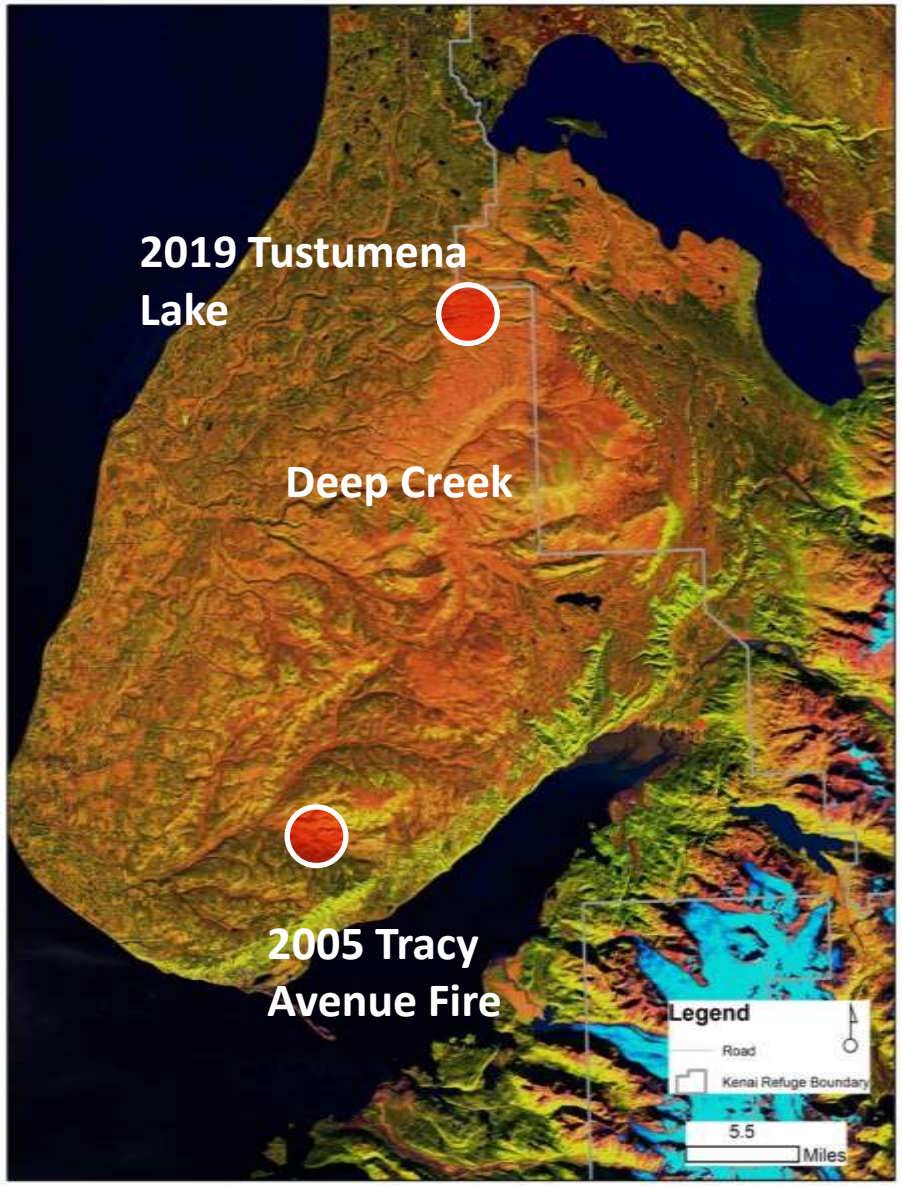
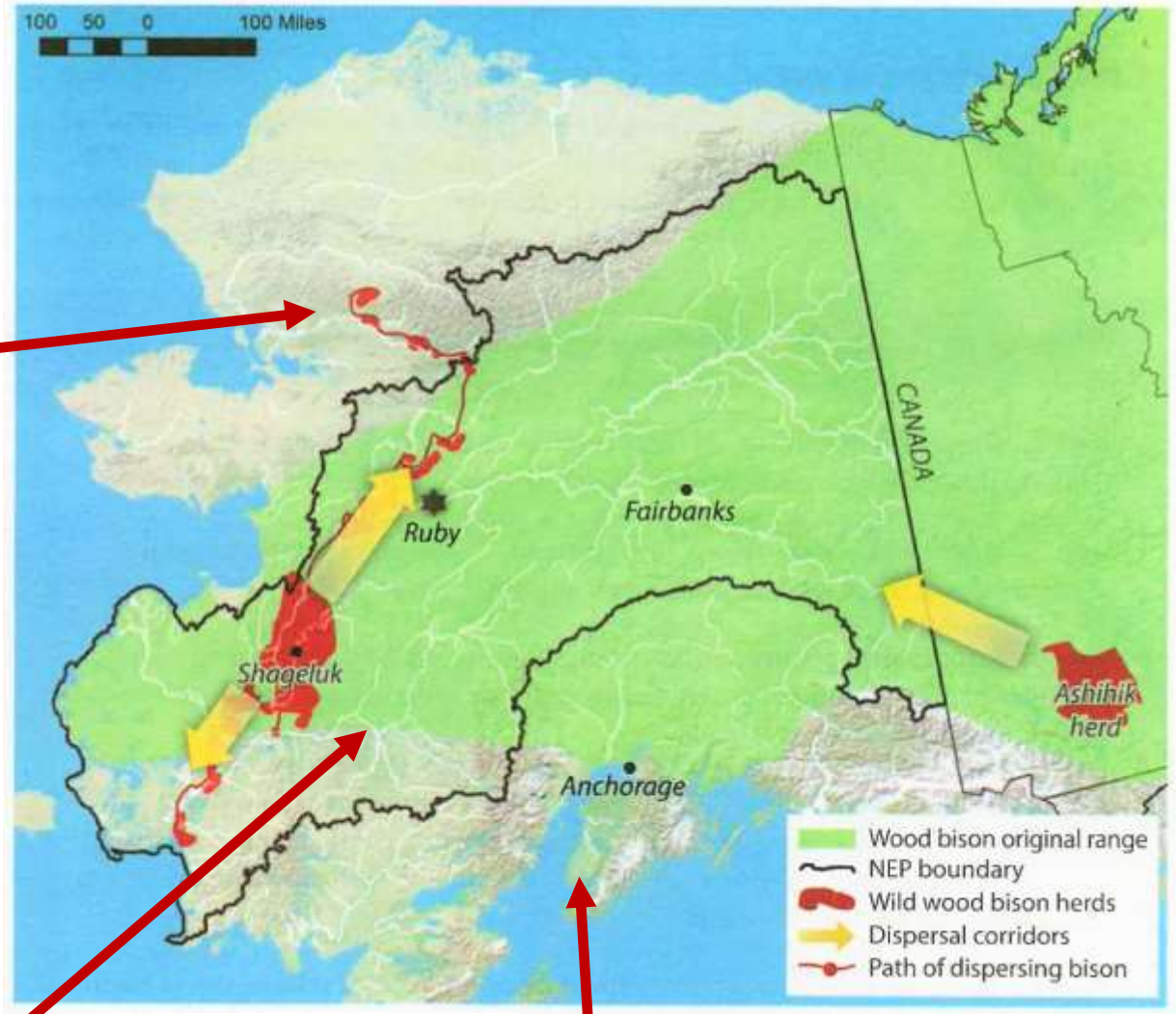


SEPT 2014

Deforestation
North Fork of Deep Creek

Bison? Grasslands need a functional grazer

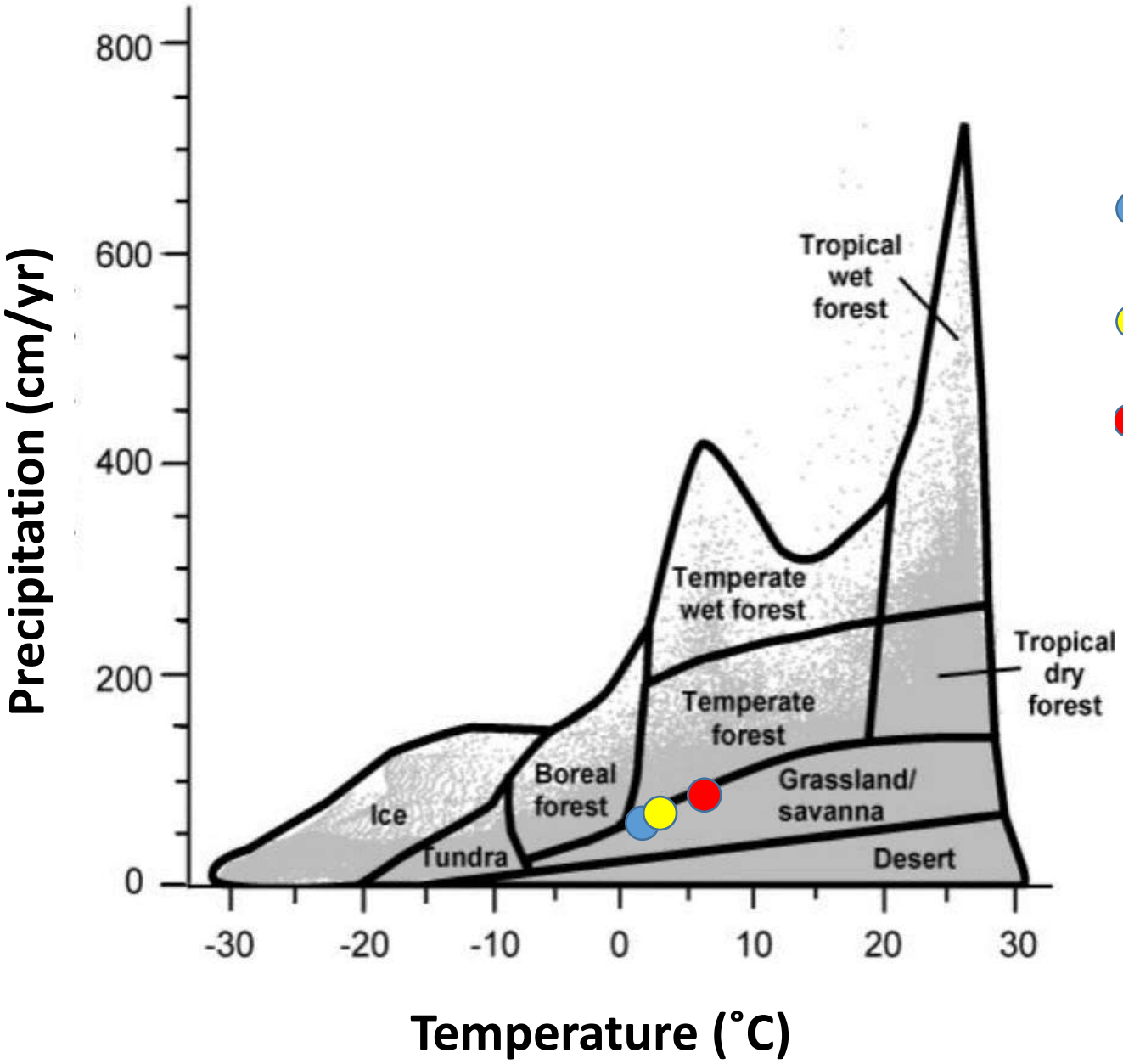
2018 outside historic range



Historic range circa 19th century

Historic range circa 40,000 years ago in Caribou Hills

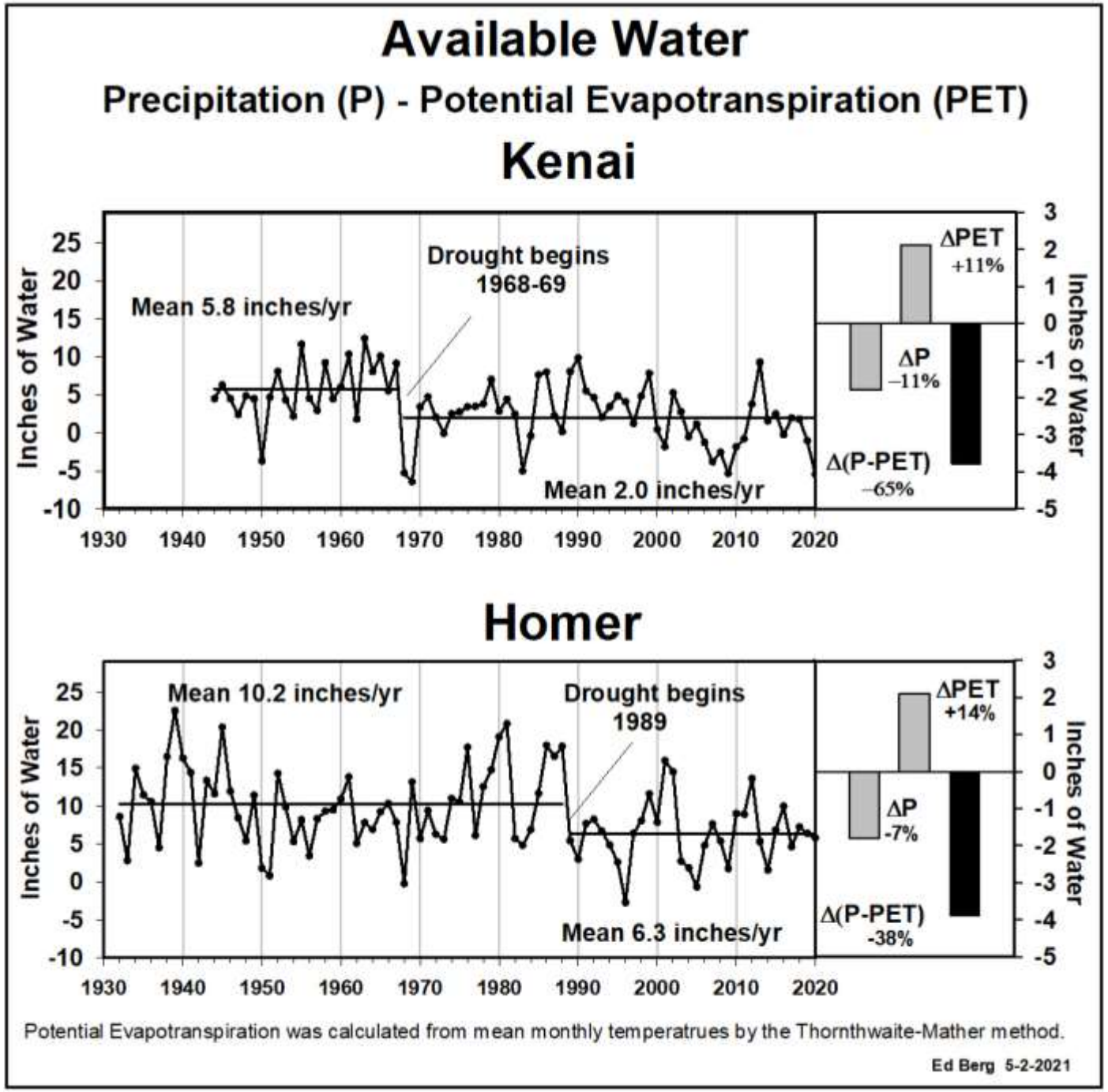

SPECIES RICHNESS
500
450
400
350
300
250
200
150
100
50
0
Inside AWCC
Outside AWCC
Caribou Hills
FUNGI
SOIL ARTHROPODS
ARTHROPODS
VASCULAR PLANTS



Caribou Hills

- 1900 68 cm, 2.3° C
- 1980 73 cm, 3.3° C
- 2090 84 cm, 6.8° C

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



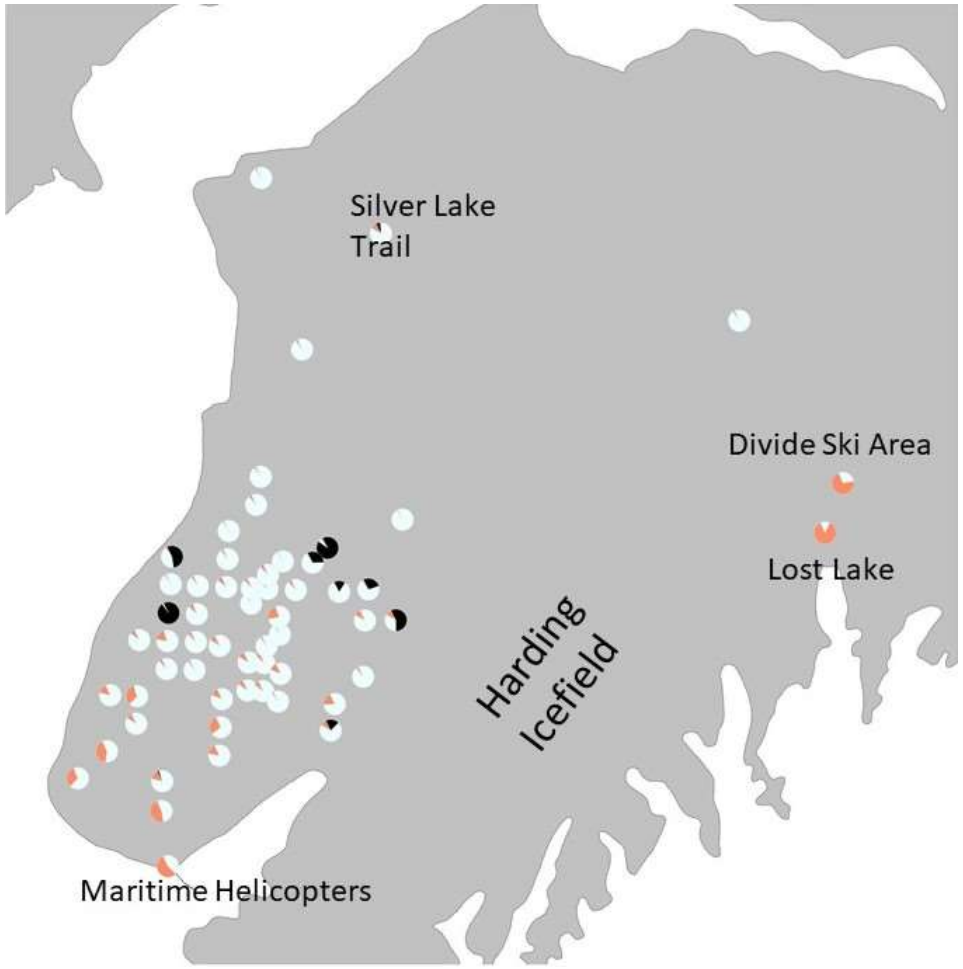
Kenai and Homer airports have declined 65% and 38%, respectively, in mean annual available water in last 5 decades

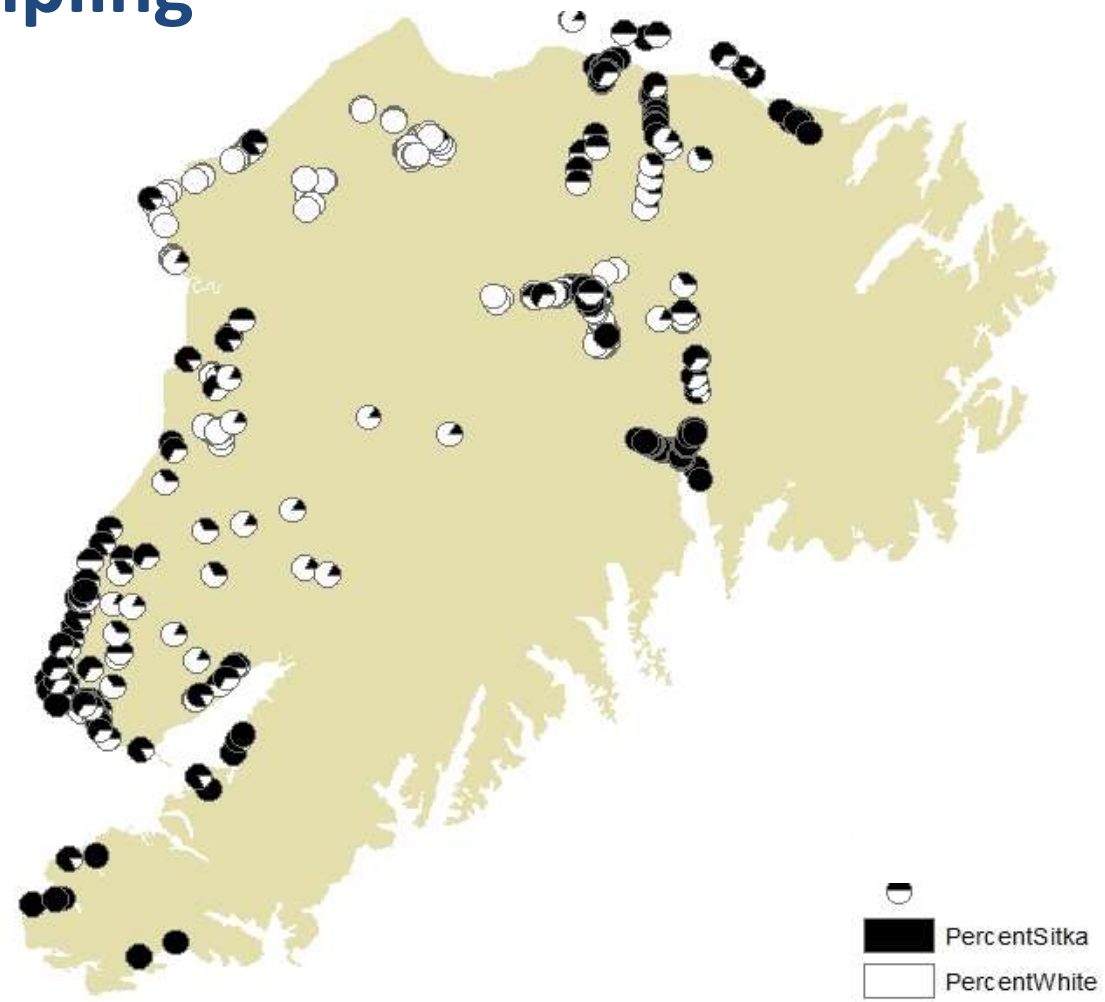
Hybrid spruce (Lutz) attributes

Bioclimatic variable	KP mean (SD)	White mean (SD)	Lutz mean (SD)	Sitka mean (SD)
BFFP = Julian date on which the frost-free period begins	144.1 (9.0)	149.1 (5.8)	149.0 (5.7)	141.5 (4.1)
EXT = extreme maximum temperature over 30 years (°C)	28.4 (1.6)	29.8 (0.9)	28.8 (0.7)	28.6 (0.6)
MAP = mean annual precipitation (mm)	1725.5 (1223.8)	564.6 (134.7)	782.7 (298.3)	1332.1 (641.6)
MAR = mean annual solar radiation (MJ m-2 d-1)	12.1 (0.8)	11.5 (0.3)	11.6 (0.6)	11.9(0.6)
MAT = mean annual temperature (°C)	1.9 (1.2)	2.2 (0.6)	1.8 (0.6)	2.5(0.6)
TD = difference between mean temperatures (°C) of coldest and warmest months (a measure of continentality)	20.0 (2.4)	21.3 (2.1)	20.6 (2.0)	19.7 (1.3)

- Cooler MAT
- Intermediate MAP, TD
- Greater intolerance to spruce bark beetle attack

Sitka, Lutz and White spruce sampling

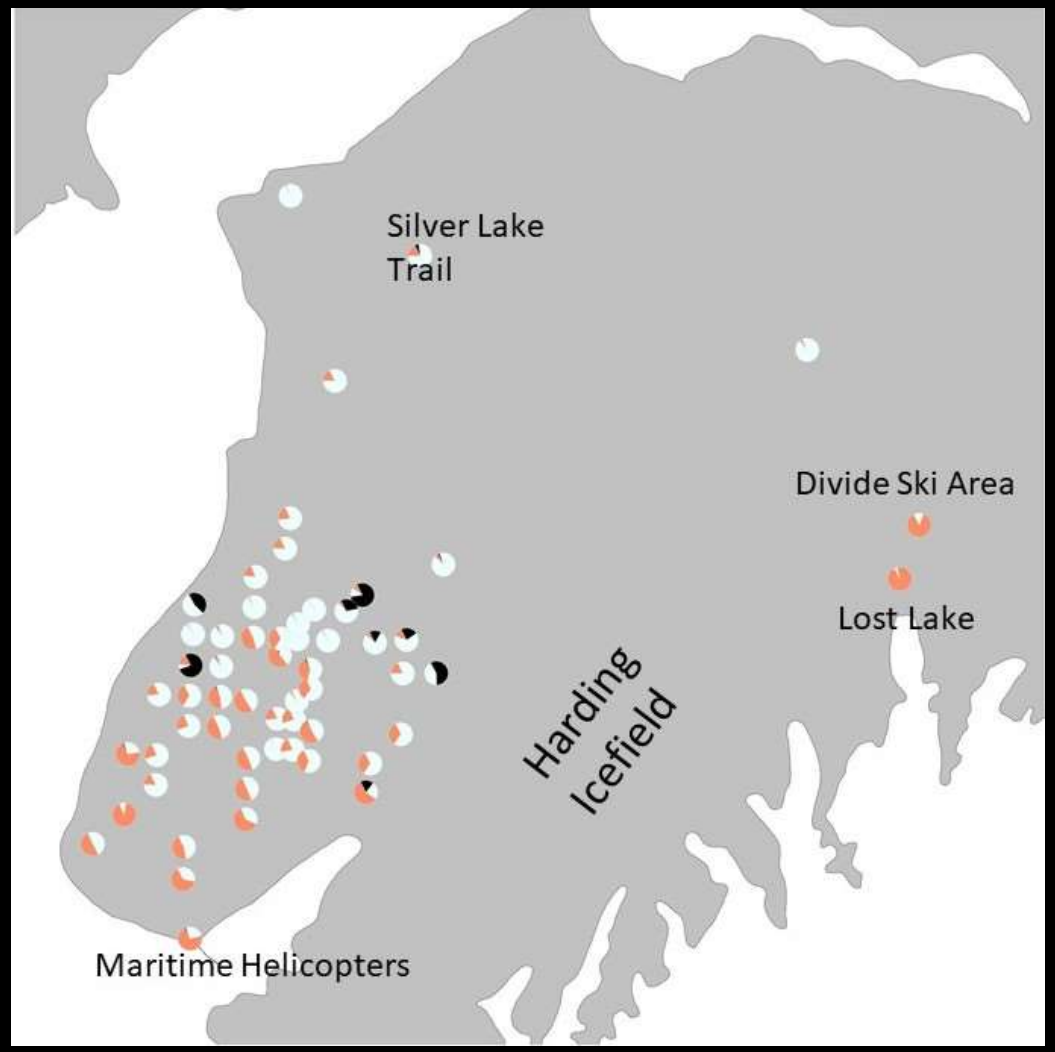




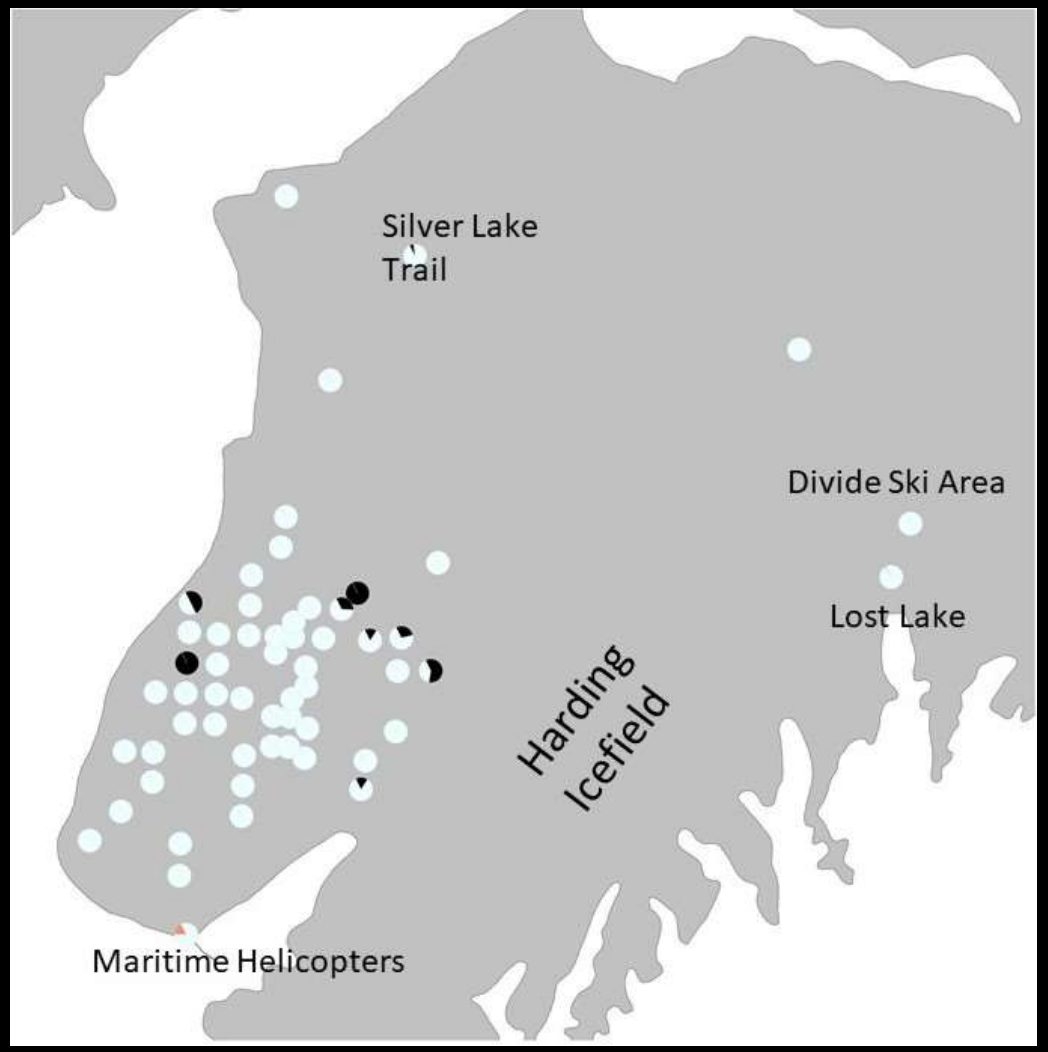
microsatellites (genotypic)

cones and foliage (phenotypic)

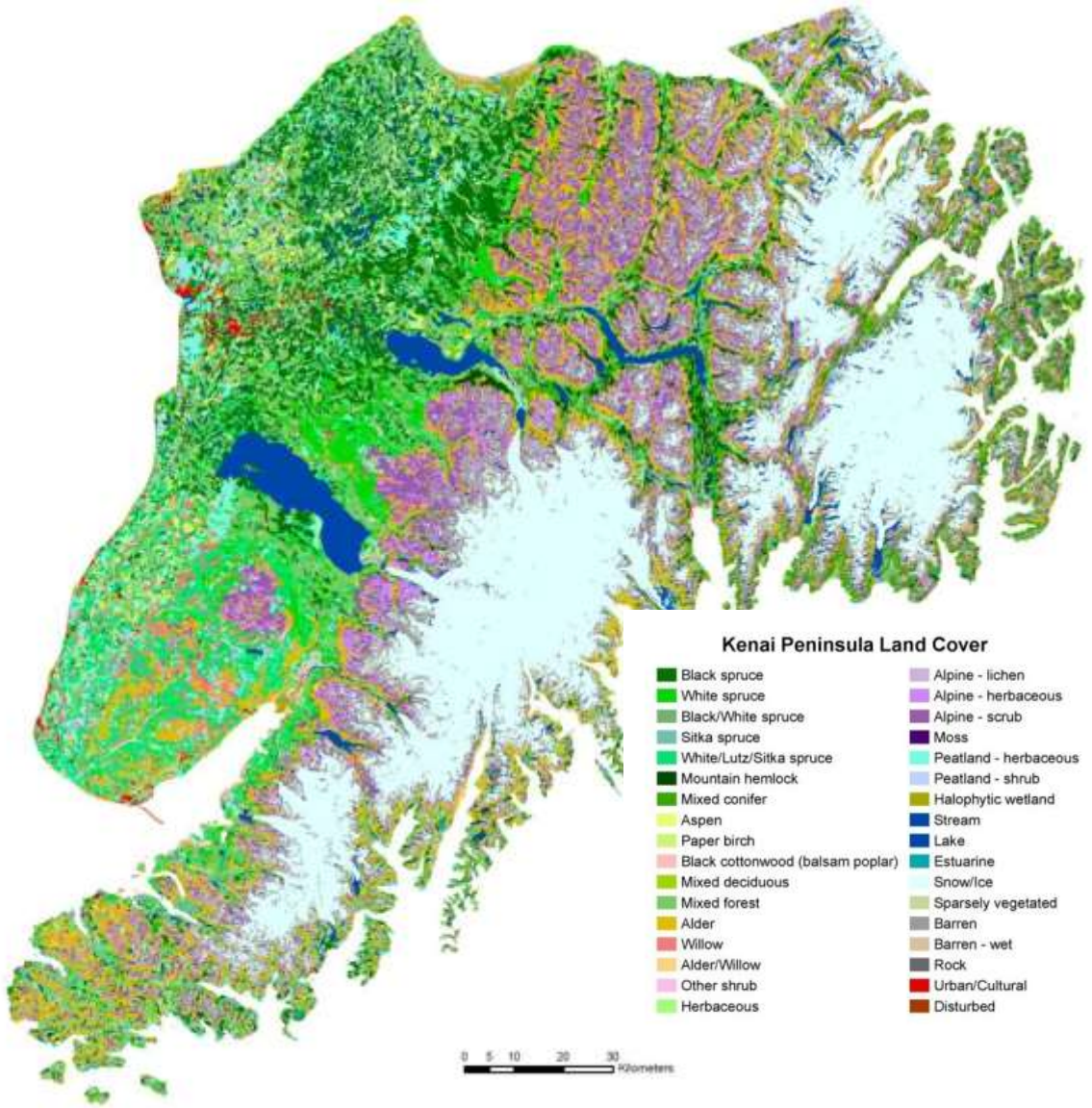
black = black spruce, white = white spruce, and orange = Sitka spruce



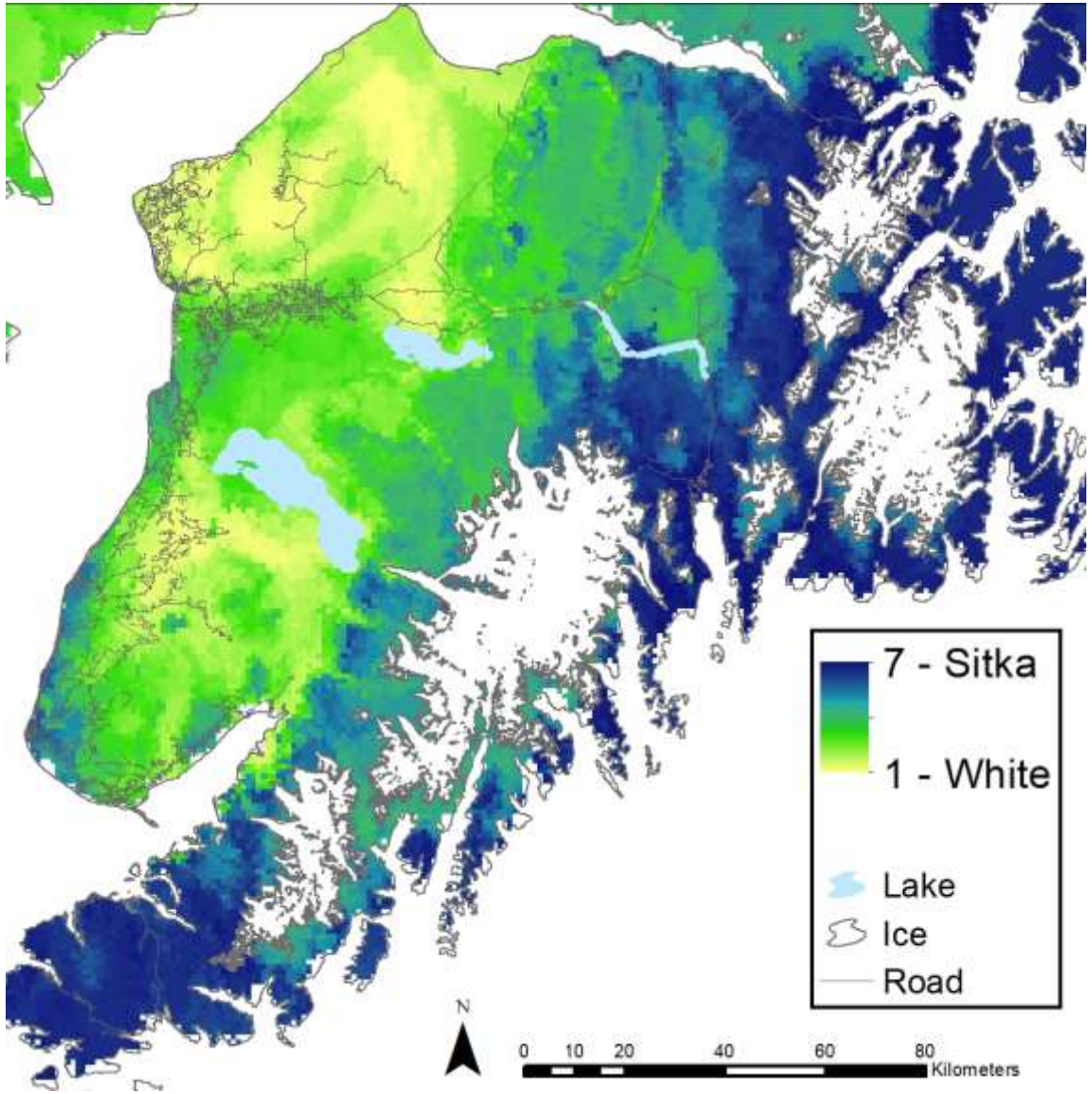
trnT-L **(chloroplast♂)**



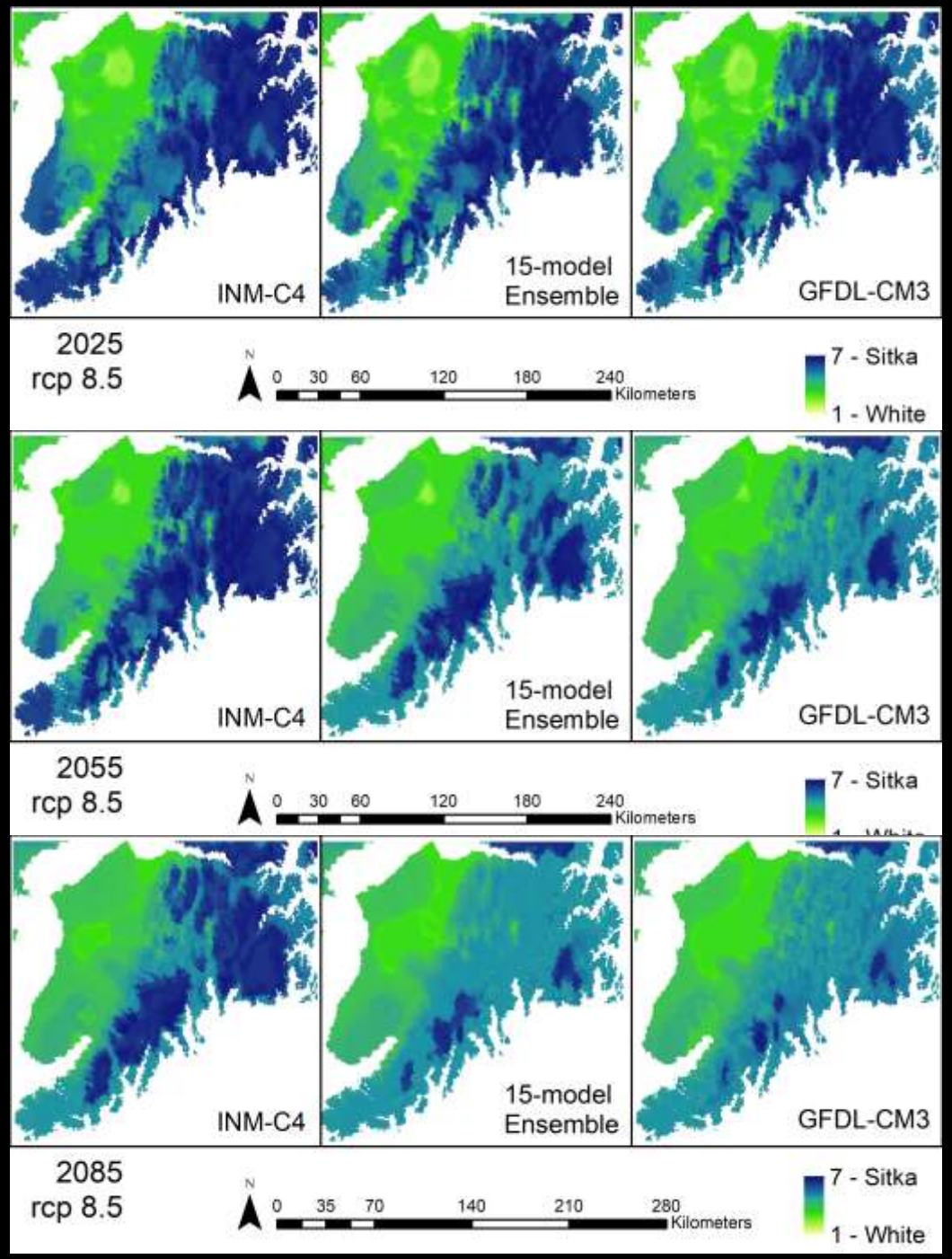
Nad5 **(mitochondrial♀)**



Landcover



Lutz spruce distribution

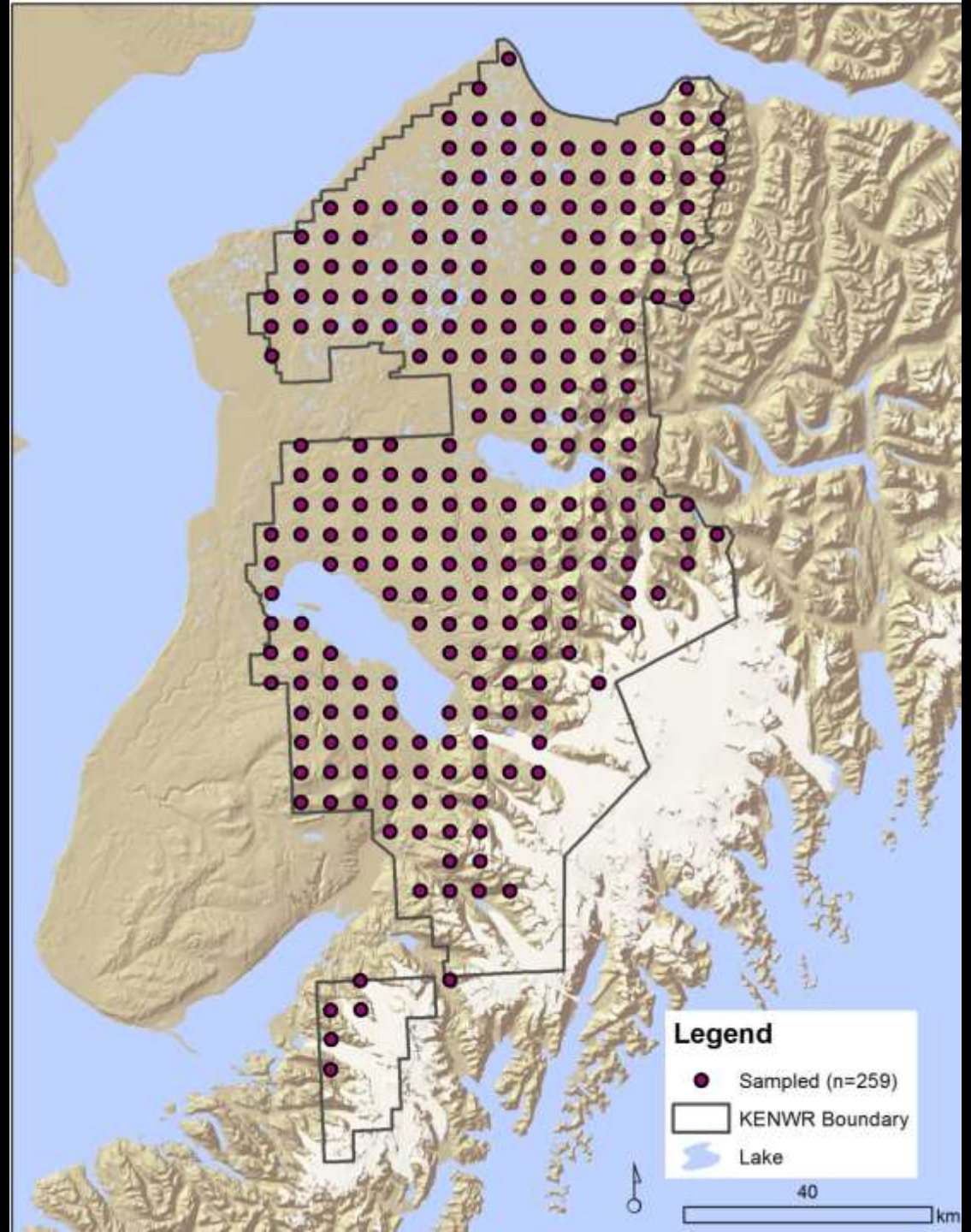


Future

White spruce likely to be extirpated and conditions for Sitka spruce decline

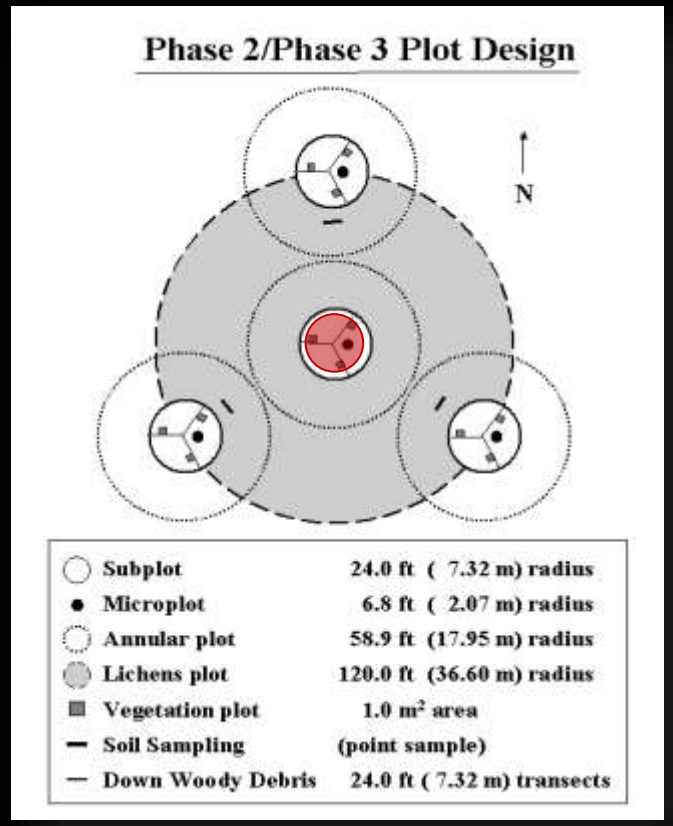
Kenai National Wildlife Refuge's Long Term Ecological Monitoring Program

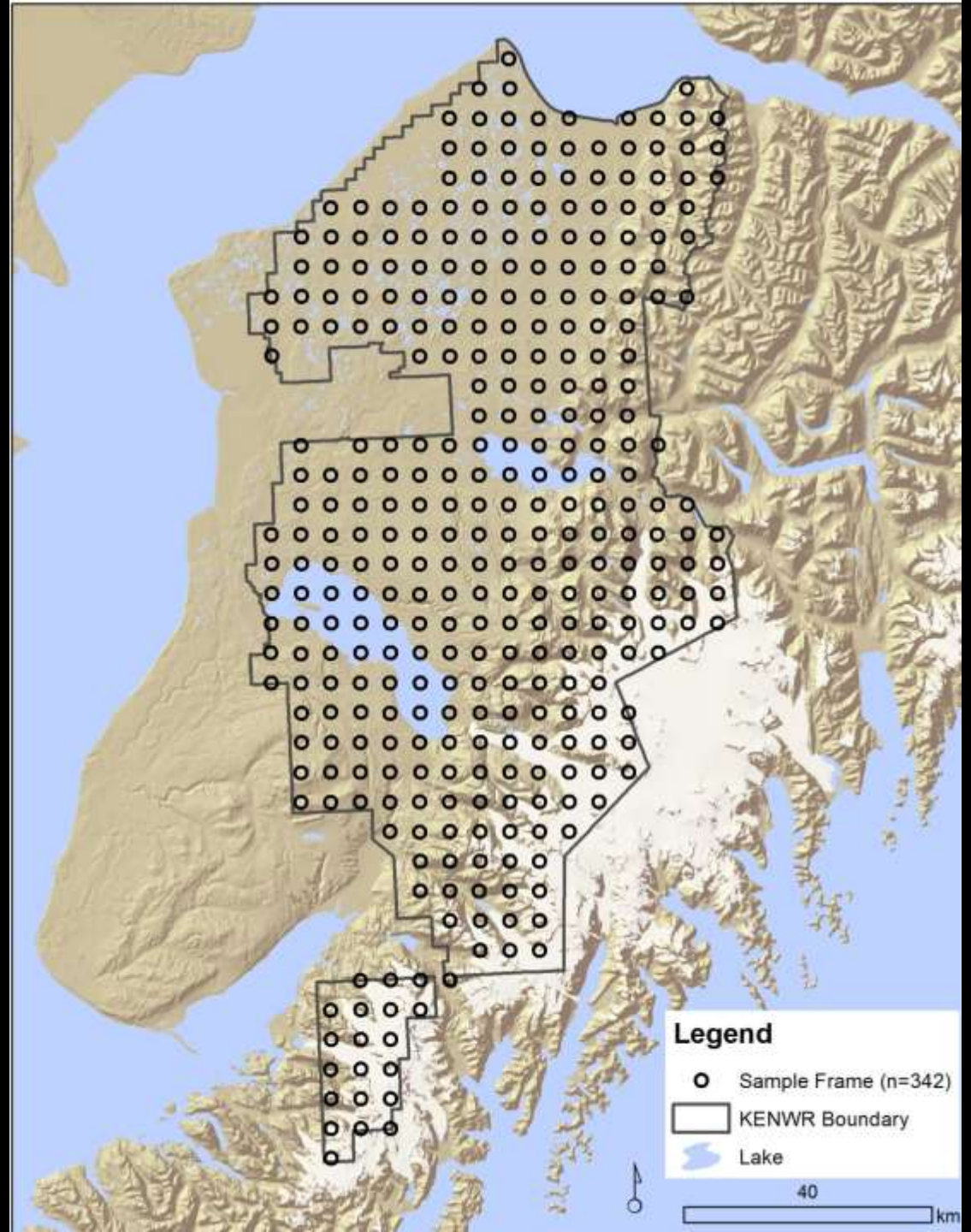
- **Inventory** the co-occurrence and distribution of selected terrestrial floral & faunal species and assemblages
- **Monitor** trends in co-occurrence and distribution of selected terrestrial floral & faunal species and assemblages
- **Model** the effects of physical, biological, and anthropogenic factors on occurrence and distributions



LTEMP

342 permanent plots systematically arrayed at 5-km intervals, of which 259 plots were sampled cooperatively with USDA-FIA





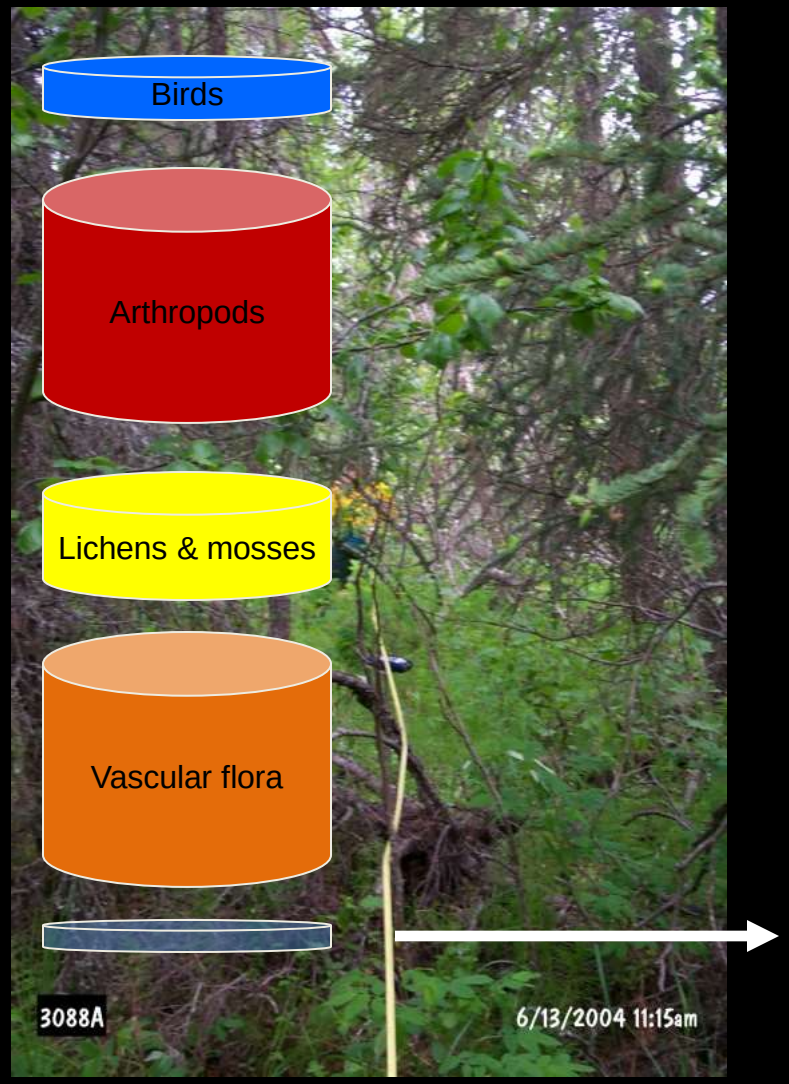
Although regionally scaled, data from LTEMP are representative of Kenai Refuge…

HABITAT	PLOTS (%)	ACRES (%)
Forest	161 (47)	945,896 (48)
conifer	105 (31)	550,996 (28)
deciduous	12 (4)	72,805 (4)
mixed	44 (13)	322,095 (16)
Shrub/grass	26 (7)	141,819 (7)
Barren/sparsely vegetated	59 (17)	329,293 (17)
Wetlands	20 (6)	122,292 (6)
Snow/ice	51 (15)	289,974 (15)
Water	25 (7)	159,242 (8)
$\sum$	342 (100)	1,988,516 (101)

Data collected in 2004, 2006 & 2008

- Vascular (including exotics) & nonvascular flora on nonforested points (modified line intercept)
- Breeding bird densities (VCP)
- Insect relative abundance (sweep nets)
- Heavy metal uptake (Hylocomium)
- Rose galls as disturbance index
- Ambient noise recordings

LTEMP site 3088

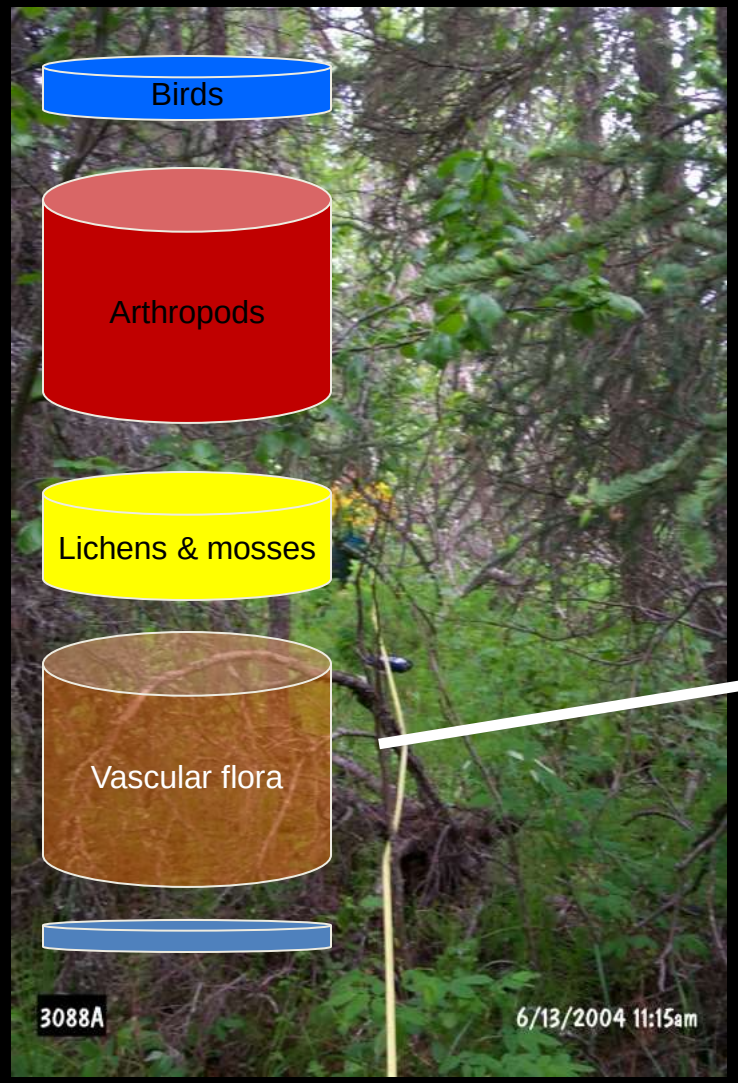


100 m^2

GIS derived data

black spruce (IA2F), 40 years old
elevation = 20 m
patch size = 57 ha
nearest stream = 105 m
nearest road = 2725 m
nearest border = 1119 m
Leq = 46.4 dBa
Rose galls = 0
mean annual temp = 3.2°C
mean annual precip= 433 mm

LTEMP site 3088

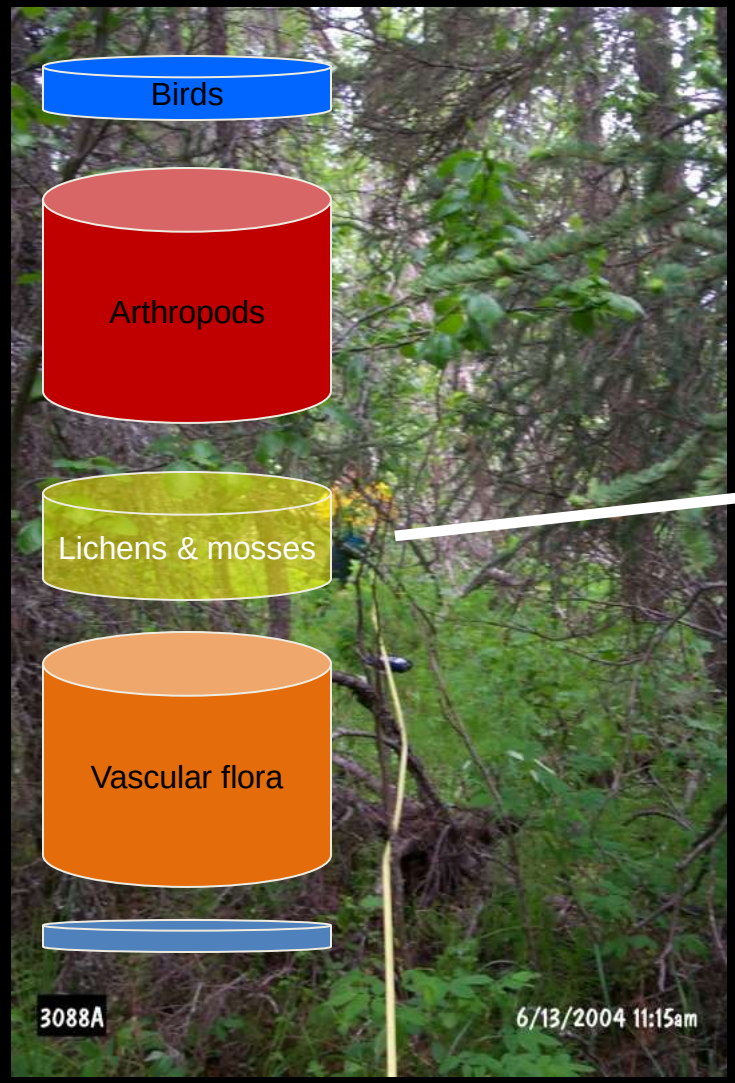


100 m^2

26 species of vascular plants

Alanus incana
Athyruium filiz-femina
Betula nana
Calamagrostis candadensis
Chamerion angustifolium
Cornus canadensis
Dryopteris expansa
Empetrum nigrum
Equisetum sylvaticum
Equisetum arvense
Gymnocarpium dryopteris
Linnaea borealis
Mertensia paniculata
Picea mariana
Pyrola minor
Ribes glandulosum
Ribes hudsonianum
Ribes triste
Rosa acicularis
Rubus arcticus
Saliz pulchra
Sanguisorba candadensis
Spiraea stevenii
Trientalis europaea
Vaccinium uliginosum
Vaccinium vitis-idaea

LTEMP site 3088

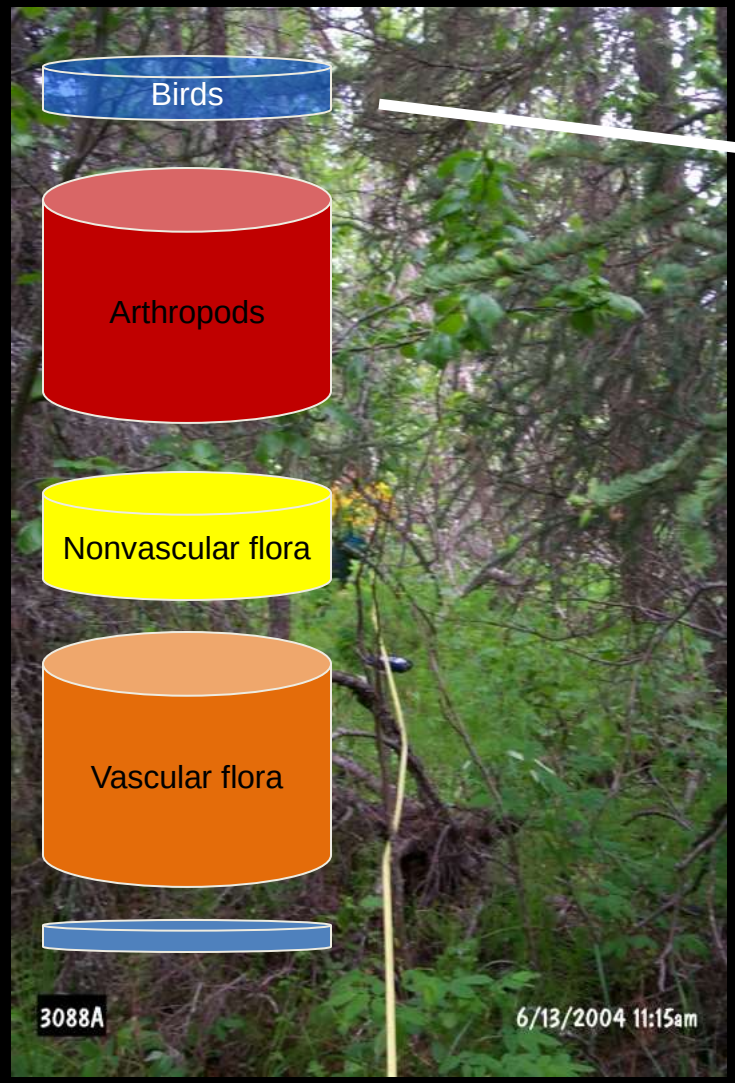


100 m^2

9 lichen & moss species

Ptilidium ciliare
Drepanocladus uncinnatus
Stereocaulon alpinum
Aulacomnium palustre
Cladonia umbricola
Parmelia sulcata
Pleurozium schreberi
Rhizomnium nudum
Brachythecium sp.

LTEMP site 3088

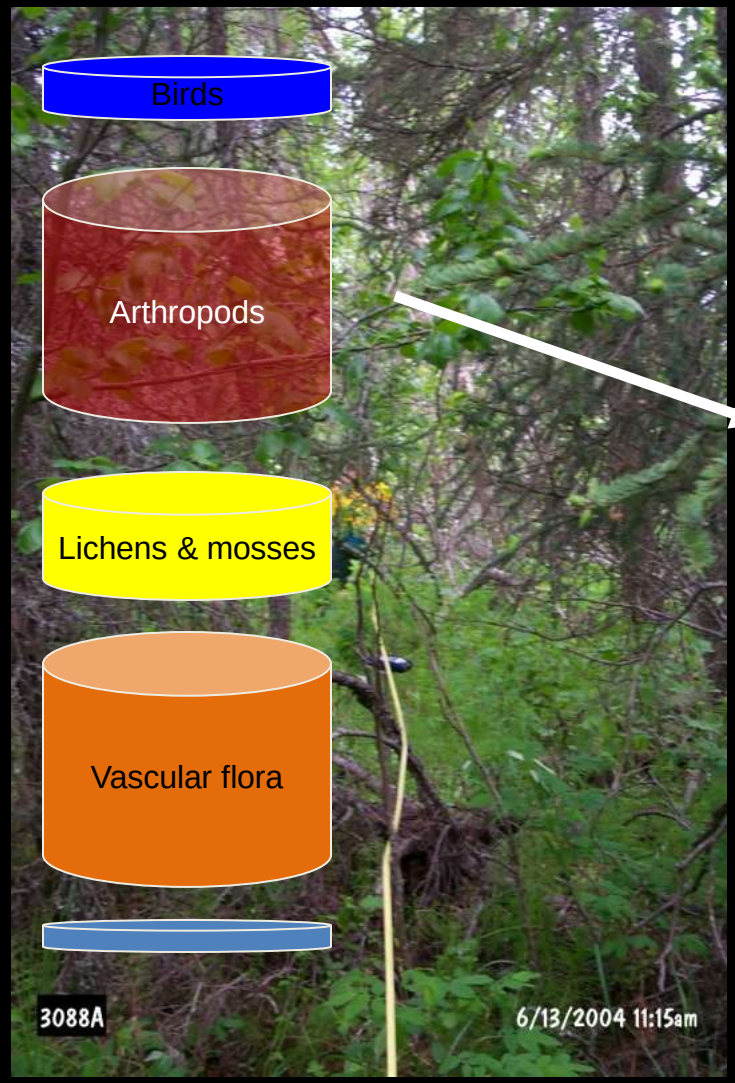


100 m^2

7 bird species

Alder flycatcher
Cliff swallow
Orange crowned warbler
Ruby-crowned kinglet
Swainson's thrush
White-winged crossbill
Wilson's snipe

LTEMP site 3088

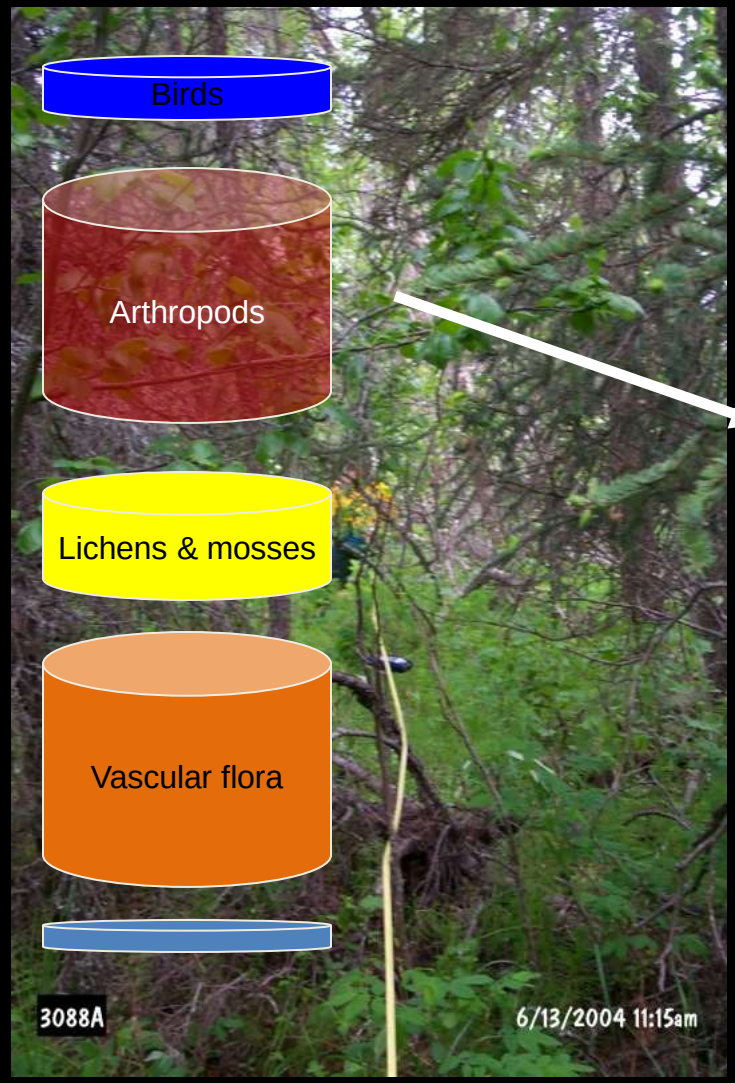


100 m^2

Aphididae
Aphidius
Araneae
Balclutha manitou
Braconidae
Craspedolepta
Culicidae
Diptera
Dismodicus modicus
Ephedrus lacertosus
Euthyneura nr. albipennis
Fannia postica
Fannia serena
Fannia spathiophora
Fannia subpellucens
Hemerobiidae
Ichneumonidae
Javesella pellucida
Lepidoptera
Melanostoma mellinum
Mycetophilidae
Phaenoglyphis kenaii
Podabrini
Sapromyza TAW1 BOLD:AAG6931
Simuliidae
Sminthurus

26 arthropod taxa

LTEMP site 3088



100 m^2

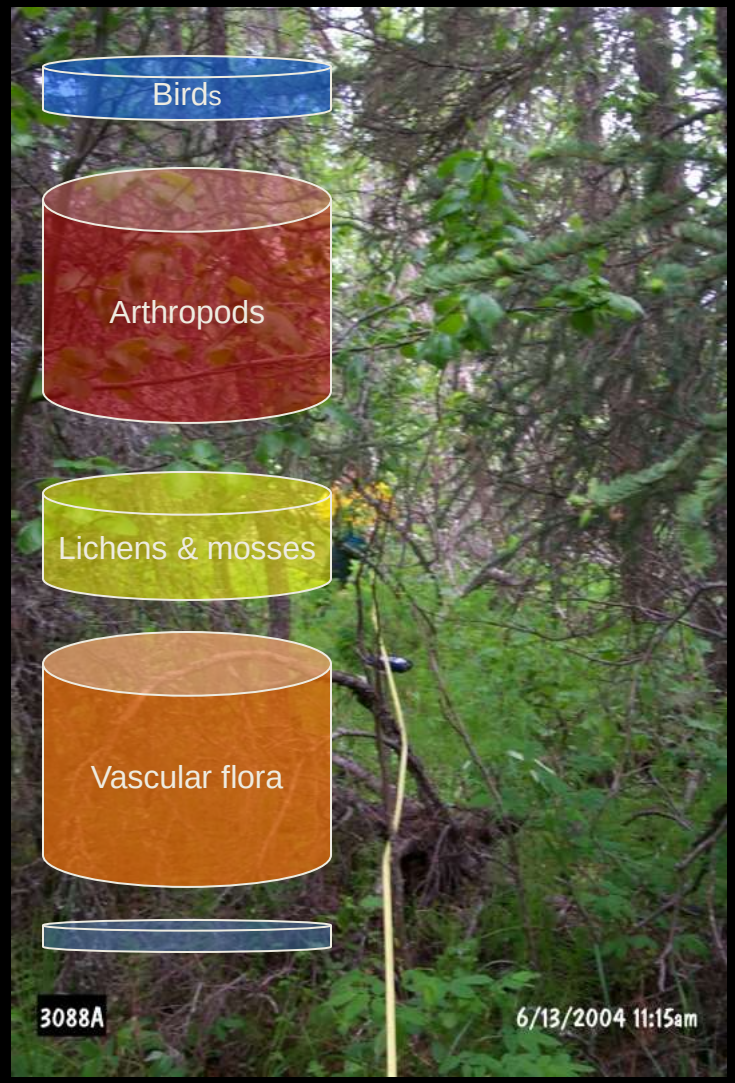
Aphididae
Aphidius
Araneae
Balclutha manitou
Braconidae
Craspedolepta
Culicidae
Diptera
Dismodicus modicus
Ephedrus lacertosus
Euthyneura nr. albipennis
Fannia postica
Fannia serena
Fannia spathiophora
Fannia subpellucens
Hemerobiidae
Ichneumonidae
Javesella pellucida
Lepidoptera
Melanostoma mellinum
Mycetophilidae
Phaenoglyphis kenaii
Podabrini
Sapromyza TAW1 BOLD:AAG6931
Simuliidae
Sminthurus

26 arthropod taxa

Kenai Figitid wasp

saprophitic fly

LTEMP site 3088



100 m^2

Alder flycatcher
Cliff swallow
Orange crowned warbler
Ruby-crowned kinglet
Swainson's thrush
White-winged crossbill
Wilson's snipe

Aphididae
Aphidius
Araneae
Balclutha manitou
Braconidae
Craspedolepta
Culicidae
Diptera
Dismodicus modicus
Ephedrus lacertosus
Euthyneura nr. albipennis
Fannia postica
Fannia serena
Fannia spathiophora
Fannia subpellucens
Hemerobiidae
Ichneumonidae
Javesella pellucida
Lepidoptera
Melanostoma mellinum
Mycetophilidae
Phaenoglyphis kenaii
Podabrini
Sapromyza TAW1 BOLD:AAG6931
Simuliidae
Sminthurus

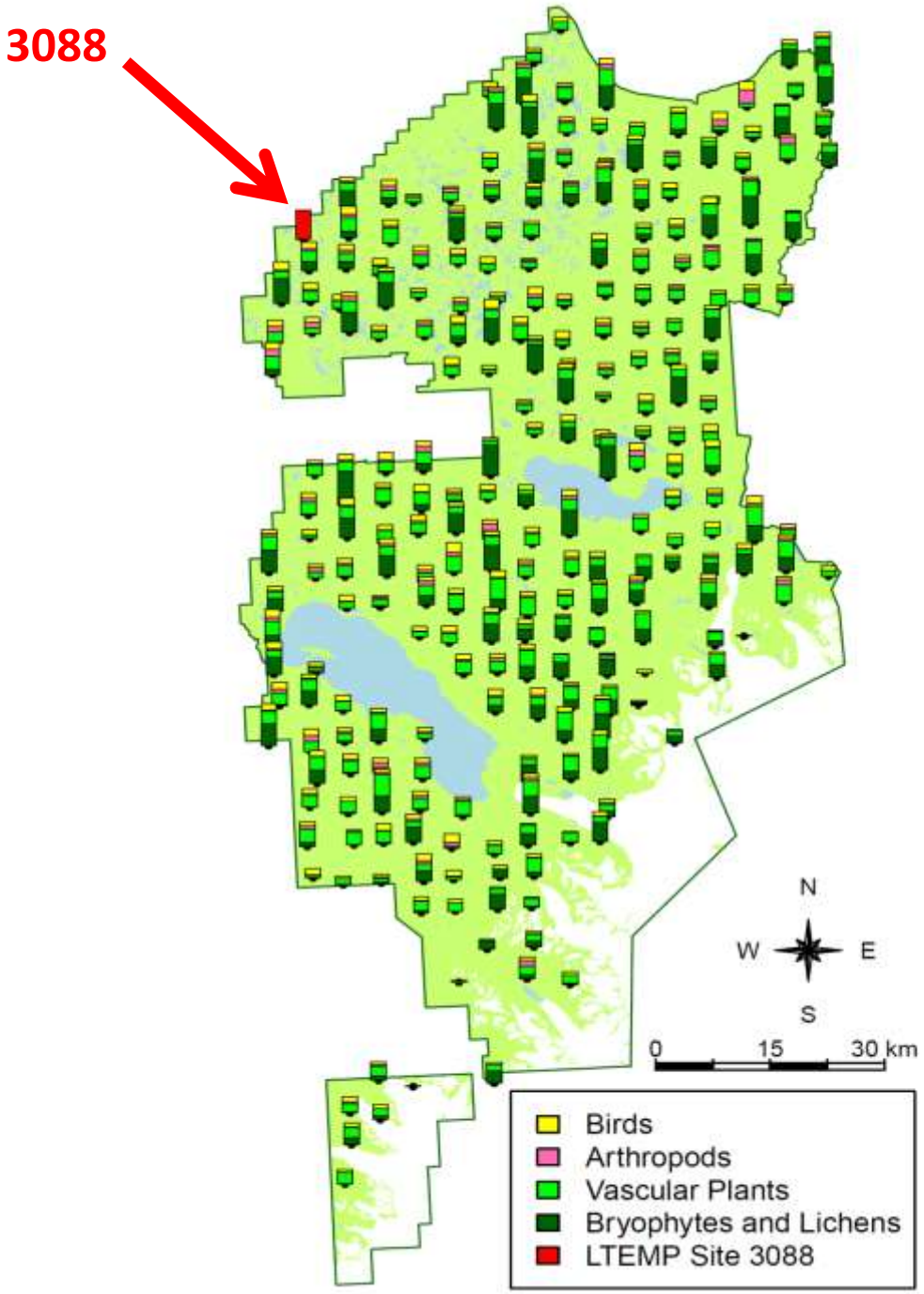
Ptilidium ciliare
Drepanocladus uncinnatus
Stereocaulon alpinum
Aulacomnium palustre
Cladonia umbricola
Pamelia sulcata
Pleurozium schreberi
Rhizomnium nudum
Brachythecium sp.

Alanus incana
Athyruium filiz-femina
Betula nana
Calamagrostis candadensis
Chamerion angustifolium
Cornus canadensis
Dryopteris expansa
Empetrum nigrum
Equisetum sylvaticum
Equisetum arvense
Gymnocarpium dryopteris
Linnaea borealis
Mertensia paniculata
Picea mariana
Pyrola minor
Ribes glandulosum
Ribes hudsonianum
Ribes triste
Rosa acicularis
Rubus arcticus
Saliz pulchra
Sanguisorba candadensis
Spiraea stevenii
Trientalis europaea
Vaccinium uliginosum
Vaccinium vitis-idaea

black spruce (IA2F), 40 years old
elevation = 20 m
patch size = 57 ha
nearest stream = 105 m
nearest road = 2725 m
nearest border = 1119 m
Leq = 46.4 dBa
Rose galls = 0
mean annual temp = 3.2°C
mean annual precip= 433 mm

1,106 species on 259 plots!

- 80 birds
- 256 invertebrates
- 324 vascular plants
- 297 lichens
- 149 bryophytes



1 — 105 species per 100m^2 plot with mean = 41

Taxonomic Impediment

>15,000 specimens collected on 259 plots but only 256 species identified over 8 years

Identification by morphology or Sanger sequencing for cryptic species is impractical for monitoring

Bulk sampling (< $100) using metagenomics or metabarcoding

AATAATATATTTTATTTTCGCTATATGATCAGGAATAATTGGTTC
ATCTATAAGATTATTAATTCGAATAGAATTAAGTCATCCTGGAAT
ATGAATTAATAATGATCAGATTTATAATTCTTTAGTAACTAGACA
CGCATTTTTAATAATTTTTTTTATAGTTATACCATTTATAATTGGA
GGATTTGGAAATTATTTAATTCCATTAATATTAGGATCGCCAGA
TATAGCTTTTCCTCGAATAAATAATATTAGATTTTGACTTTTACC
CCCATCATTATTTATACTTCTATTAAGAAATATATTTACACCTAAT
GTAGGAACAGGATGAACTGTATATCCTCCTTTATCCTCTTATTT
ATTTCATTCATCTCCATCAATTGATATTGCAATCTTTTCTTTACAT
ATGTCAGGAATTTCTTCTATTATTGGATCATTAAATTTTATTGTT
ACTATTTTAATAATAAAAAATCTTTCATTAAATTATGACCAAATT
AATTTATTCTCATGATCAGTATGTATTACTGTAATTTTATTAATTT
TATCTTTACCGGTTTTAGCCGGAGCTATTACTATATTACTATTCG
ATCGAAATTTTAATACTTCATTCTTTGATCCTATGGGAGGAGG
GGATCCAATTTTATACCAACATTTATTT

http://arctos.database.museum/guid/KNWR:Ento:2800

Western bumble bee
(*Bombus occidentalis*)

Article

« Previous TOC Next »

Building a DNA barcode library of Alaska's non-marine arthropods

Derek S Sikes, Matthew Bowser, John M. Morton, Casey Bickford, Sarah Meierotto, Kyndall Hildebrandt

PDF (1095 K)

PDF-Plus (600 K)

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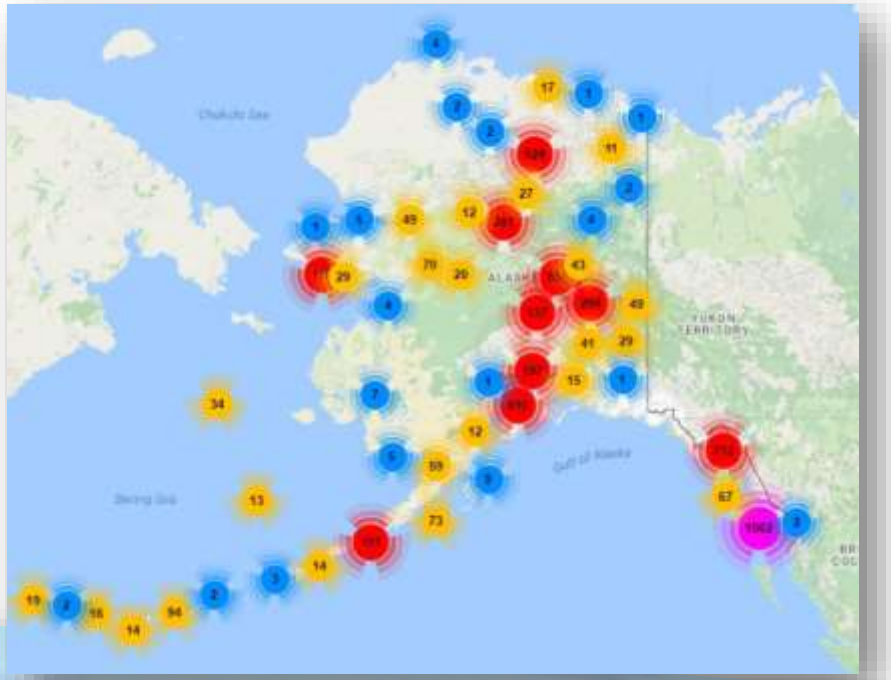
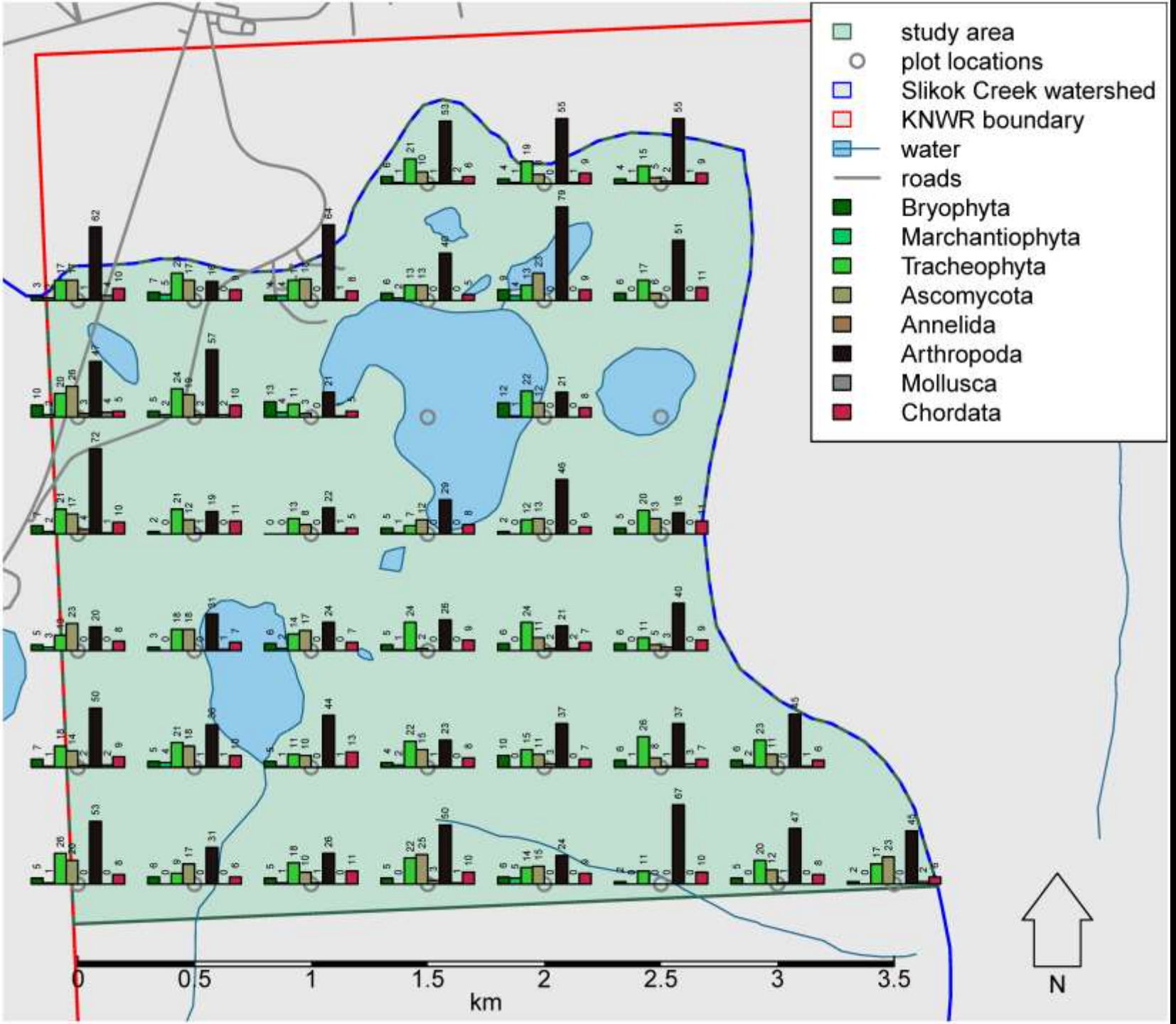
Genome, 10.1139/gen-2015-0203

ABSTRACT

Climate change may result in ecological futures with novel species assemblages, trophic mismatch, and mass extinction. Alaska has a limited taxonomic workforce to address these changes. We are building a DNA barcode library to facilitate a metabarcoding approach to monitoring non-marine arthropods. Working with the Canadian Centre for DNA Barcoding, we obtained DNA barcodes from recently collected and authoritatively identified specimens in the University of Alaska Museum Insect Collection and the Kenai National Wildlife Refuge collection. We submitted tissues from 4,776 specimens, of which 81% yielded DNA barcodes representing 1,662 species and 1,788 BINs, of primarily terrestrial, large-bodied arthropods. This represents 84% of the species available for DNA barcoding in the UAM Insect Collection. There are now 4,020 Alaskan arthropod species represented by DNA barcodes, after including all records in BOLD of species that occur in Alaska – i.e. 48.5% of the 8,277 Alaskan, non-marine-arthropod, named species have associated DNA barcodes. An assessment of the identification power of the library in its current state yielded fewer species-level identifications than expected, but the results were not discouraging. We believe we are the first to deliberately begin development of a DNA barcode library of the entire arthropod fauna for a North American state or province. Although far from complete, this library will become increasingly valuable as more species are added and costs to obtain DNA sequences fall.



50% of 8,421 terrestrial arthropod species known from Alaska now barcoded!



Biodiversity Data Journal 8: e50124
doi: 10.3897/BDJ.8.e50124

Research Article

Towards conserving natural diversity: A biotic inventory by observations, specimens, DNA barcoding and high-throughput sequencing methods

Matthew Lewis Bowser[1], Rebekah Brassfield[2], Annie Dziarpowski[3], Todd Eskelin[1], Jennifer Hester[4], Dawn Robin Magness[5], Mariah McInnis[6], Tracy Melvin[6], John M. Morton[7], Joel Storie[8]

[1] U.S. Fish & Wildlife Service, Kenai National Wildlife Refuge, Soldotna, Alaska, United States of America
[2] Sabal Analytical Colleges, Public Members, Homer, Alaska, United States of America
[3] U.S. Fish & Wildlife Service, North Florida Ecological Services Office, Jacksonville, Florida, United States of America
[4] City of Soldotna, Planning and Zoning Commission, Soldotna, Alaska, United States of America
[5] Auburn University, School of Forestry & Wildlife Sciences, Auburn, Alabama, United States of America
[6] Michigan State University, College of Agriculture & Natural Resources, Department of Fisheries and Wildlife, East Lansing, Michigan, United States of America
[7] U.S. Fish & Wildlife Service (retired), Soldotna, Alaska, United States of America
[8] University of Alaska Fairbanks, Fairbanks, Alaska, United States of America

Corresponding author: Matthew Lewis Bowser (matt_bowser@fws.gov)

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Abstract

The Kenai National Wildlife Refuge has been given a broad conservation mandate to conserve natural diversity. A prerequisite for fulfilling this purpose is to be able to identify the species and communities that make up that biodiversity.

We tested a set of varied methods for inventory and monitoring of plants, birds and terrestrial invertebrates on a grid of 40 sites in a 938 ha study area in the Slikok Creek watershed, Kenai Peninsula, Alaska. We sampled plants and lichens through observation and specimen-based methods. We surveyed birds using bird call surveys on variable

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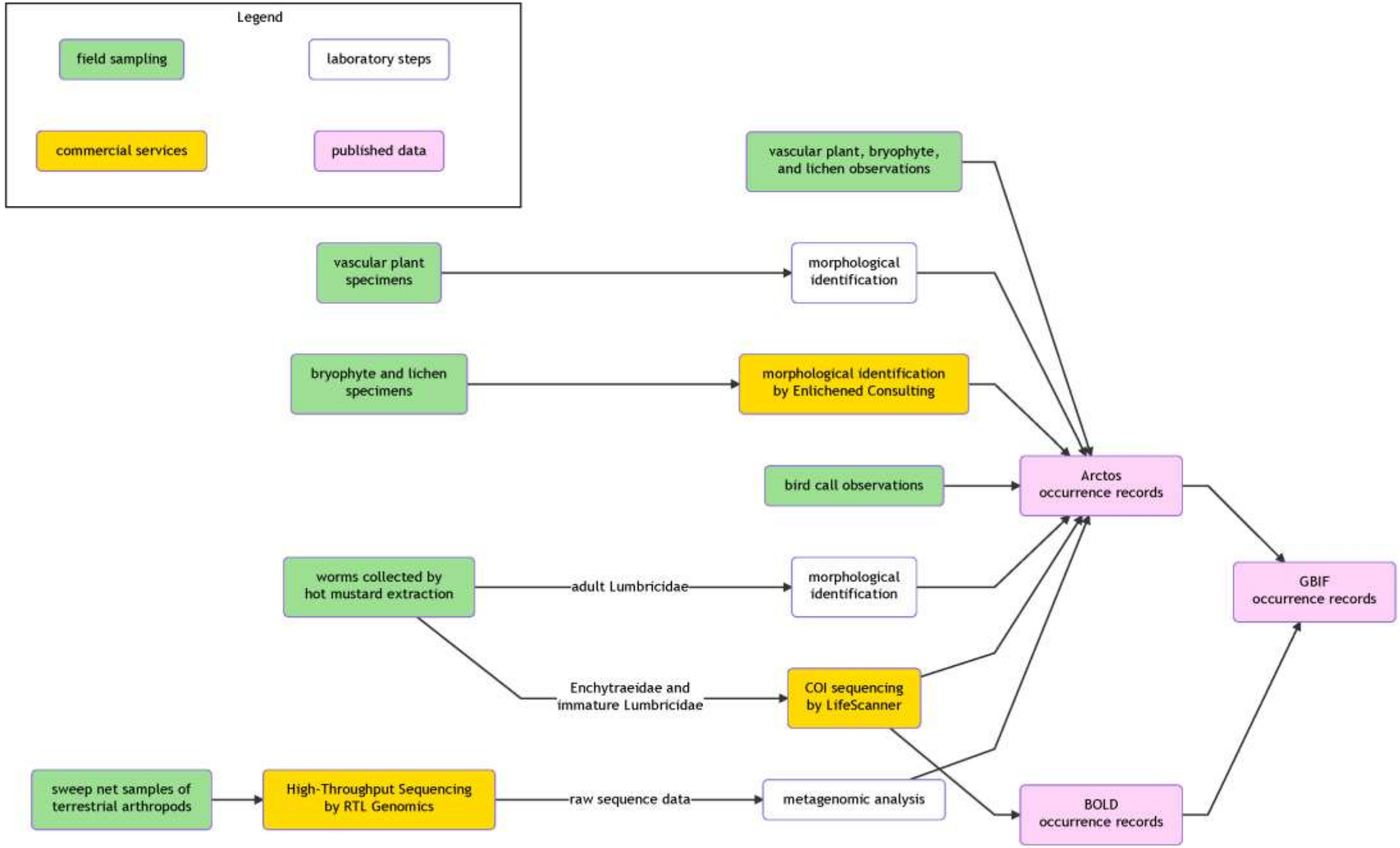
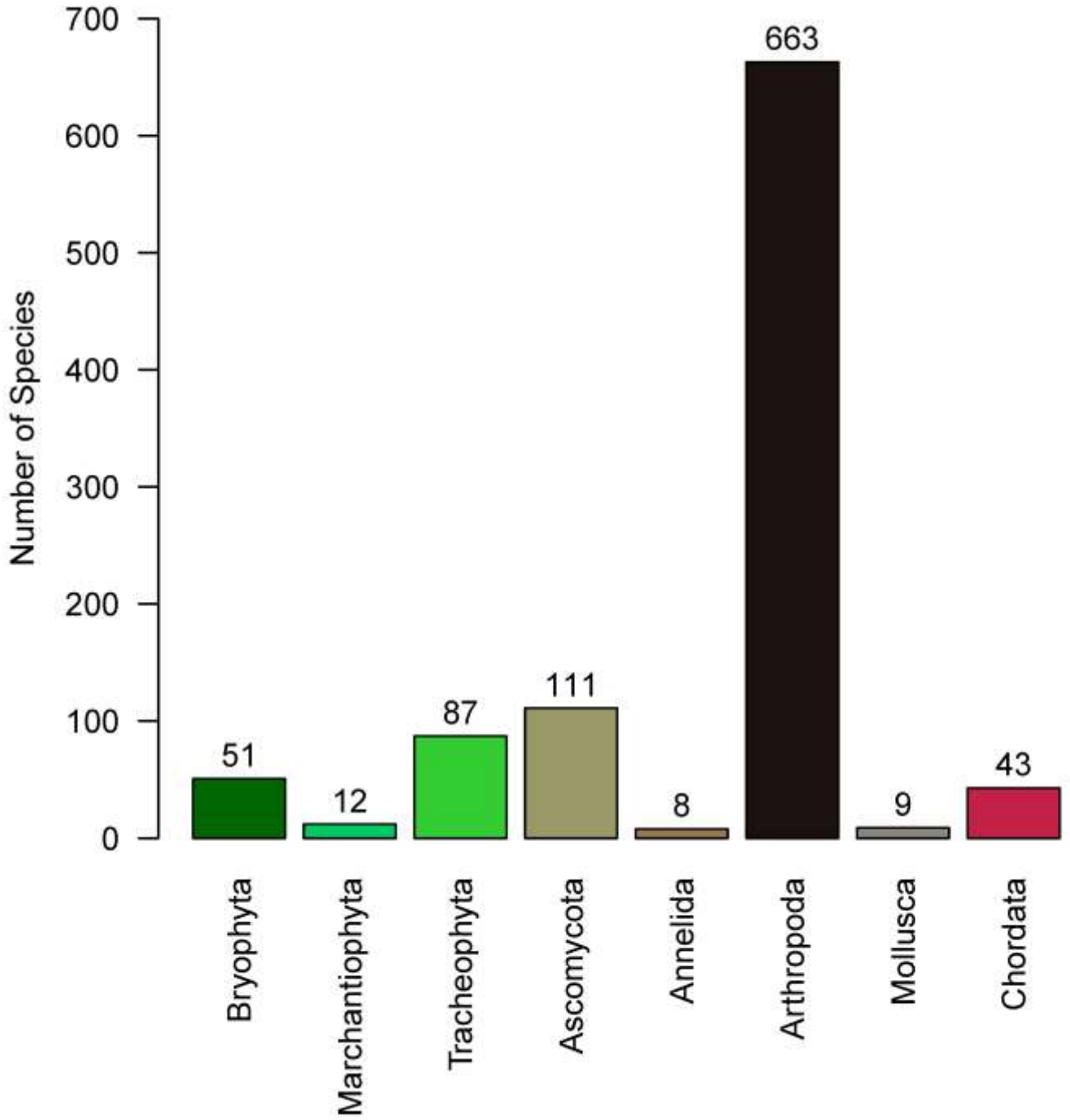
40 sites 500 meters apart on 2300 acres


Legend
field sampling
laboratory steps
commercial services
published data
vascular plant, bryophyte, and lichen observations
vascular plant specimens
morphological identification
bryophyte and lichen specimens
morphological identification by Enlichened Consulting
bird call observations
Arctos occurrence records
GBIF occurrence records
worms collected by hot mustard extraction
adult Lumbricidae
morphological identification
Enchytraeidae and immature Lumbricidae
COI sequencing by LifeScanner
sweep net samples of terrestrial arthropods
High-Throughput Sequencing by RTL Genomics
raw sequence data
metagenomic analysis
BOLD occurrence records



4,764 occurrences of 984 species and molecular operational taxonomic units:

- **87 vascular plants**
- **51 mosses**
- **12 liverworts**
- **111 lichens**
- **43 vertebrates**
- **663 arthropods**
- **9 molluscs**
- **8 annelid worm**

102 arthropod species new records for Alaska!

Inventorying species richness

The current list is 2251 species, including 2140 native, 116 non-native, 1 vagrant, and 3 of uncertain origin

Questions?