Fertilizing western rangelands for sagebrush habitat improvement: an assessment
Ruckelshaus Institute
Energy Mitigation and Outreach Initiative
Fertilizing Western Rangelands

Increased natural gas production

(EIA 2013)
Much of that NG is in sagebrush-steppe
Habitat loss on winter range

Since 2001, >40% population decline (Sawyer and Nielson 2011)
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Mule deer declines

- Direct habitat loss
- Indirect habitat loss
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Mule deer declines trigger mitigation

2009 ROD required **sequential** mitigation if 15% decline in a year or average over all years (since 05/06)

**On-site**
1. Protect flanks
2. Habitat enhancements

**On-site/off-site**
3. Conservation easements

**Modification of operations**
4. Change pace or pattern of development
How to mitigate energy development impacts through on-site habitat enhancements?
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Sagebrush fertilization

- Pilot study initiated in 2010
- Federal approval of up to 30,598 ac (also in Rawlins DEIS)
- Goals: Improve production and quality/palatability

2010
- 90 kg/ha

2011
- 45 kg/ha
- 45 kg/ha
Aerial applications of pellet urea

$(\text{CO(NH}_2\text{)}_2)\cdot\text{N}$

~$55/ac$ ($54,430$ in 2011)
What are the likely benefits to wildlife and potential costs/risks?

- Literature review
- Range management + ungulate nutrition + semi-arid land biogeochemistry = 145 papers
2-4X background rates of N deposition/fixation

Graphics by Emilene Ostlind
NH₃ (ammonia gas – 20%)

Fertilizer (urea)

CO(NH₂)₂ → NH₄⁺
Fertilizer (urea)

$\text{CO(NH}_2\text{)}_2 \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_3^-$

$\text{NO}_x$ (nitrogen oxides)
$\text{N}_2\text{O}$ (nitrous oxide)
$\text{NH}_3$ (ammonia gas)

Graphics by Emilene Ostlind
NO\textsubscript{x} (nitrogen oxides)
N\textsubscript{2}O (nitrous oxide)
NH\textsubscript{3} (ammonia gas)

Fertilizer (urea)

\[
\text{CO(NH}_2\text{)}_2 \rightarrow \text{NH}_4^+ + \text{NO}_3^- 
\]

<10\% NO\textsubscript{3}

Graphics by Emilene Ostlind
NO\textsubscript{x} (nitrogen oxides)
N\textsubscript{2}O (nitrous oxide)
NH\textsubscript{3} (ammonia gas)

Fertilizer (urea)

\[ \text{CO(NH}_2\text{)} \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_3^- \]

Soil microbes

Big sagebrush
Wet yr.
Dry yr.

Perennial grasses
Native forbs
Cool-season annuals

Groundwater

Graphics by Emilene Ostlind
NOx (nitrogen oxides)
N2O (nitrous oxide)
NH3 (ammonia gas)

Fertilizer (urea)

Big sagebrush
Wet yr.
Dry yr.

Perennial grasses
Native forbs
Exotics

Soil microbes

Graphics by Emilene Ostlind
NO\(_x\) (nitrogen oxides)
N\(_2\)O (nitrous oxide)
NH\(_3\) (ammonia gas)

Fertilizer (urea)

CO\((\text{NH})_2\) → NH\(_4^+\) → NO\(_3^-\)

Soil microbes

Big sagebrush

Wet yr.  Dry yr.

Perennial grasses  Native forbs  Exotics

Graphics by Emilene Ostlind
FERTILIZING WESTERN RANGELANDS

What are the likely **benefits** to wildlife and potential costs/risks?
DOES FERTILIZATION INCREASE SAGEBRUSH PRODUCTION, QUALITY, OR PALATABILITY?

Fertilization **might** increase production

- Leader growth with N (sometimes)
  - No effect at 31 kg/ha (Upper Green = 45.0) 
    (Carpenter and West 1987)
  - ≤ 0-30% increase at 84-252 kg/ha (Barrett 1979)
  - 36% increase at 34 kg/ha | 103% at 100 kg /ha
    (Bayoumi and Smith 1976)
DOES FERTILIZATION INCREASE SAGEBRUSH **PRODUCTION**, QUALITY, OR PALATABILITY?

**Longer leaders = more digestible energy / cover**

But....

- Minimal effect in low-precipitation years
- Transitory – decline in year 2
  (Bayoumi and Smith 1976)
- Is protein or DE limiting?
BENEFITS TO MULE DEER

Mule deer response to enhanced winter nutrition

• Increased DE can improve fitness
  ↑ Fetal and overwinter fawn survival
  ↑ Adult female survival
  (Artificial feeding study; Bishop et al. 2009)

• Caveat:
  Artificial feed ≠ enhanced native forage
No increase in crude protein of winter sagebrush

Increased crude protein of leaves and stems in spring/summer: 2.4-4.6% (Bayoumi and Smith 1976)

- Transitory: Increase in protein lost by fall (Barrett 1979)—leaf fall or translocated to twigs
- High inter-annual variation (precipitation-dependent?)
Fertilization does not affect terpenoid compounds

- No significant effect on volatile oil concentrations at fertilization rates similar to Upper Green (Sneva et al. 1983)
- Mule deer: no relationship between terpenoid compounds and diet preference (Black Sagebrush: Behan and Welch 1985)
- Sage grouse: loss of monoterpenoids during digestion (Welch et al. 1989)
Realized mitigation potential

- No significant difference in leader length (DE) between treatment and control plots
Limited benefits to sagebrush obligates

- Crude protein
- Terpenoids (palatability)
- Digestible energy (DE)
- Sagebrush cover
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What are the likely benefits to wildlife and potential costs/risks?
Atmospheric consequences

$\text{NO}_x$ (nitrogen oxides)
Ozone production

\[ \text{NO}_x \text{ (nitrogen oxides)} + \text{VOCs} + \text{cold/sunlight} = \text{O}_3 \]

(Schnell et al. 2009)
Atmospheric consequences

NO\textsubscript{x} (nitrogen oxides)

N\textsubscript{2}O (nitrous oxide): greenhouse gas and stratospheric ozone depleting substance

NH\textsubscript{3} (ammonia gas): N deposition

Graphics by Emilene Ostlind
Ammonia gas

Major source of N deposition in Class I Airsheds (Ellis et al. 2013)
Ecosystem shifts seen in shortgrass steppe

Effects are often persistent, irreversible, and delayed (Milchunas and Lauenroth 1995, Vinton and Burke 1995)

- Cool-season grasses
- Exotics
- Forbs

Cool-season grasses
Exotics
Forbs

Graphics by Emilene Ostlind
Expense

- $55/acre (from PAPO)
- To treat 30,000 acres = $1.65M annually
- Opportunity cost?
What are the likely benefits to sage grouse and potential costs/risks?

**Benefits**
- On-site strategy
- Increased sagebrush cover / digestible energy under certain conditions

**Risks and Costs**
- Exotics ➔ ecosystem shifts, change in fire regime
- Loss of forbs (brood habitat)
- Atmospheric/water pollution
- Expensive
- Transitory and uncertain benefit

Scientific Uncertainty
Minimizing risks

1. No application where there are weeds
2. Long-term monitoring for ecosystem shifts and invasions before widespread treatment
3. Application timing?
Thanks

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NOX (+ sunlight + VOC \xrightarrow{} ground-level O3 pollution)

N2O (greenhouse gas and stratospheric O3 depleting substance)

NH3

Atmosphere

Snow

Fertilizer (urea)

\[
\text{CO(OH)}_2 \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_3^- 
\]

Native bunch-grasses

Native forbs

Invasive plants

Big sagebrush response in wet years

Big sagebrush response in dry years

Soil microbes

Ground-water

Graphics by Emilene Ostlind
Alternatives

1. Avoidance of initial impacts

1. Successful reclamation

1. Protection/management of summer and transitional ranges
Alternatives

1. Avoidance of initial impacts

- Avoid
  - Keeping wilderness or recreation areas off-limits to development;
  - Use of EIS for initial off

- Minimize
  - Creating 500 ft. riparian buffers
  - Seasonal stipulations for drilling activities; establishing well density maximums; fluid collection systems

- Compensate
  - Protecting or enhancing existing habitat or creating new habitats away

Example Activities
Alternatives

1. Avoidance of initial impacts

2. Grazing management

and summer ranges
What’s limiting for mule deer?

- White-tailed deer selected diets with higher digestible energy than protein (Berteaux et al. 1998)

- Wyoming Big Sagebrush overwinter crude protein content in leaves/stems: 8.3 - 14.5% (Welch and McArthur 1979, Wambolt 2004)
  - Exceeds 7.5% crude protein maintenance requirement