Diet Quality of Sagebrush

Diet Selection, Habitat Selection, and Influences of Restoration Practices

Jennifer S. Forbey and Marcella R. Fremgen, Boise State University
John W. Connelly, Idaho Fish and Game, retired
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Wild Herbivores Forage Selectively

Photos by Jen Forbey
Closer to Home: pygmy rabbits are selective

Photo by Jen Forbey
Why do herbivores forage selectively?

1. Acquire protein/nutrients
2. Avoid toxin consumption
Why do animals select for protein?

Many positive effects on energetically expensive activities:

• 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
Diet Quality Impacts Reproduction

Brushtail possum

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

DeGabriel et al. 2009

Photo by J.J. Harrison
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

More polar

Less polar

Black - Browsed
Black - Nonbrowsed
Wyoming

Concentration (milliAbsorbance Units)

Individual phenolics (based on retention time)
Toxins limit habitat use by pygmy rabbits

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

- Landscape scale
- Patch scale
- Plant scale

- Wyoming
- Dwarf
- Habitat Scale
- Plant Scale
- Patch Scale
Habitat Scale: Sage-grouse selected habitats with black sagebrush

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Used</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming Sagebrush</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Black sagebrush</td>
<td>54</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>55</strong></td>
<td><strong>55</strong></td>
</tr>
</tbody>
</table>

Fisher’s exact test, $P < 0.0001$, odds ratio = 27.8
Grouse select habitats with low sagebrush

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Used</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming sagebrush</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td>Low sagebrush</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>50</td>
<td>49</td>
</tr>
</tbody>
</table>

Chi-squared test, $P < 0.001$, df=1, $X^2=41.76$
Selection at the Plant Scale For Protein and Against Toxins

Crude Protein (%)

Toxin Concentration (AUC/100ug)

Browsed  Non  Random

Browsed  Non  Random

Figure from Frye 2012

Photo by Alan Krakauer
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 wavelengths.
What factors can change diet quality?

Mowing, herbicide
(Beck- UW, BLM)

Juniper removal
(U Idaho, Oregon BLM)

Fire history
(Connelly – IDFG)

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

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Used</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming sagebrush</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Three-tip sagebrush</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Mixed</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

Chi-squared analysis: $p = 0.5258$, $df = 2$, $U = 0.030$
Craters Protein Analysis

<table>
<thead>
<tr>
<th>Species</th>
<th>Average</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming sagebrush</td>
<td>13.303</td>
<td>0.3806</td>
</tr>
<tr>
<td>Three-tip sagebrush</td>
<td>10.411</td>
<td>0.2619</td>
</tr>
</tbody>
</table>

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

Wyoming: \( p = 0.0875, \text{df} = 1, U = -39.500 \)
Three-tip: \( p = 0.1250, \text{df} = 1, S = -13.500 \)
Craters Toxins

Total toxin concentration (AUC/mg DW)

Three-tip

Wyoming

\[ p < 0.0001, \text{ df } = 1, \text{ } F = 124.4455 \]

But no difference between browsed and non-browsed
Craters Toxins

p < 0.0001, df = 1, F = 491.8574
But no difference between browsed and non-browsed
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
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

Dr. Jeff Beck (UW), Dr. Jennifer Forbey (BSU)
Project underway, anticipated completion in 2015
Wyoming
Juniper Removal Treatments

John Severson (UI), Dr. Kerry Reese, Dr. Jennifer Forbey (BSU)
Project underway, anticipated completion in 2015
South-central Oregon

Photo by Karli Graski and Kayla Luke
Sagebrush out-competed by juniper, restoration efforts underway to re-establish healthy sagebrush

Photo by Karli Graski and Kayla Luke
Low sagebrush (above) and Mountain Big Sagebrush (below) at site in Oregon

Photos by Karli Graski and Kayla Luke
Pre-treatment (2013) Crude Protein

<table>
<thead>
<tr>
<th></th>
<th>Crude protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-C13</td>
<td>13</td>
</tr>
<tr>
<td>LS-NC</td>
<td>12</td>
</tr>
<tr>
<td>LS-NJ</td>
<td>11</td>
</tr>
<tr>
<td>MBS-C13</td>
<td>10</td>
</tr>
<tr>
<td>MBS-NC</td>
<td>9</td>
</tr>
<tr>
<td>MBS-NJ</td>
<td>8</td>
</tr>
</tbody>
</table>
Post-treatment (2014) Crude Protein
Average Protein Difference Between 2013 and 2014 at Treatment Sites

<table>
<thead>
<tr>
<th>Treatment Site</th>
<th>Average Protein Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-C13</td>
<td>*</td>
</tr>
<tr>
<td>LS-NC</td>
<td>*</td>
</tr>
<tr>
<td>LS-NJ</td>
<td></td>
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<td>*</td>
</tr>
<tr>
<td>MBS-NC</td>
<td>*</td>
</tr>
<tr>
<td>MBS-NJ</td>
<td>*</td>
</tr>
</tbody>
</table>

Note: * indicates significant difference.
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
Juniper treatment- pile and burn, hand-cut

Photos by Karli Graski and Kayla Luke
Impacts of Extensive Treatments?
Risks of toxins are predicted to increase with climate change.

Toxins increase with increased aridity.

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 “foodscapes”

Chemical composition of tropical forest
http://spectranomics.stanford.edu/

Forest Carbon

Amazon Drought
Application of monitoring food quality in conservation

Prioritize conservation

Prioritize restoration

Response in management

Concentration of toxin
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?
Conservation Status and Habitat Quality Implications

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

Photo by Geneva W. Chong

Sage-grouse Range

- **Current Range**
- **Historical Range**

Map showing the current and historical range of the Sage-grouse across the western United States. The map includes a scale in kilometers and a smaller inset map highlighting the specific area.
Selective Foraging

Patch Selection

Photo by Mark Summers

Figure from Frye 2012
Diet quality (especially protein) impacts reproduction

More protein in diet → Better body condition → Higher success

Most commonly studied in females

Diet Quality Impacts Reproduction

Blue petrels

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

Chastel et al. 1995
Diet Quality Impacts Reproduction

Field Crickets

- 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

$F_{11} = 4.15, p = 0.07$

A. Arbuscula  A. t. wyomingensis
Objective 3: Sage grouse select for high patch diversity

The chart shows the number of patches at different diversity levels (number of morphotypes in patch). The data is broken down into two categories: Random and Used. The chart indicates that the majority of the patches selected by the sage grouse have a high diversity, with a significant number of patches having 2 morphotypes. The numbers of patches are as follows:

- Diversity 1: 20 Random, 6 Used
- Diversity 2: 20 Random, 31 Used
- Diversity 3: 8 Random, 12 Used
- Diversity 4: 1 Random, 1 Used
Monitor visual cues: quantify toxins in sagebrush using Near Infrared sensors.