Ungulate Browsing Behavior in Relation to Plant Mineral Nutrition

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Deer at the Garden

‘If I can keep my garden
flourishing while more and more gaunt deer
keep coming from the woods,
since there’s only so much room within a garden
whether filled with people or with deer;
some must make do within the woods
where there can never be enough,’

Excerpt from “Deer at the Garden” by Robert Pack 2002

Ungulate Behavior

What drives behavior

Mating

Hunger / Thirst

What influences behavior

Weather

Landscape

People

Ungulate Behavior

Success of an individual is based on reproductive fitness

To maximize fitness:

- **Minimize Energy Expenditures**
- **Maintain homeostasis (stable internal environment)**
- **Consume high quality food sources (forage)**

Geist (1982)

Ungulate Behavior

Forage selection is based on sight, taste, and olfactory senses

Ungulates unfamiliar with an area and/or plants:

1. Taste for forage quality
2. Adverse digestion creates negative feedback
3. Build association with smell and/or sight

The Damage

http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/minnesota/howwework/oh-deer-the-mammal-that-ate-the-northwoods.xml

Damage on the Rise

Reasons

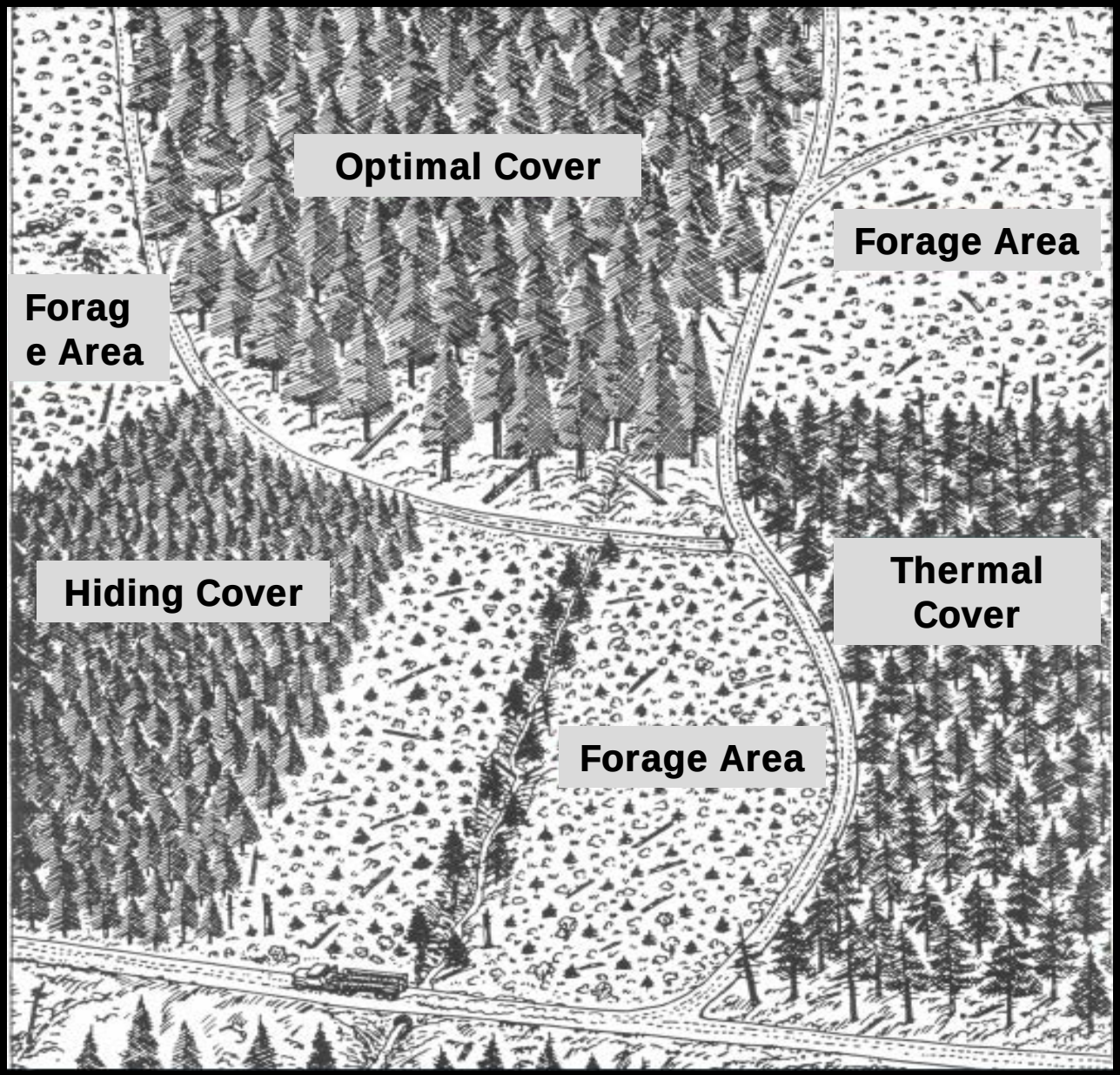
- Habitat is fragmented
- Decrease in natural predators
- Over abundance in ungulate populations

Problems

- Shifts in plant species composition
- Conflicts with domestic herbivores
- Impacts on Forest Regeneration

Impacts of Ungulates on Forest Regeneration

Forest regeneration sites promote animal browse due to enhanced forage quantity and quality.



Impacts of Ungulates on Forest Regeneration

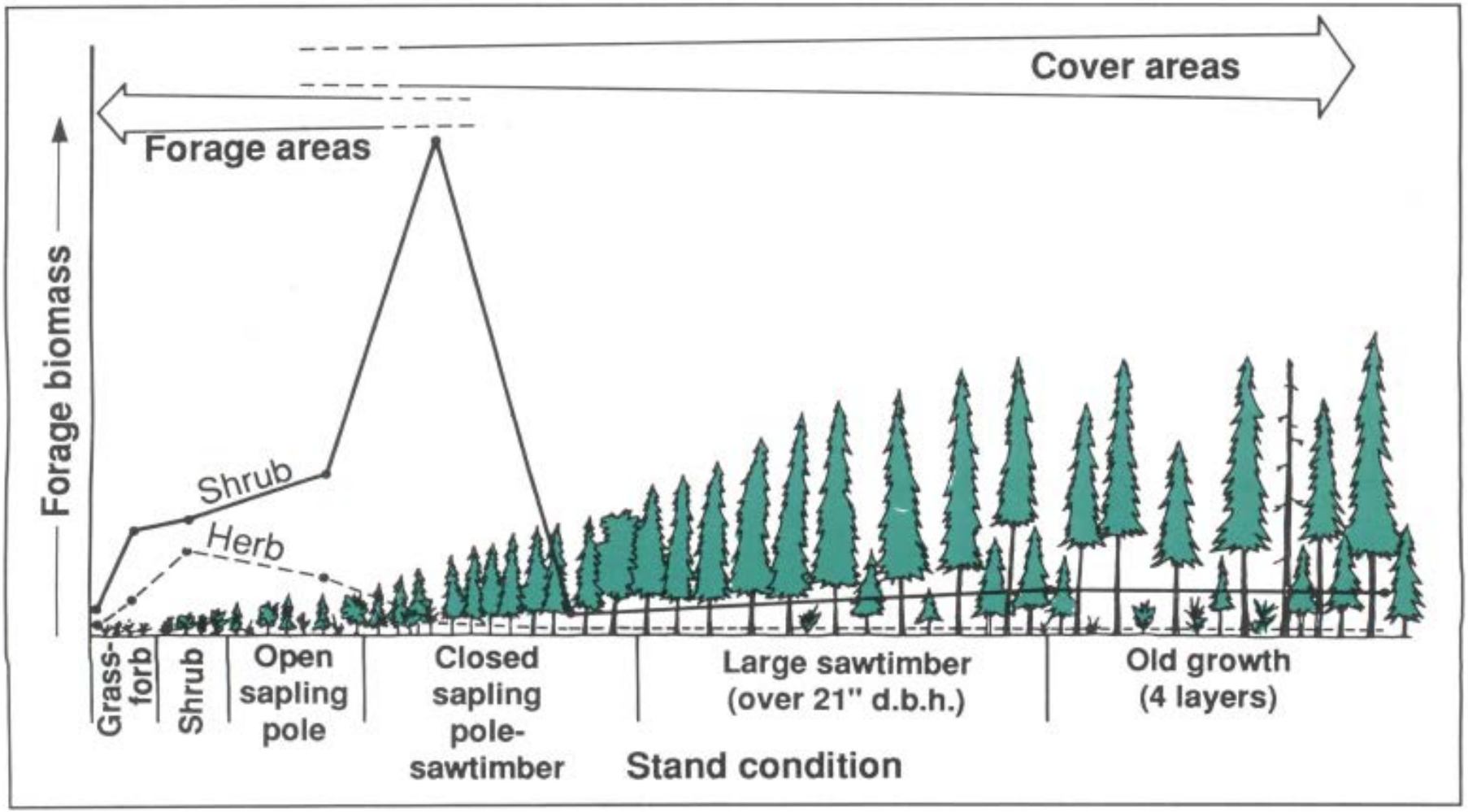


Figure 1—Relation of forest stand condition (or seral stage) to deer and elk forage and cover areas (biomass curves adapted from Long 1976, Witmer and others 1985).

Impacts of Ungulates on Forest Regeneration

Typical browse preference for elk and deer:

grass > forbs > shrubs > trees

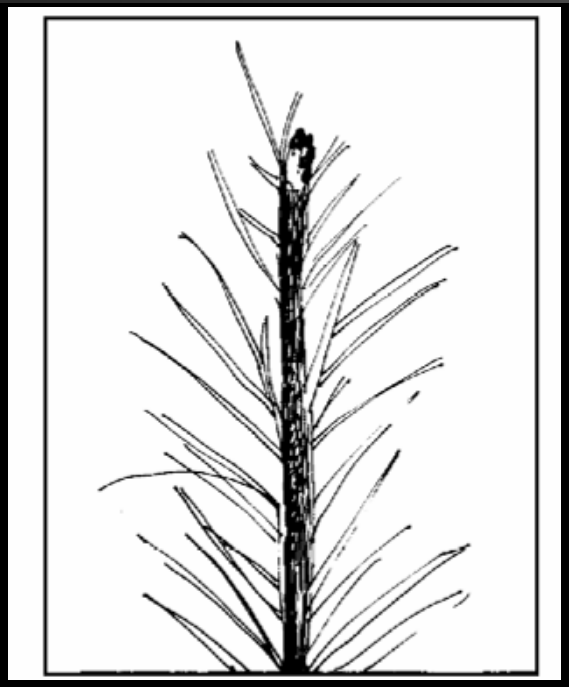
NOT a static selective process.

Conifer seedlings represent a crucial component of the diet during the WINTER.

Hardwoods generally have greater browse during summer (due to presence of foliage)

Ramsey and Krueger 1986; Nelson and Leege 1982; Mansson et al. 2009

Impacts of Ungulates on Forest Regeneration



DAMAGE:

- Terminal Shoot
- Lateral Shoot
- Entire Seedling (browsed or trampled)
- Pulled Seedling

Efforts to Mitigate Browse

THERE IS NO BLANKET PRESCRIPTION

- **Fencing**
- **Hunting**
- **Chemical Repellents**
- **Physical Barriers (tubing, bud caps)**
- **Frightening Devices (air canons)**
- **Habitat Manipulation (multiple openings)**
- **Fertilization**

Fertilization

Nutrients applied at the nursery and/or in the field

Controlled-release fertilizers have shown to promote early growth and development of seedlings

Advantage: - rapid growth above browse line
- recovery from browse due to nutrient reserve

Disadvantage: - higher browse probability?

Application Methods at Time of Planting

- Broadcast
- Dibbled
- Planting hole
- Incorporated into media

Influence of Fertilization on Palatability

Why fertilization attracts herbivory?

Fertilization increases foliar nitrogen and thus foliar protein, the highest valued nutritional component of ungulate food sources

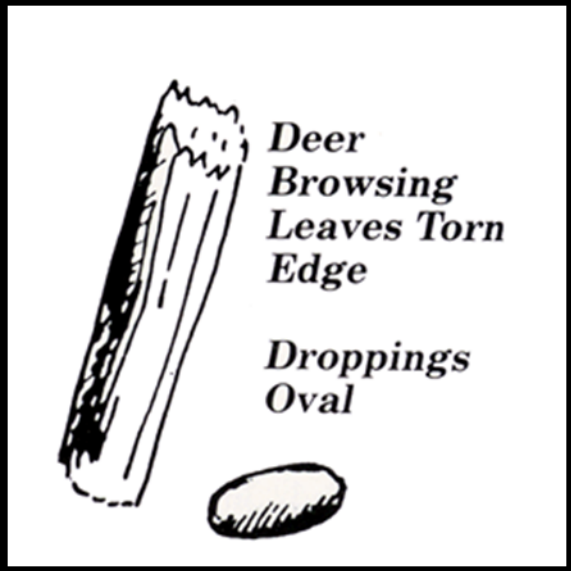
Why fertilization deters herbivory?

Production of toxic compounds (i.e., 2^{nd} metabolites)

Measuring Browse

1. Bites or Plant Damage
    - amount and/or severity over time
    - terminal, lateral, whole plant

2. Animal Droppings
    - abundance over time



Browse Response to Fertilization

Most evidence for relationships between fertilization and browse is outdated.

Year	Author(s)	Animal / Location	Impact
1936	Mitchell and Hosley	Deer / NE USA	^ Fert = ^ Browse
1956	Knott	Deer / NW USA	^ Fert = ^ Browse
1961	Crouch et al.	Deer / NW USA	^ Fert = slight ^ Browse
1970	Oh et al.	Elk Deer / NW USA	^ Fert = ^ Browse
1973	Behrend	Deer / NE USA	^ Fert = ^ Browse
1977	George and Powell	Deer / Central USA	^ Fert = ^ Browse
1980	Laine et al.	Elk / Finland	^ Fert = ^ Browse
1983	Anderson	Deer / NW USA	^ Fert = ^ Browse

Browse Response to Fertilization – CURRENT STUDIES

Ball et al.
2000

Moose

Sweden

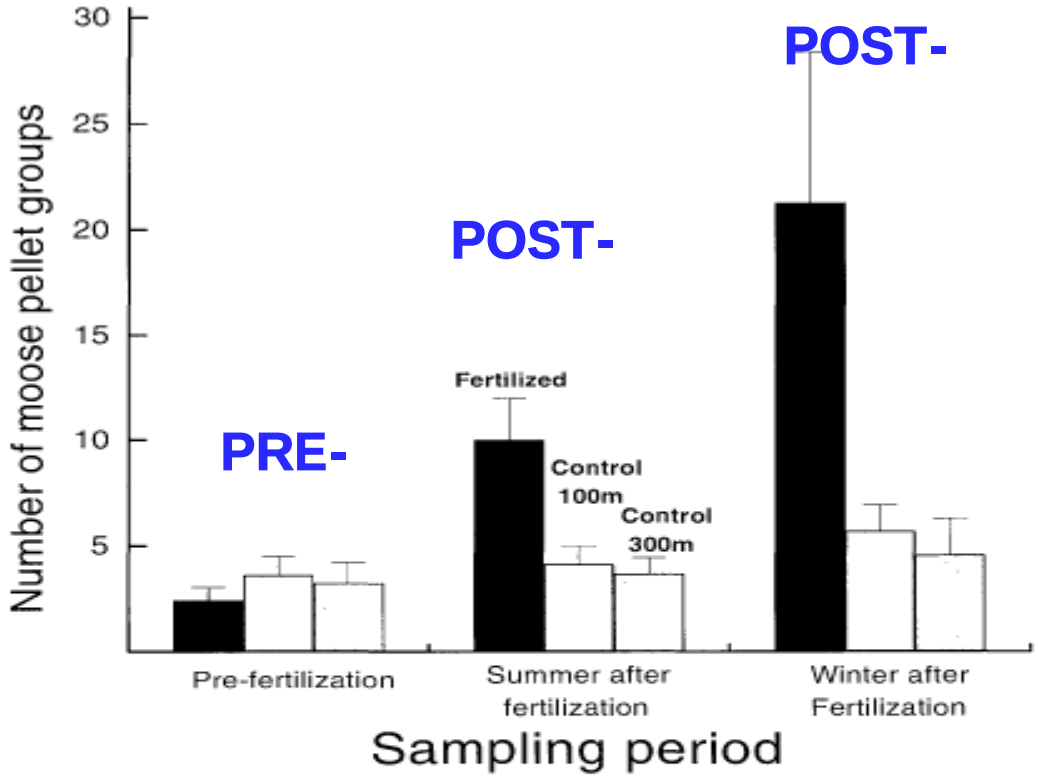


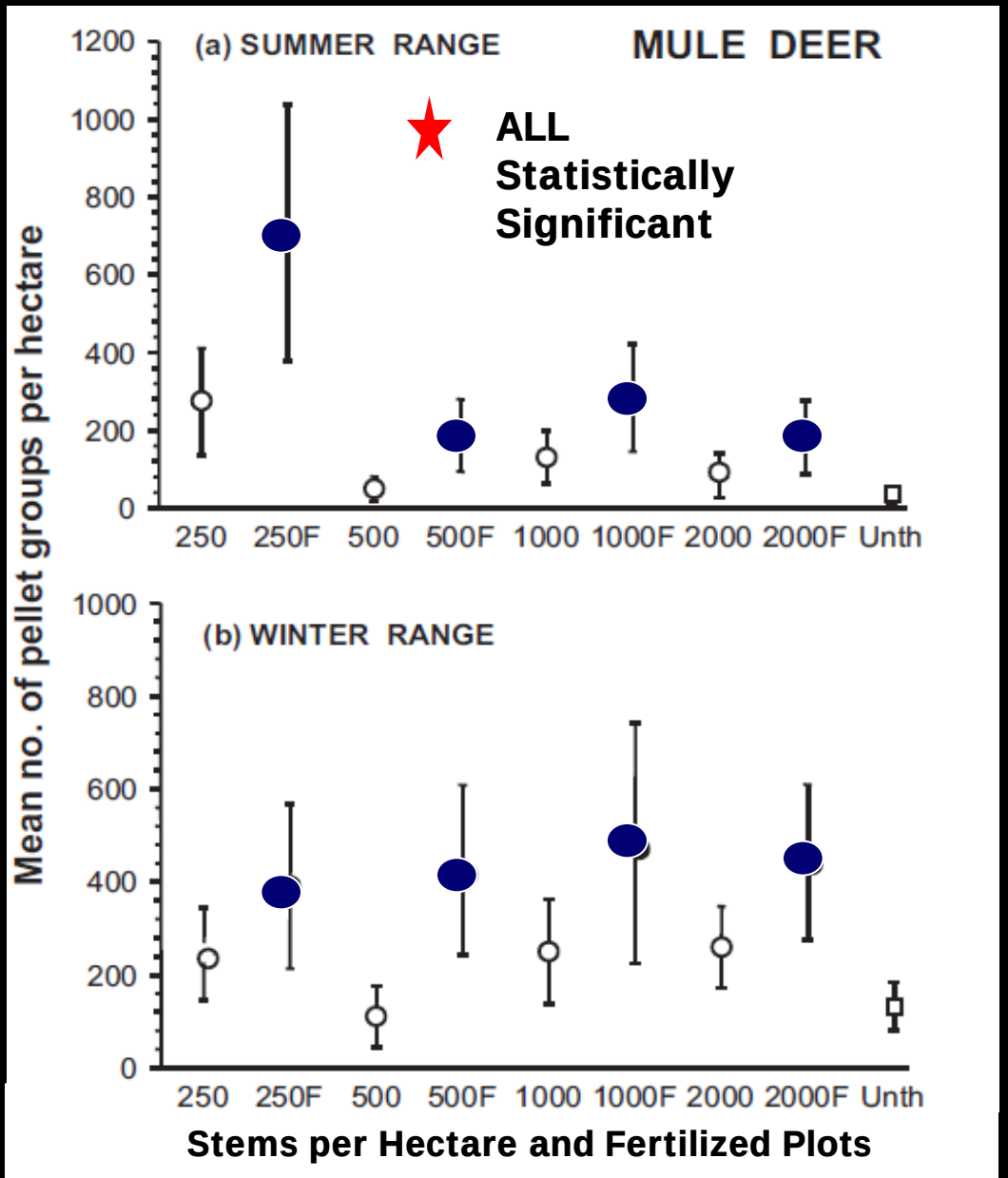
Fig. 5. The intensity of use (as indexed by pellet counts) by moose *Alces alces* of fertilized, close control and distant control. No differences existed before the experimental fertilizations, but moose used fertilized areas significantly more than controls during the summer following fertilization as well as during the following winter. Means ± standard errors are given.

Browse Response to Fertilization – CURRENT STUDIES

Sullivan et al.
2006

Mule Deer

Canada



Browse Response to Fertilization – CURRENT STUDIES

Månsson et al.
2009

Moose and Reindeer

Sweden

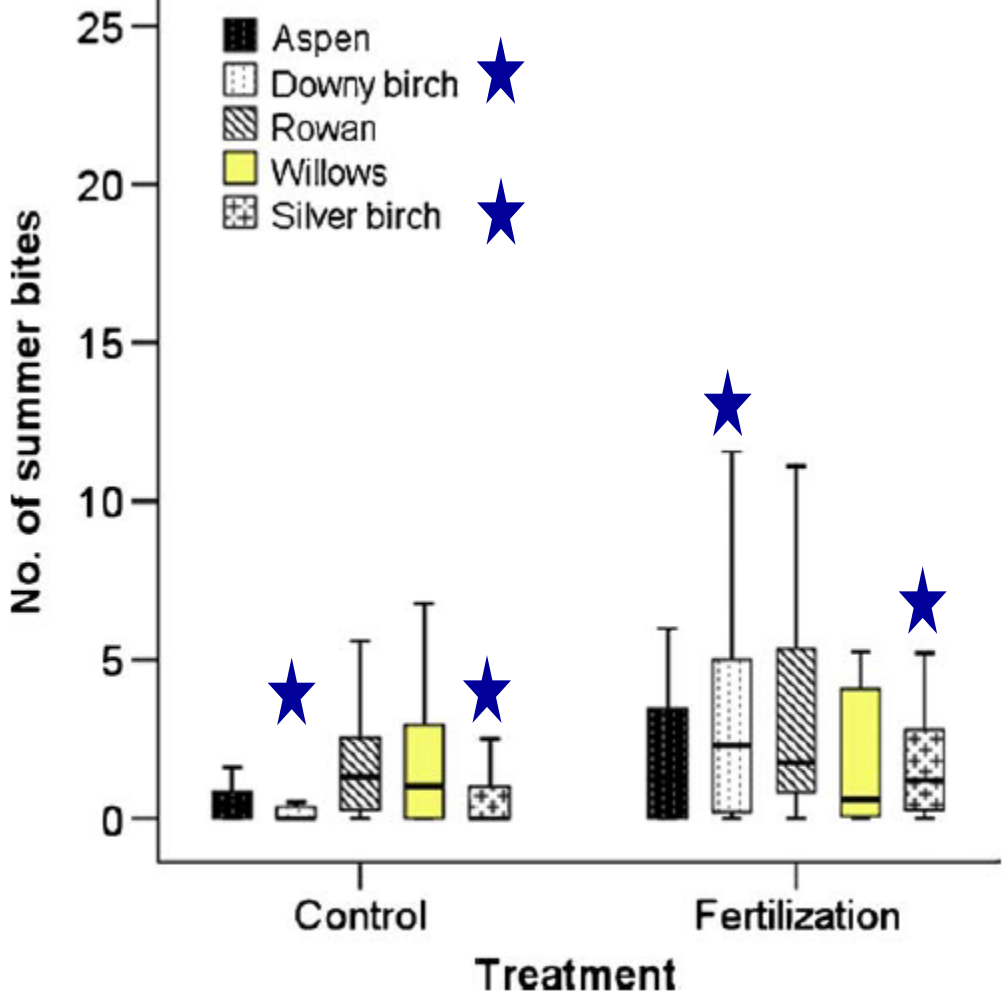


Fig. 5. Boxplot (median, quartiles (lower; upper) and whiskers showing 1.5 interquartile range) of number of summer bites in unfertilized and fertilized sites recorded in August. Sample sizes as in Table 1.

Browse Response to Fertilization – CURRENT STUDIES

Kimball et al.
2011

Elk and Deer

Oregon, USA

NO BROWSE RESPONSE TO FERTILIZATION

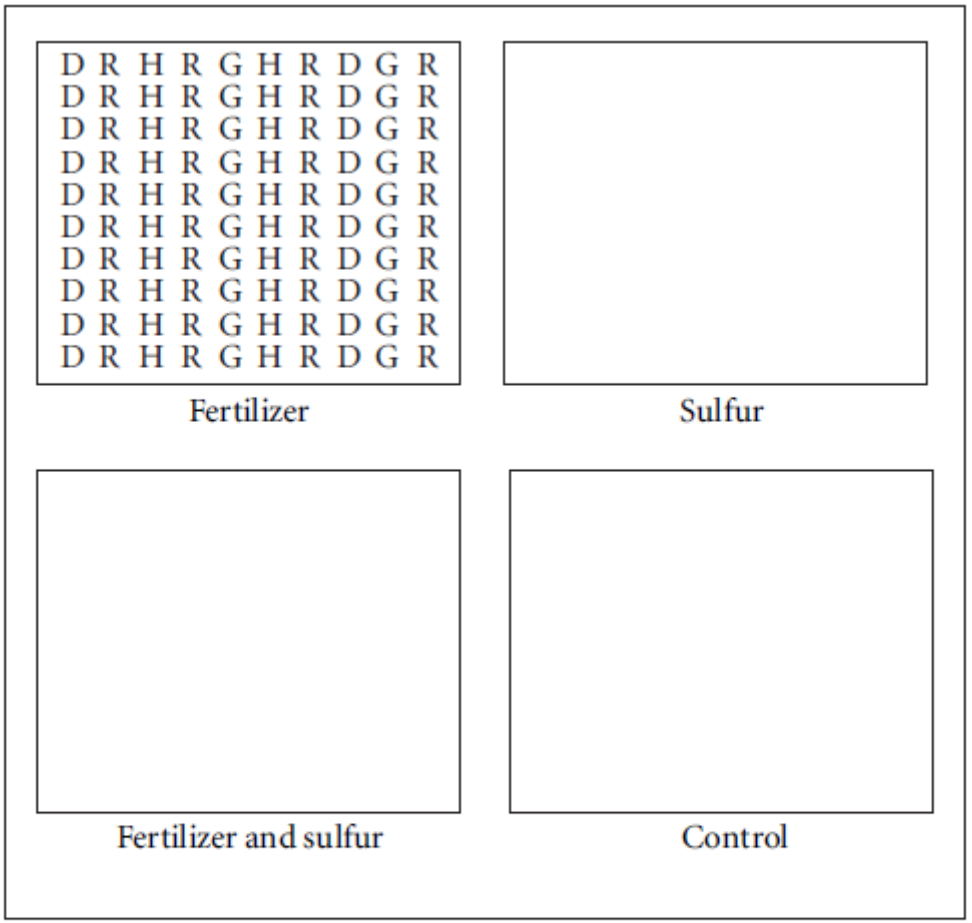


FIGURE 1: Block layout: three replicate blocks located at seven sites in Western Oregon were employed for the field experiment. Four treatment plots (whole plot) contained four species (split-plot) of conifers planted in rows of ten seedlings (D: Douglas-fir; G: grand fir; H: western hemlock; R: western redcedar).

Browse Response to Fertilization – CURRENT STUDIES

Burney and Jacobs
2011

Douglas-fir Logistic Regression – Odds Ratio

Contrast	2007	2008
0 vs 40g	-1.5	-4.0

Example:

2008 - Control treatment is 4 times less likely to be browsed compared to the 40 gram treatment

Browse Response to Fertilization – CURRENT STUDIES

Burney et al.
2011

Western red-cedar Logistic Regression – Odds Ratio

Contrast	2007	2008
0 vs 40g	3.6	3.8

Example:

2008 - Control treatment is 3.8 times more likely to be browsed compared to the 40 gram treatment

Browse Response to Fertilization

WHY ARE THERE DIFFERENCES

IN BROWSE PREFERENCE ?

Browse Response to Fertilization

‘The effect of fertilization upon browsing resistance may be a consequence of the effect of plant carbon-nutrient balance upon secondary metabolite production.’

Bryant et al. 1983

Plant Defenses

Plants develop complex array of 2nd metabolites

- many functions in plants including chemical defenses (e.g., toxins)

3 Types of 2nd metabolites

- Alkaloids (i.e., caffeine)
- Phenylpropanoids (i.e., tannins)
- Terpenoids (i.e., terpenes – scents, oils)

Carbon / Nutrient Balance Hypothesis

Increase in nutrient availability = Increase in plant growth = Decrease in production of 2nd metabolites

However, this is not static. Allocation of resources are:

Fixed = no influence from environmental resources

and/or

Flexible = influence from environmental resources

- **Based on species**, phenological stage, individual plant genetics, and age (Lerdau et al. 1995)

Allocation of Resources – Terpenoid Production

Species	Year	Fertilizer Rate			
		0g	20g	40g	60g
Western red-cedar	*Fall 2007*	1.3ab	1.7bc	2.0c	2.6d
Douglas-fir	*Fall 2007*	0.5	0.6	0.7	0.5
Western hemlock	*Fall 2007*	0.5	0.3	0.4	0.5

mg g^{-1} [foliar dry weight]

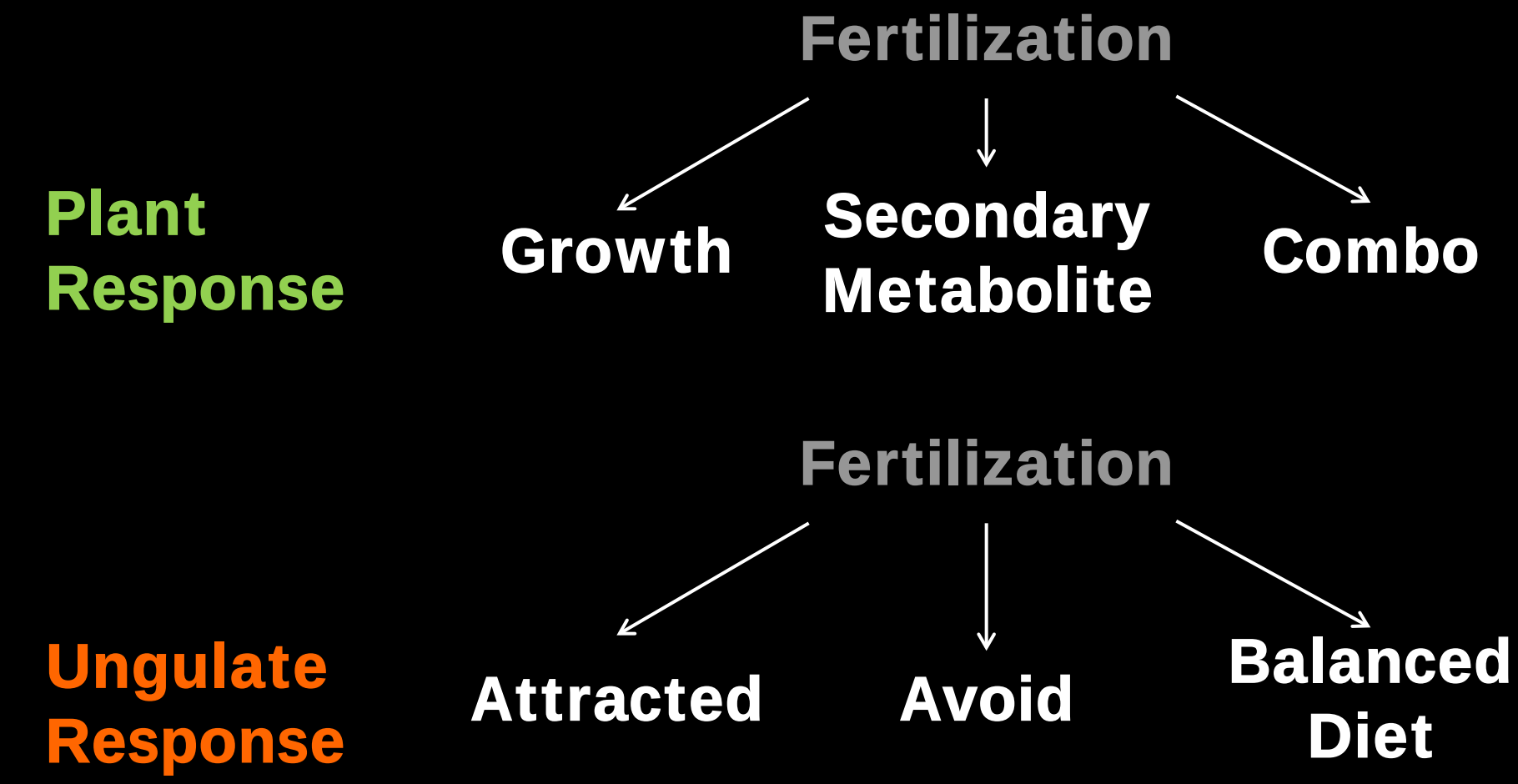
Over 60% of the total monoterpenes for western red-cedar were oxygenated monoterpenes alpha and beta-thujone, known to inhibit rumen activity

Burney and Jacobs 2011

Allocation of Resources

Variable	Supplemental Nutrition
Height	↑
Diameter	↑
Foliar Nitrogen	↑
Douglas-fir Browse	↑
Douglas-fir Terpene	0
Western Hemlock Browse	↑
Western Hemlock Terpene	0
Western Red-cedar Browse	↓
Western Red-cedar Terpene	↑

Allocation of Resources / Ungulate Reactions



Allocation of Resources / Ungulate Reactions

Why do ungulates ingest phytotoxins?

With lower forage quality and quantity (i.e., winter), ungulates balance diet with some level of toxicity to maintain adequate energy and protein inputs.

How?

- **binding the compound,**
- **metabolizing the compound,**
- **tolerating the compound**

(Provenza et al. 1992)

OVERALL CONCLUSIONS

INCREASED PLANT NUTRITION

- Increase growth of regenerating stand
- Increase quality of forage
- Increase production of toxic 2nd metabolites, thus decrease palatability
- Allow recovery to browse due to stored carbohydrates

Allocation of supplemental nutrients vary by species and individual plants.

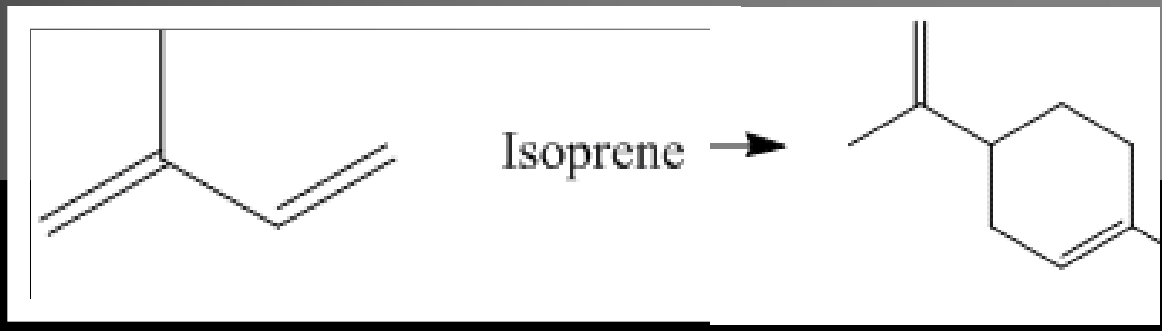
OVERALL CONCLUSIONS

Regardless of plant mineral nutrition and defensive chemical composition, the dynamic behavior of ungulates has a powerful influence in the fate of forest regeneration.

QUESTIONS?

END

Terpenes



What are Terpenes?

- Secondary metabolites found in most plants (>25,000 known compounds with few having been studied)
- Broken into groups based on size: mono-, sesqui-, di-, ...
- Formed by repetitive fusion of isoprene unit making: floral scents, carotenoids, plant hormones, natural rubber
- Plants produce for chemical resistance and defense against: fungi, bacteria, and animal herbivory
- Smaller terpene compounds are extremely volatile and can be sensed by ungulates (taste and odor)
- Specific terpenes inhibit rumen activity in ungulates

Terrain

Field Site at Planting

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Impacts of Ungulates on Forest Regeneration

The impacts of browsing on young tree seedlings are well-known and have been documented in the scientific literature for decades. Elevated deer populations intensify these impacts. More than 17,000 peer-reviewed articles have been published on the topic since the early 1990s.

- The Nature Conservancy

Impacts of Ungulates on Forest Regeneration

Google Scholar Search 1990–2012

“browse, seedling, elk, deer”
= 2,530

“ ’fertilization’, browse, seedling, elk, deer”
= 748, HOWEVER FEW ABOUT THIS RELATIONSHIP