Diet Quality of Sagebrush

Diet Selection, Habitat Selection, and Influences of Restoration Practices

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John W. Connelly, Idaho Fish and Game, retired
March 25, 2015

Wild Herbivores Forage Selectively

Photos by Jen Forbey

Closer to Home:
pygmy rabbits are selective

Photo by Jen Forbey

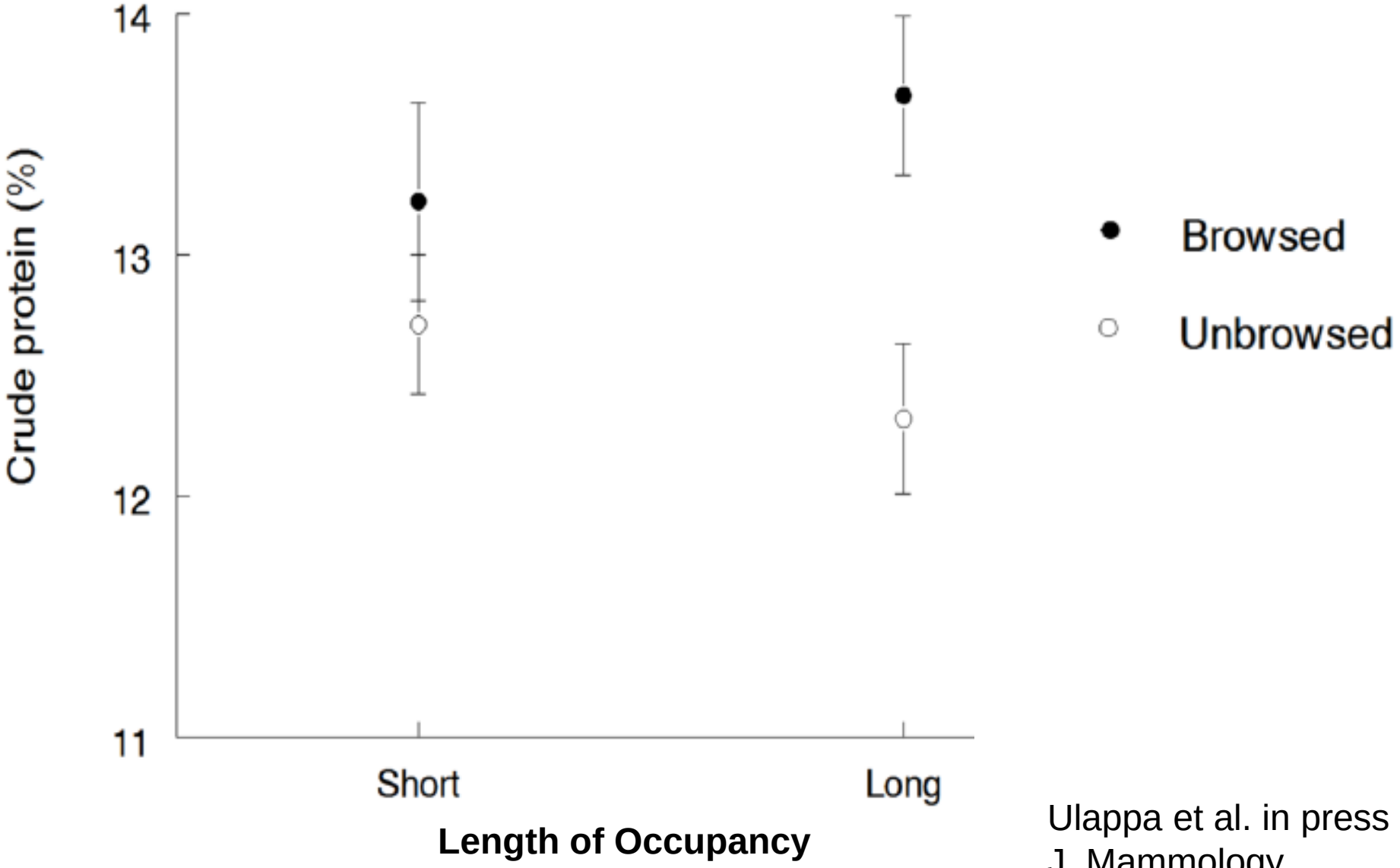
Photo by Jen Forbey

Why do animals select for protein?

<u>Many positive effects on energetically expensive activities:</u>

- Maintain body condition
- Growth
- Movement
- Reproduction

Protein influences habitat use by pygmy rabbits



Ulappa et al. in press
J. Mammology

Protein Impacts Movement

- Variation in forage quality drives animal movements
- Migratory species most commonly studied

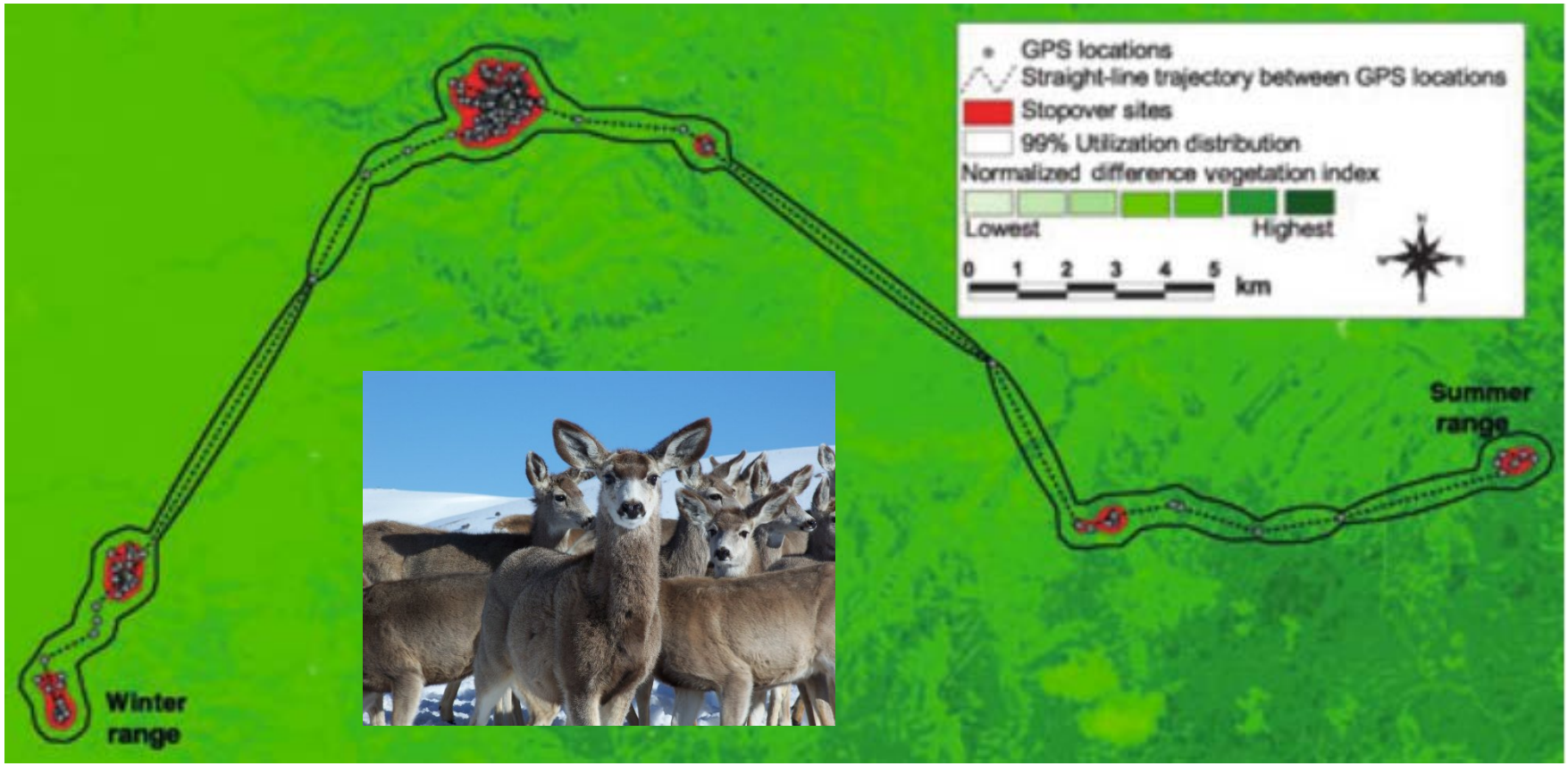
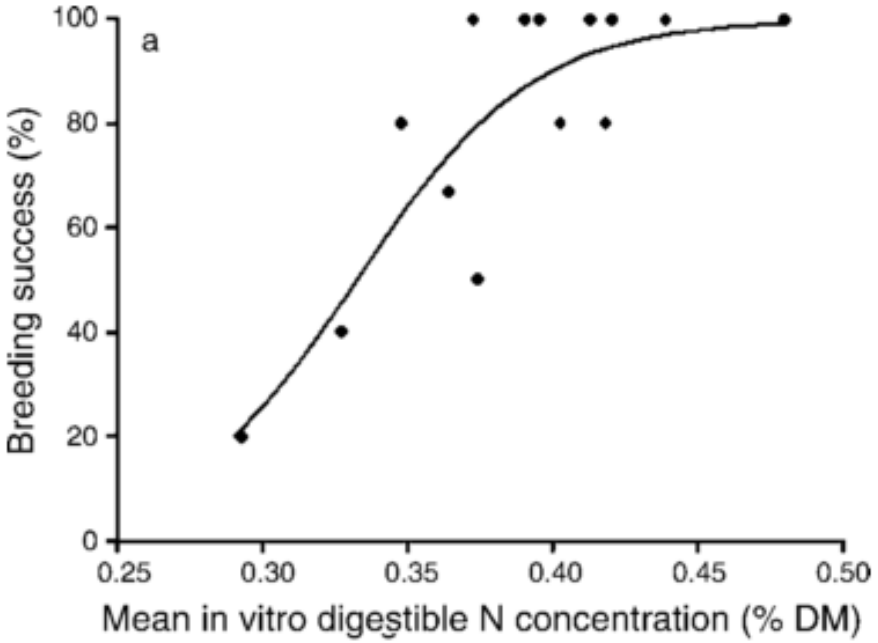


Figure from Sawyer and Kaufmann 2011

Diet Quality Impacts Reproduction

Brushtail possum

- Reproductive success is up to 5 times higher for individuals consuming high quality diets



DeGabriel et al. 2009

Plants are not an easy source to acquire protein from…

- Co-evolutionary arms race between plants and herbivores
- Plants physically and/or chemically defended

Why do animals avoid toxins?

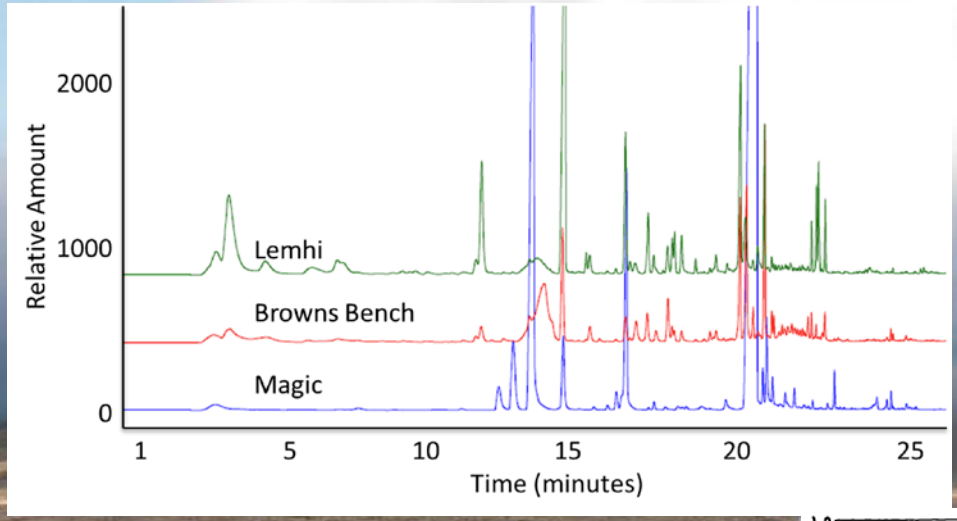
Many negative effects:

- Bitter taste
- Nausea
- Oxidative stress (leads to cell death)
- Inhibit digestive enzymes
- Energetically expensive to metabolize

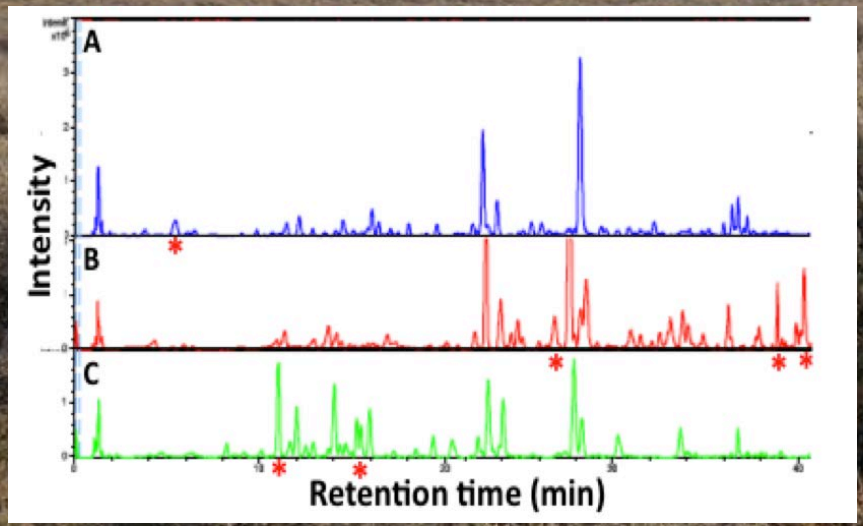
Therefore, toxins regulate behavior…

Selective foraging is an adaptation to avoid toxins in diets

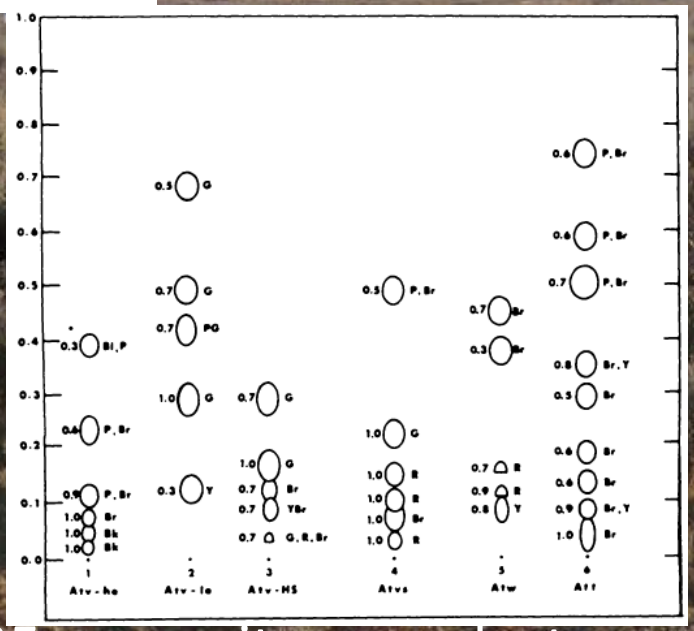
Diverse chemicals in sagebrush are TOXIC!



30+ volatile compounds (monoterpenes)

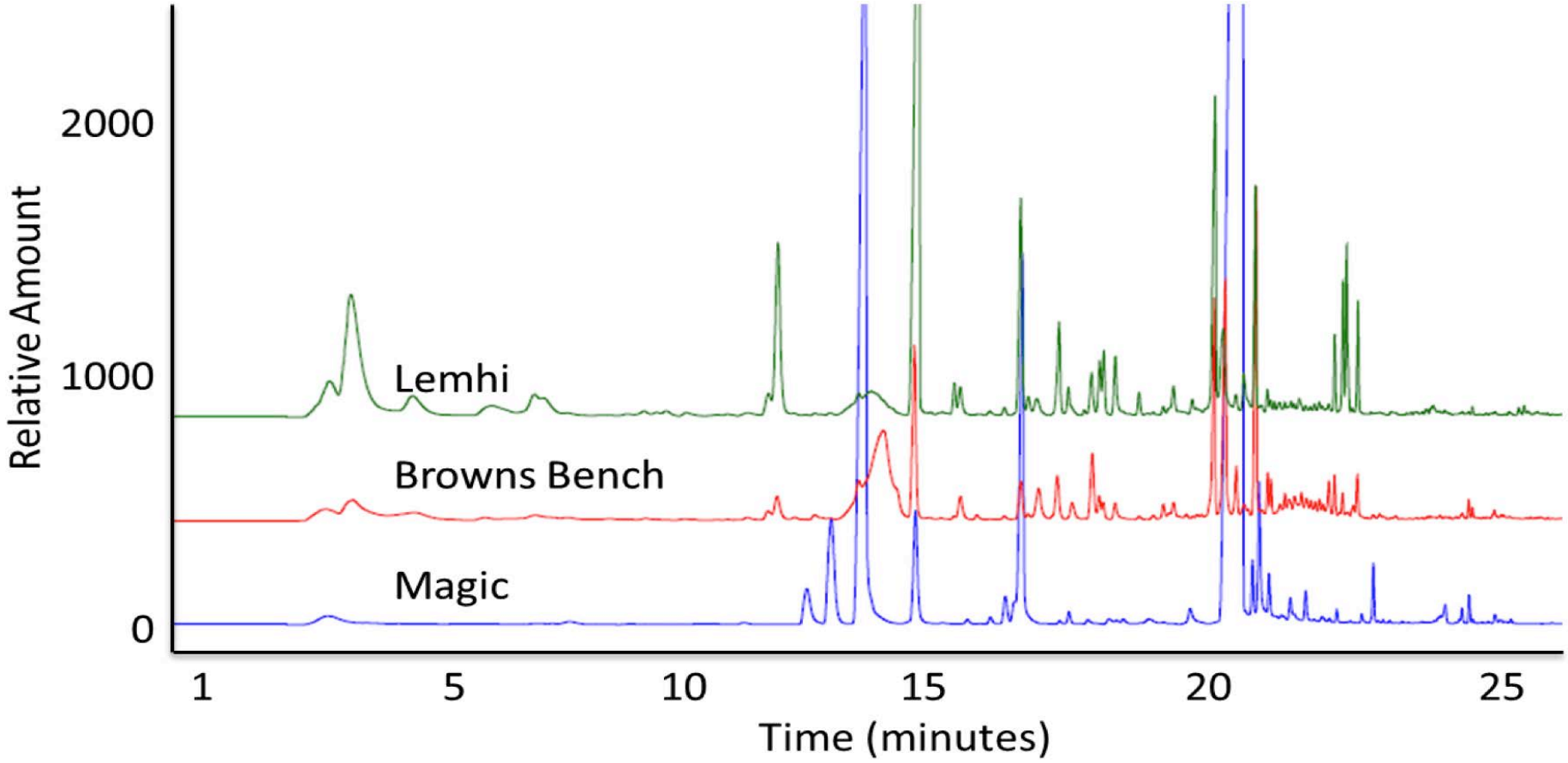


75+ polyphenols (include coumarins)



35+ sesquiterpene lactones

Monoterpene Content in Sagebrush

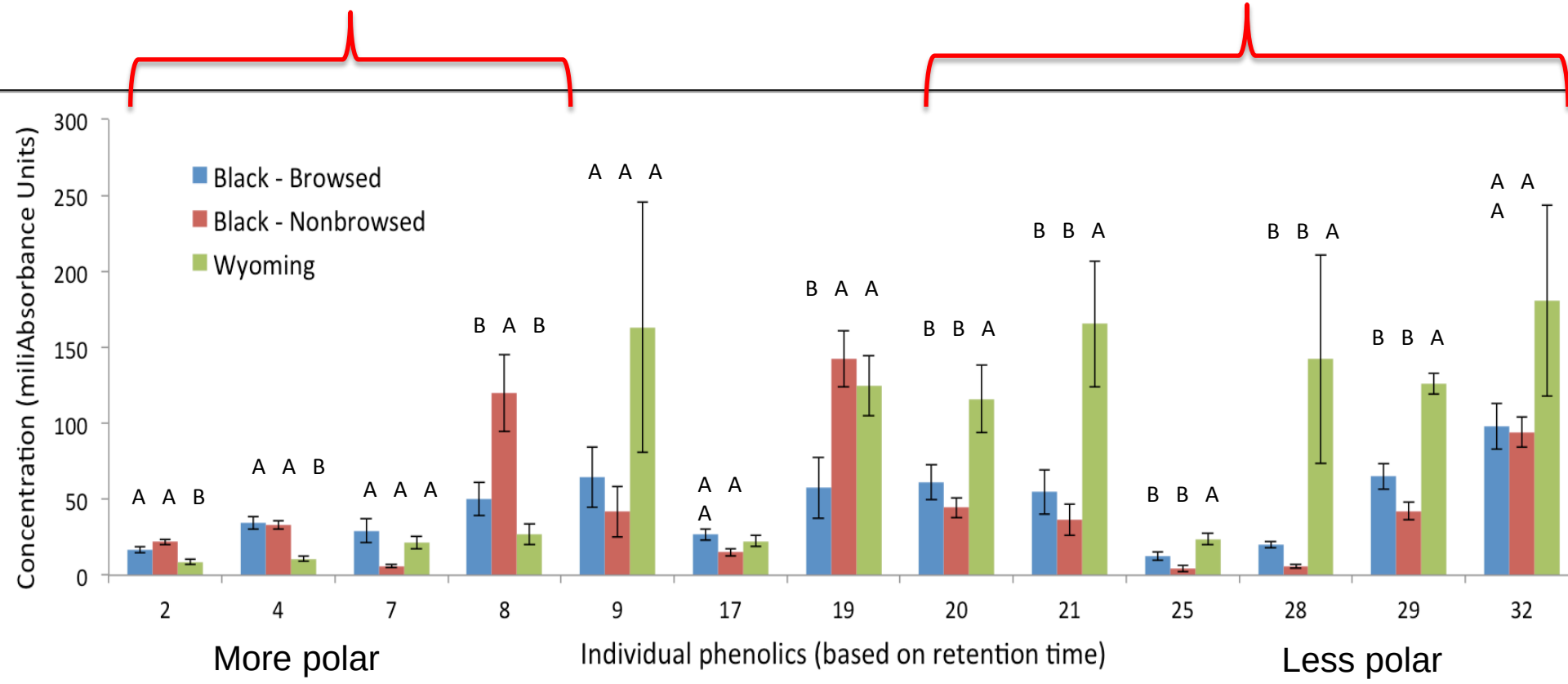


Phenolics (polyphenols)

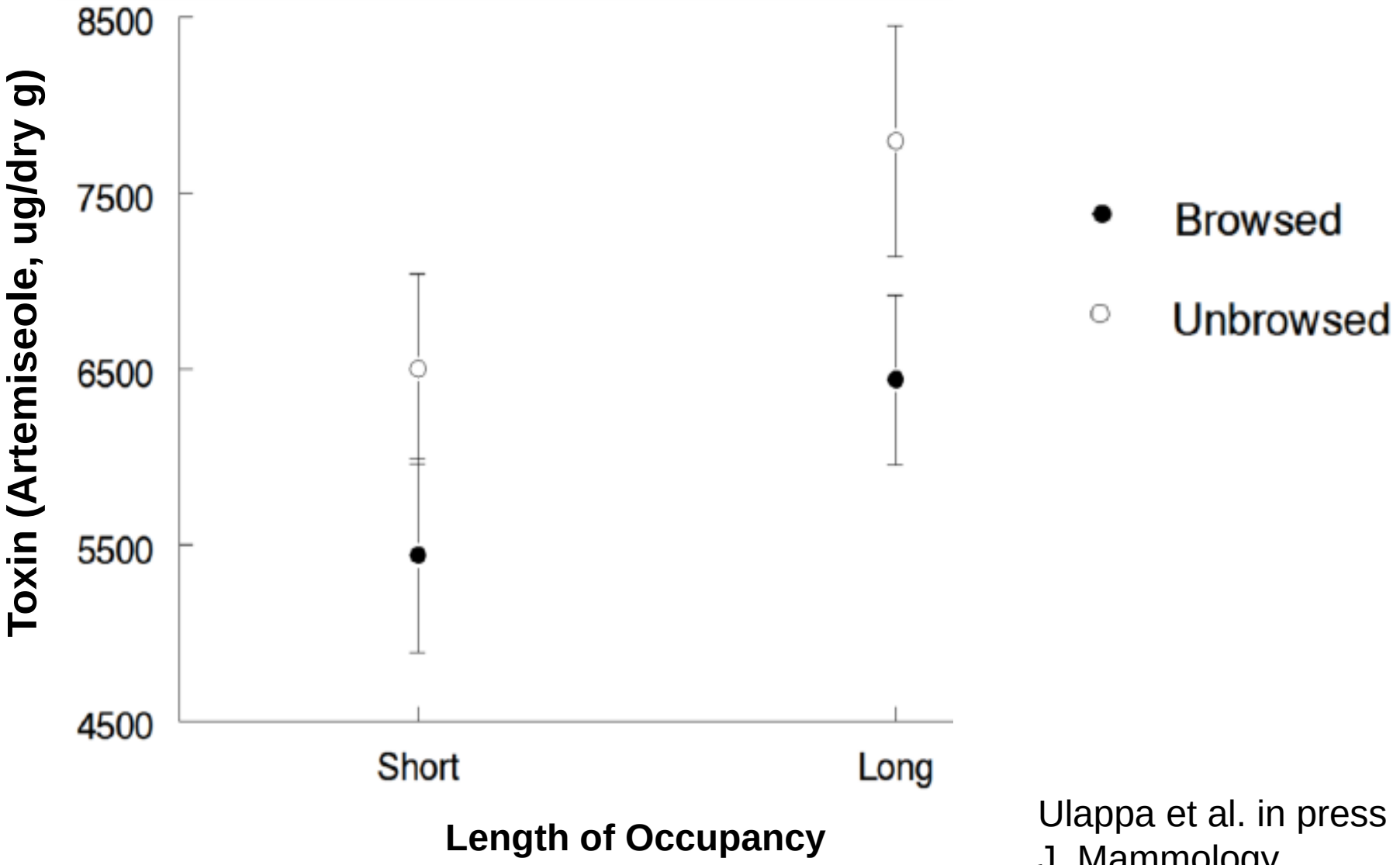
Include coumarins

Polar phenolics
Black > Wyoming

Less polar phenolics
Wyoming > Black



Toxins limit habitat use by pygmy rabbits



Ulappa et al. in press
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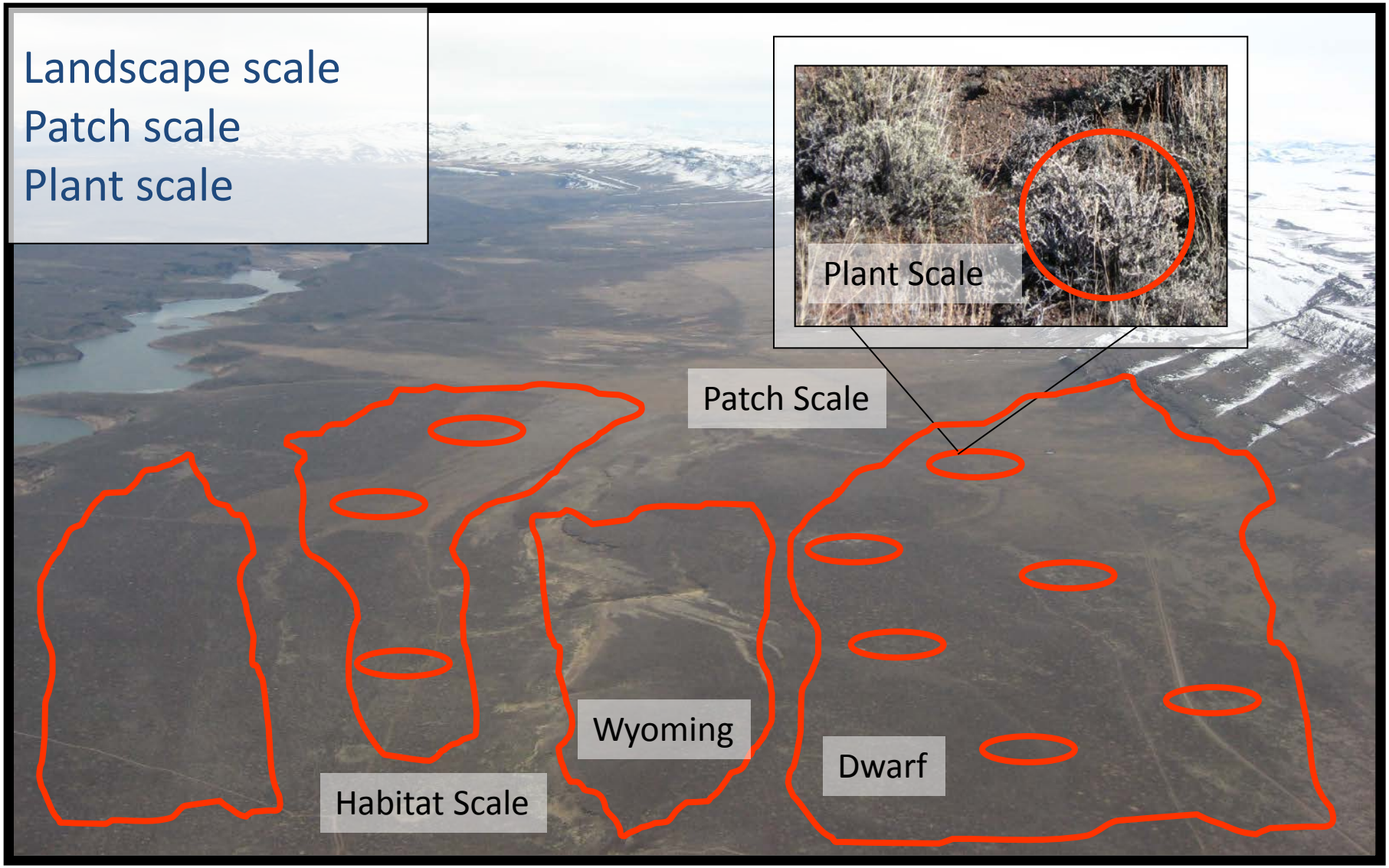
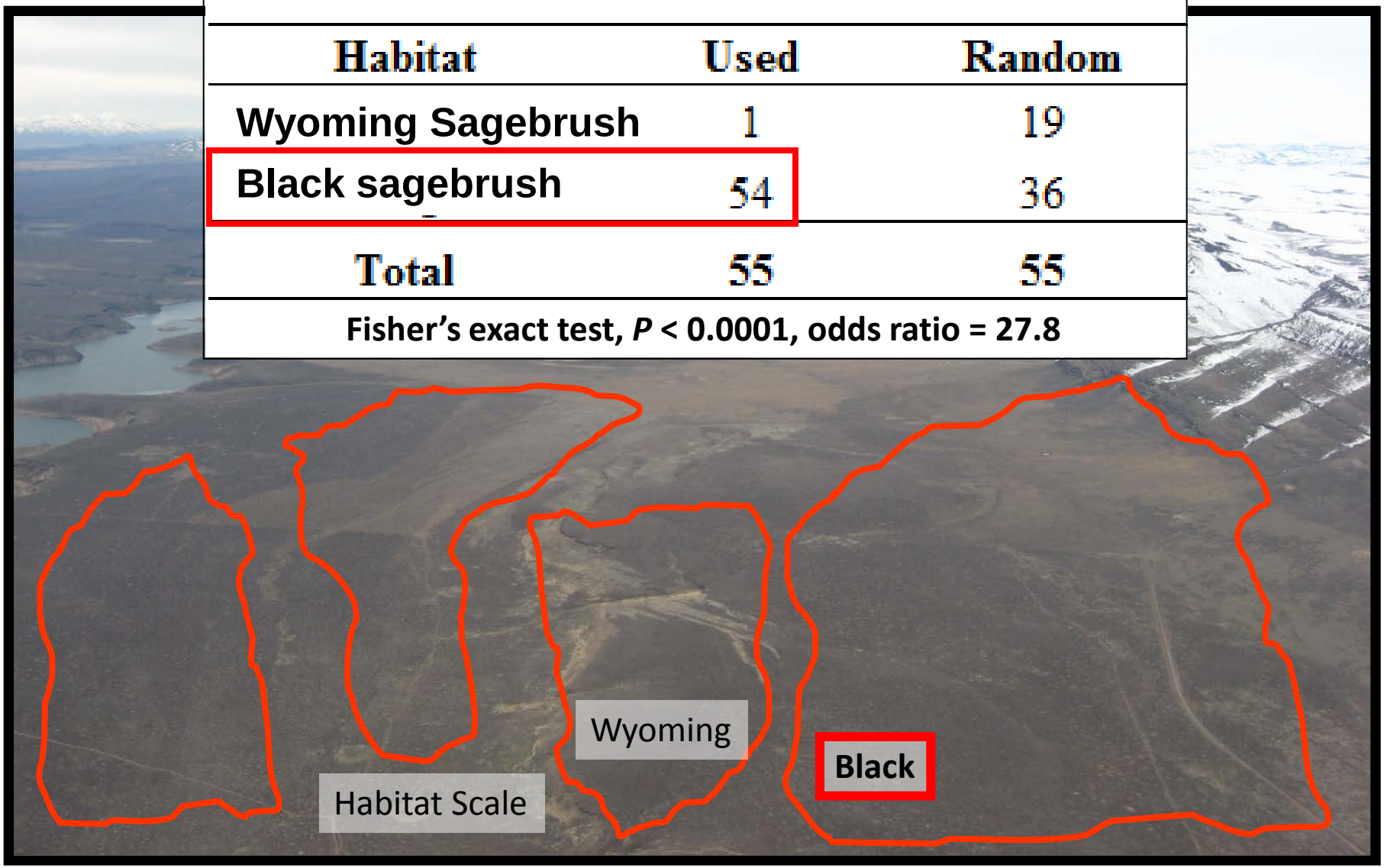
Sage-grouse avoid toxins at multiple spatial scales



Habitat Scale: Sage-grouse selected habitats with black sagebrush

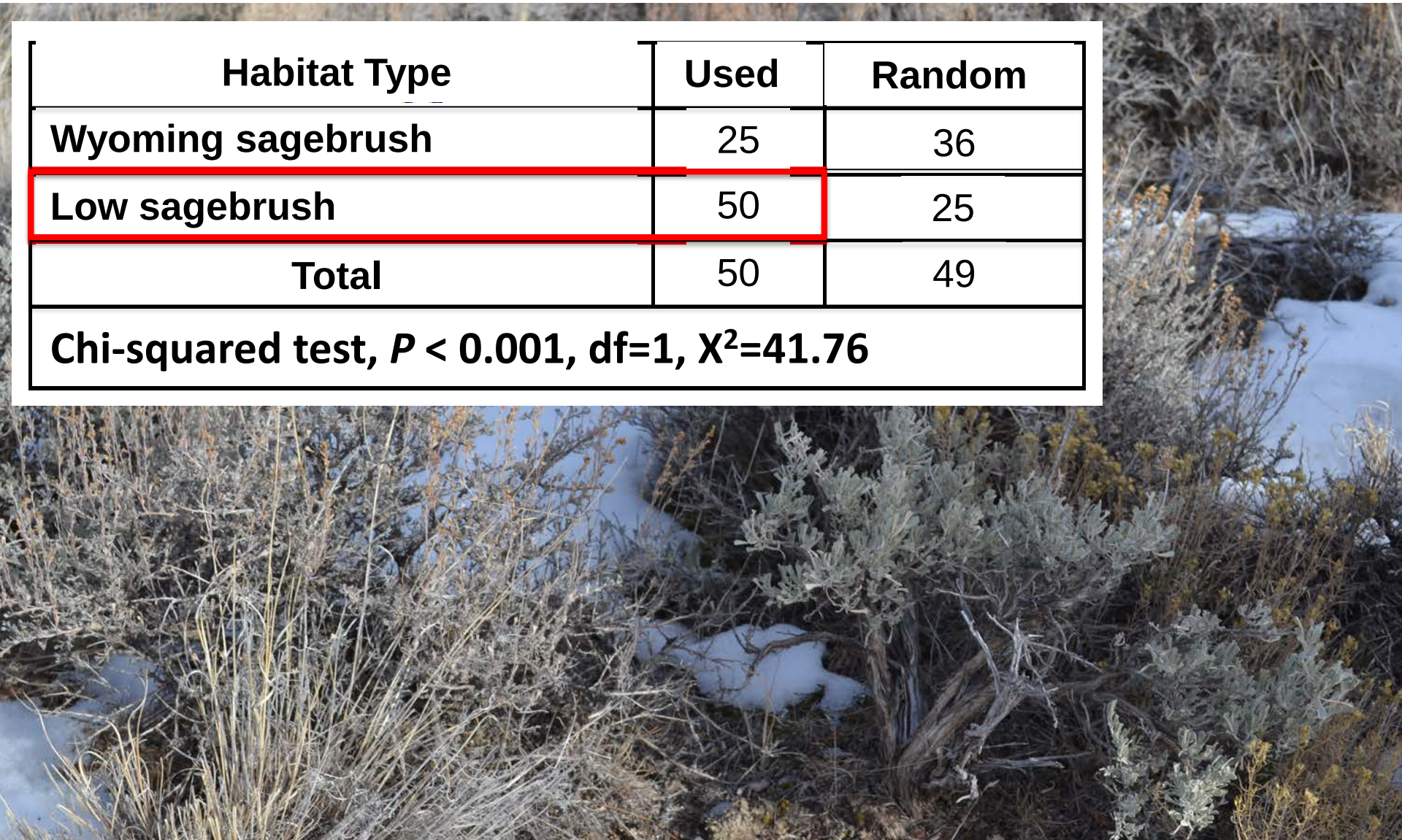
Habitat	Used	Random
Wyoming Sagebrush	1	19
Black sagebrush	54	36
Total	55	55

Fisher's exact test, $P < 0.0001$, odds ratio = 27.8



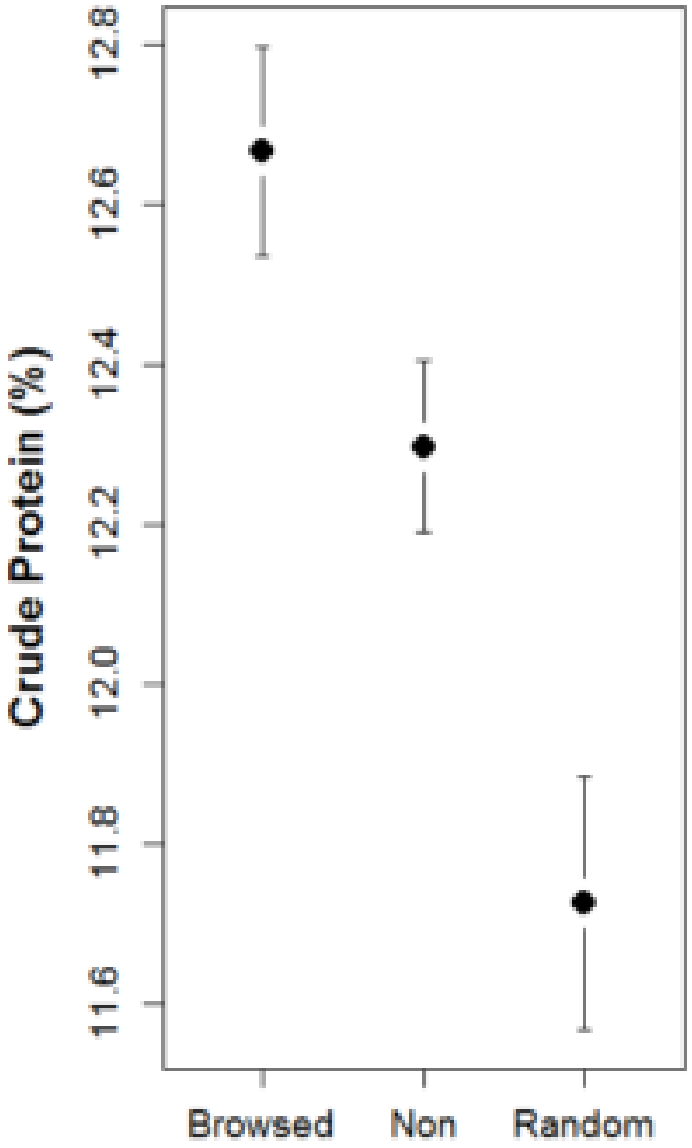
Grouse select habitats with low sagebrush

Habitat Type	Used	Random
Wyoming sagebrush	25	36
Low sagebrush	50	25
Total	50	49
Chi-squared test, $P < 0.001$, df=1, $X^2=41.76$		



Selection at the Plant Scale For Protein and Against Toxins

Photo by Alan Krakauer



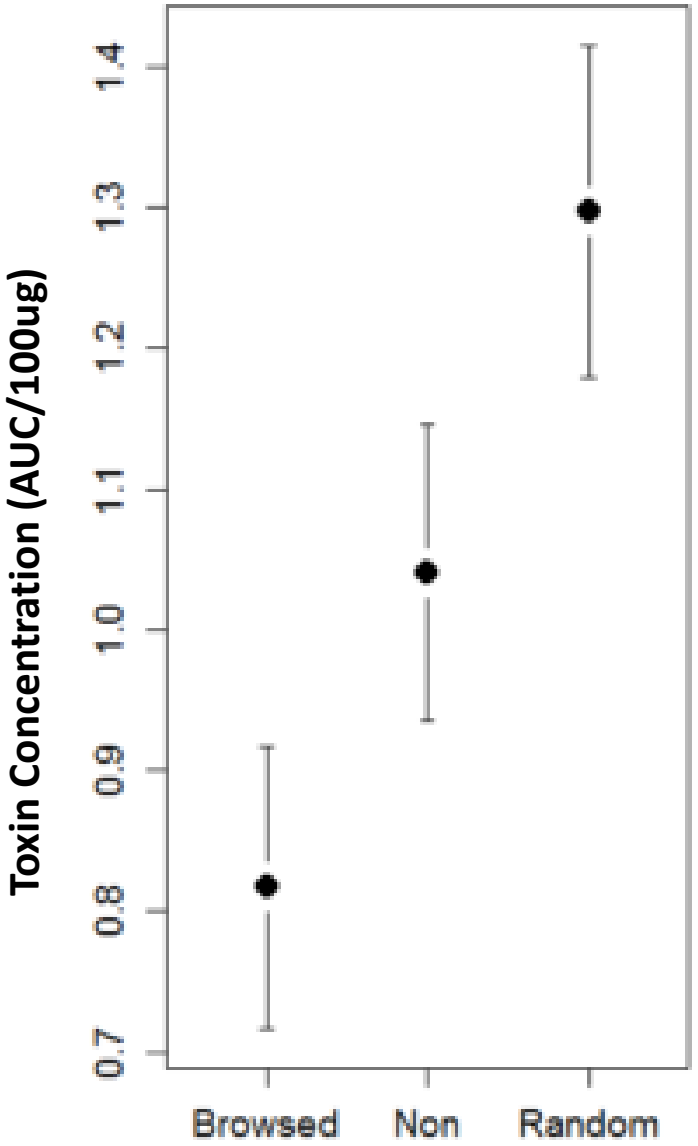
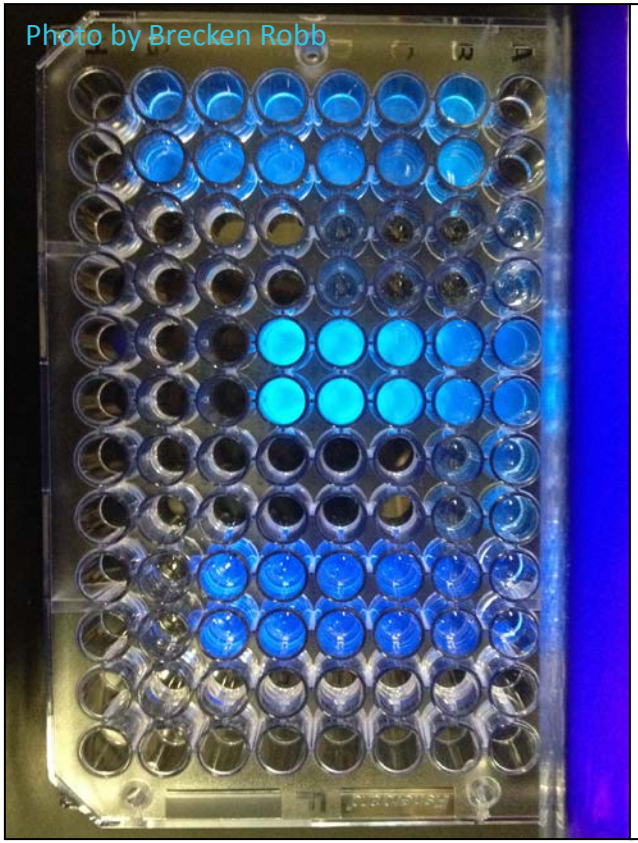
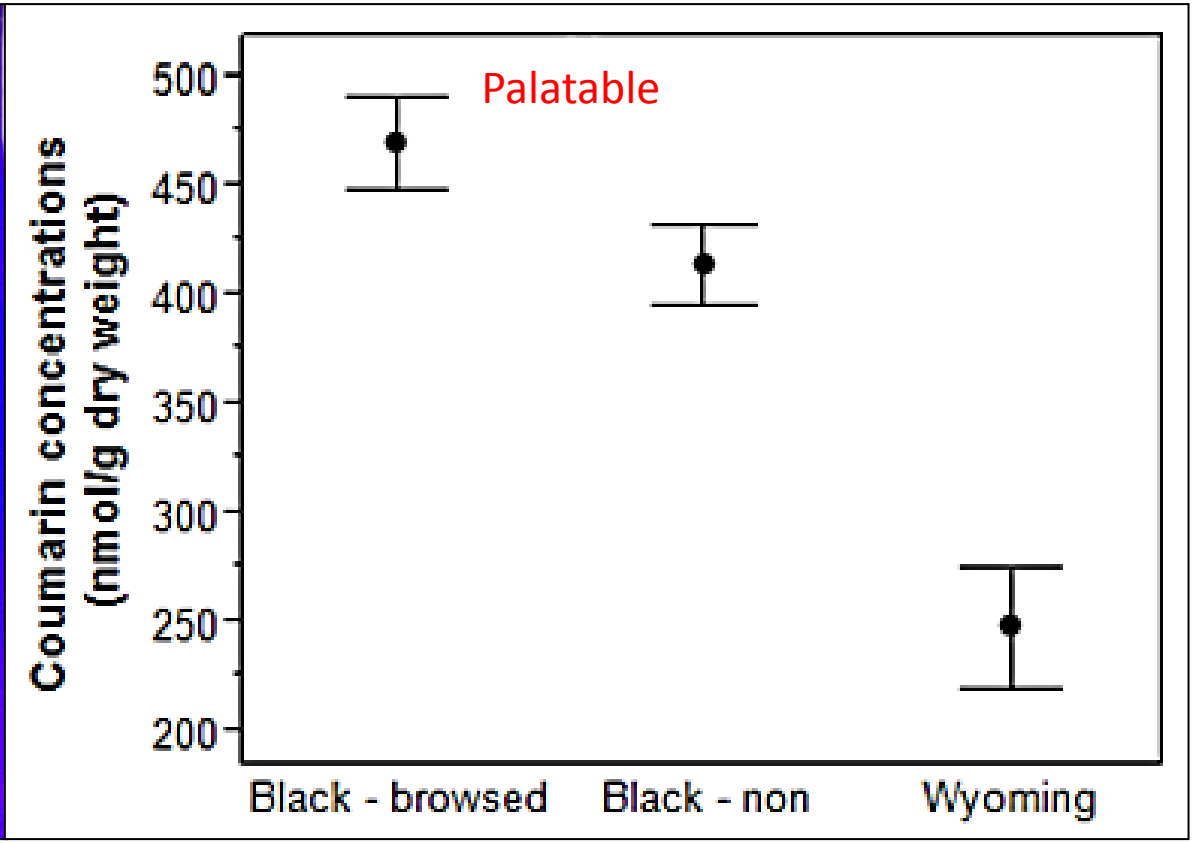


Figure from Frye 2012

Sage grouse select for more coumarins

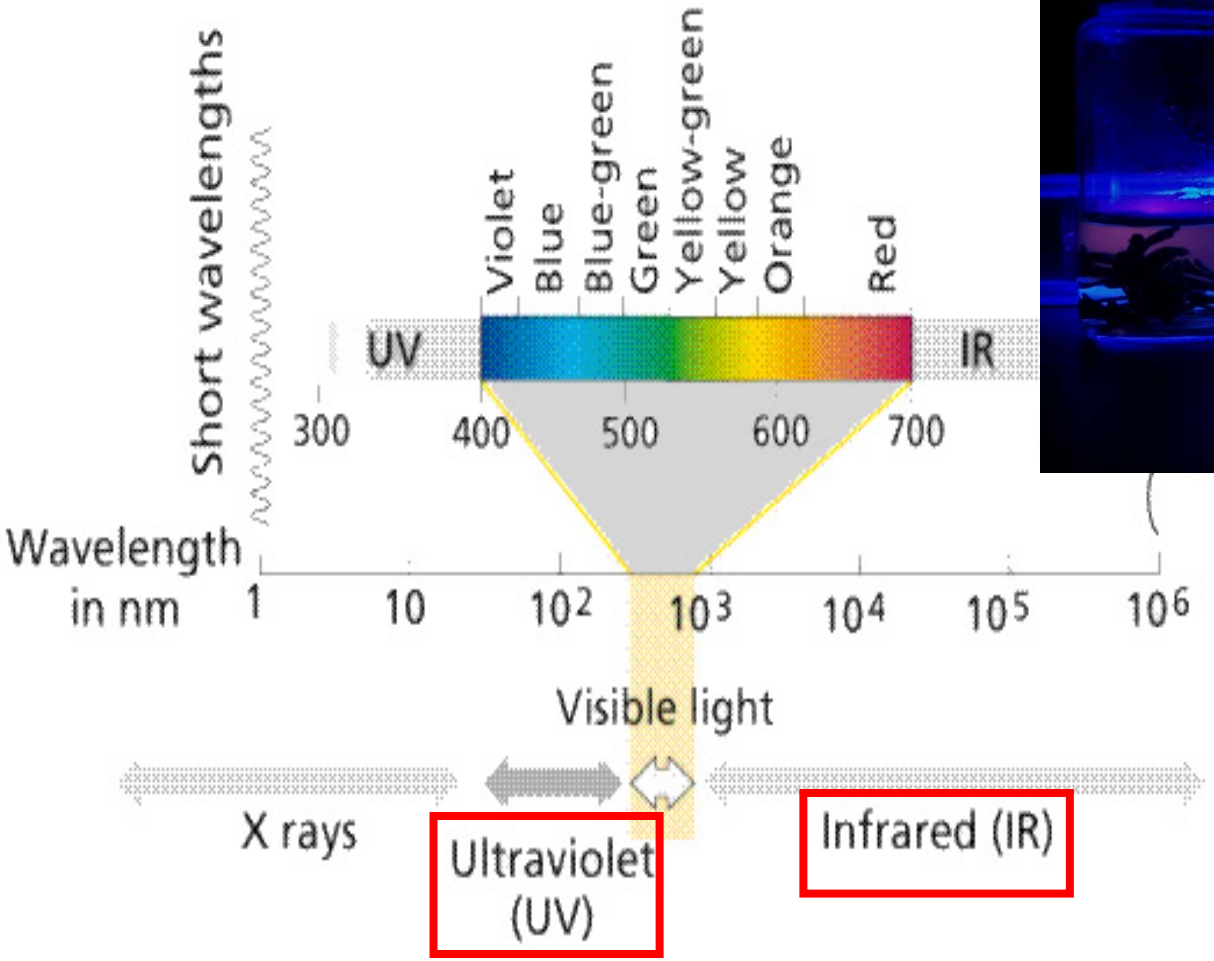




- Coumarins a TYPE of phenolic
- UV fluorescent, used to identify sagebrush species

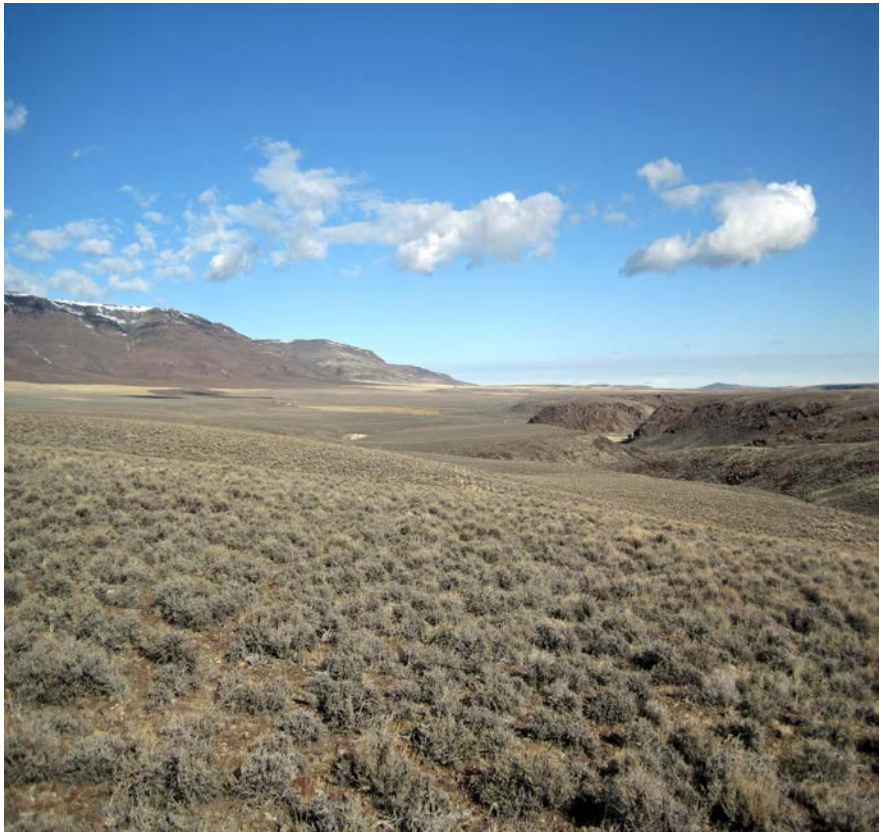
How do grouse select coumarins?

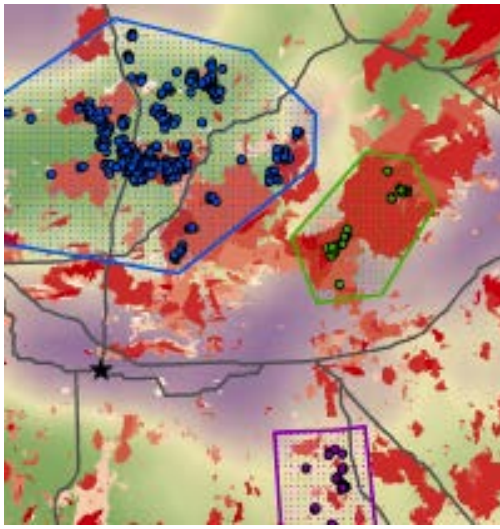
- Toxins may reflect light in the Ultraviolet (UV), Near Infrared (NIR) and visible spectrum
- Birds can see in these wavelength



What factors can change diet quality?

Mowing, herbicide
(Beck- UW, BLM)





Fire history
(Connelly – IDFG)

Juniper removal
(U Idaho, Oregon BLM)

Climate change
(Germino - USGS)

Impacts of Fire on Diet Quality

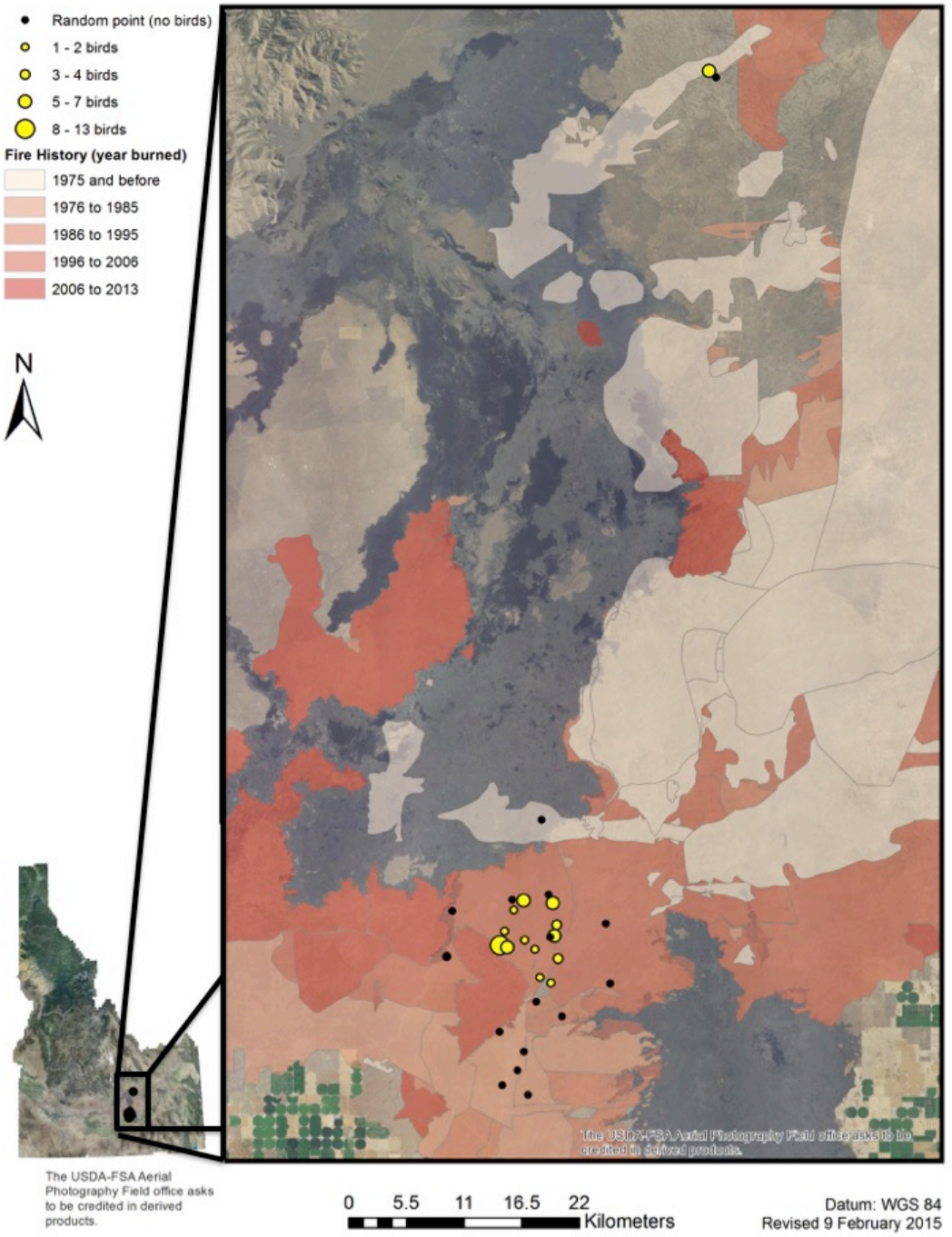
Marcella Fremgen, Dr. John W. Connelly, Dr. Jennifer Forbey (BSU)

Project underway, anticipated completion in 2015

South-central Idaho

Craters Study Site

- Southern end of Craters of the Moon National Monument
- Every used patch has been burned in the last 30 years
- Relatively low flock sizes
- Little sagebrush cover
- Dominant sagebrush species:
  - Wyoming big sagebrush
  - Three-tip sagebrush



Craters Habitat Use

No landscape scale habitat selection

Habitat Type	Used	Random
Wyoming sagebrush	6	8
Three-tip sagebrush	3	1
Mixed	7	7
Total	**16**	**16**

Chi-squared analysis p = 0.5258, df = 2, U = 0.030

Craters Protein Analysis

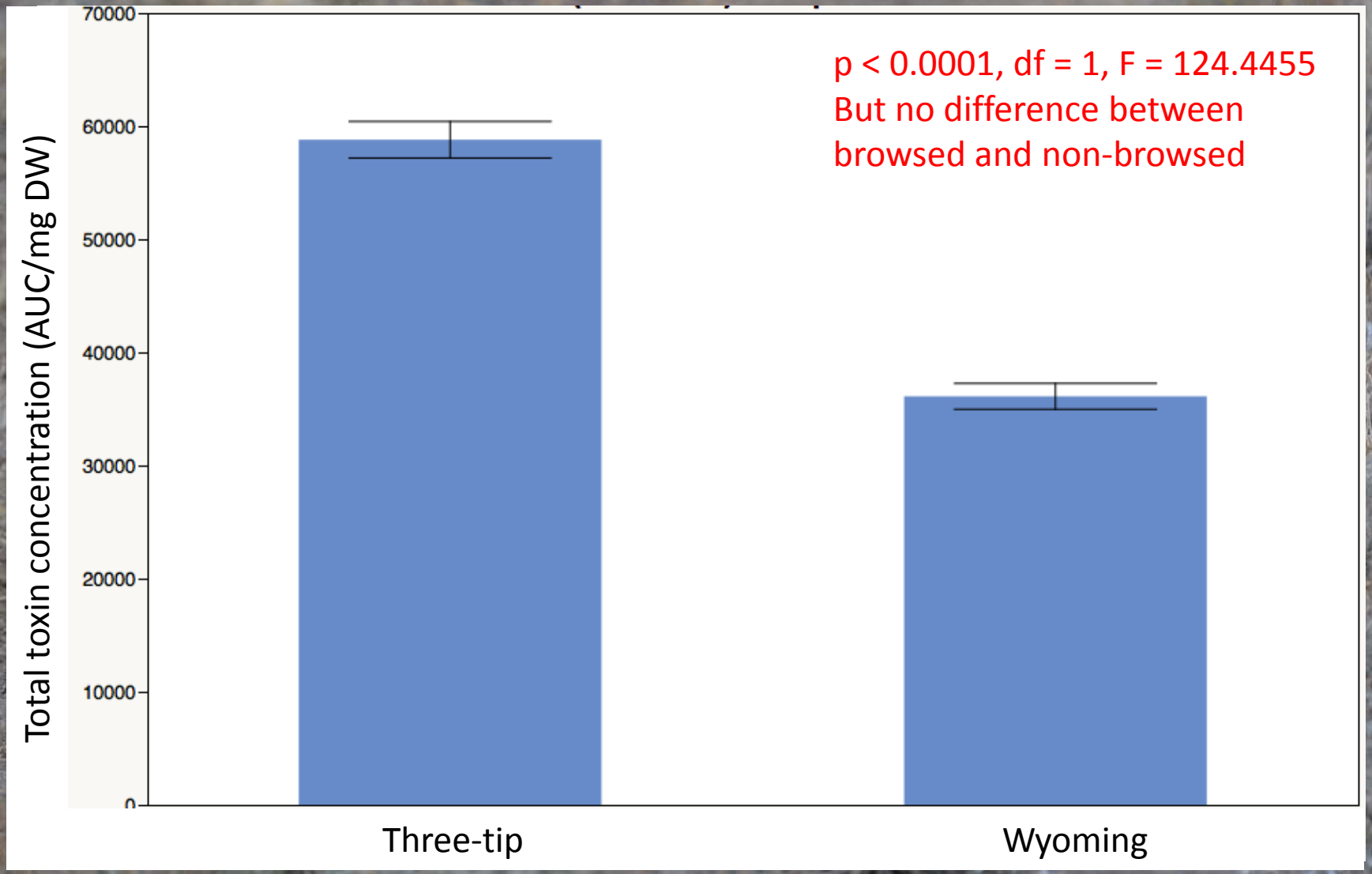
Species	Average	Std. Error
Wyoming sagebrush	13.303	0.3806
Three-tip sagebrush	10.411	0.2619

Matched pairs analysis comparing browsed and non-browsed (trends towards higher in browsed):

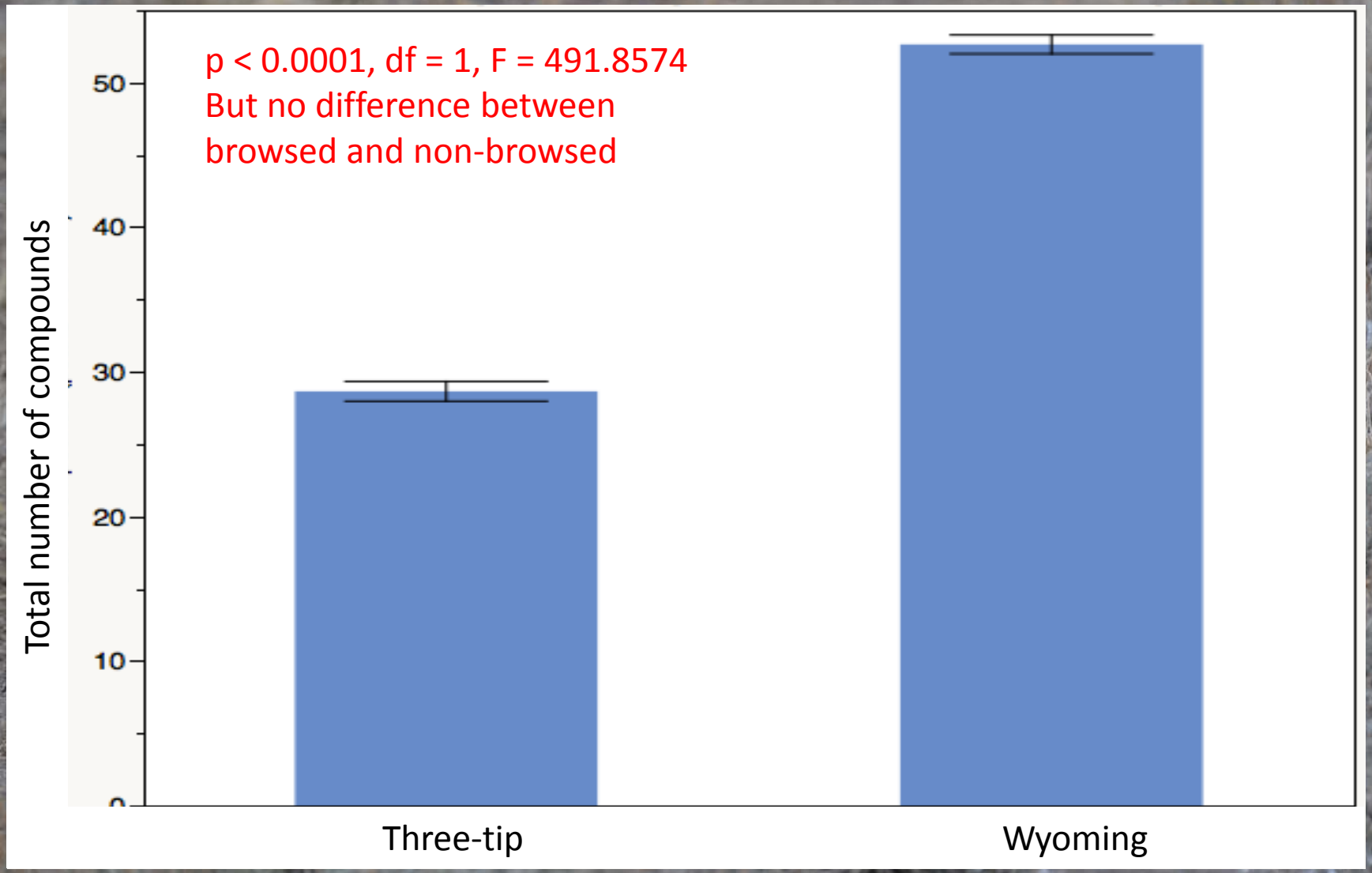
Wyoming: p = 0.0875, df = 1, U = -39.500

Three-tip: p = 0.1250, df = 1, S = -13.500

Craters Toxins



Craters Toxins



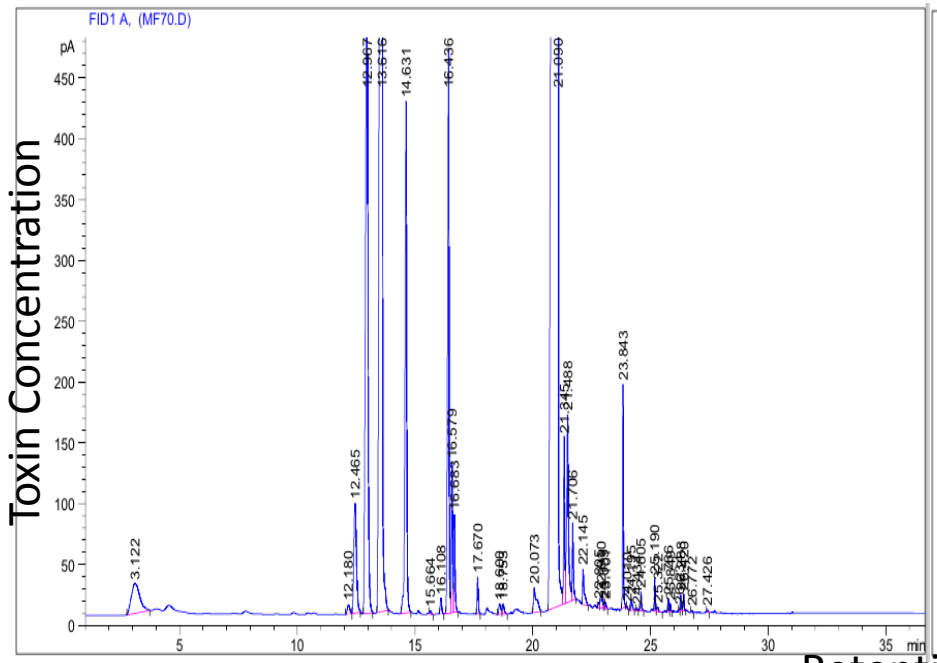
Species Comparison

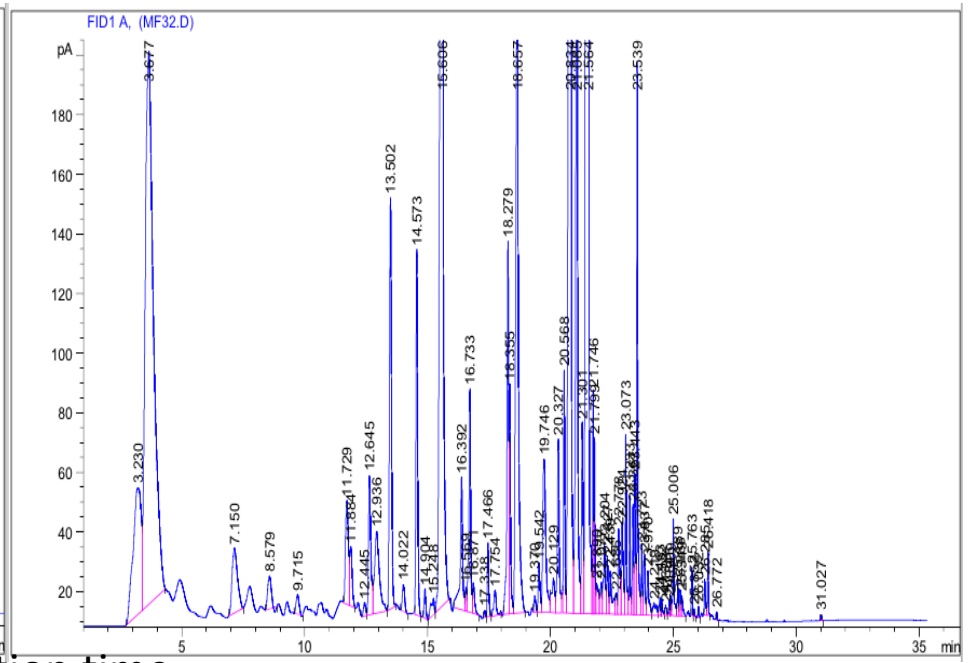
Three-tip sagebrush

- Lower protein
- Higher total AUC
- Lower number of compounds

Wyoming big sagebrush

- Higher protein
- Lower total AUC
- Higher number of compounds





Toxin Concentration

Retention time

Impacts of Fire on Diet Quality

No selection occurred between sagebrush species

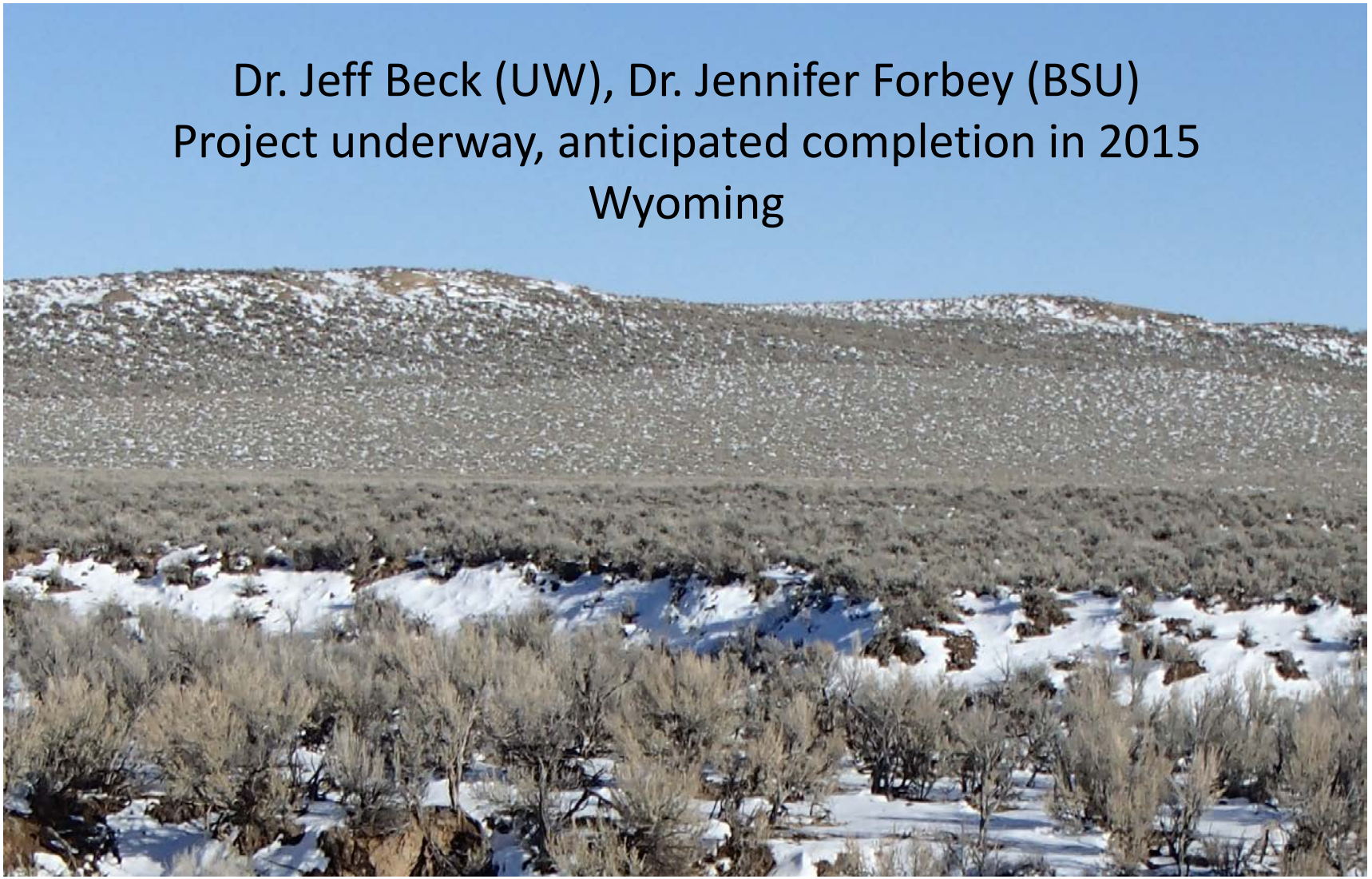
May simply not have a choice (overall low food availability)

- Craters: 13% live sagebrush cover
- Brown's Bench: 17.6% live sagebrush cover
- Raft River: 25% live sagebrush cover

Three-tip re-sprouts after fire

May provide food source during restoration efforts

Mowing and Herbicide Treatments



Juniper Removal Treatments

Photo by Karli Graski and Kayla Luke

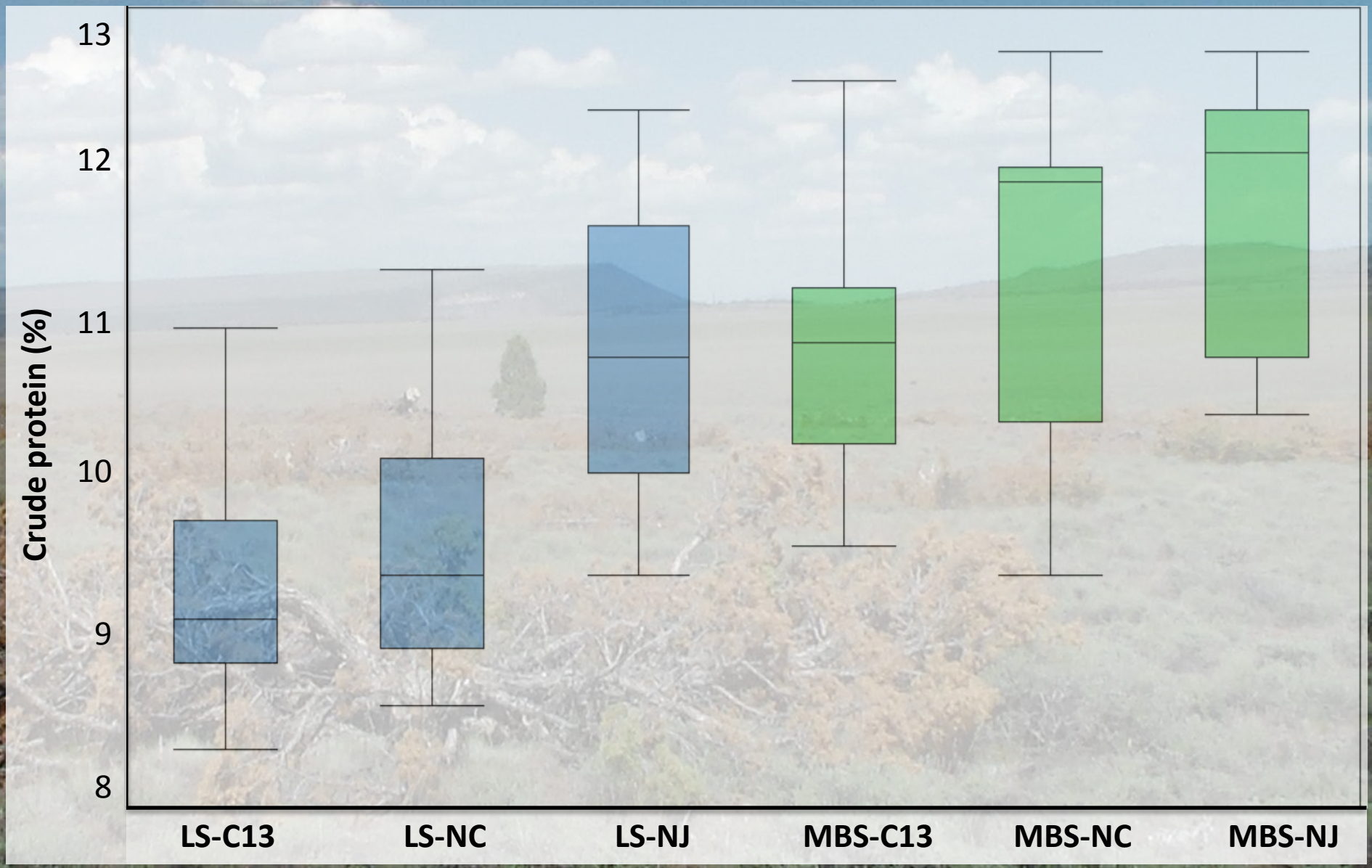
Photo by Karli Graski and Kayla Luke

Sagebrush out-competed by juniper, restoration efforts underway to re-establish healthy sagebrush

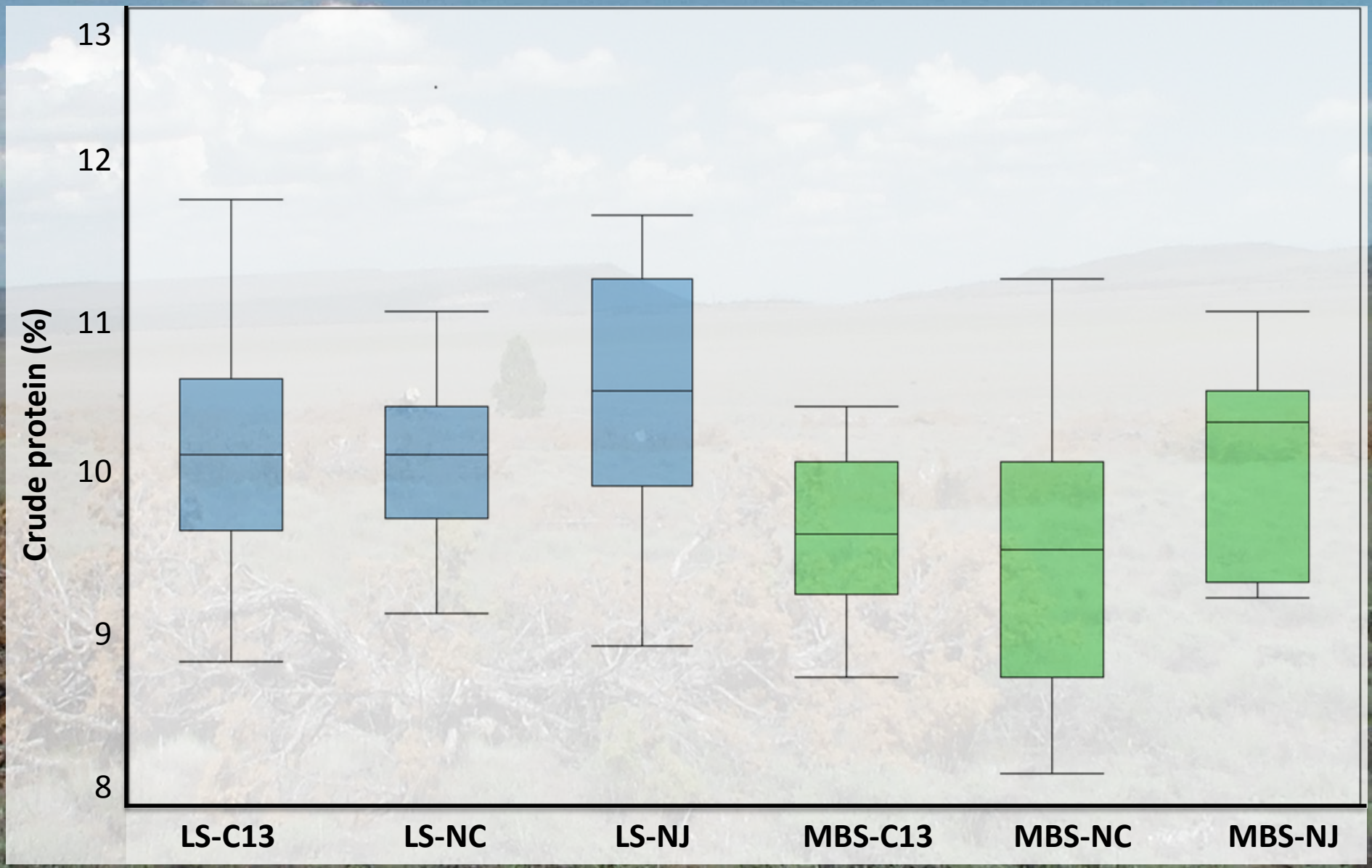
Low sagebrush (above) and Mountain Big Sagebrush (below) at site in Oregon

Photos by Karli Graski and Kayla Luke

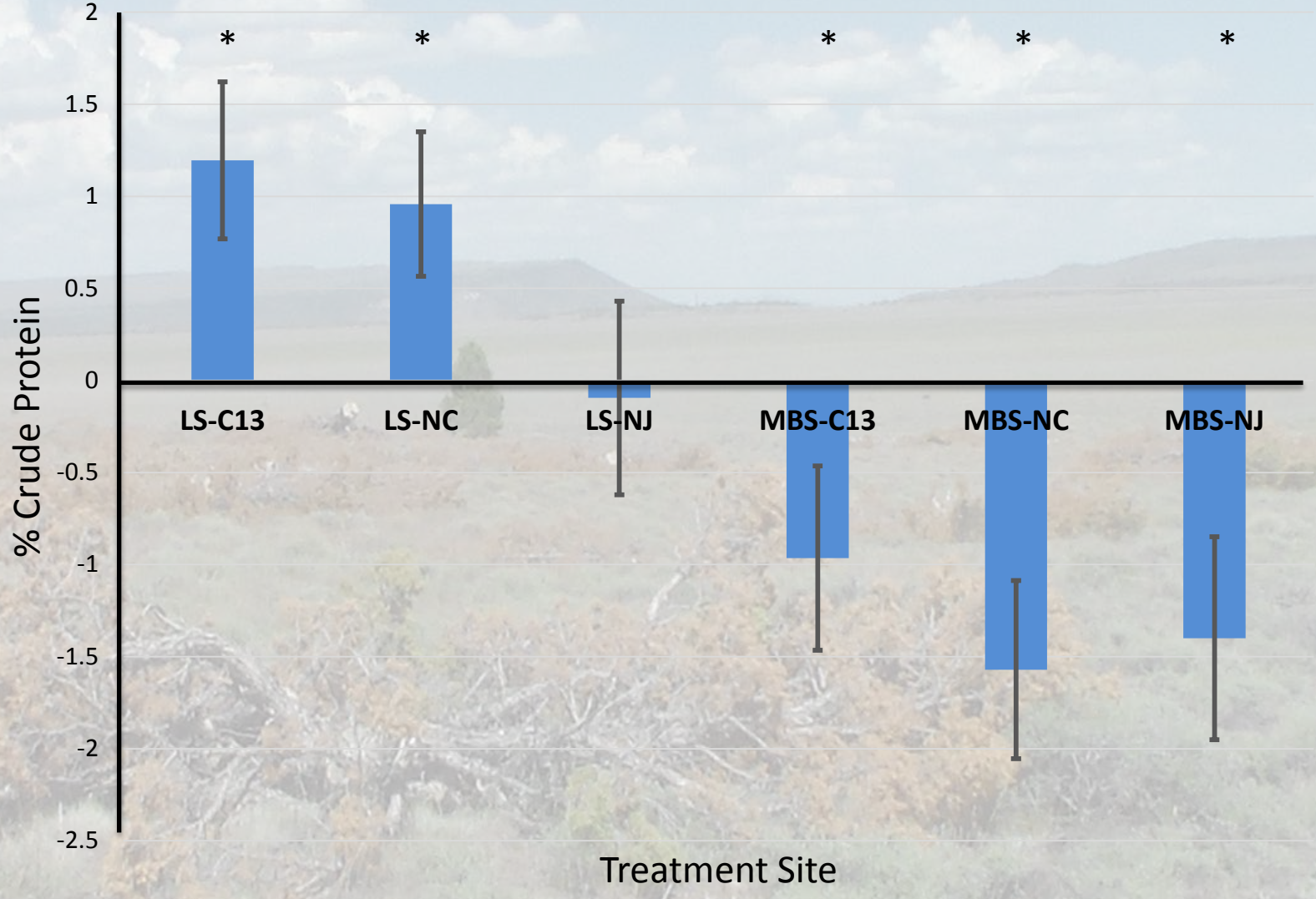
Pre-treatment (2013) Crude Protein



Post-treatment (2014) Crude Protein



Average Protein Difference Between 2013 and 2014 at Treatment Sites



Juniper Treatment Effects on Protein

- Complex, may take more long-term monitoring
- Current monitoring: no treatment effect
  - BUT annual variation in protein content
- Species specific variation

- Other chemical analysis (phenolics, monoterpenes) pending

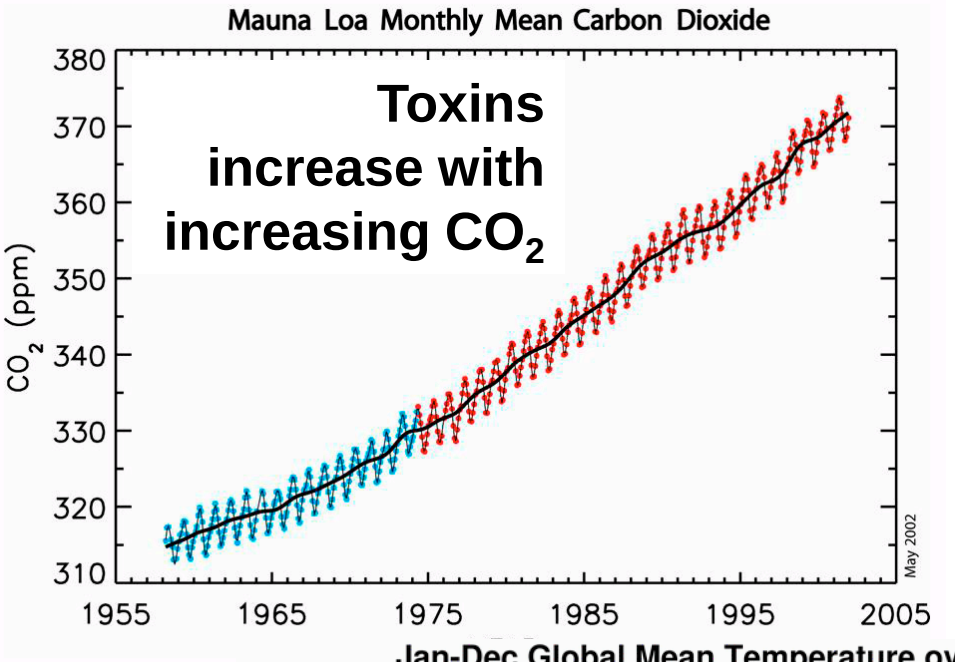
Photo by Karli Graski and Kayla Luke

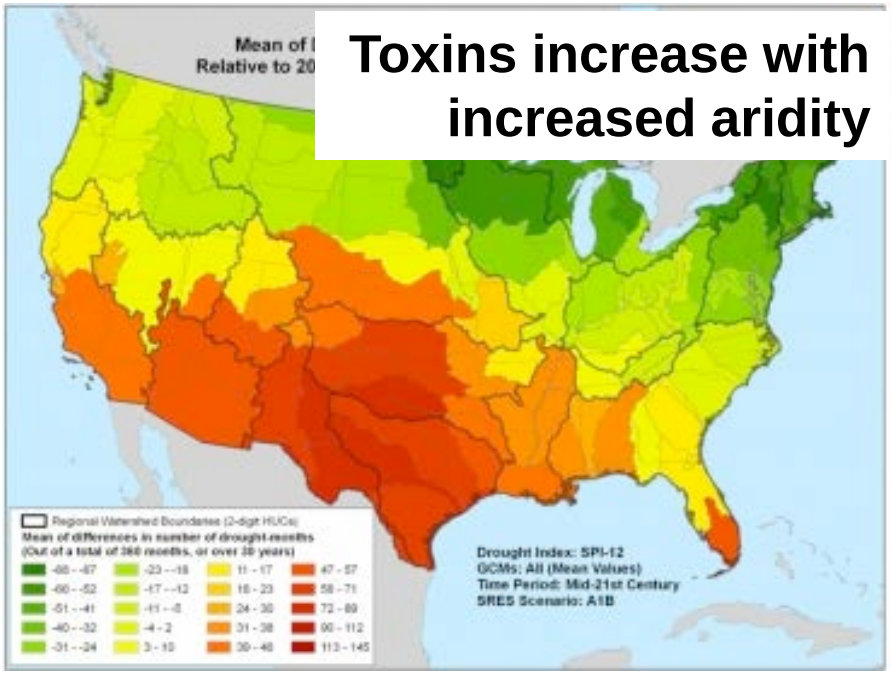
Photos by Karli Graski and Kayla Luke

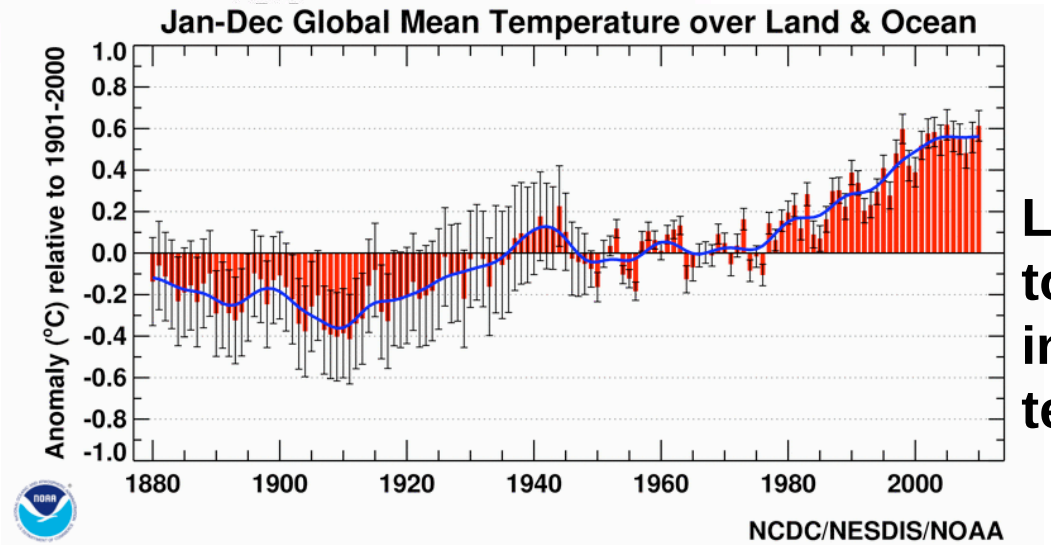
Juniper treatment- pile and burn, hand-cut

Impacts of Extensive Treatments?

Risks of toxins are predicted to increase with climate change



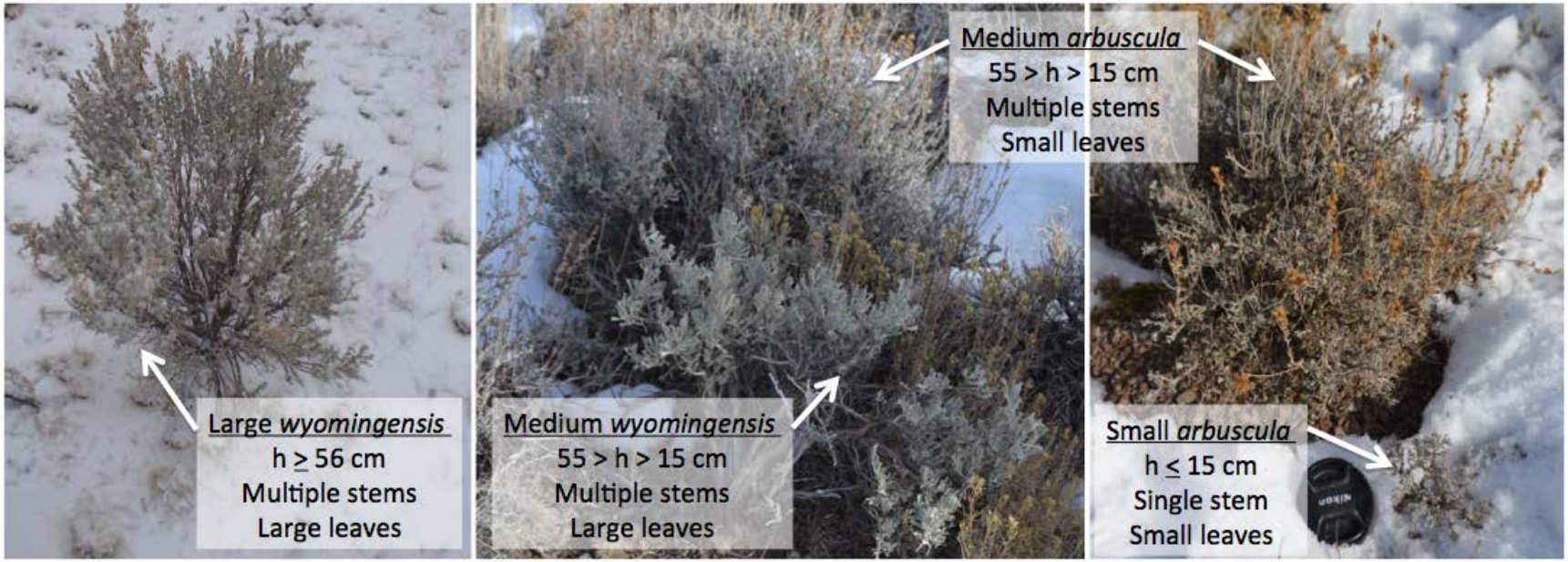




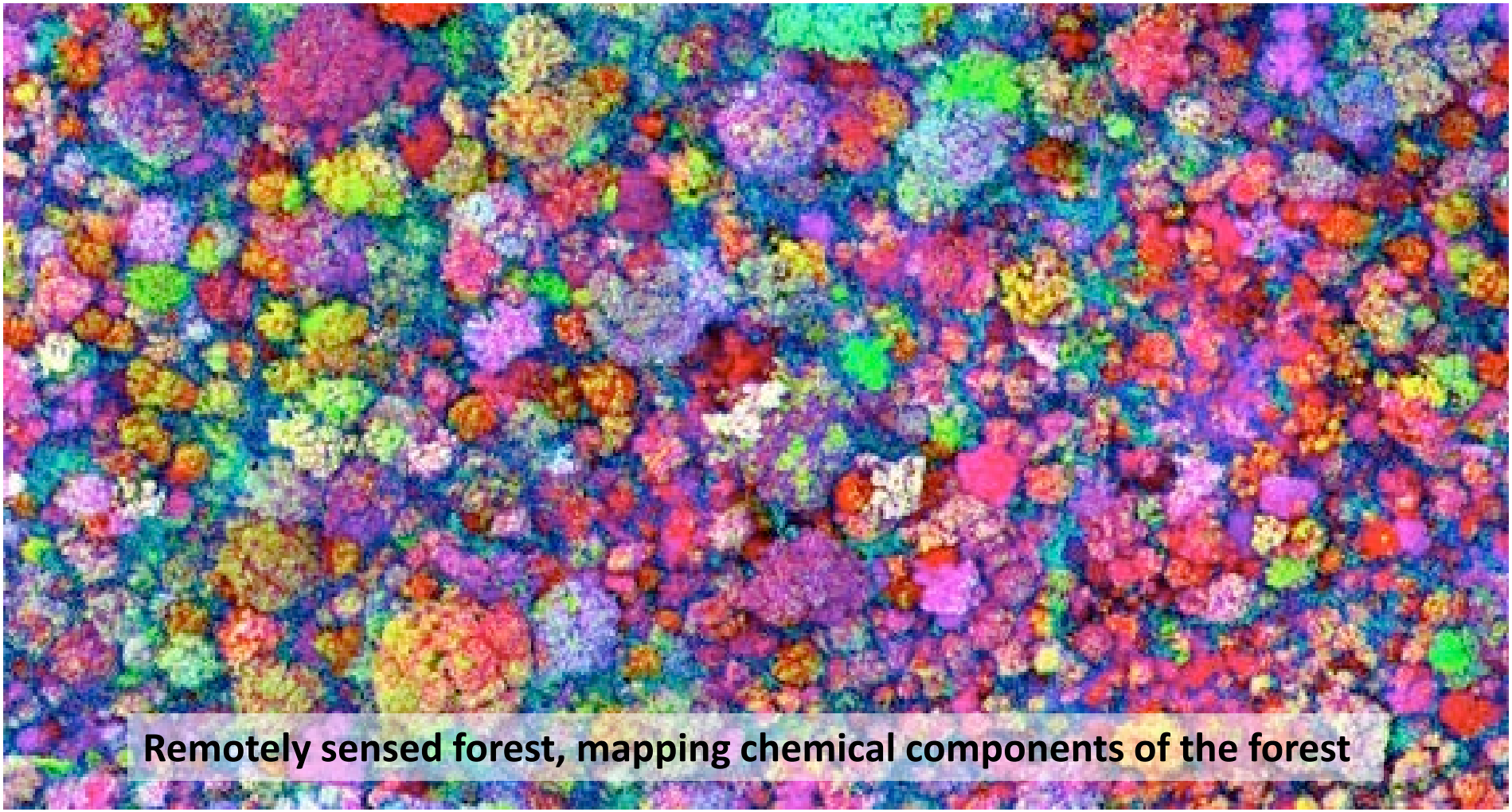
Lower tolerance to toxins with increased temperatures

Diversity and Climate Change

- Chemical diversity may provide some resilience
- Allow herbivores to select best food as food quality and physiology change

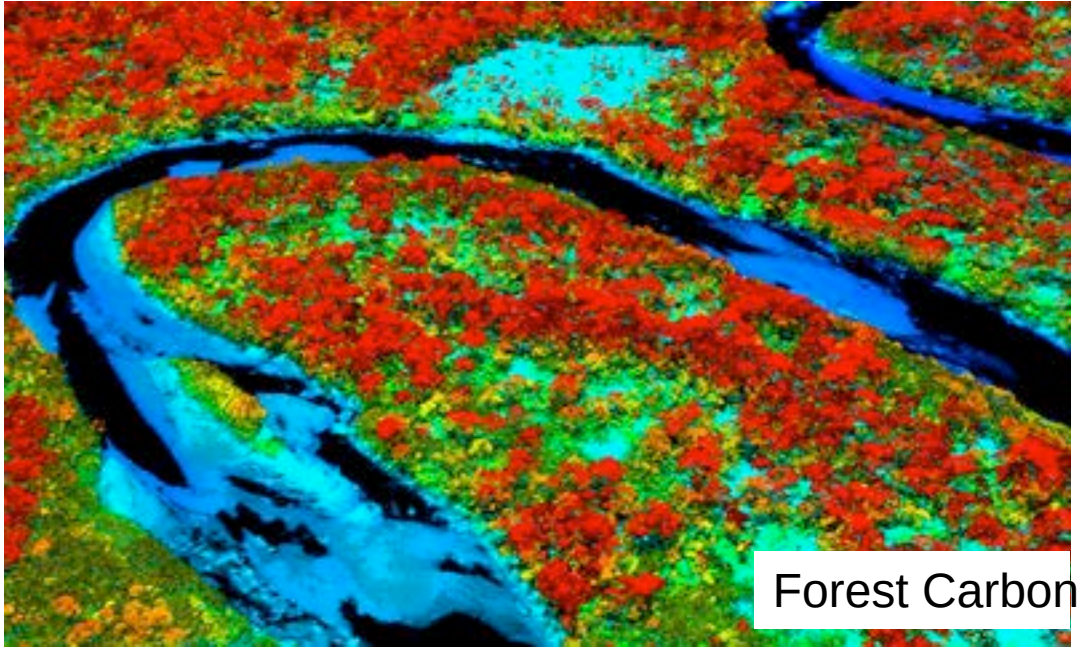


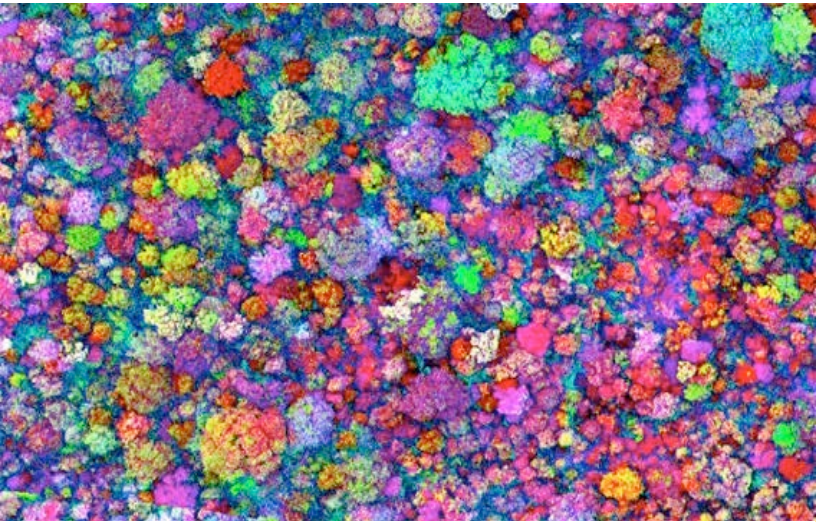
If Diet Quality Matters, How Do We Monitor and Manage It?



Remotely sensed forest, mapping chemical components of the forest

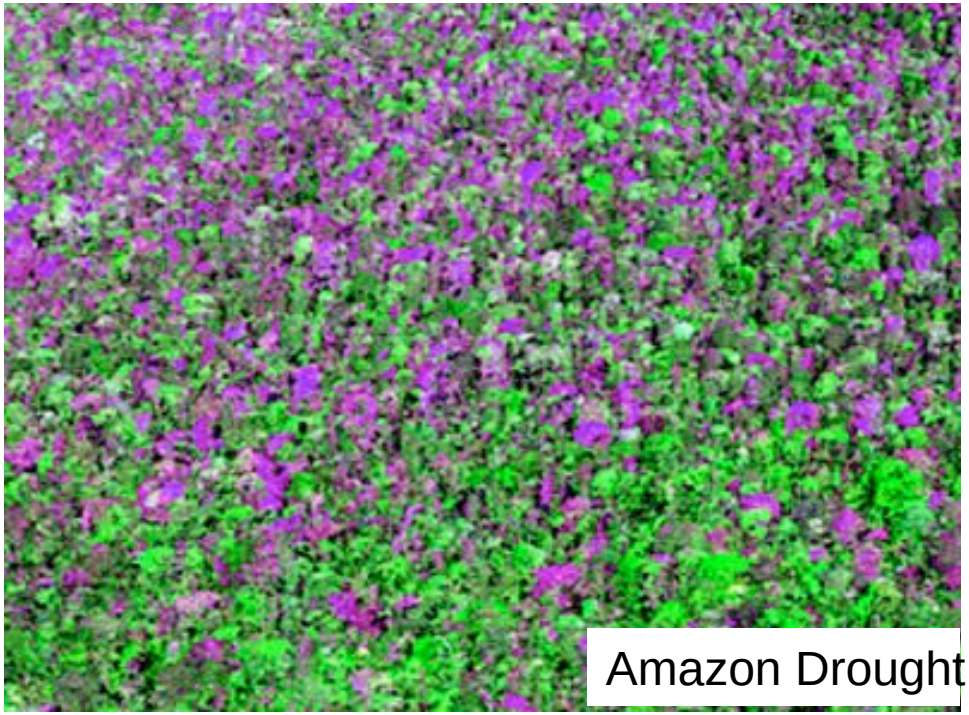
Monitor visual cues at larger spatial scales: Hyperspectral imagery for “food-scapes”



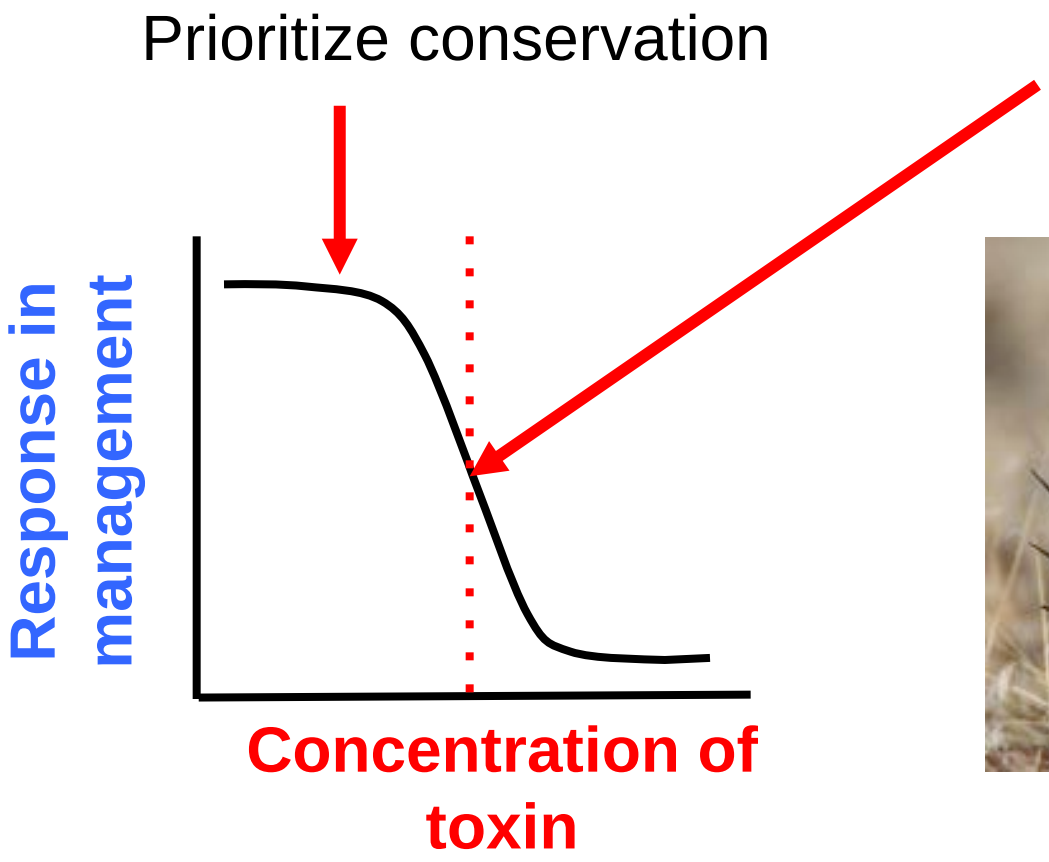


Chemical composition of tropical forest

http://spectranomics.stanford.edu/



Application of monitoring food quality in conservation



Summary: Diet Quality Is Important!

Diet quality impacts habitat use, reproduction and movement in some species

Certain types of habitat restoration may influence diet quality – need to understand for proper management

Acknowledgements

Dr. Jen Forbey
Dr. Jack Connelly
Dr. Jeff Beck

Dr. Kerry Reese
John Severson
Forbey lab members

Questions?

Photo by Aleshia Fremgen

Conservation Status and Habitat Quality Implications

Photo by Geneva W. Chong

Sage-grouse Range

Current Range

Historical Range

Kilometers

0 125 250 500 750 1,000

Map by Center for Native Ecosystems, Washington Department of Fish and Wildlife, M. Schroeder

Selective Foraging


Photo by Mark Summers

Patch Selection

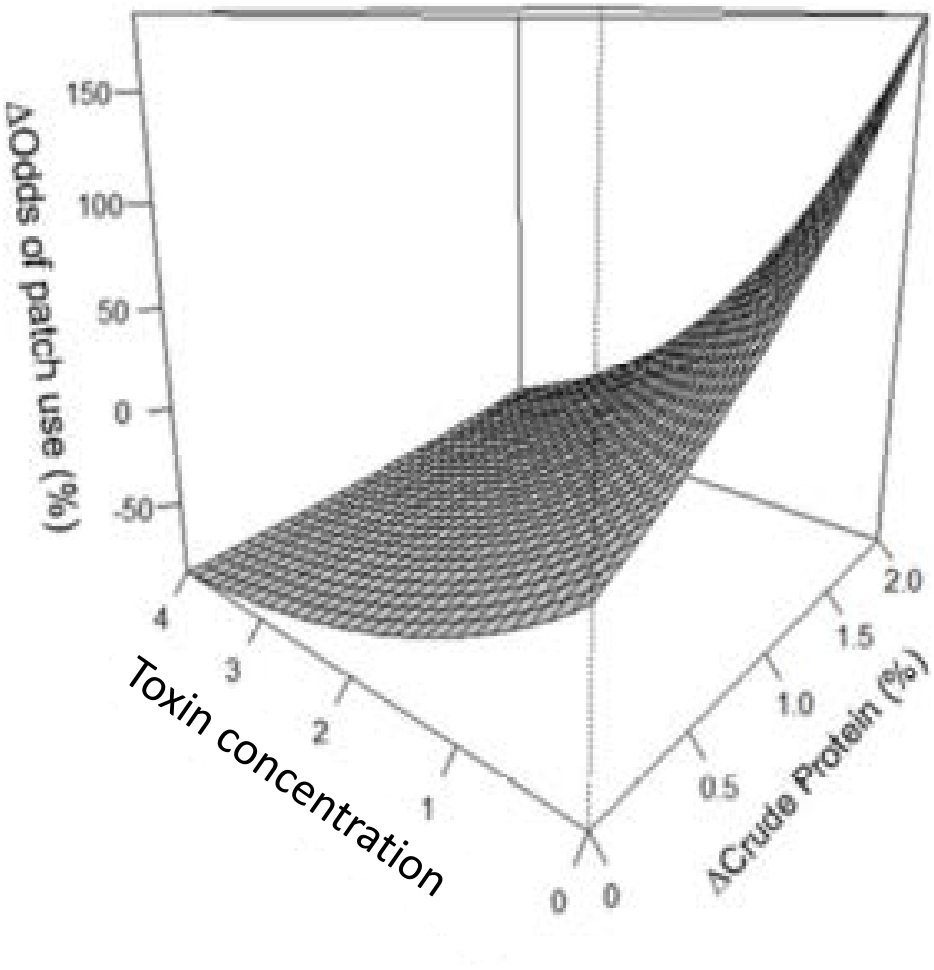
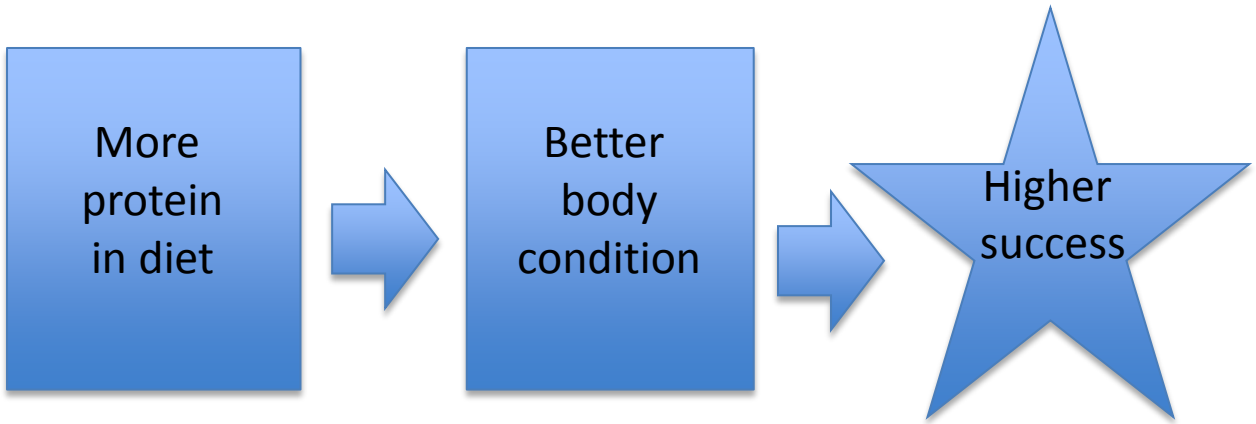


Figure from Frye 2012

Diet quality (especially protein) impacts reproduction

Most commonly studied in females



Chastel et al. 1995, Hunt et al. 2004, DeGabriel et al. 2009

Diet Quality Impacts Reproduction

- Low foraging success means an individual is not able to invest in reproduction that season

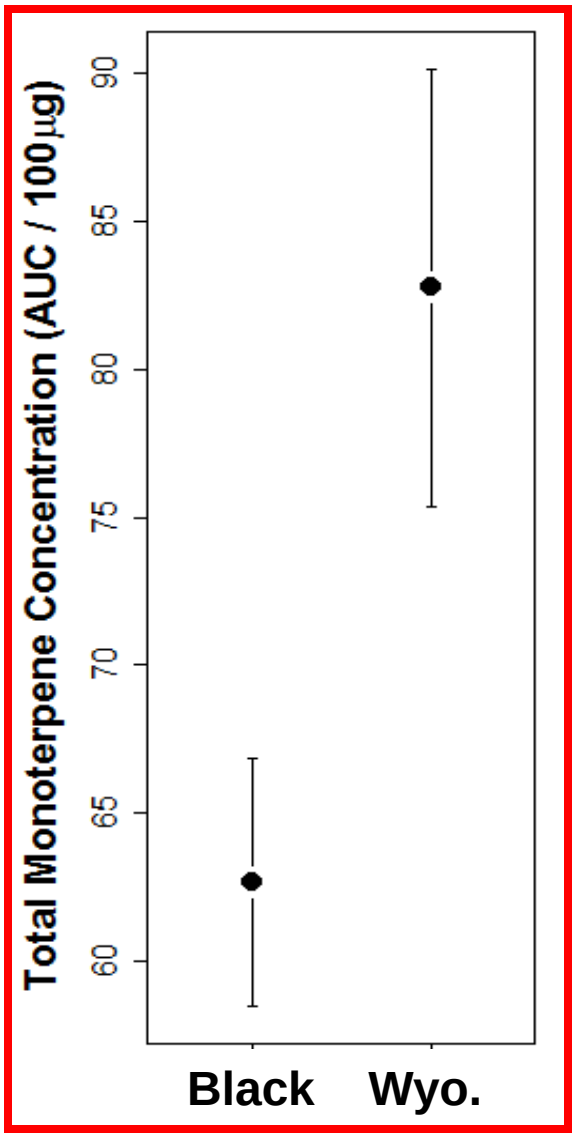
Chastel et al. 1995

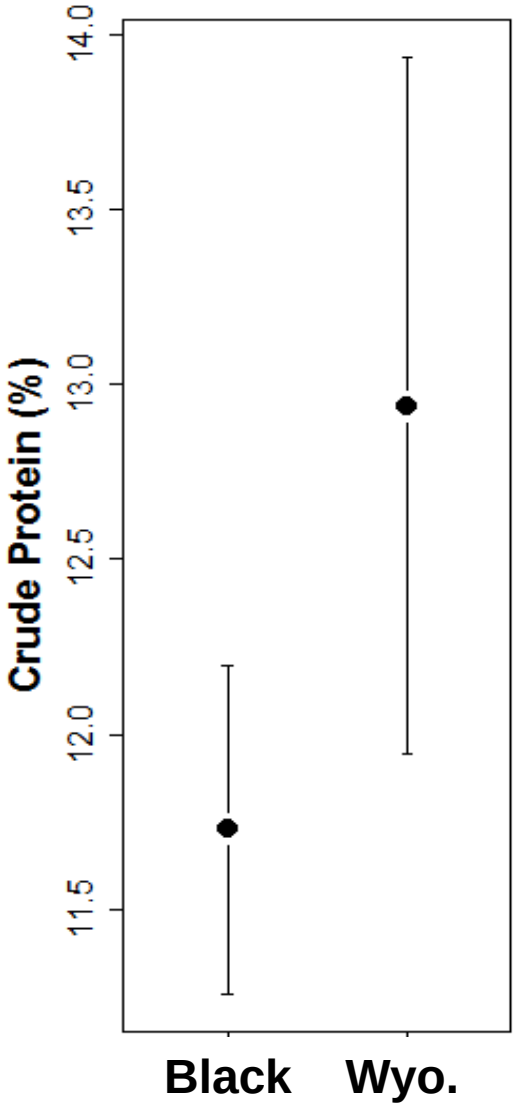
Diet Quality Impacts Reproduction

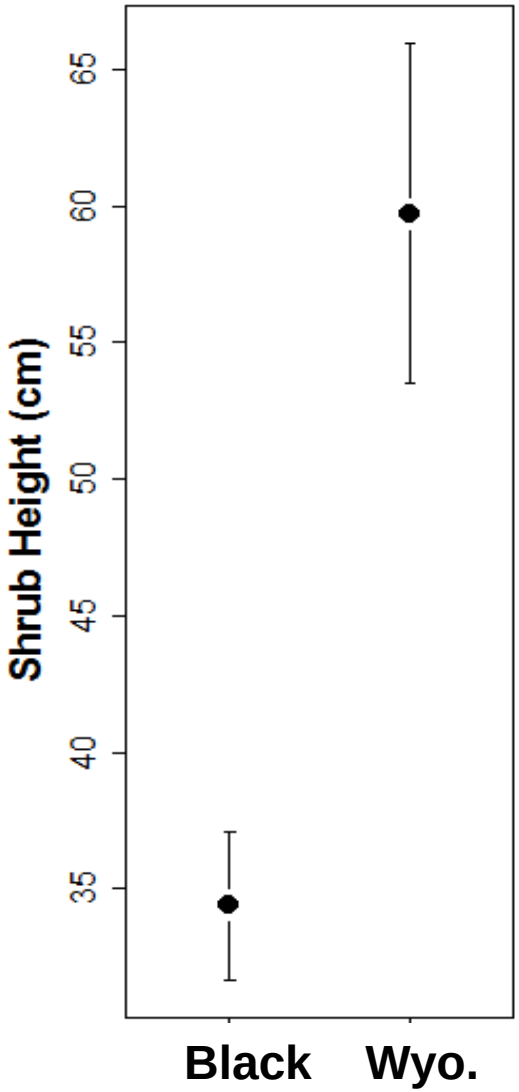
- Males with more protein in diet able to maintain higher display rates and attract more females

Hunt et al. 2004

Habitat Scale: Sage-grouse selected patches with black sagebrush **to avoid toxins**

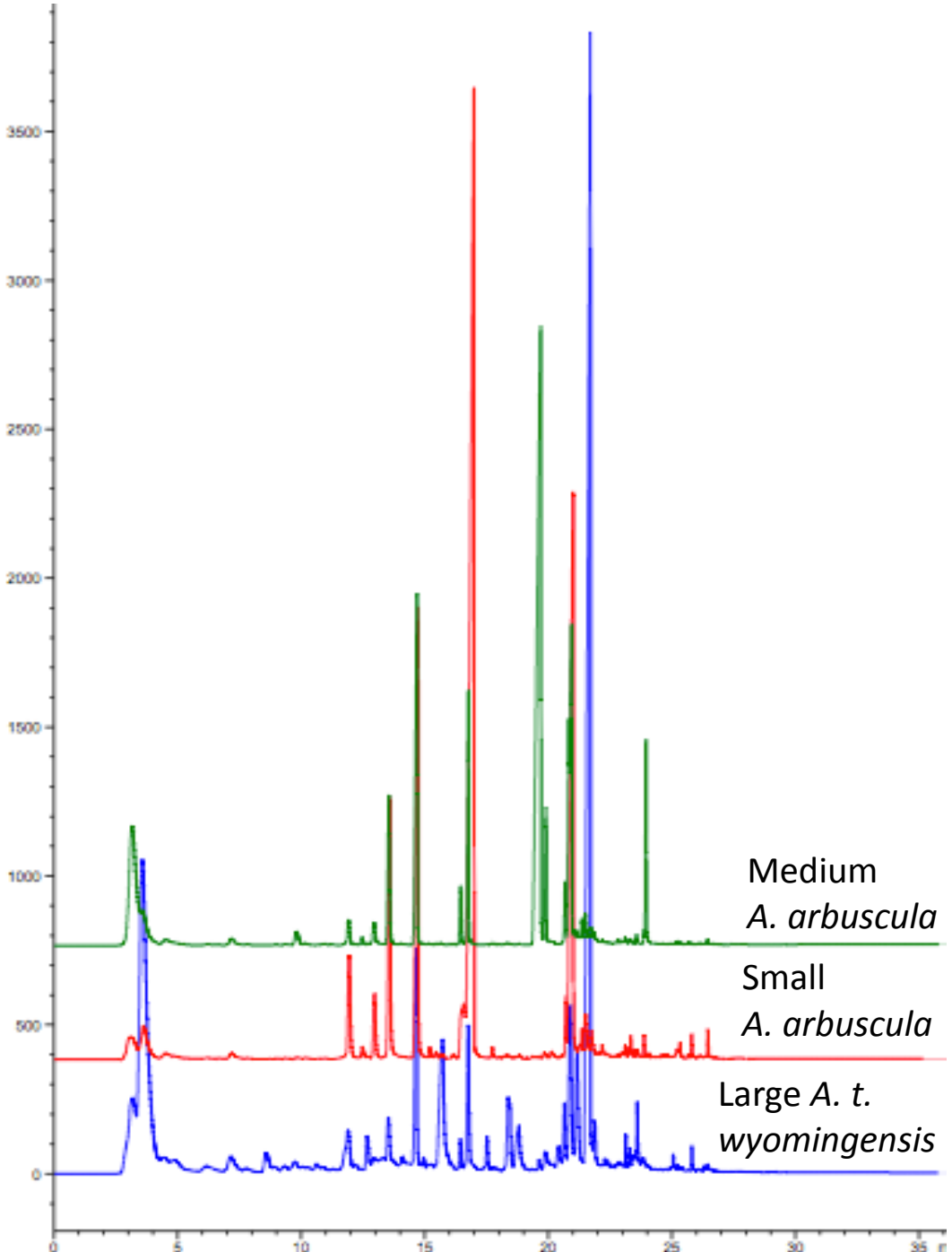




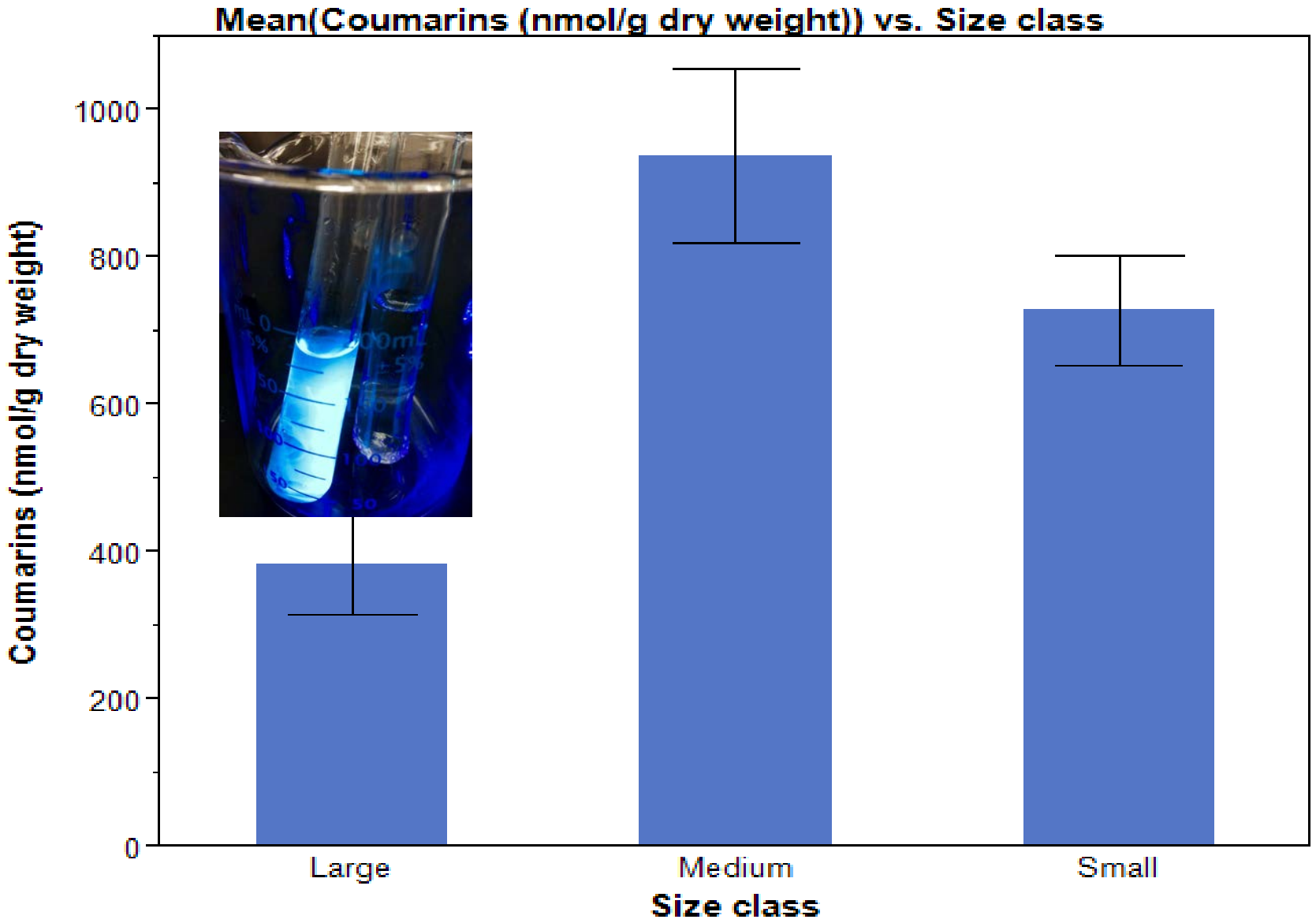


Frye et al. Forbey. 2013

Objective 1: Structural diversity reflects chemical diversity (monoterpenes)



Objective 1: Structural diversity reflects chemical diversity (coumarins)



Results at Raft River: chemical diversity within patches (coumarins)

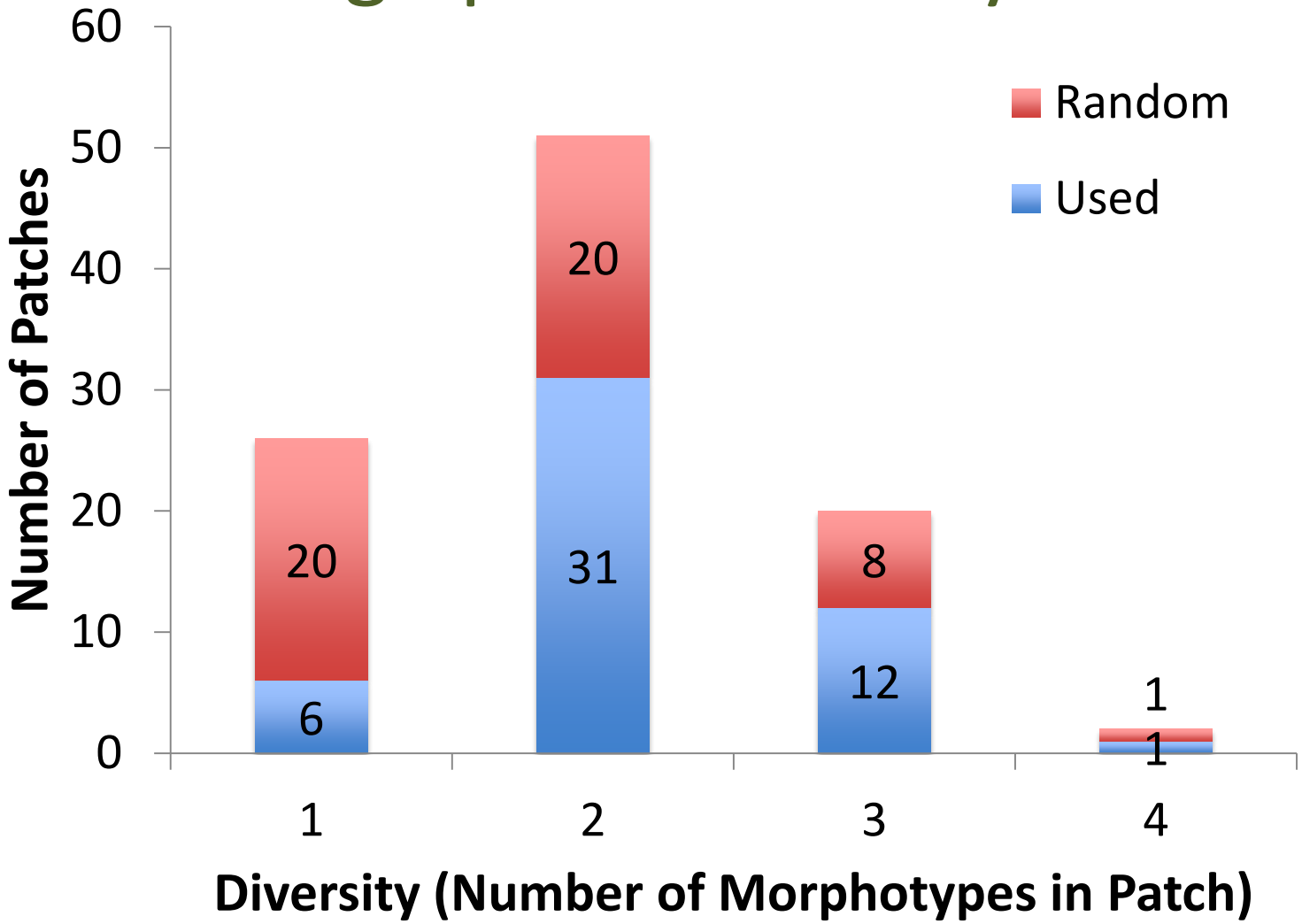
Mean(Coumarins (nmol/g dry weight)) vs. Species

Coumarins

F_{11}= 4.15, p = 0.07

A. Arbuscula A. t. wyomingensis

Objective 3: Sage grouse select for high patch diversity



Monitor visual cues: quantify toxins in sagebrush using Near Infrared sensors