

Modeling the Acoustic Footprint of Human-made Noise in an Alaskan Wilderness

Timothy C. Mullet¹

Stuart H. Gage²

Falk Huettmann¹

John M. Morton³

¹EWHALE Lab, Biology & Wildlife Dept, University of Alaska Fairbanks

²Dept of Entomology, Michigan State University

³Kenai National Wildlife Refuge, US Fish and Wildlife Service

The Wilderness Act of 1964

- Intended to preserve areas of the US in their natural condition
- Unaffected by:
 - Population growth
 - Urban sprawl
 - Mechanization



Wilderness Definition

- Four distinct characteristics:
 1. **Untrammeled** – not manipulated by man
 2. **Undeveloped** – no buildings, trails, or roads
 3. **Natural** – natural processes are unimpeded
 4. **Outstanding Opportunities for Solitude & Unrestricted Recreation** – human experience of wilderness

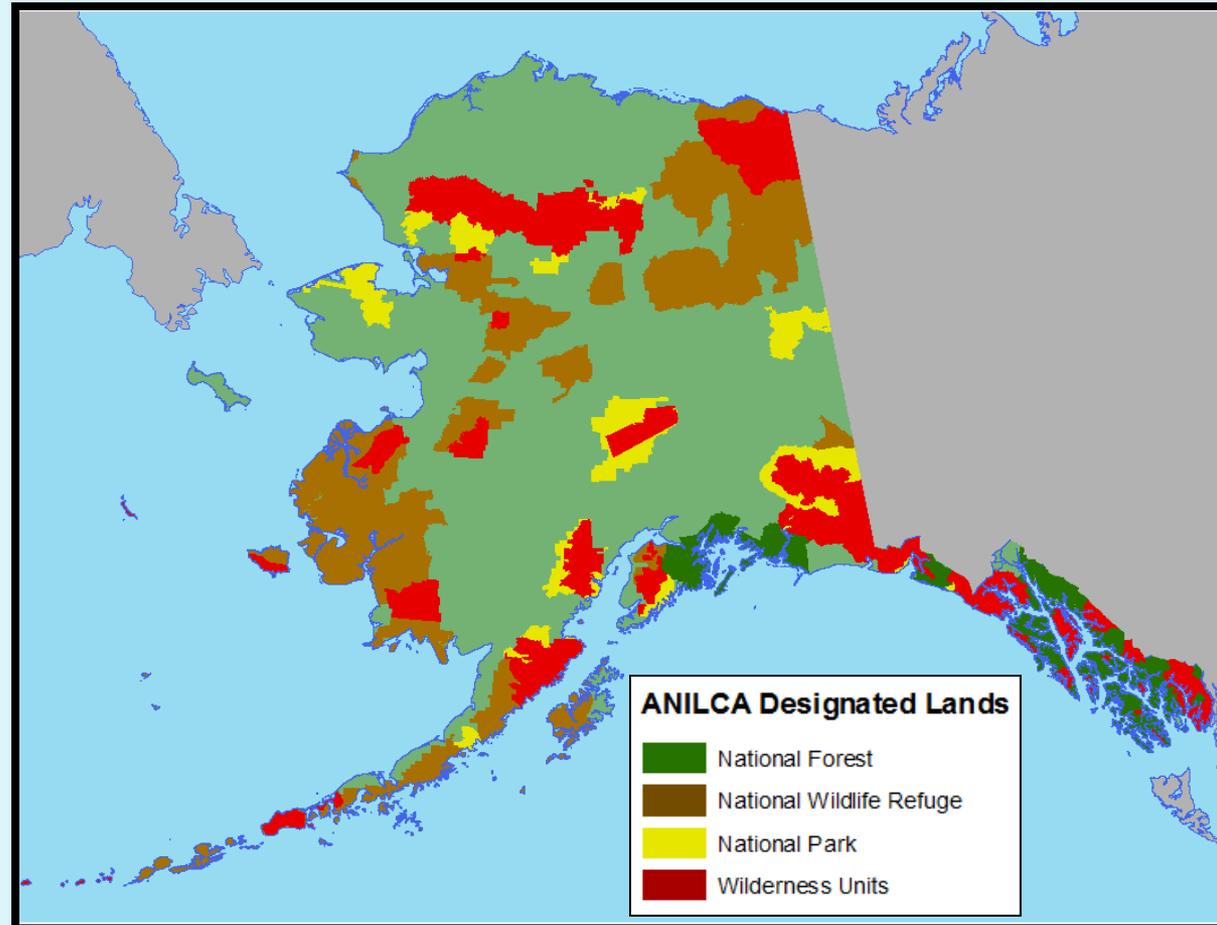
Sound is Important to Wilderness

- Sound serves natural processes
- Noise is known to affect:
 - Animal behavior
 - Community composition
 - Species diversity
 - Human health
 - Perception of Wilderness
- **Is Alaskan Wilderness an Acoustic Refuge?**



Alaska National Interest Lands Conservation Act (ANILCA)

- Signed in 1980
- Set aside:
 - 13 National Parks
 - 17 Wildlife Refuges
 - 5 National Forests
- 420,000 km²
- ½ Designated as Wilderness



ANILCA: Provisions for Access

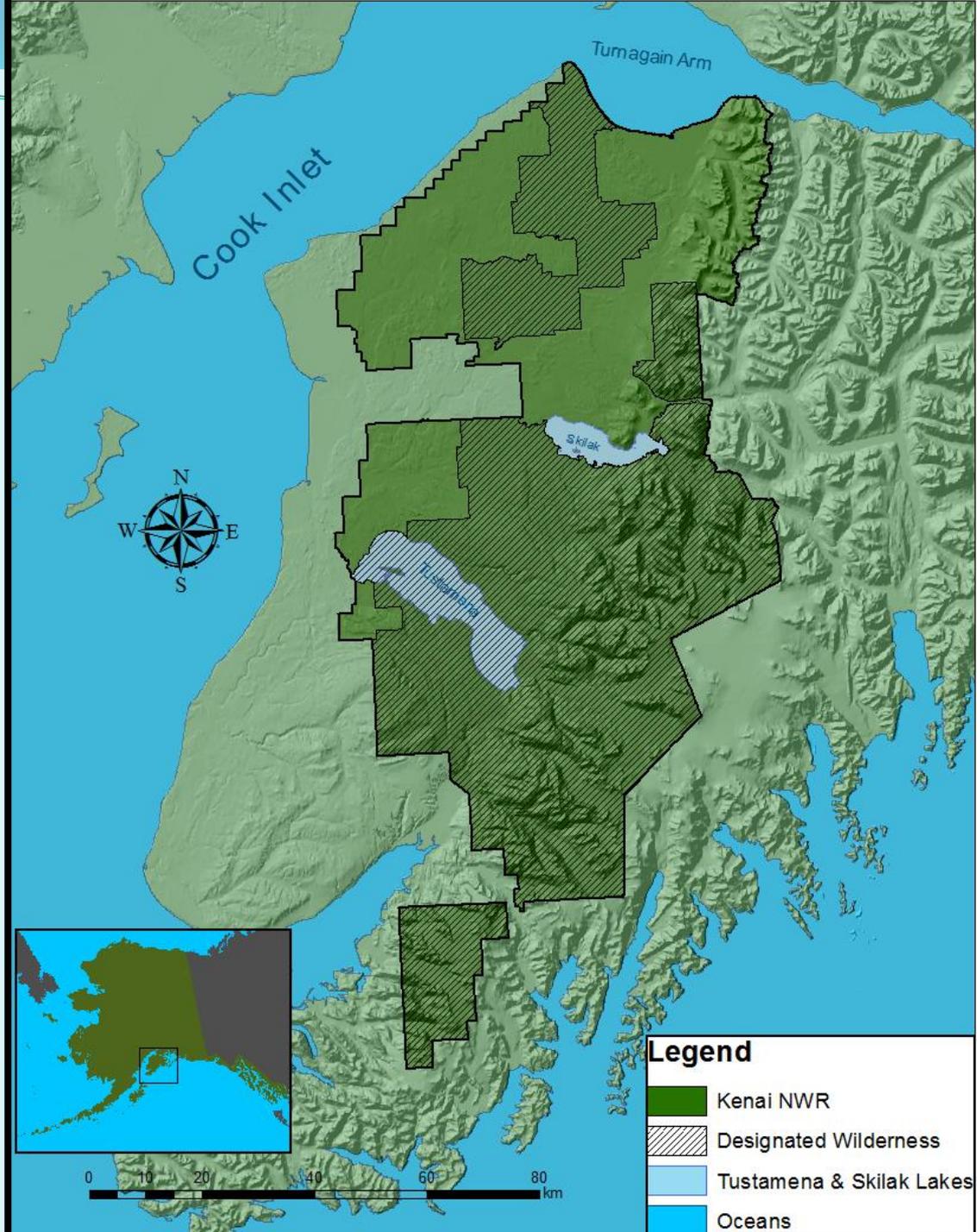
Section 1110(a)

- Allows motorized access for **“Traditional Activities”** by:
 - *Snowmobile*
 - *Motorboat*
 - *Fixed-wing Aircraft*
- Includes Wilderness areas
- Overwrites Wilderness Act
- Degrades Wilderness Character?



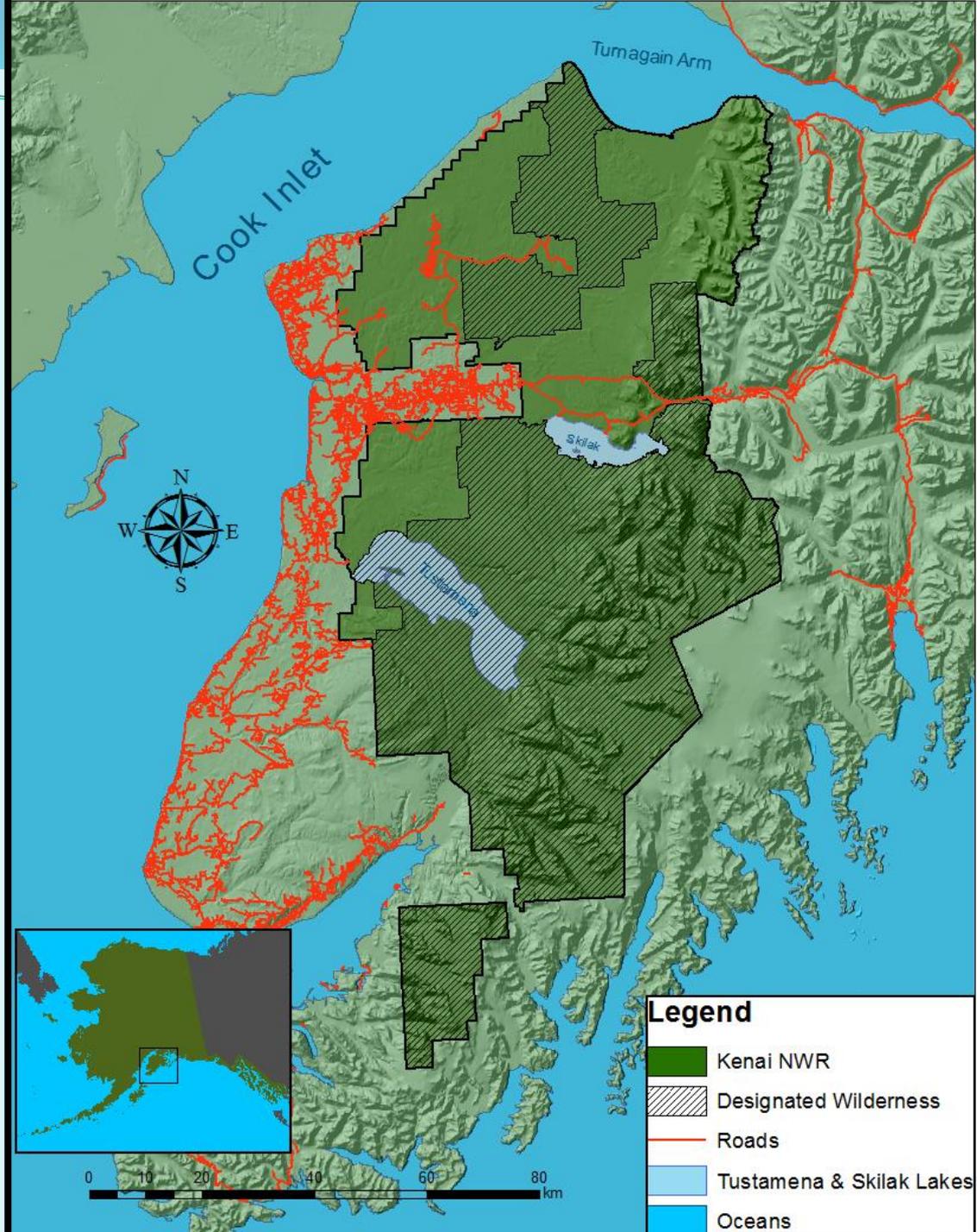
Kenai NWR

- 8,000 km²
- 5,250 km² of Wilderness
- 1 million visitors/yr



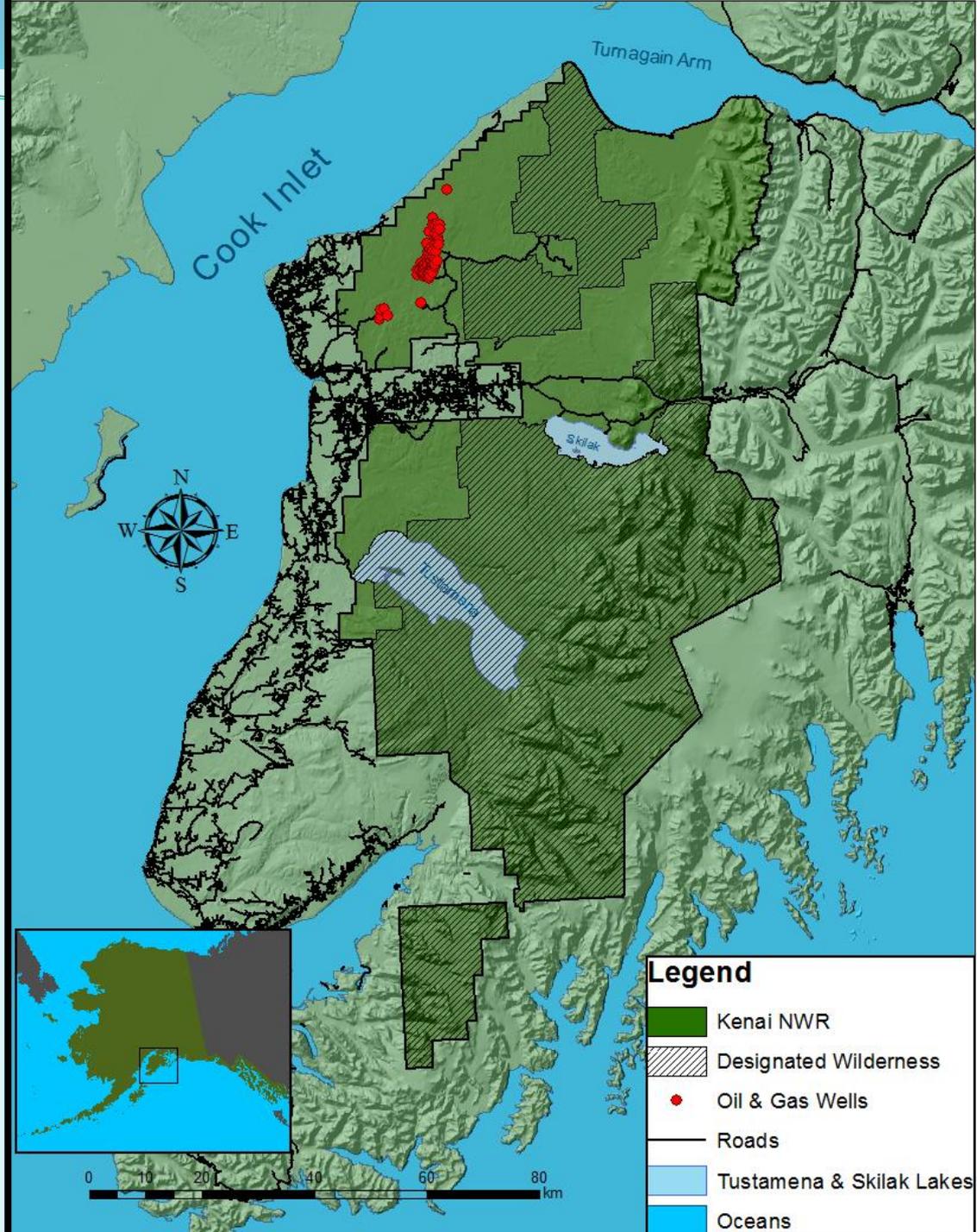
Kenai NWR

- 8,000 km²
- 5,250 km² of Wilderness
- 1 million visitors/yr
- Urban interface
- Intersecting highway



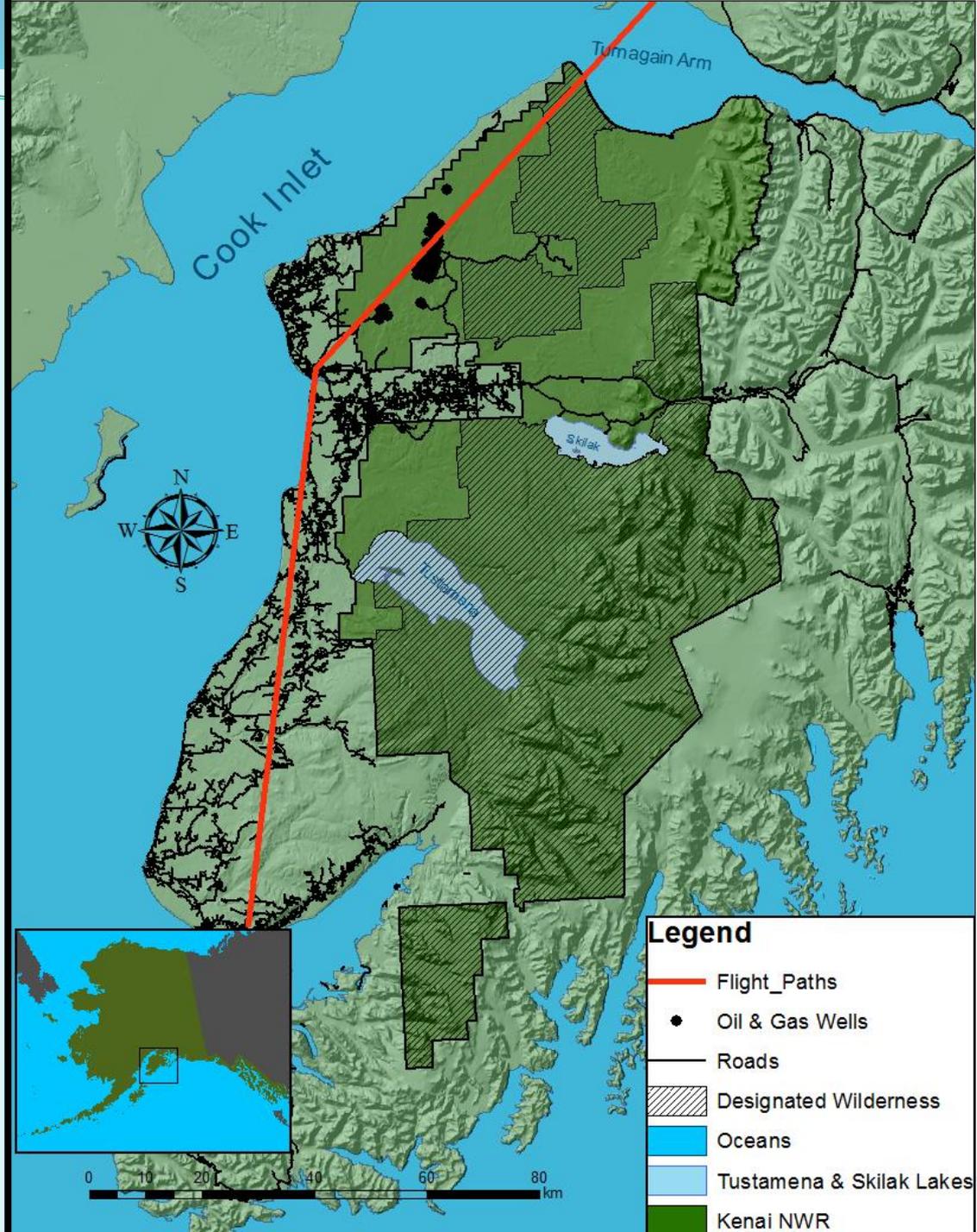
Kenai NWR

- 8,000 km²
- 5,250 km² of Wilderness
- 1 million visitors/yr
- Urban interface
- Intersecting highway
- Oil & gas development



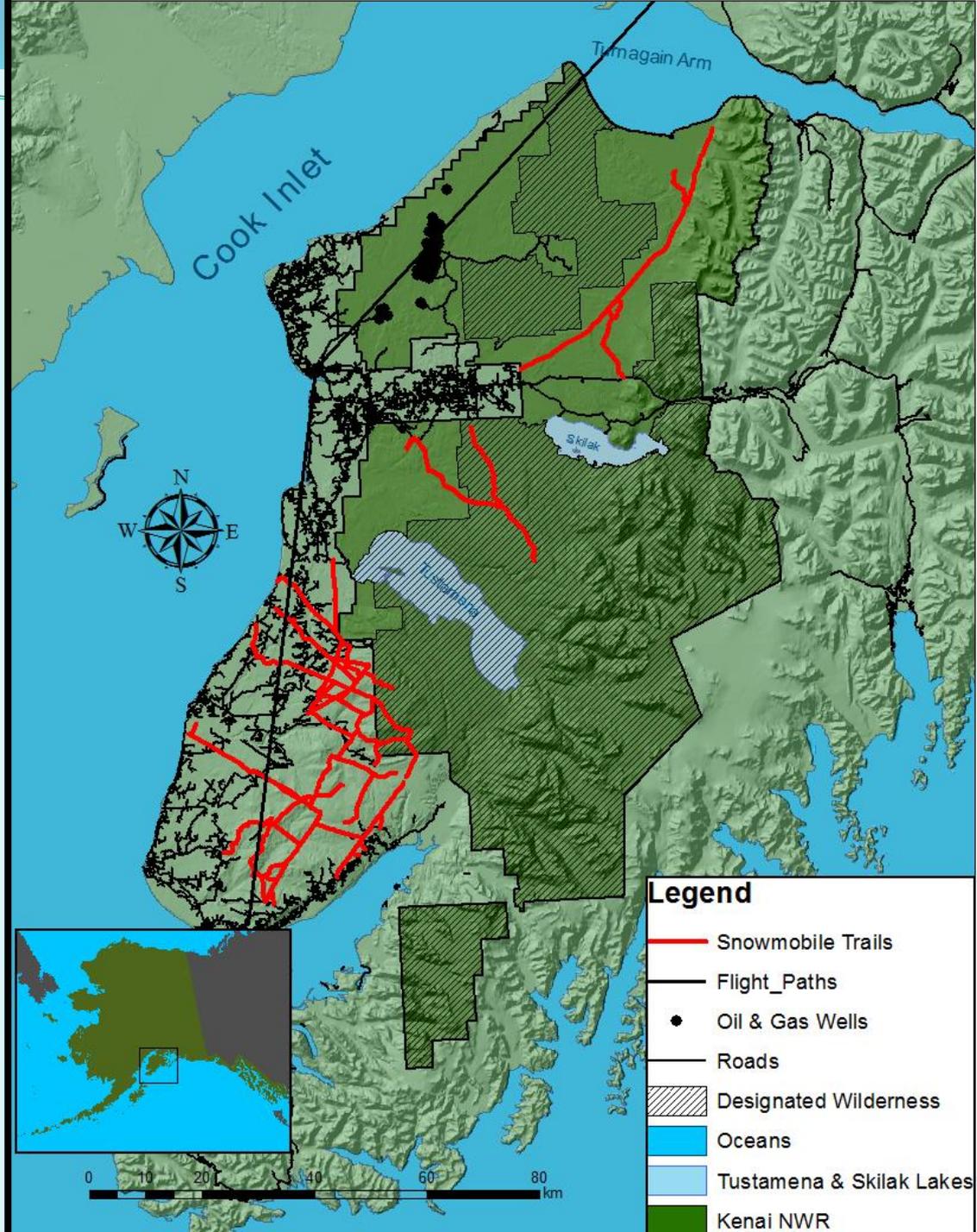
Kenai NWR

- 8,000 km²
- 5,250 km² of Wilderness
- 1 million visitors/yr
- Urban interface
- Intersecting highway
- Oil & gas development
- Major flyway



Kenai NWR

- 8,000 km²
- 5,250 km² of Wilderness
- 1 million visitors/yr
- Urban interface
- Intersecting highway
- Oil & gas development
- Major flyway
- Snowmobiling



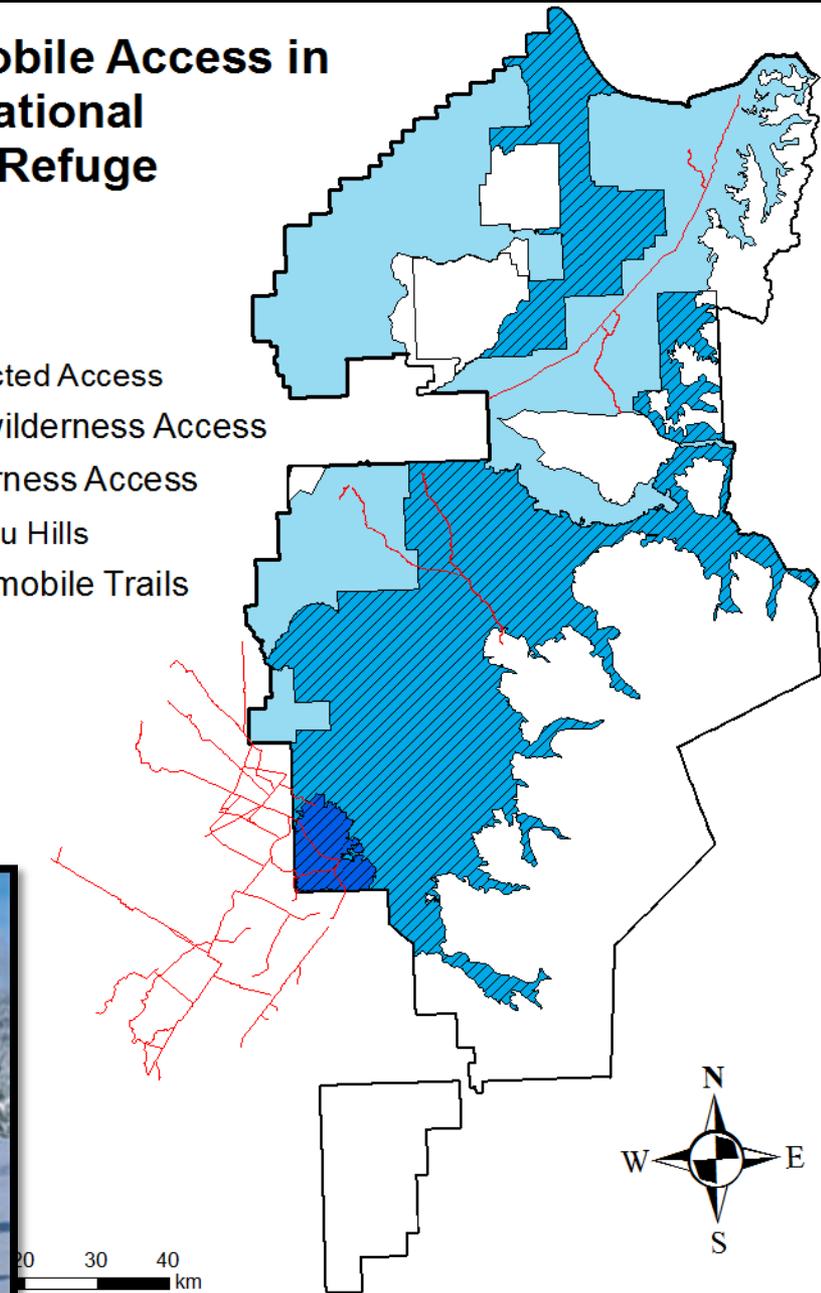
Snowmobiling in Kenai Wilderness

- Noticeable increase over last 10 yrs
- Restricted to lowlands and Caribou Hills (Dec – Apr)
- 12+ trails used for access
- Free-range over 2,500 km²

Snowmobile Access in Kenai National Wildlife Refuge

Legend

- ◻ Restricted Access
- ◻ Non-wilderness Access
- ▨ Wilderness Access
- ▨ Caribou Hills
- Snowmobile Trails



Winter Soundscapes

- 3 recognized soundscape components:
 - Biophony + Anthrophony + Geophony
- Winter is a time of low biological activity and intermittent geophony
- Natural Quiet is prevalent in Winter
- Anthrophony changes composition of Winter's Natural Soundscapes



Free-range of airplanes and snowmobiles in wilderness begs the question:

What is the spatial extent of human-made noise in Kenai Wilderness?

Objectives:

1. Sample the acoustic composition of the soundscape
2. Identify human-made noise sources in wilderness
3. Model and quantify the spatial extent of human-made noise

Sampling the Soundscape

- 37 non-wilderness areas
- 25 wilderness areas
- Dec 2011 to Apr 2012
- Wildlife Acoustics SM2 sound recorders
- Recorded 1 min/30 min
- 22 kHz sample rate

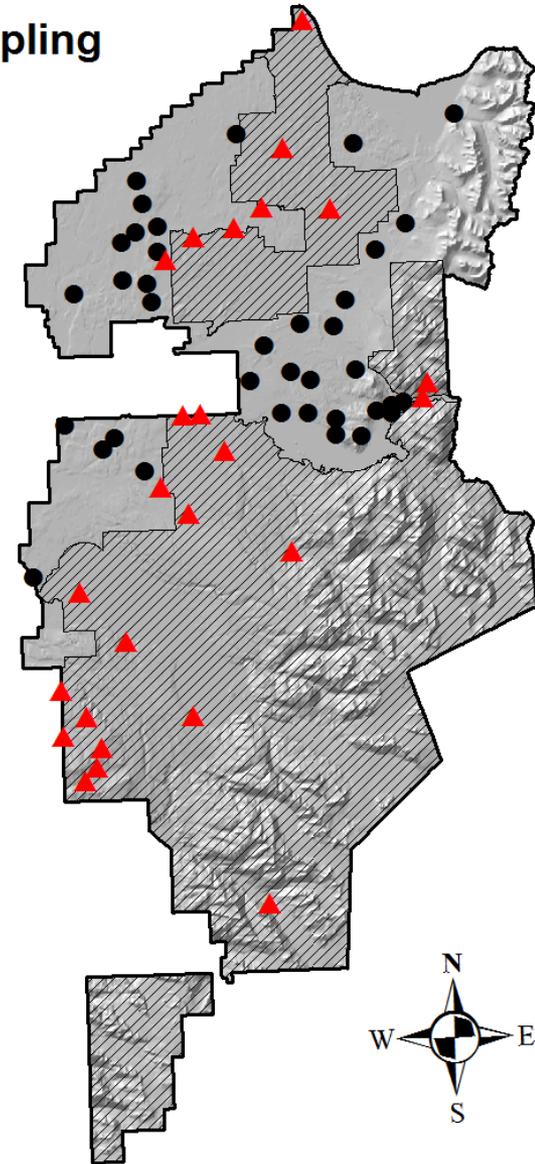


Soundscape Sampling Distribution

Legend

Designatio

- Non-wilderness
- ▲ Wilderness
- Kenai NWR
- ▨ Wilderness Areas



Quantifying Sound

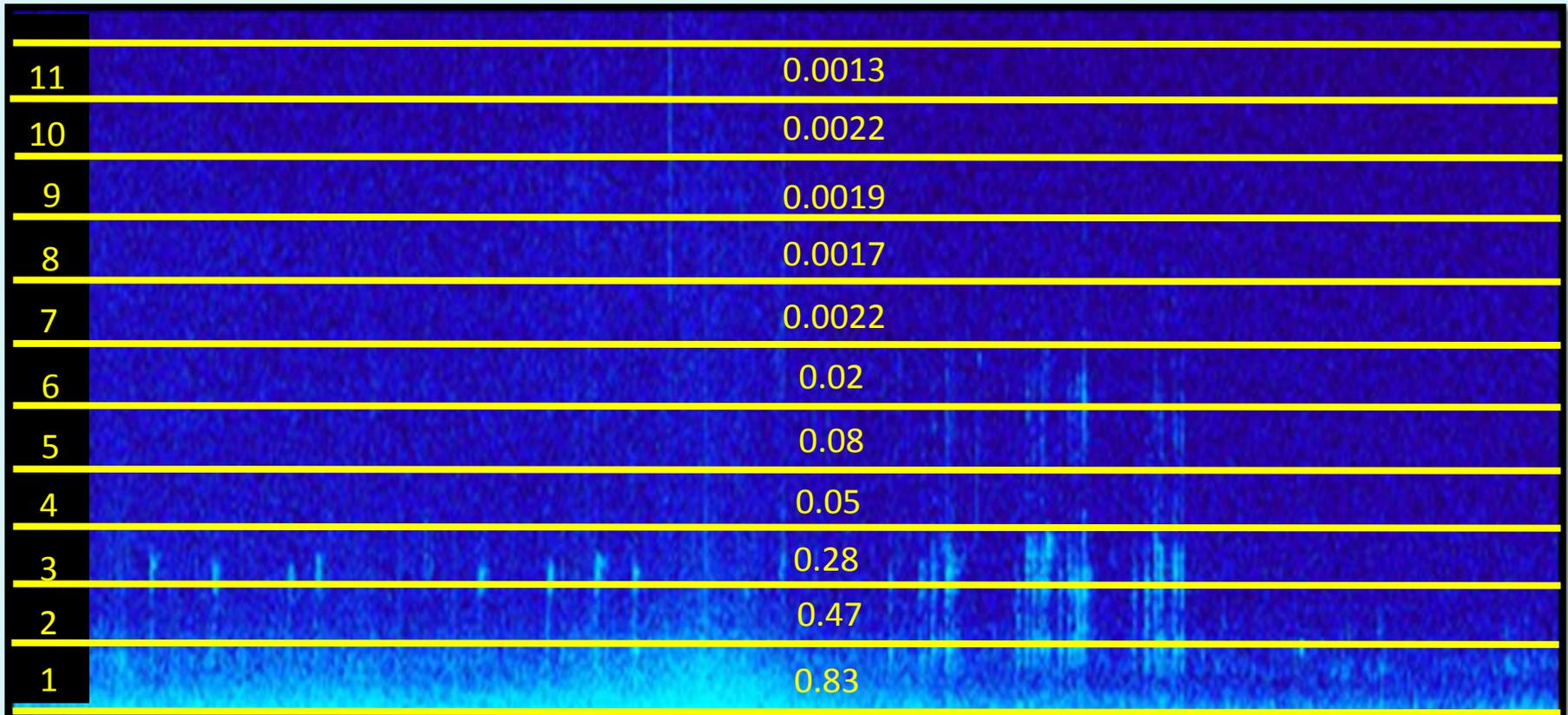
- Sound files entered into REAL sound library
- Listened to 74,000 files to ID sound sources

Sound Frequency
Bins (1 kHz) intervals

Power Spectral Density (PSD)
normalized values (watts/kHz)



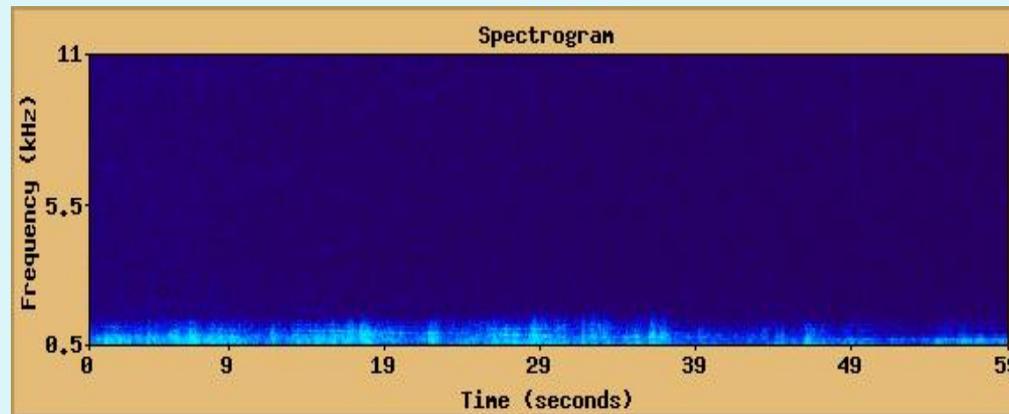
PSD = Welch (1968)



Summarizing PSD for Modeling

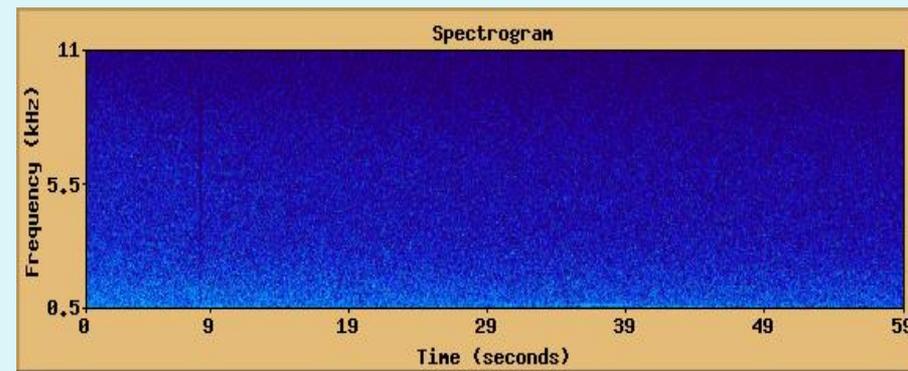
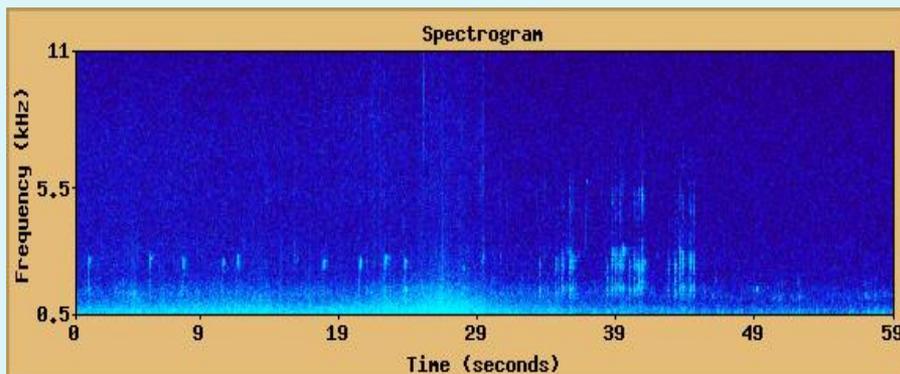
- Most anthrophony in 1-2 kHz interval
- Weighted Average = $\overline{X}_{\text{PSD}}$ * Proportion of recordings

Anthrophony



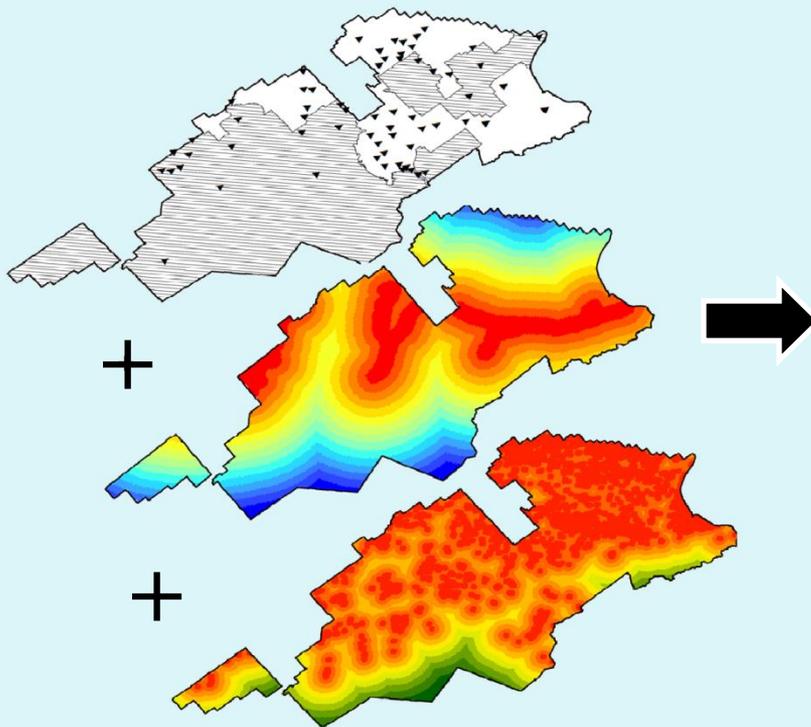
Biophony
&
Geophony

Natural Quiet



Building a Predictive Model

- Overlaid spatial layer of sound data w/ environmental covariates in ArcGIS
- Entered data into TreeNet Machine Learning Software
- Calculates predictions using regression and error-correcting decision trees



Salford Predictive Modeler v7.0

Model Setup

Class Weights	Penalty	Lags	Battery	TN Advanced	Costs
Model	Categorical	Testing	Select Cases	TreeNet	

Variable Selection

Variable Name	Target	Predictor	Categorical	Weight
ALL_ANTHRO	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ALL_BIO_2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ALLSNOW	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ANTHRO_PSD	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ASPECT	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BIO_PSD	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CONIFER	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DECIDUOUS	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DEM	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Sort:

Select Predictors Select Cat.

Analysis Type

Classification

Regression

Unsupervised

Logistic Binary

Set Focus Class...

Target Variable

ANTHRO_PSD

Weight Variable

Number of Predictors

5

Automatic Best Predictor Discovery

Off

Discover only

Discover and run

Maximum variables for each class

After Building a Model

Save Grove...

Number of Predictors in Model: 5

Analysis Method

TreeNet

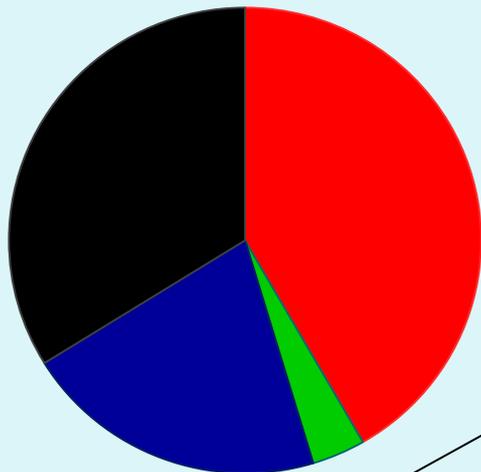
Cancel Continue Start

Model Accuracy & Affected Wilderness

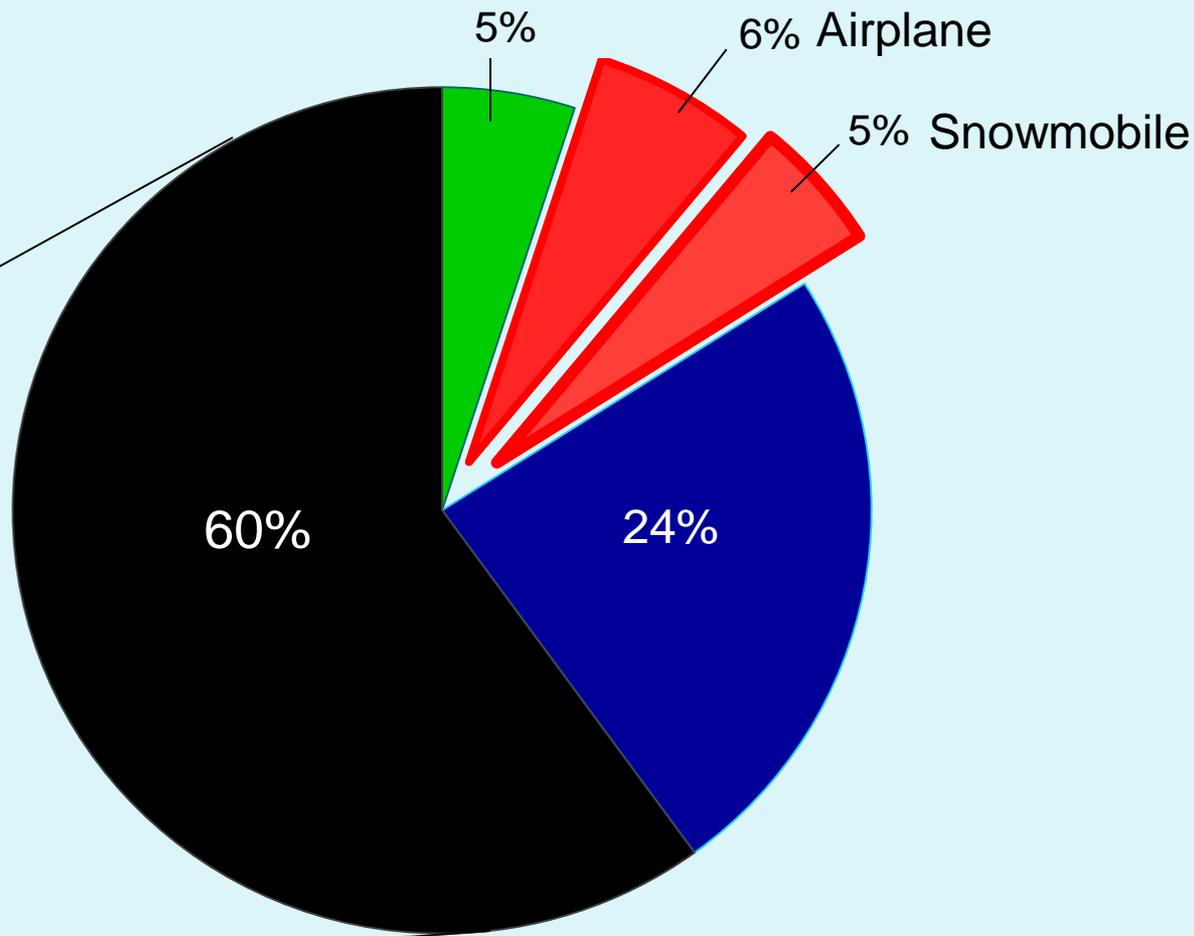
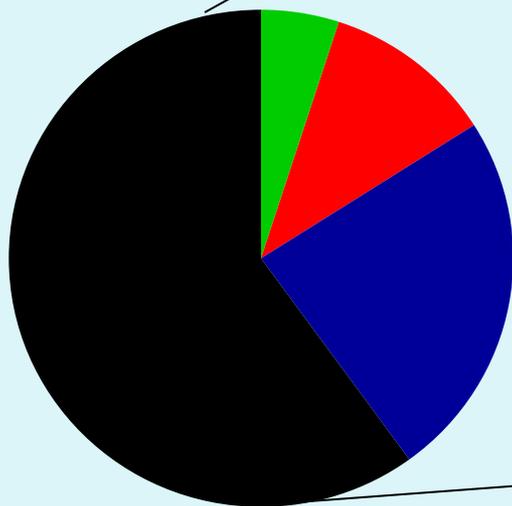
- Model Accuracy:
 - Calculated Normalized Root Mean Squared Error (nRMSE)
 - % Error Between Predicted and Reality
- Mapping Predictions in ArcGIS:
 - Scored predictions to a grid with coordinates in Kenai Refuge
 - Interpolated predictions from grid to entire Kenai Refuge
- Affected Wilderness Area:
 - Calculated proportion of noise hotspots in Kenai Wilderness

Results: Proportion of Noise

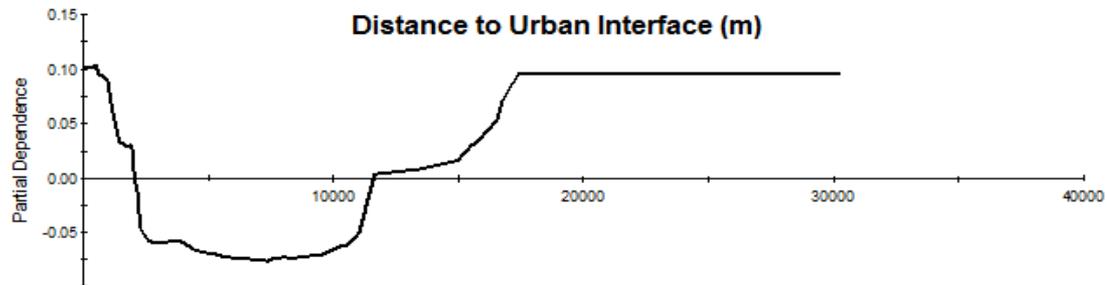
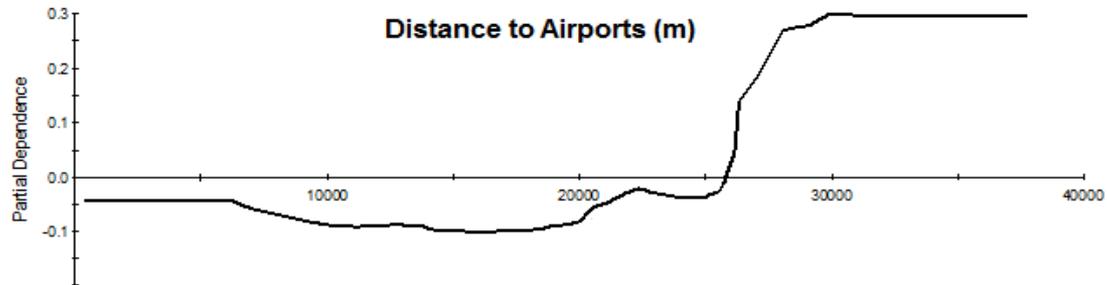
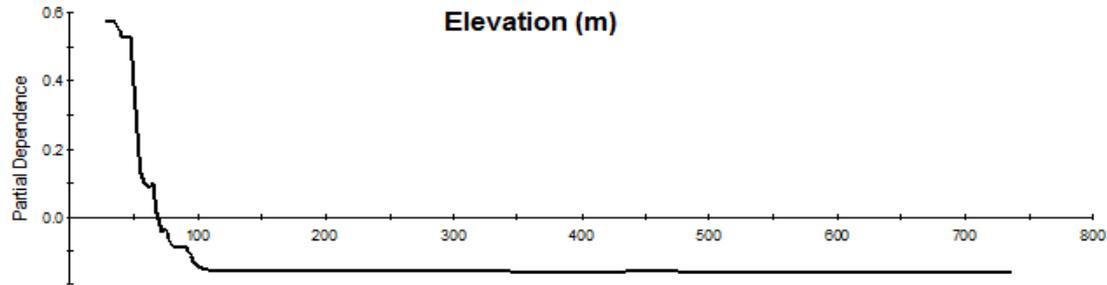
Non-wilderness



Wilderness



Airplane Noise



Variable Importance

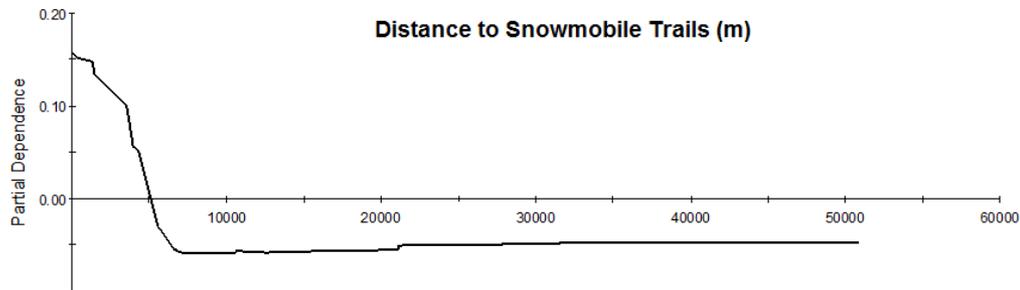
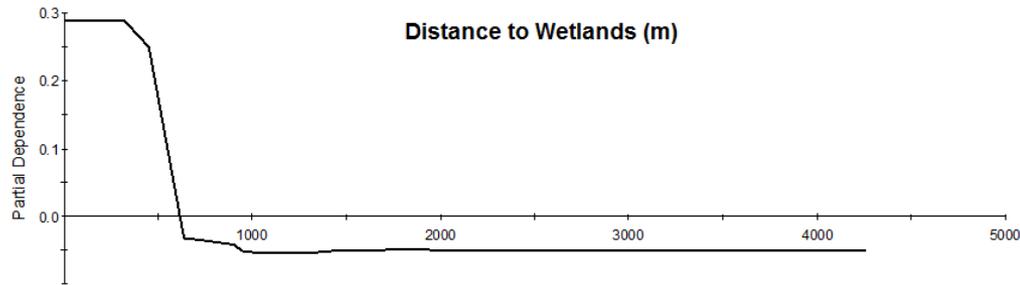
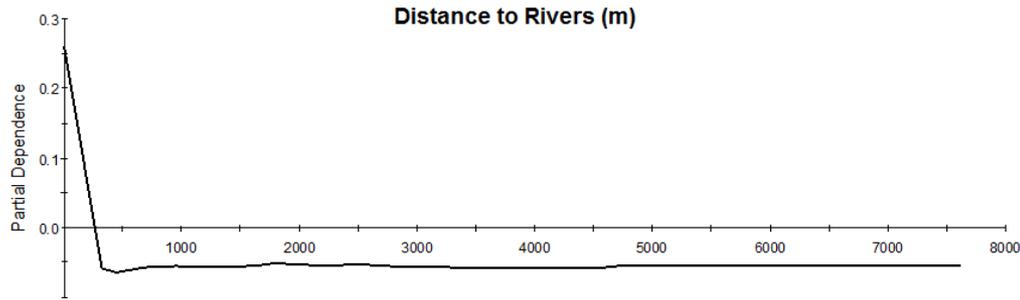
Variable	Score
Elevation	100
Distance to Airports	66
Distance to Urban Interface	56
Slope	45
Aspect	39
Distance to Lakes	30

nRMSE = 19%

Snowmobile Noise

Variable Importance

Variable	Score
Distance to Rivers	100
Distance to Wetlands	96
Distance to Snowmobile Trails	63
Distance to Lakes	51
Snow Depth	45
Distance to Seismic Lines	43
Elevation	35
Distance to Roads	27
Distance to Urban Interface	26
Distance to Forest	19



nRMSE = 15%

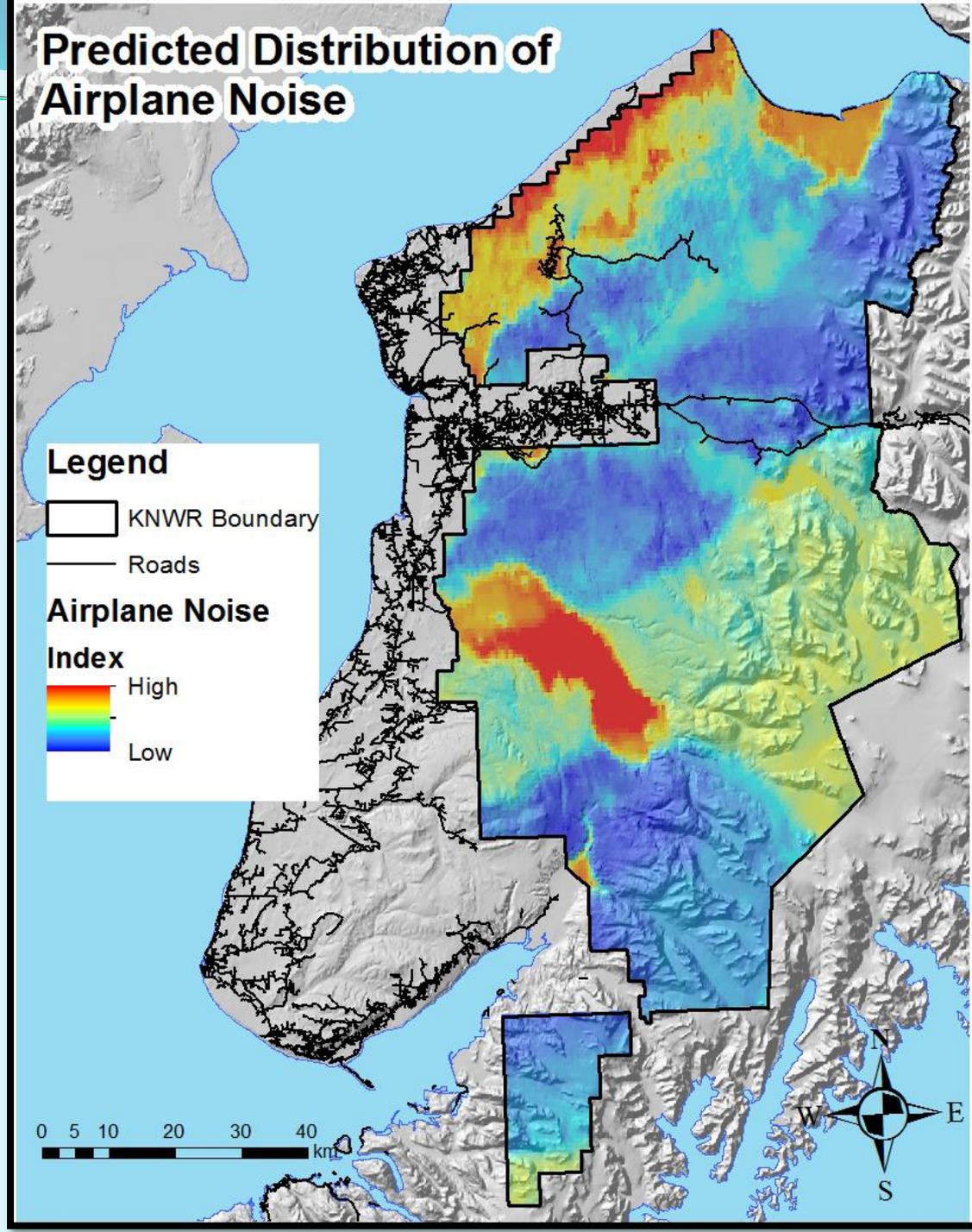
Airplane Noise Hotspots

Northwest

- Commuter Flights btwn Anchorage & Kenai

Southcentral

- Tustumena Lake
- Harding Ice Field
- Fixed-wing aircraft



Snowmobile Noise Hotspots

Northwest

- Urban Interface
- Oil and Gas field

Northcentral

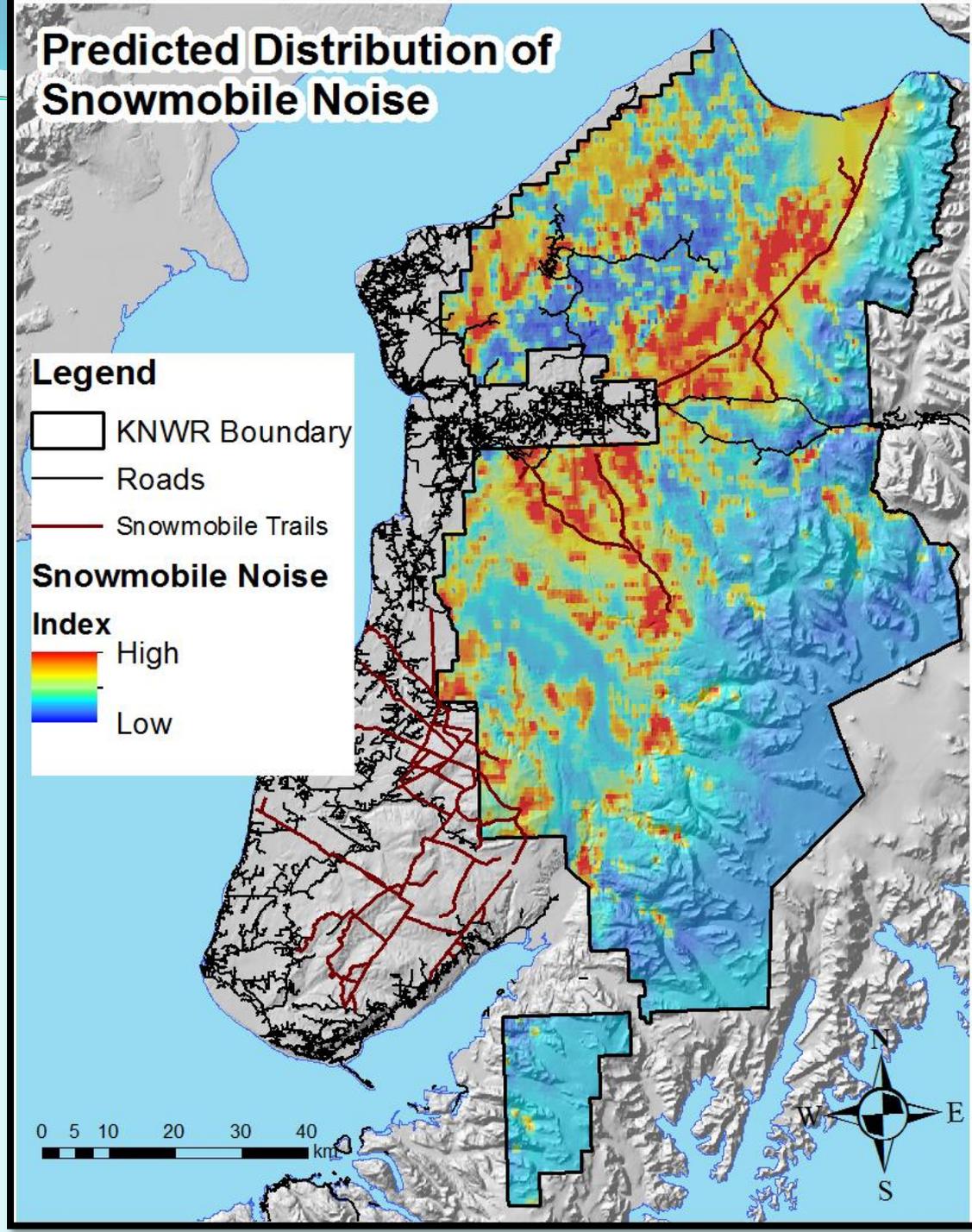
- Sterling Hwy
- Mystery Creek Rd
- Oil pipeline

West-central

- Urban Interface
- Horsetrails

Southcentral

- Snowmobile trails



Noise Affected Wilderness

Snowmobile Noise

32%

(permitted areas)

17%

(all wilderness)

Airplane Noise

23%

(all wilderness)

Total Area

(excluding overlap)

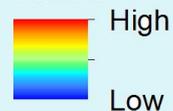
35%

Legend

-  Kenai NWR
-  Wilderness Area

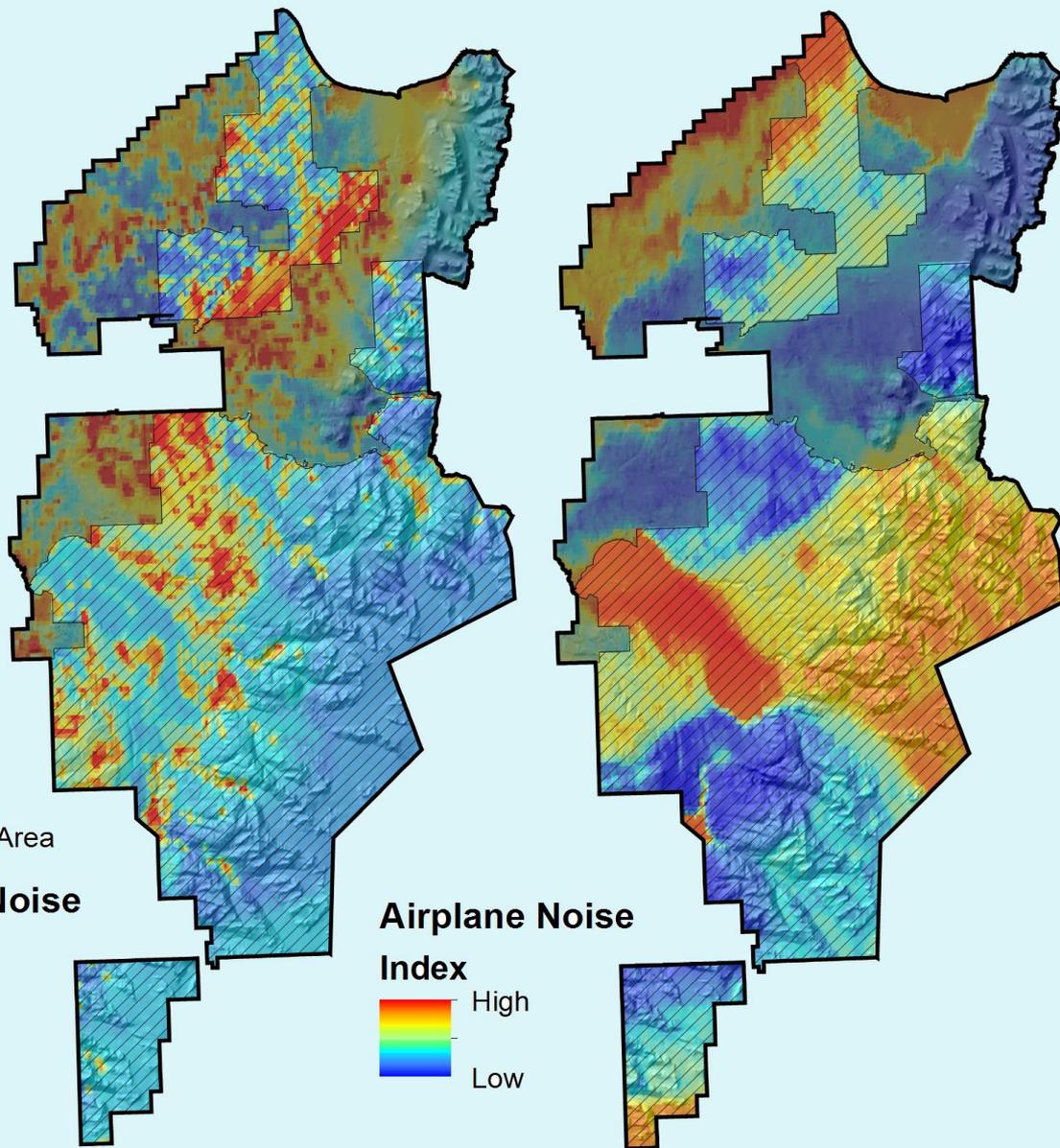
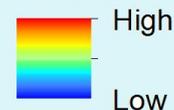
Snowmobile Noise

Index



Airplane Noise

Index



Summary

- Models accurately predicted the acoustic footprint of human-made noise in winter
- Noise extends to a large area of designated Wilderness
 - Along borders and remote areas
- Infrastructure outside Refuge still affects Wilderness areas
 - Airports, Roads, Pipelines, Snowmobile Trails
- Trails and Roads in Kenai Refuge allows snowmobiles access to remote Wilderness areas
 - through wetlands and rivers

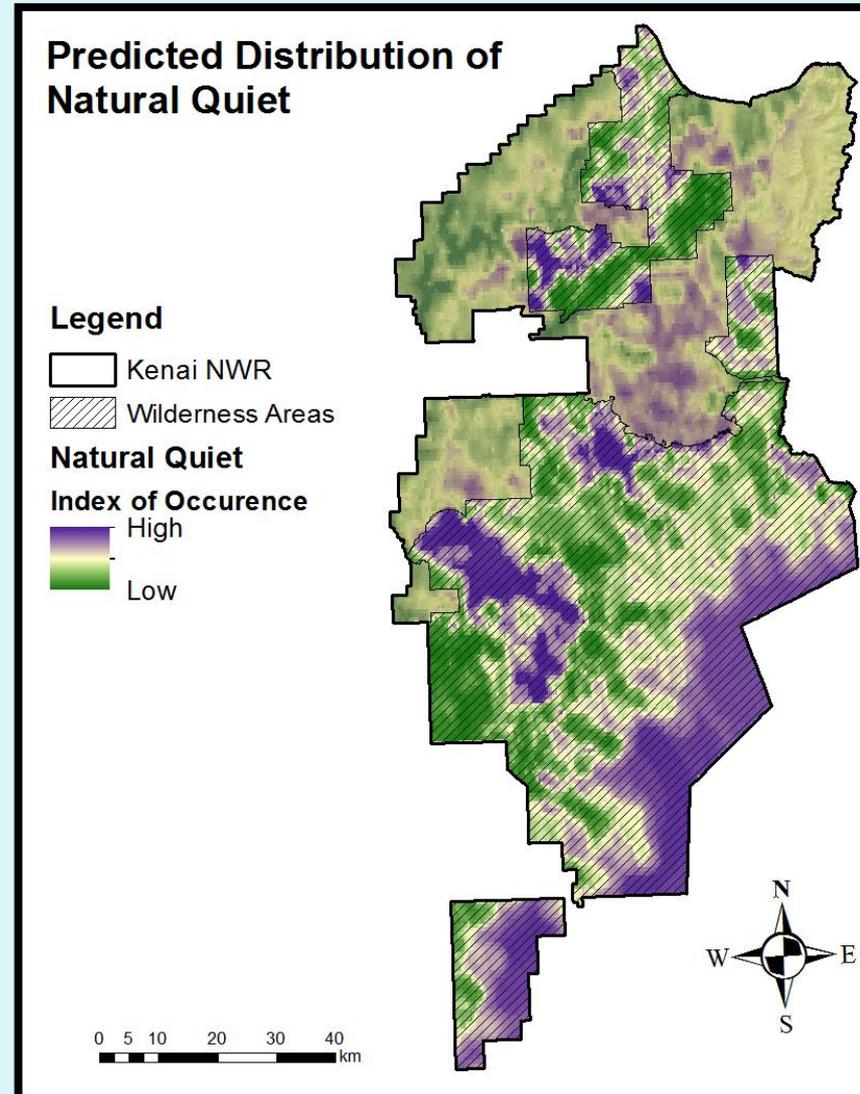
Management of Wilderness Noise

ANILCA constrains KENWR from prohibiting snowmobiles and airplanes in Wilderness

What can be done?

1. Restrict use to designated trails
2. Require quieter snowmobiles
3. Define “Traditional Activities”
4. Prohibit access in quietest areas

Treat Winter’s Natural Quiet as a Resource



Acknowledgements

- Funded by US Fish and Wildlife and Univ of Alaska
- Field and Lab Assistants:
 - R. Park
 - B. Johnson
 - M. Salmenin
 - B. Shryock
- Additional Assistance:
 - E. Krasten
 - Kenai NWR Law Enforcement & Maintenance Staff

Questions?

