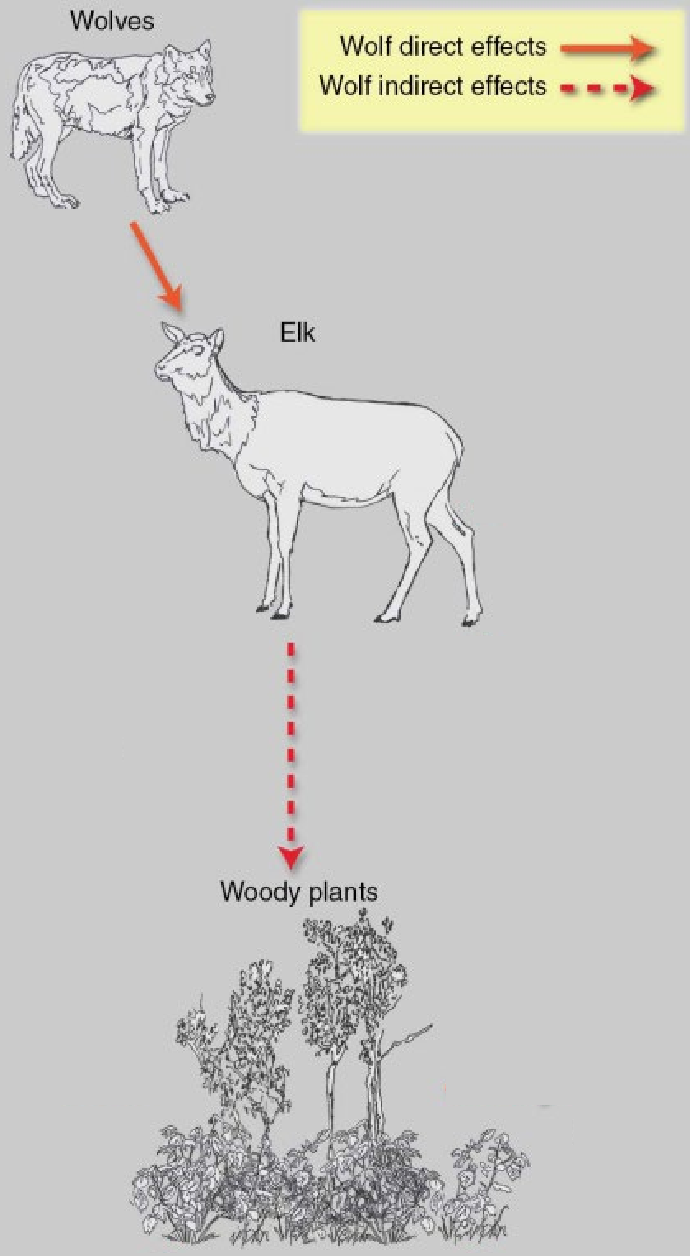
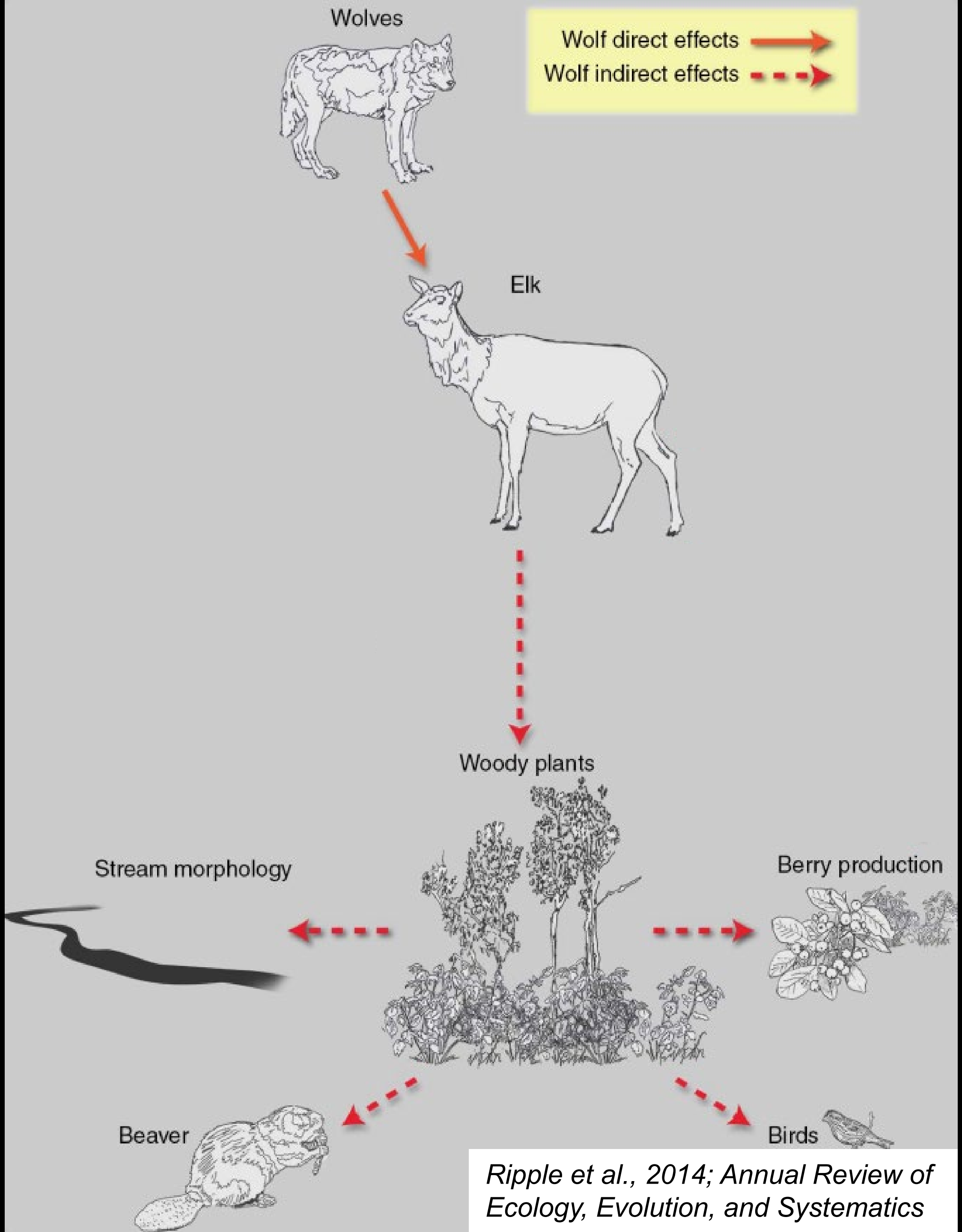
Detecting trophic cascades in heterogeneous landscapes

Michael S. Peyton[1], Ellen E. Brandell[2], Danielle B. Johnston[2], Brian D. Gerber[1,3]

[1]Department of Fish, Wildlife and Conservation Biology, CSU
[2]Colorado Parks and Wildlife
[3]US Geological Survey



Ripple et al., 2014; Annual Review of Ecology, Evolution, and Systematics



Ripple et al., 2014; Annual Review of Ecology, Evolution, and Systematics

What do we really know about terrestrial cascades?

What do we really know about terrestrial cascades?

Trophic cascade keywords

273 studies

Inclusion criteria

- ✓ Terrestrial large-mammal system
- ✓ Explicit predator contrast
- ✓ Measured vegetation response
- × Mesopredator cascades
- × Studies without empirical data
- × Inferred only from post-reintroduction conditions

46 studies

What do we really know about terrestrial cascades?

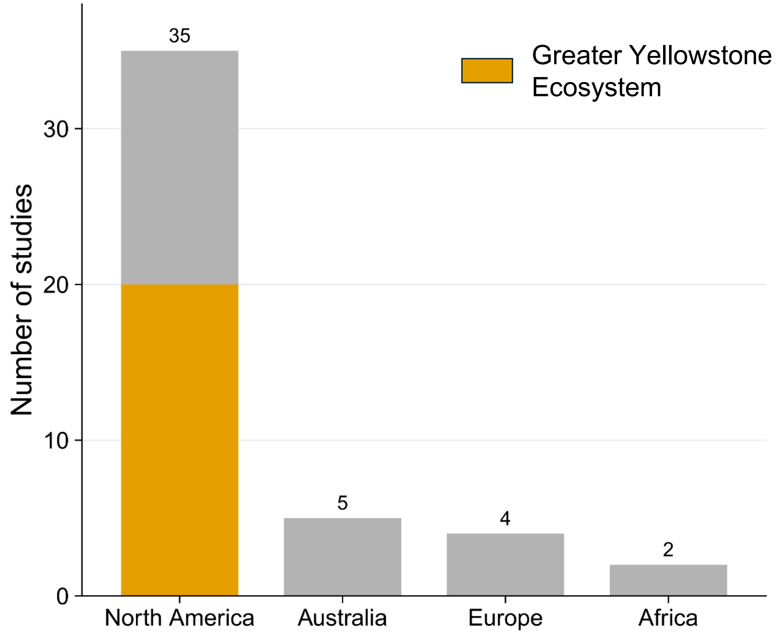
Trophic cascade keywords

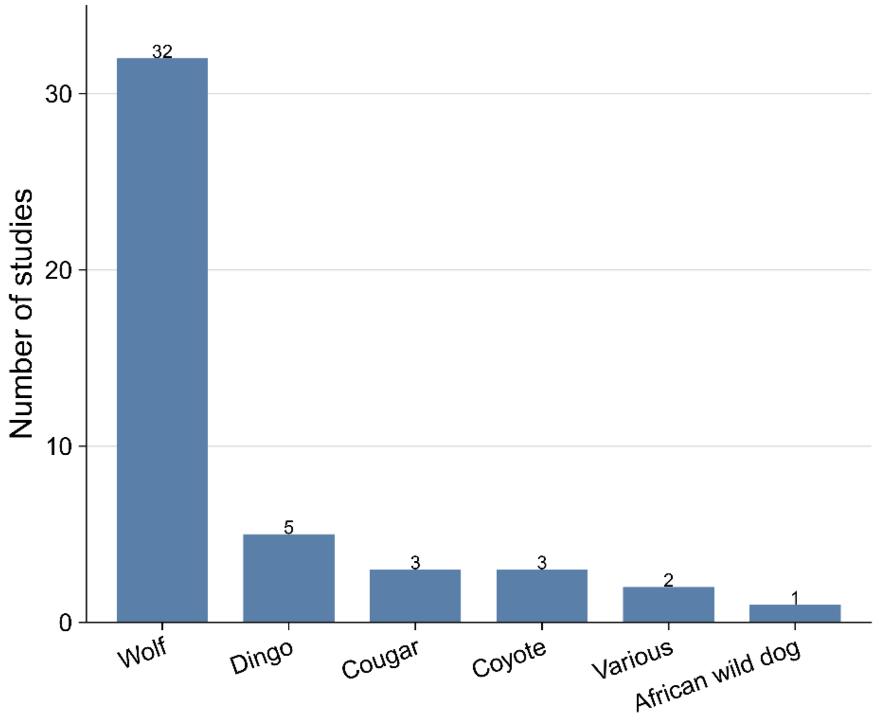
273 studies

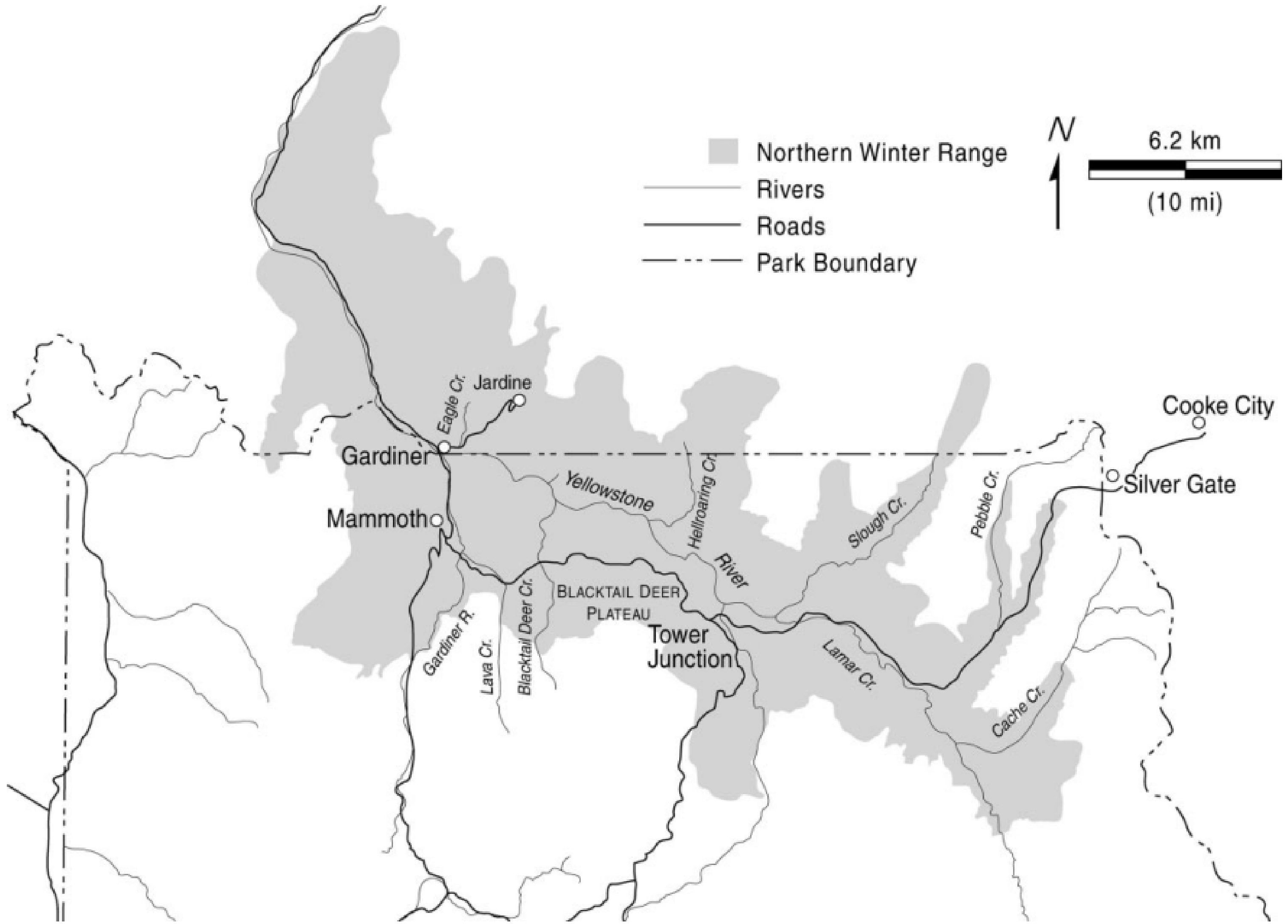
Inclusion criteria

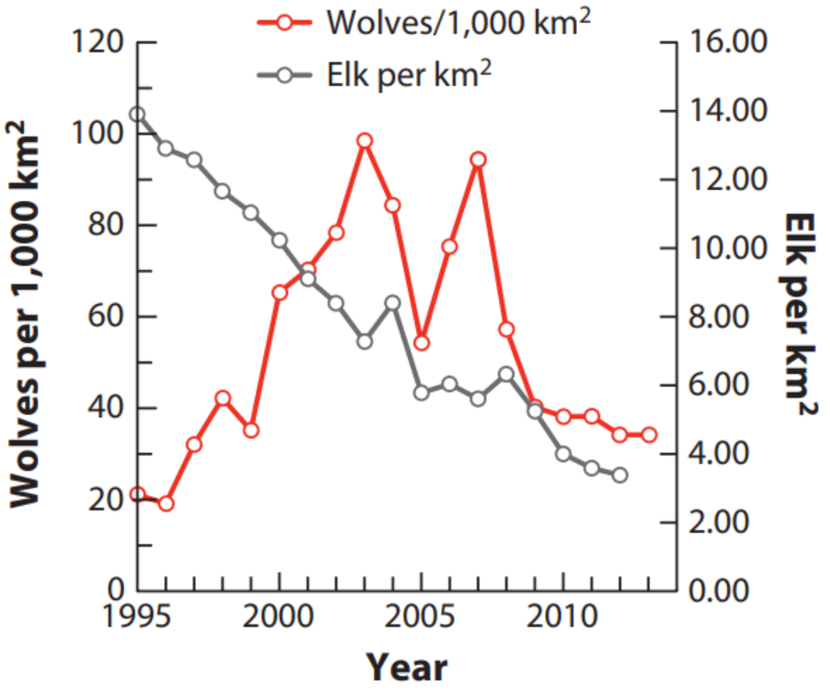
46 studies

- ✓ Terrestrial large-mammal system
- ✓ Explicit predator contrast
- ✓ Measured vegetation response
- × Mesopredator cascades
- × Studies without empirical data
- × Inferred only from post-reintroduction conditions









Ripple & Larson 2001; Biological Conservation

Peterson et al., 2014; Annual Review of Ecology, Evolution, and Systematics

Same system, conflicting evidence

BIOLOGICAL CONSERVATION 138 (2007) 514–519

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/biocon

ELSEVIER

Short communication

Restoring Yellowstone's aspen with wolves

William J. Ripple, Robert L. Beschta*

College of Forestry, Oregon State University, Corvallis, OR 97331, United States

Higher risk = reduced browsing

Same system, conflicting evidence

BIOLOGICAL CONSERVATION 138 (2007) 514–519

ELSEVIER

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/loca

BIOLOGICAL CONSERVATION

Short communication

Restoring Yellowstone's aspen with wol

William J. Ripple, Robert L. Beschta*

College of Forestry, Oregon State University, Corvallis, OR 97331, United States

Ecology, 91(9), 2010, pp. 2742–2755

Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade

MATTHEW J. KAUFFMAN,[1,5] JEDEDIAH F. BRODIE,[2,3] AND ERIK S. JULES[4]

[1]*U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Zoology and Physiology Department, University of Wyoming, Laramie, Wyoming 82071 USA*
[2]*Department of Biology, Pennsylvania State University, University Park, Pennsylvania 16802 USA*
[3]*Wildlife Conservation Society, North America Program, Bozeman, Montana 59715 USA*
[4]*Department of Biological Sciences, Humboldt State University, Arcata, California 95521 USA*

Higher risk = reduced browsing

Higher risk = increased browsing

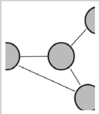
Effects are context-dependent

Photo: Colorado Parks and Wildlife

Ungulate space-use is dynamic through time

Predator traits shape ungulate response

Top-down multicausality



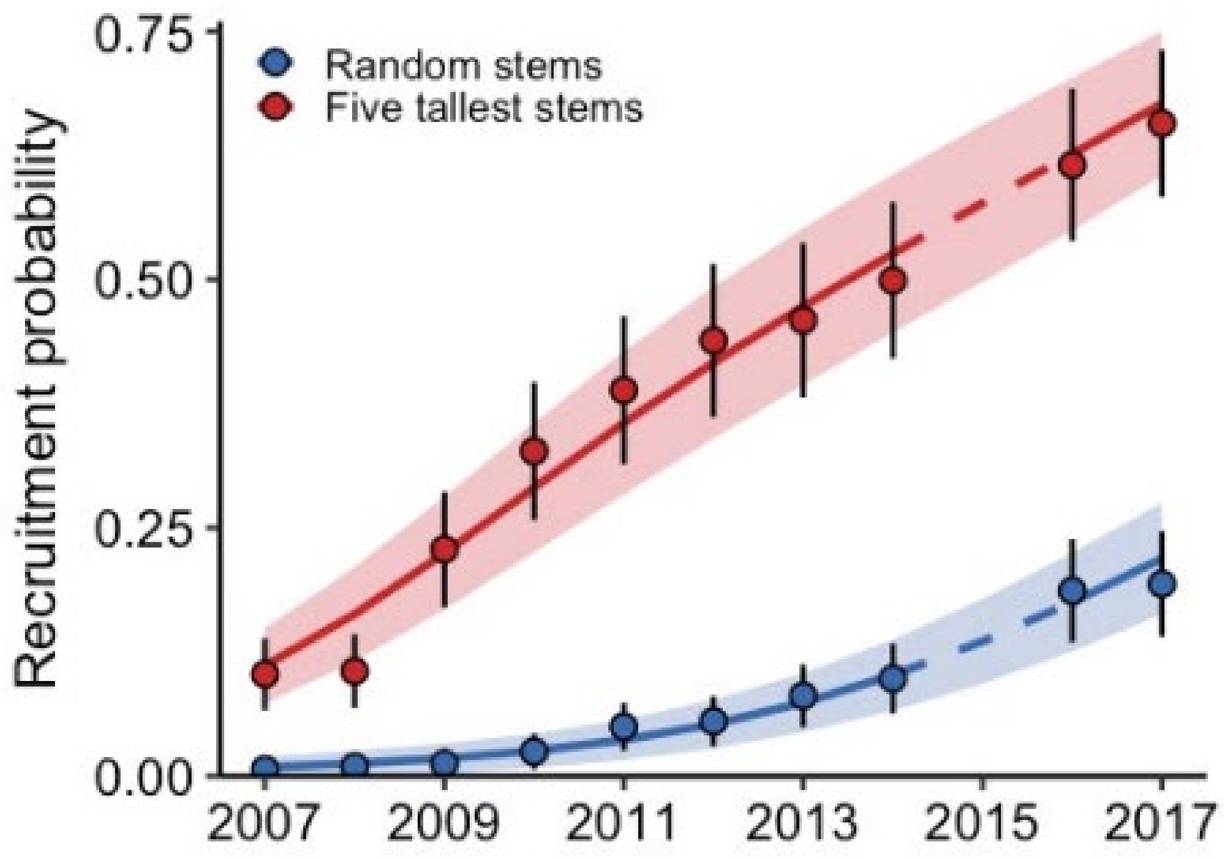
Complex systems obscure signals

Human impacts disrupt ecological networks

Effects are context-dependent

BUT mixed evidence also reflects differences in:

- Study design
- Measurement
- Evidentiary standards



Brice et al., 2021; *Ecology Letters*

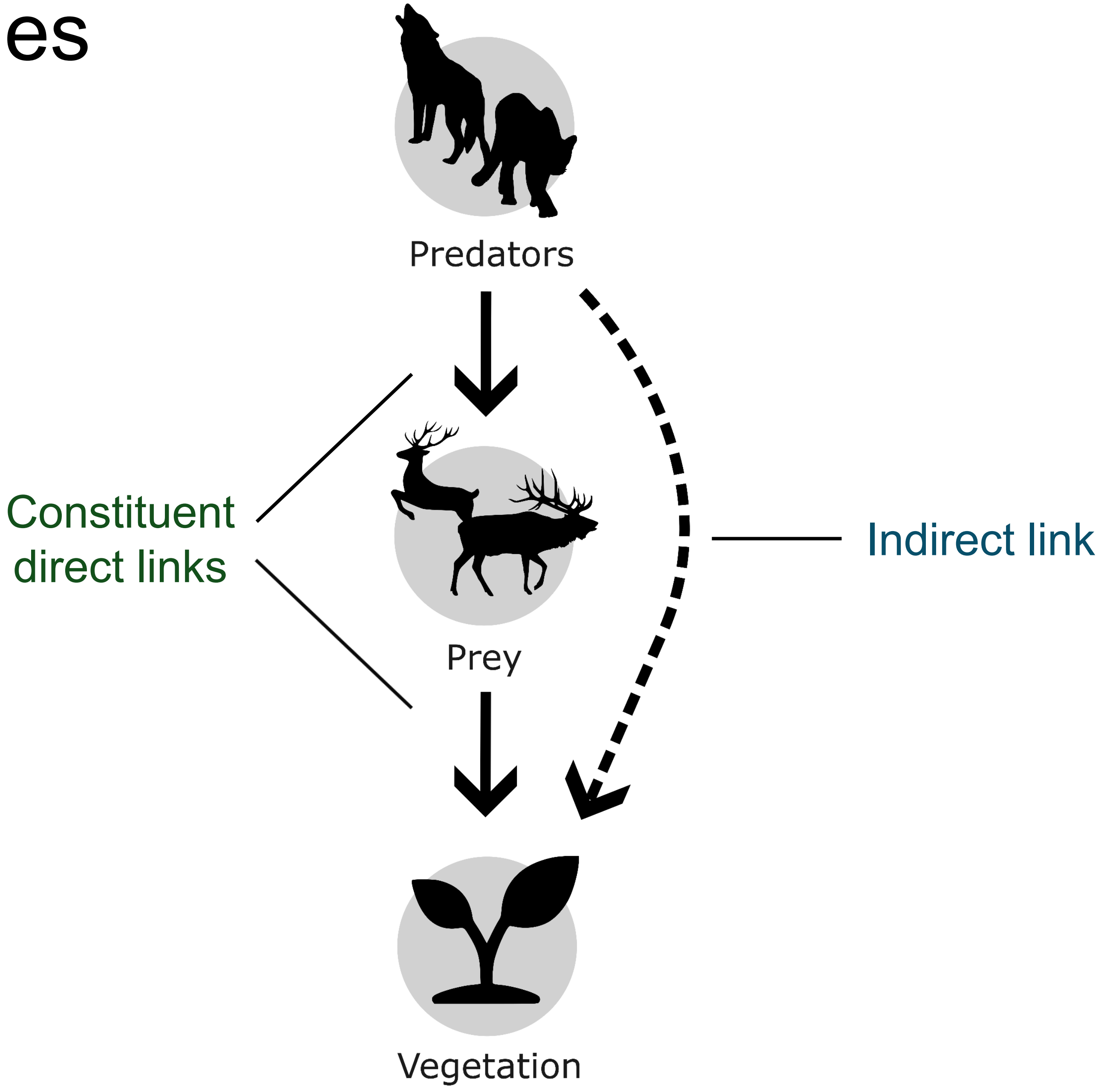
Photo: Colorado Parks and Wildlife

Evidence for trophic cascades

Indirect: Predator → vegetation

Direct: Predator → prey

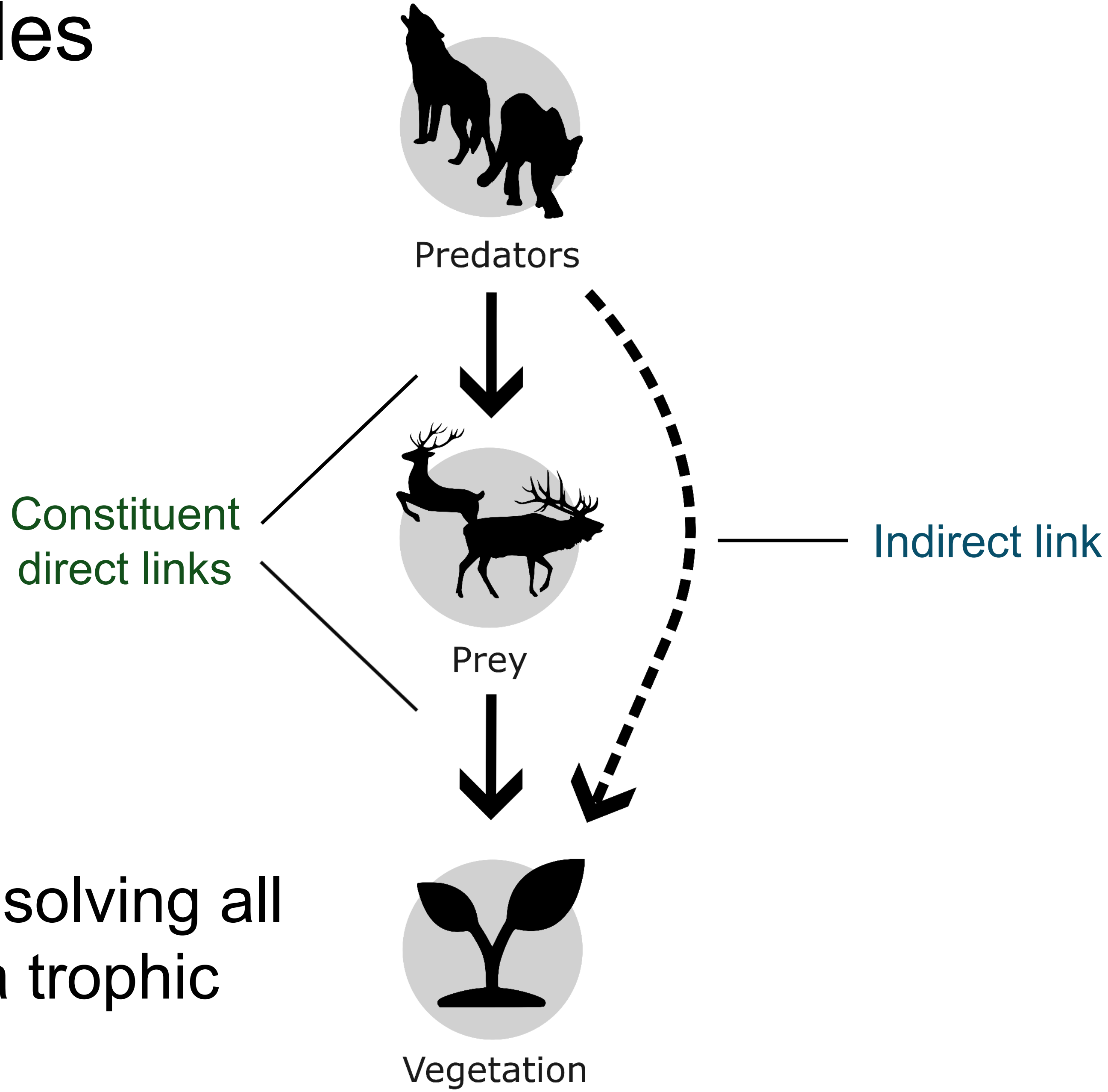
Prey → vegetation



Evidence for trophic cascades

Indirect: Predator → vegetation

Direct: Predator → prey
Prey → vegetation



Full pathway evidence requires resolving all three links to establish support for a trophic cascade

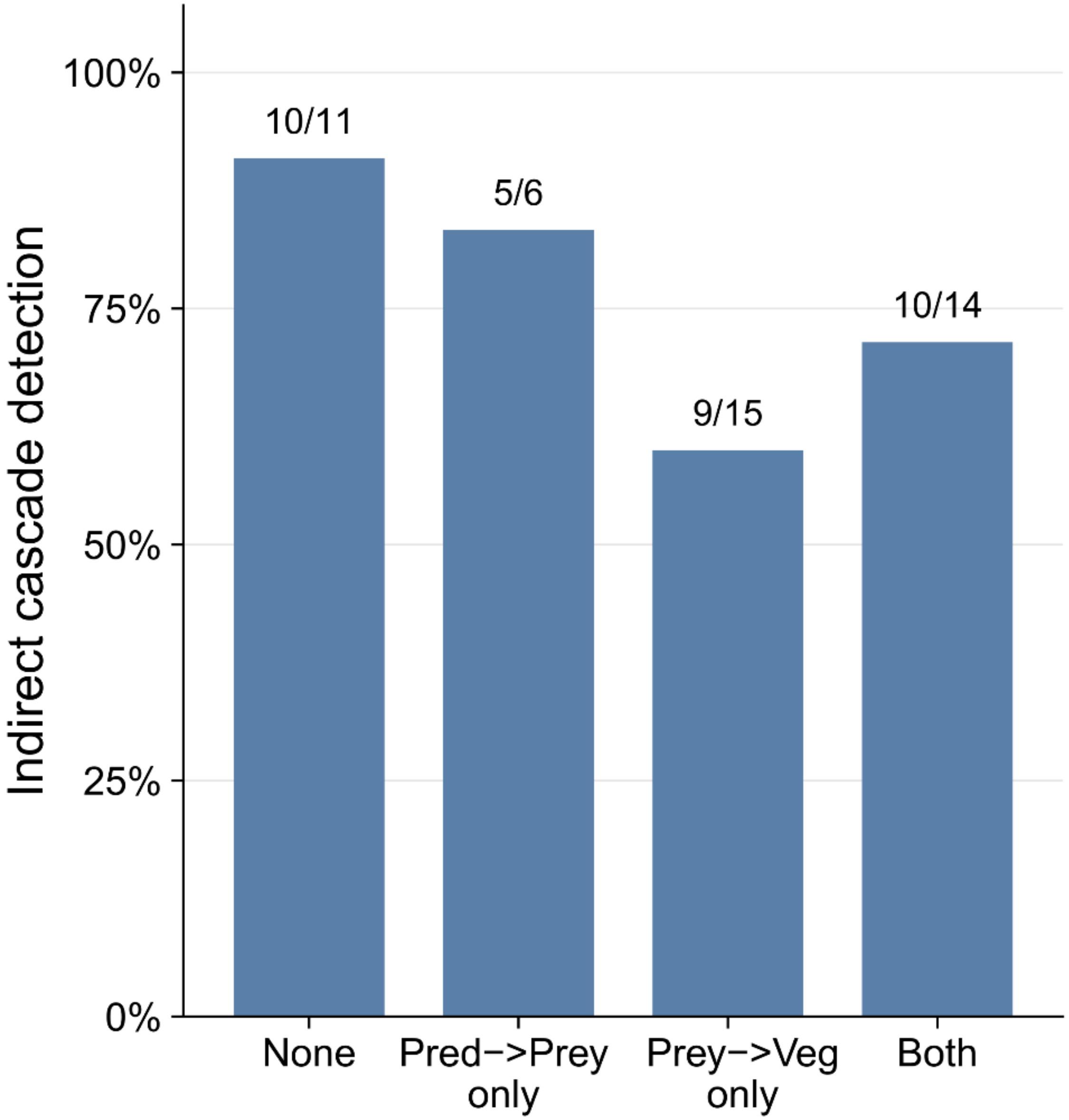
What do we really know about terrestrial cascades?

Trophic cascade keywords

273 studies

Inclusion criteria

46 studies



What do we know about terrestrial cascades?

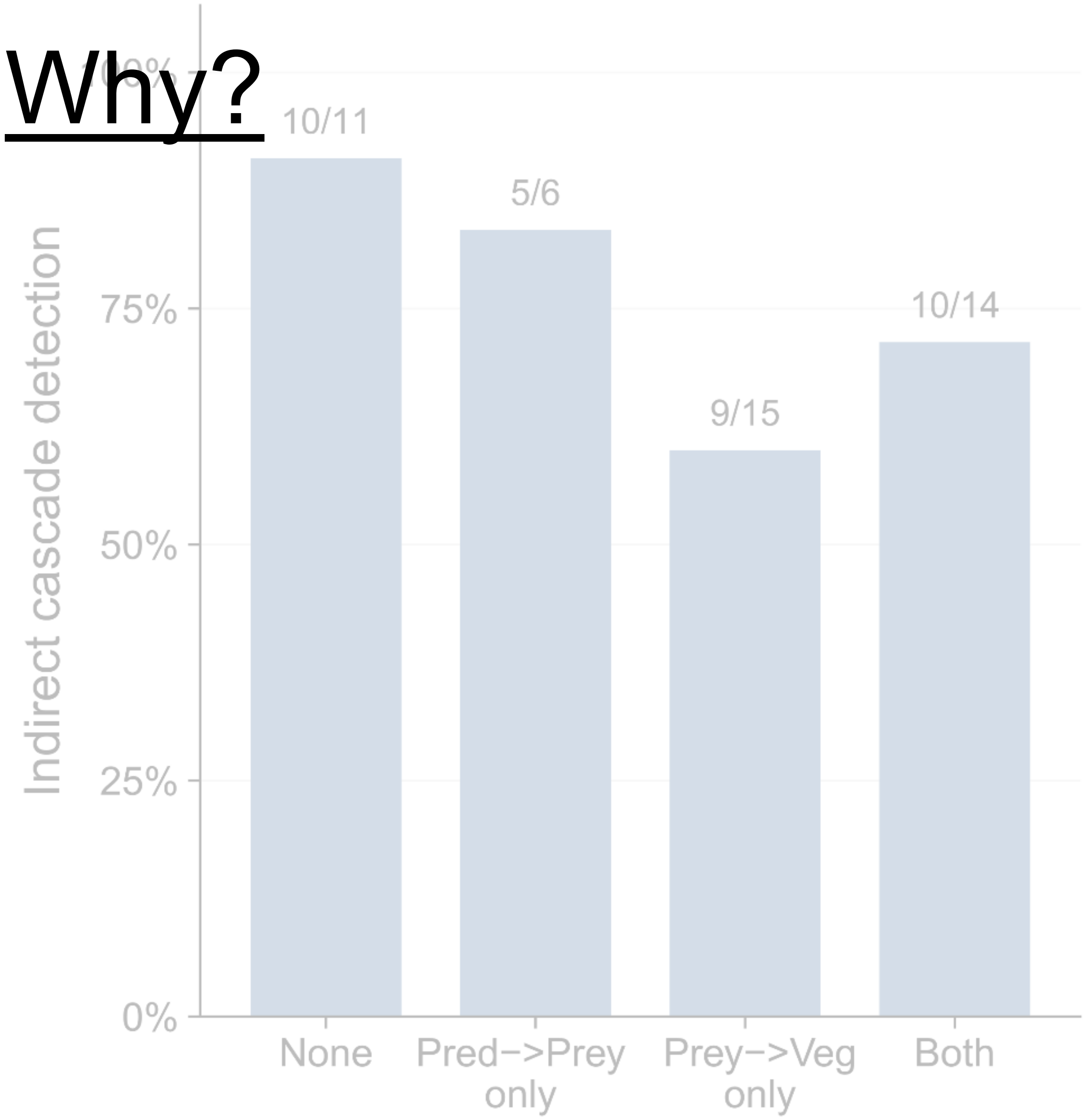
Trophic cascade keywords

273 studies

Inclusion criteria

46 studies

<u>Why?</u>



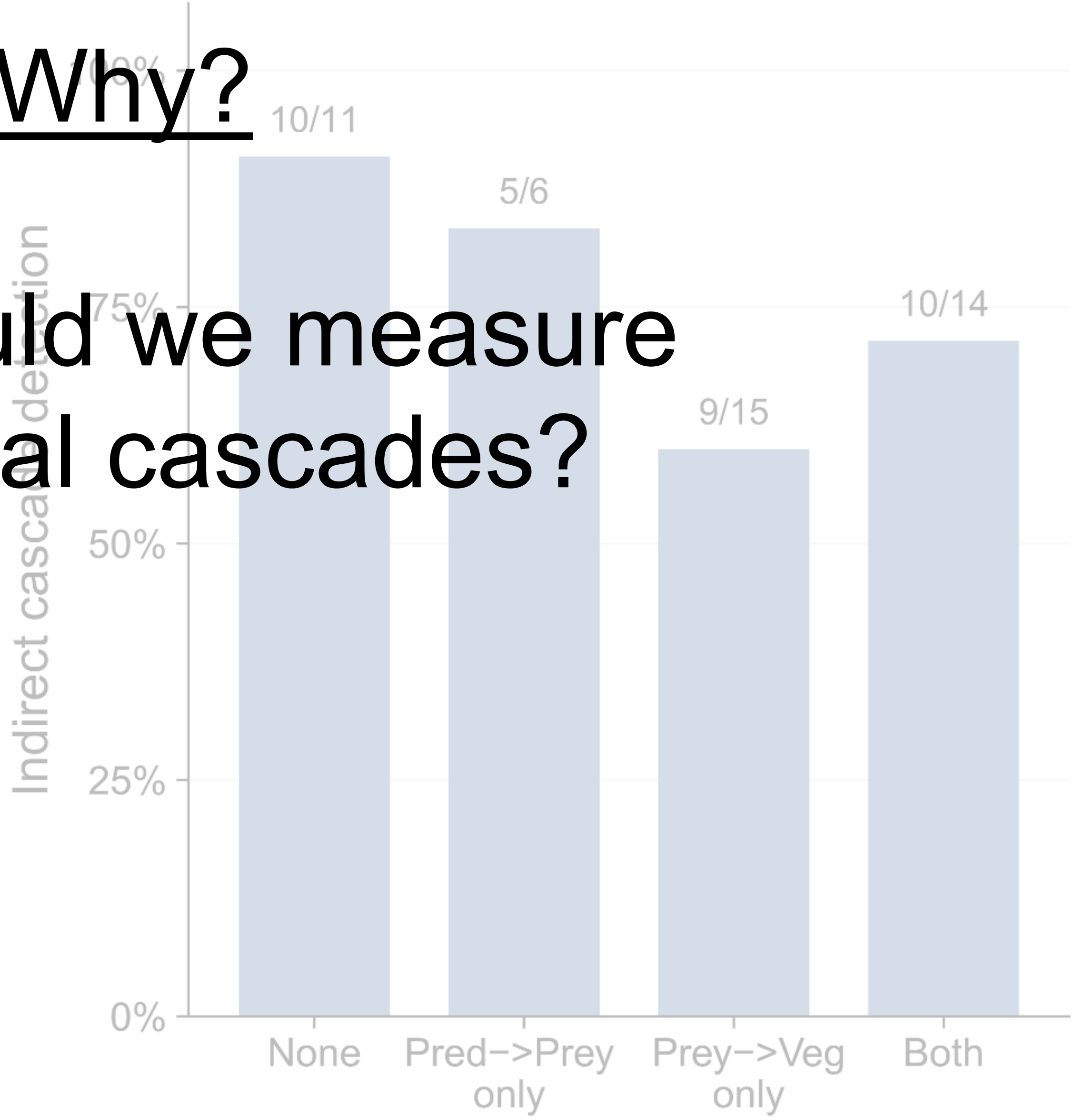
What do we know about terrestrial cascades?

Trophic cascade keywords

273 studies

Inclusion criteria

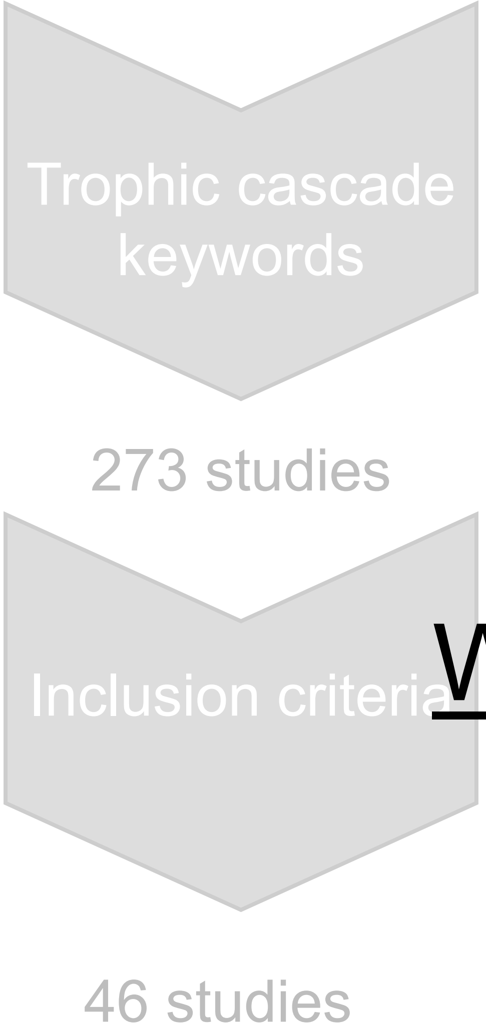
46 studies

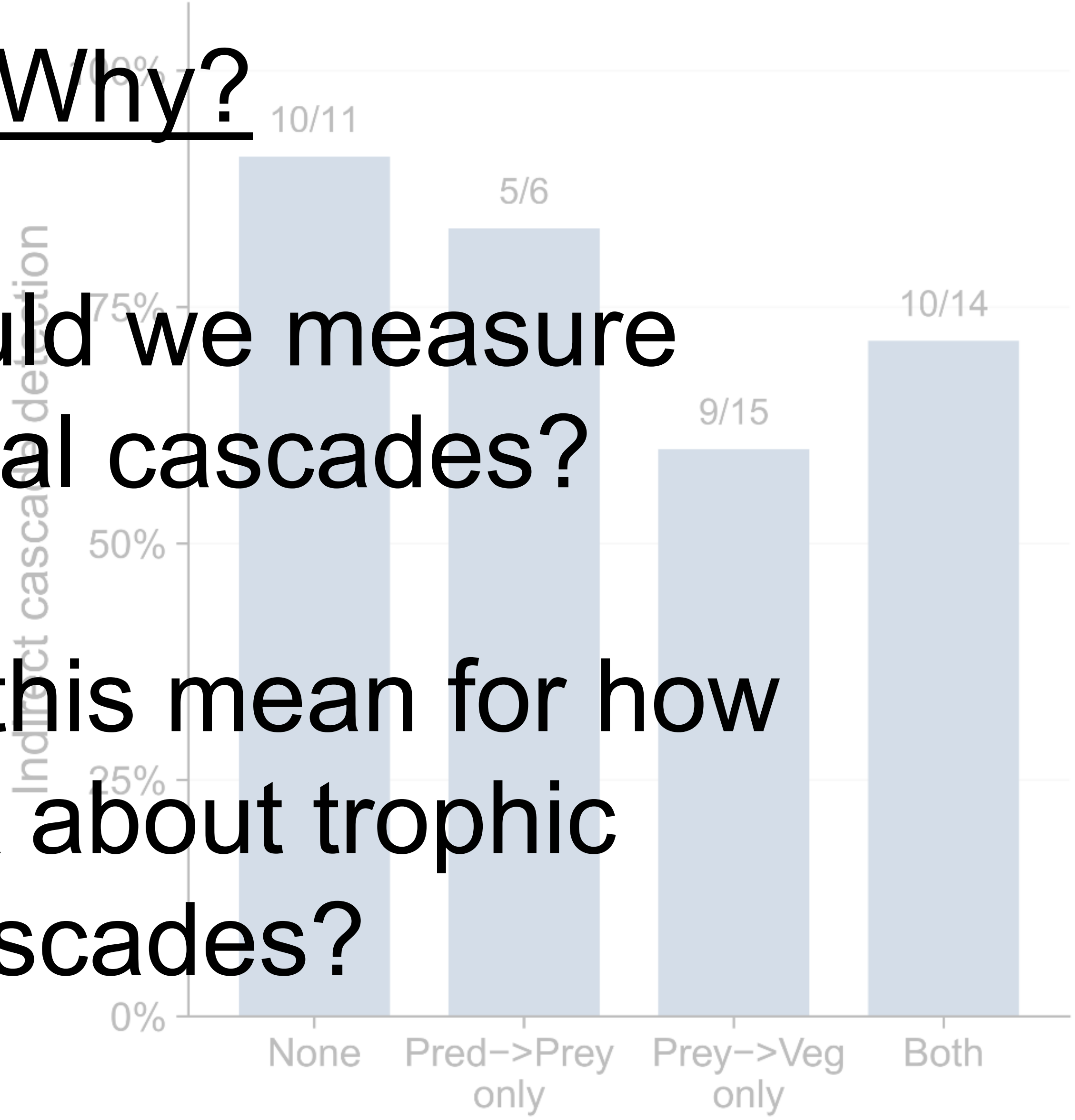


<u>Why?</u>

<u>How</u> should we measure terrestrial cascades?

What do we know about terrestrial cascades?

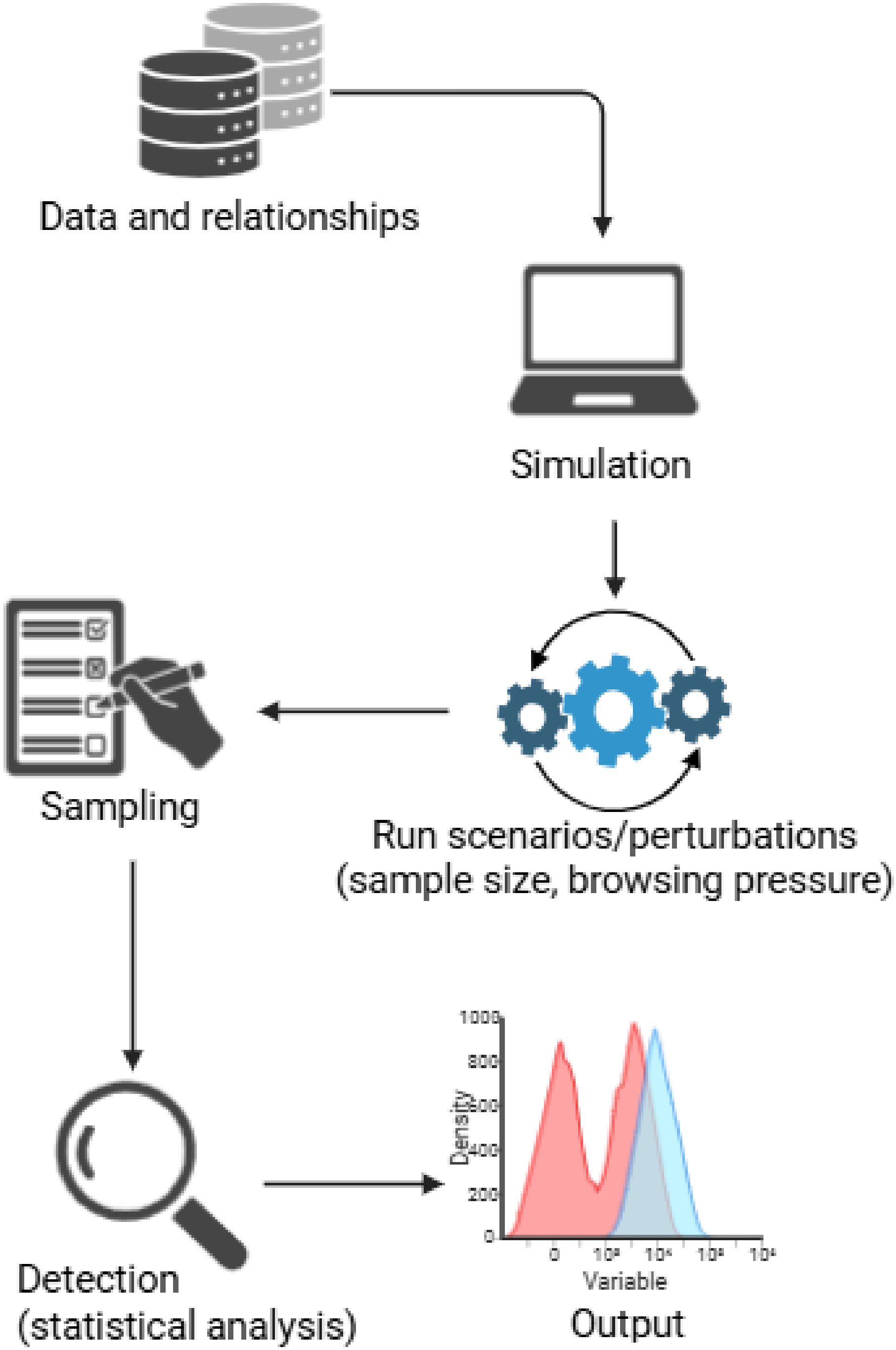




<u>Why</u>?

<u>How</u> should we measure terrestrial cascades?

<u>What</u> does this mean for how we think about trophic cascades?



Middle Park, CO

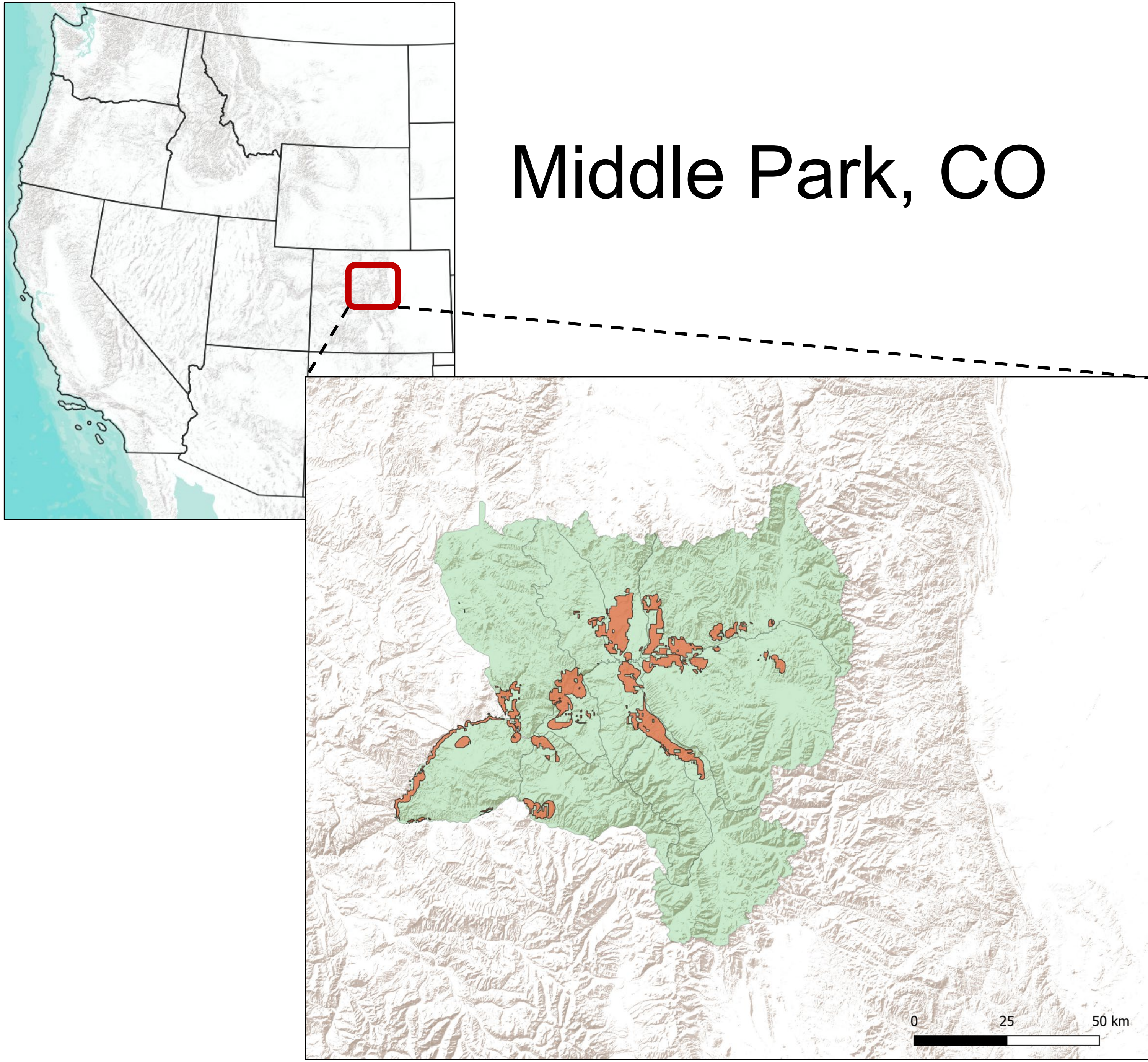
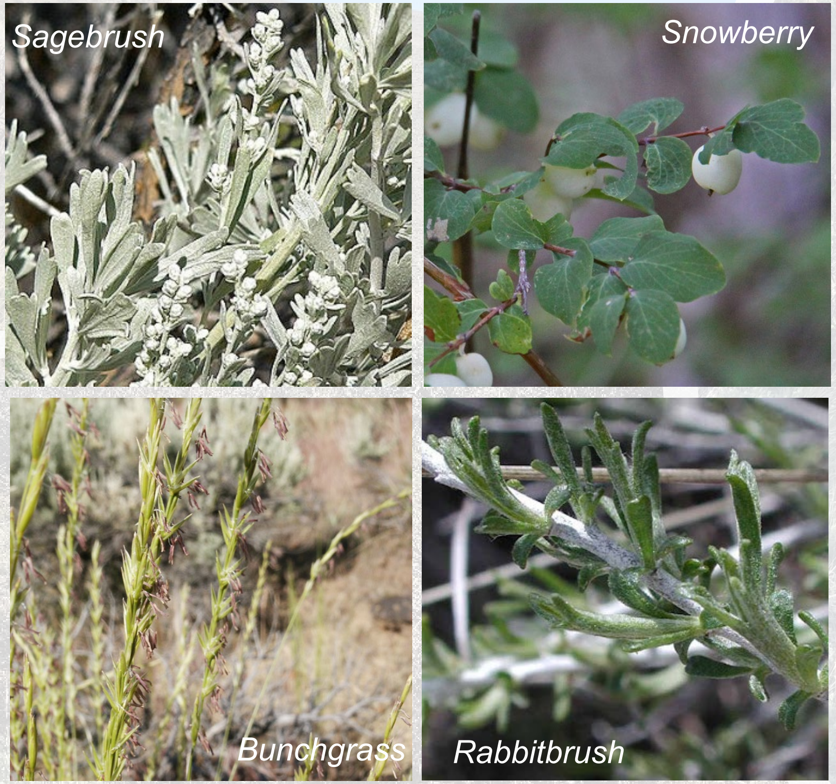


Photo: Colorado Parks and Wildlife

Sagebrush ecotype



Mountain Shrub ecotype

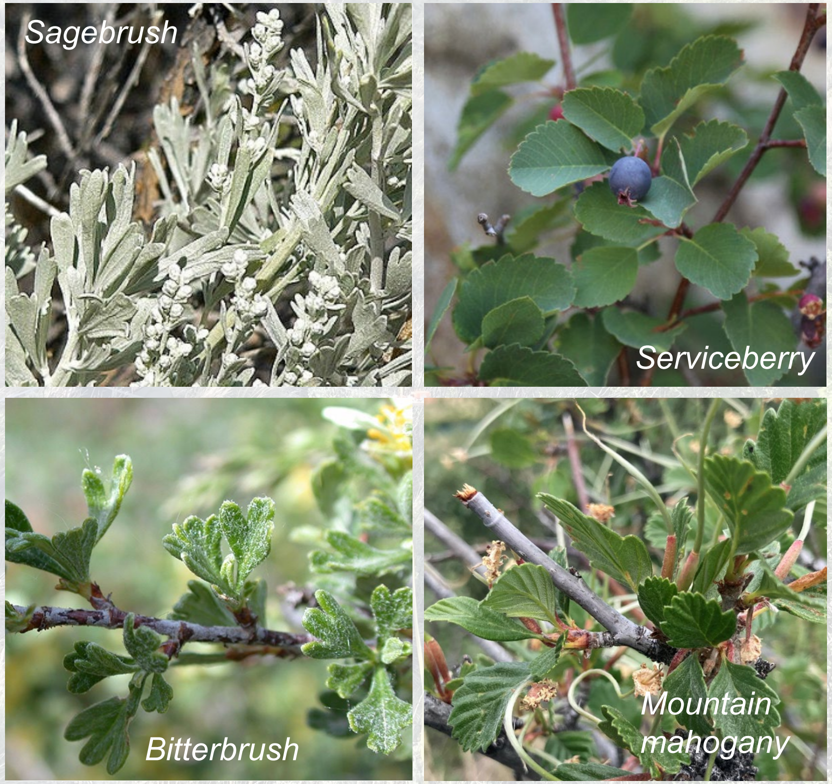
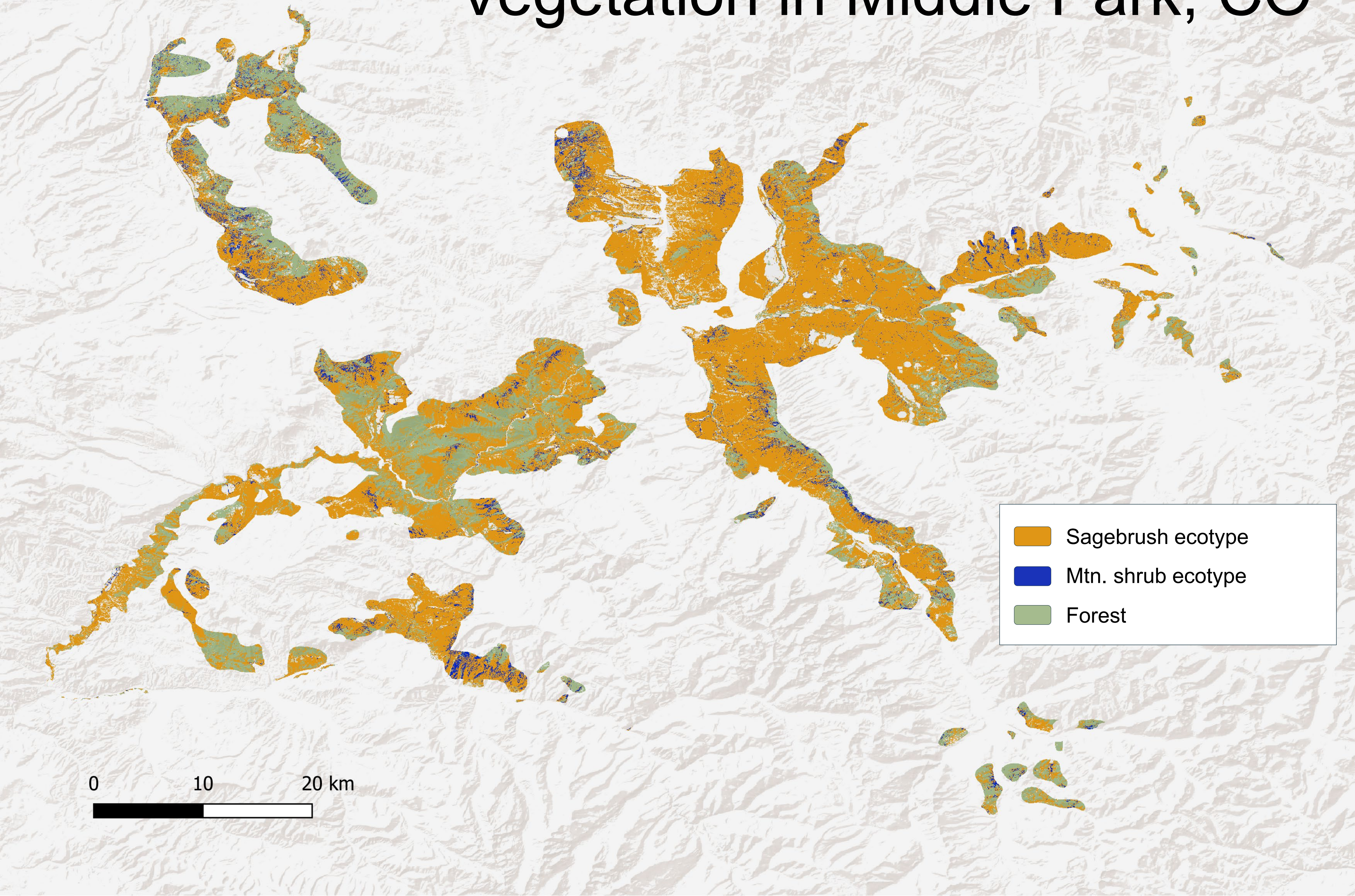
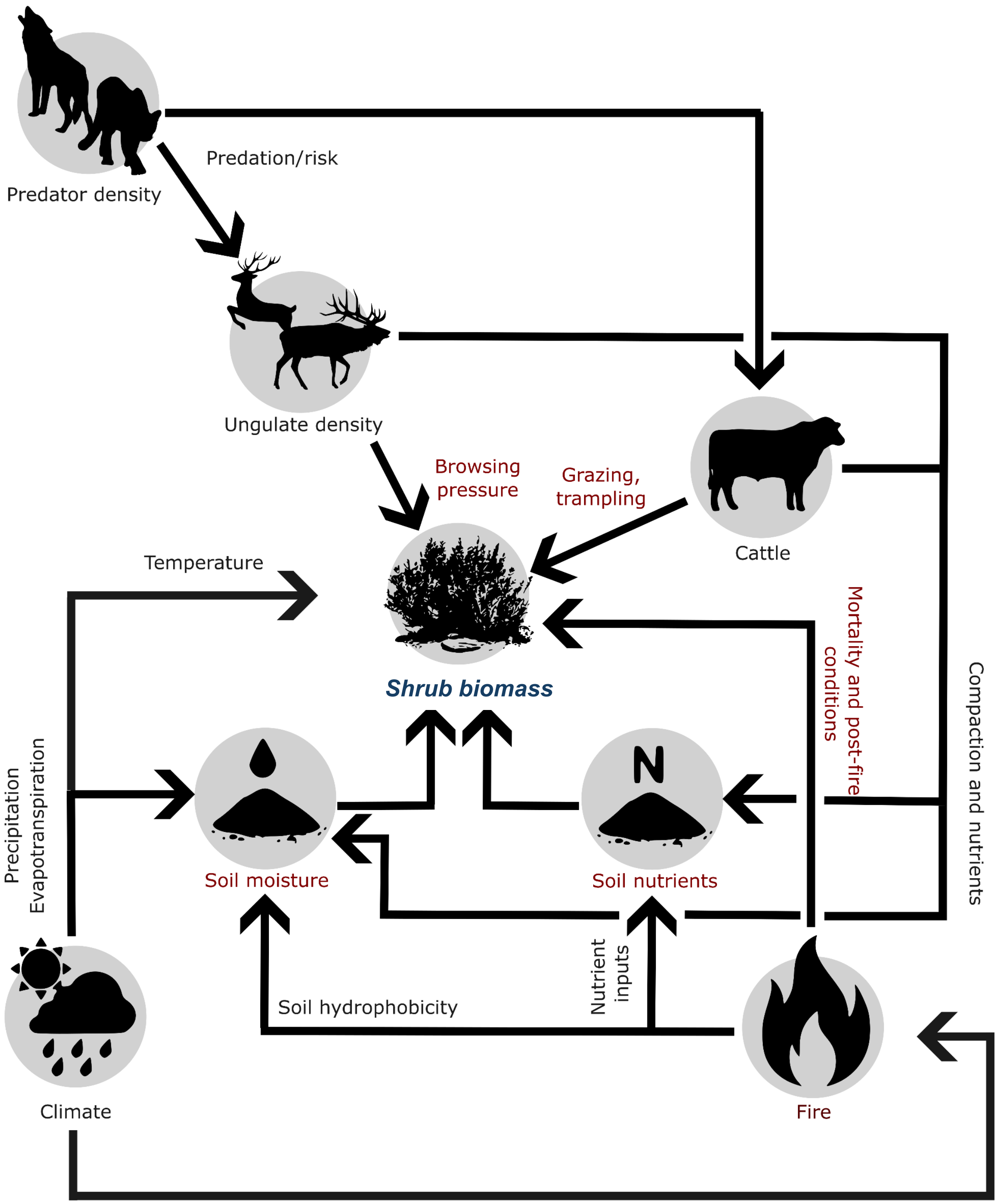


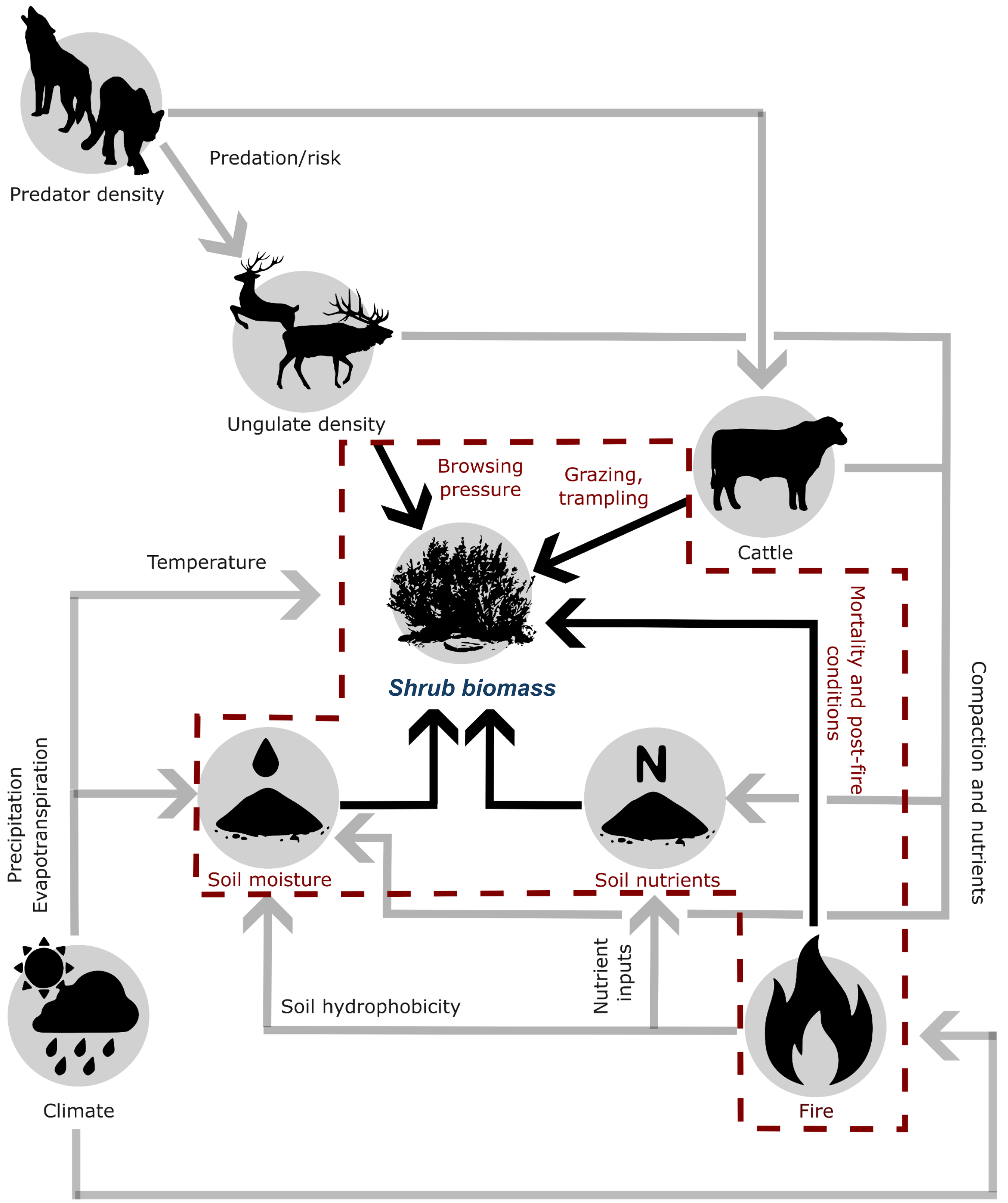
Photo: Colorado Parks and Wildlife

Vegetation in Middle Park, CO

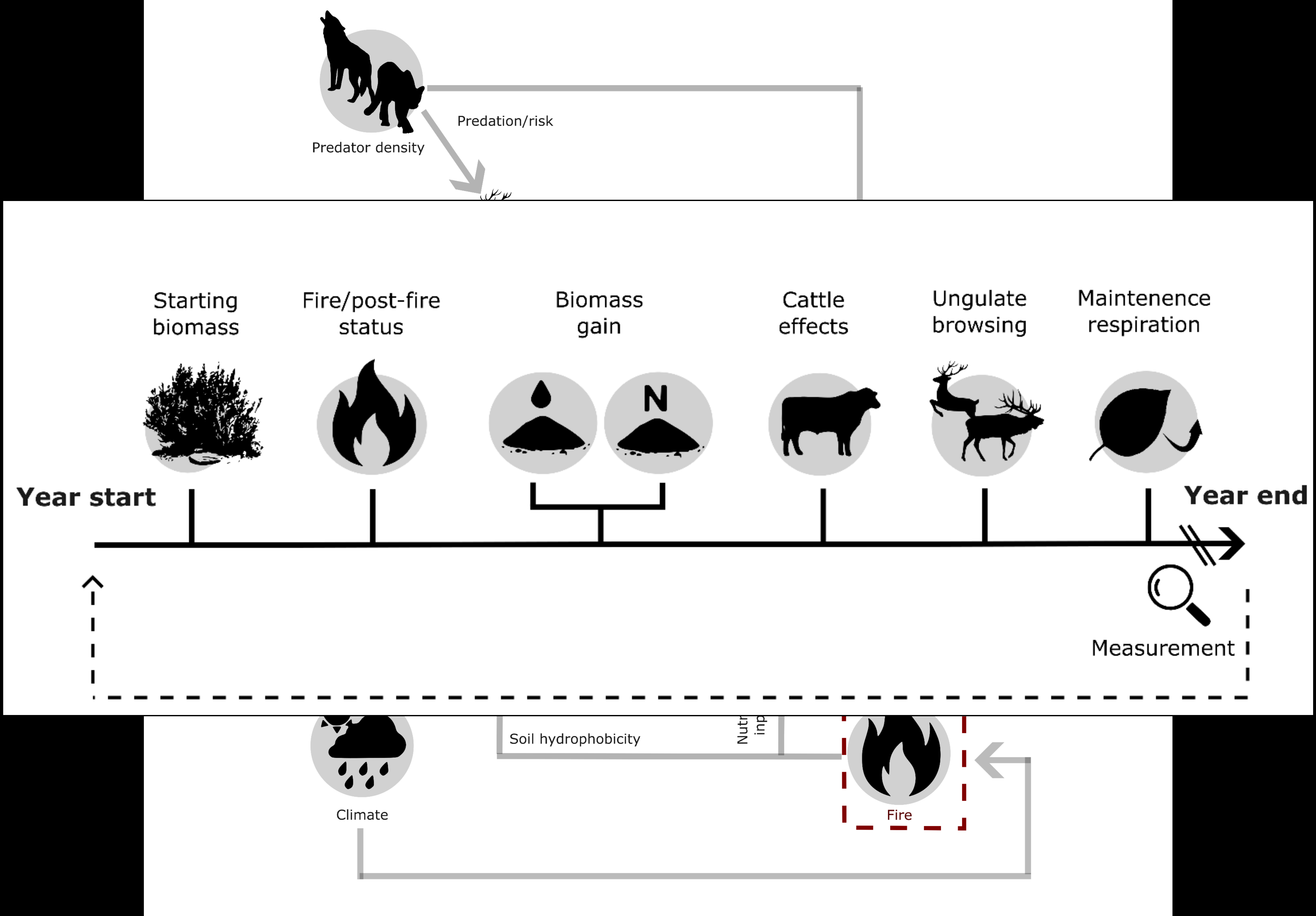




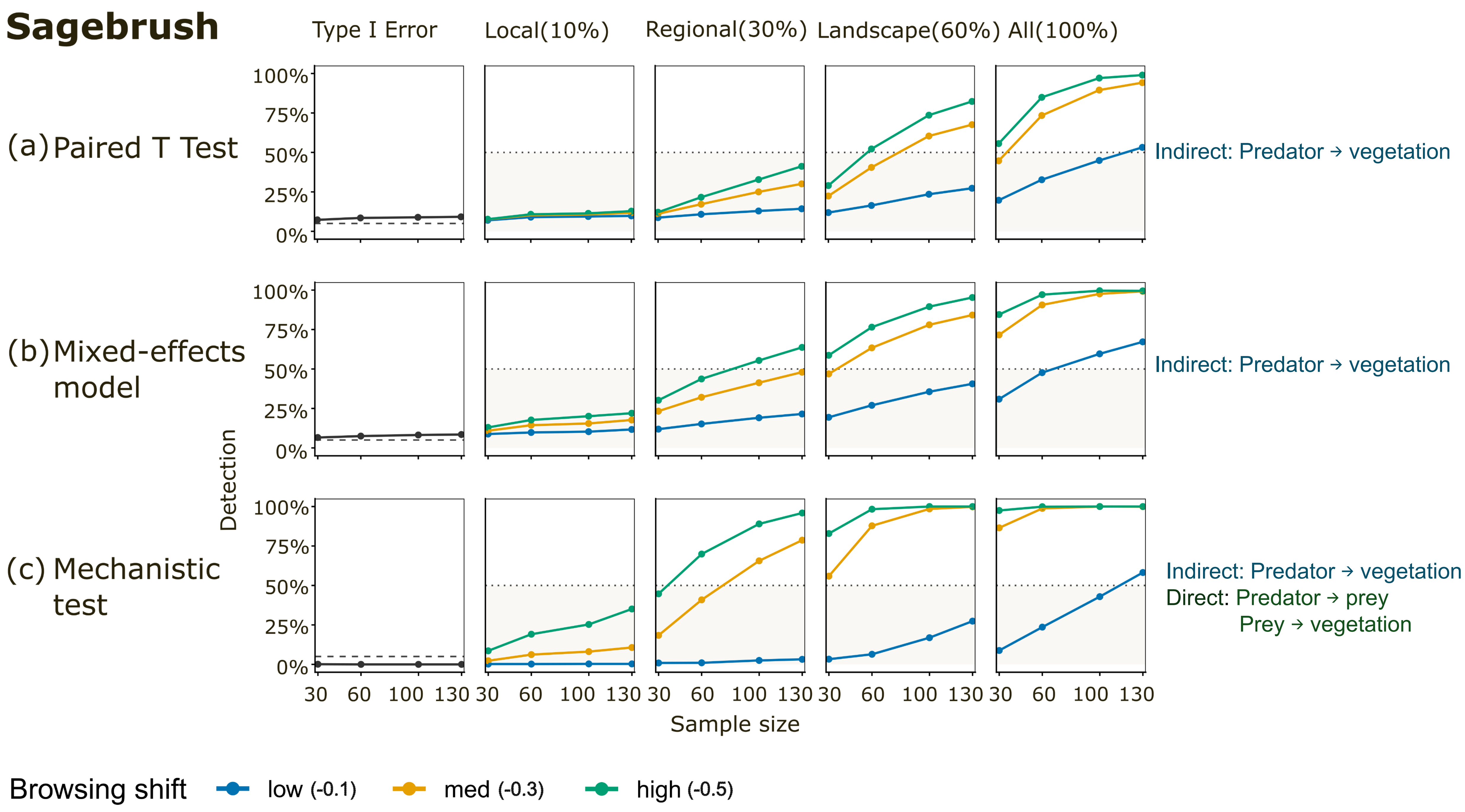
Predator density
Predation/risk
Ungulate density
Browsing pressure
Grazing, trampling
Cattle
Temperature
Shrub biomass
Mortality and post-fire conditions
Compaction and nutrients
Precipitation
Evapotranspiration
Soil moisture
Soil nutrients
N
Nutrient inputs
Soil hydrophobicity
Climate
Fire



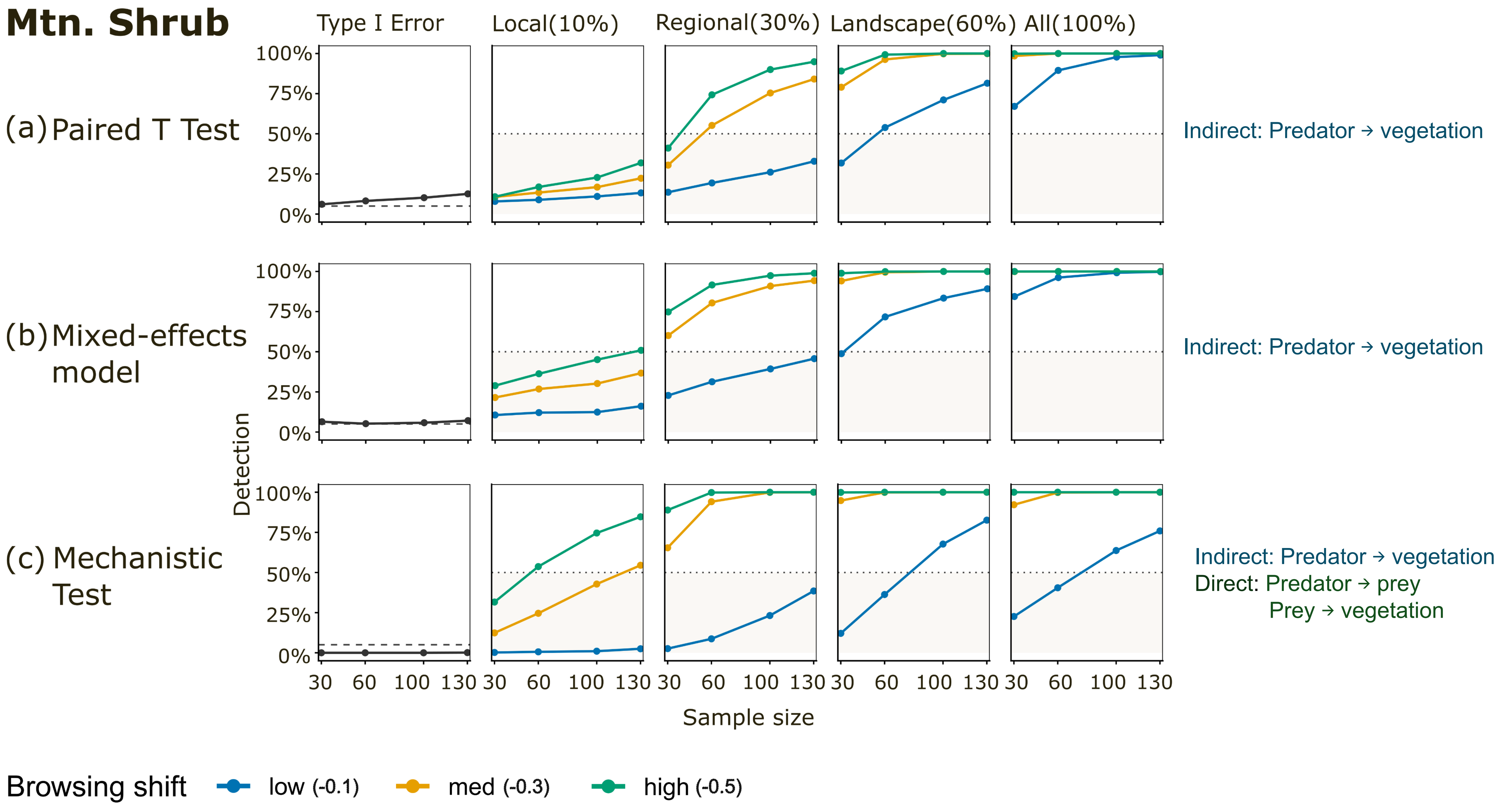
Predator density
Predation/risk
Ungulate density
Cattle
Browsing pressure
Grazing, trampling
Temperature
Shrub biomass
Mortality and post-fire conditions
Compaction and nutrients
Precipitation
Evapotranspiration
Soil moisture
Soil nutrients
N
Nutrient inputs
Soil hydrophobicity
Climate
Fire



Predator density
Predation/risk
Starting biomass
Fire/post-fire status
Biomass gain
N
Cattle effects
Ungulate browsing
Maintenence respiration
Year start
Year end
Measurement
Soil hydrophobicity
Climate
Fire

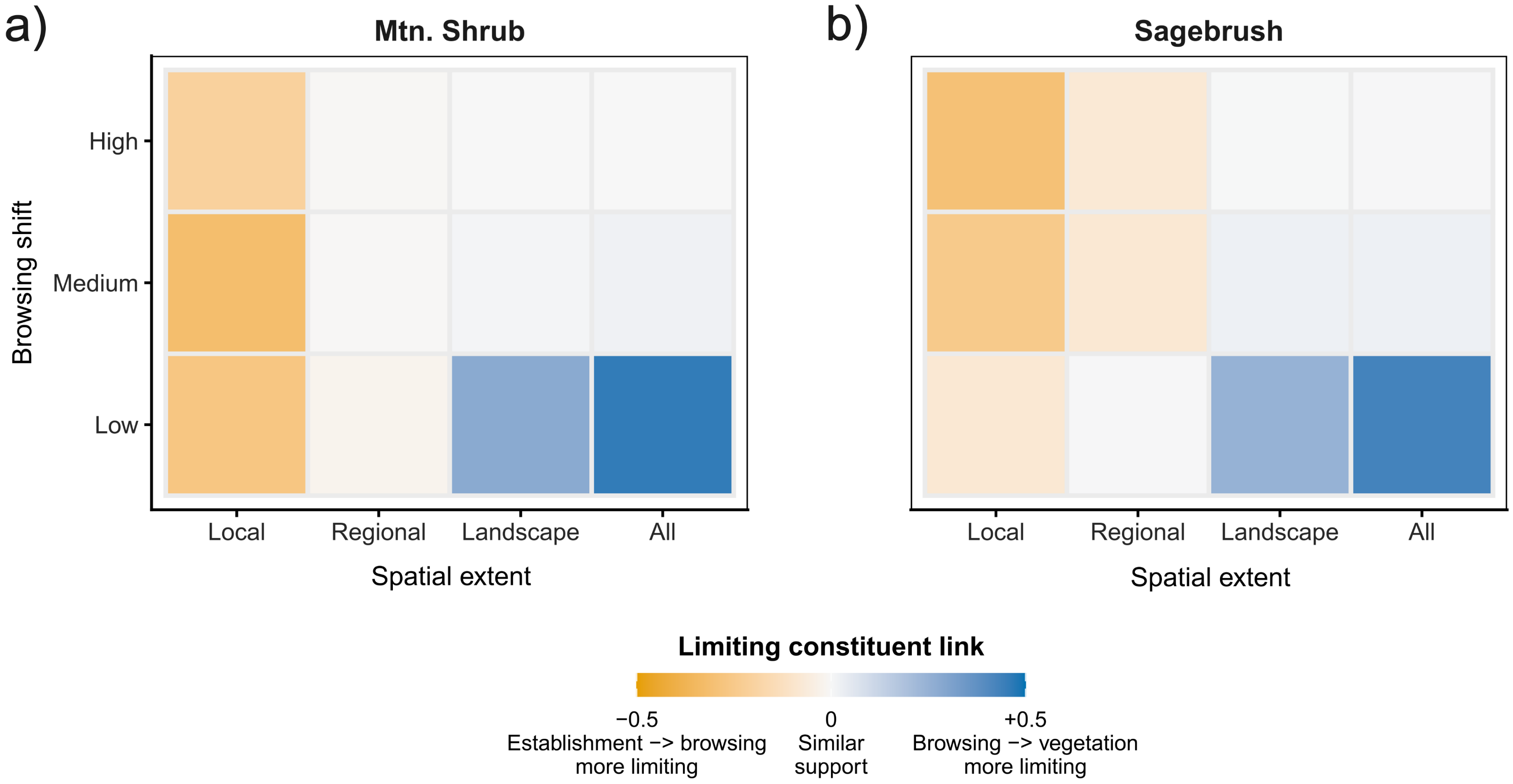


Sagebrush
Type I Error
Local(10%)
Regional(30%)
Landscape(60%)
All(100%)
(a) Paired T Test
(b) Mixed-effects model
(c) Mechanistic test
100%
75%
50%
25%
0%
Detection
30
60
100
130
Sample size
Indirect: Predator → vegetation
Indirect: Predator → vegetation
Indirect: Predator → vegetation
Direct: Predator → prey
Prey → vegetation
Browsing shift
low (-0.1)
med (-0.3)
high (-0.5)

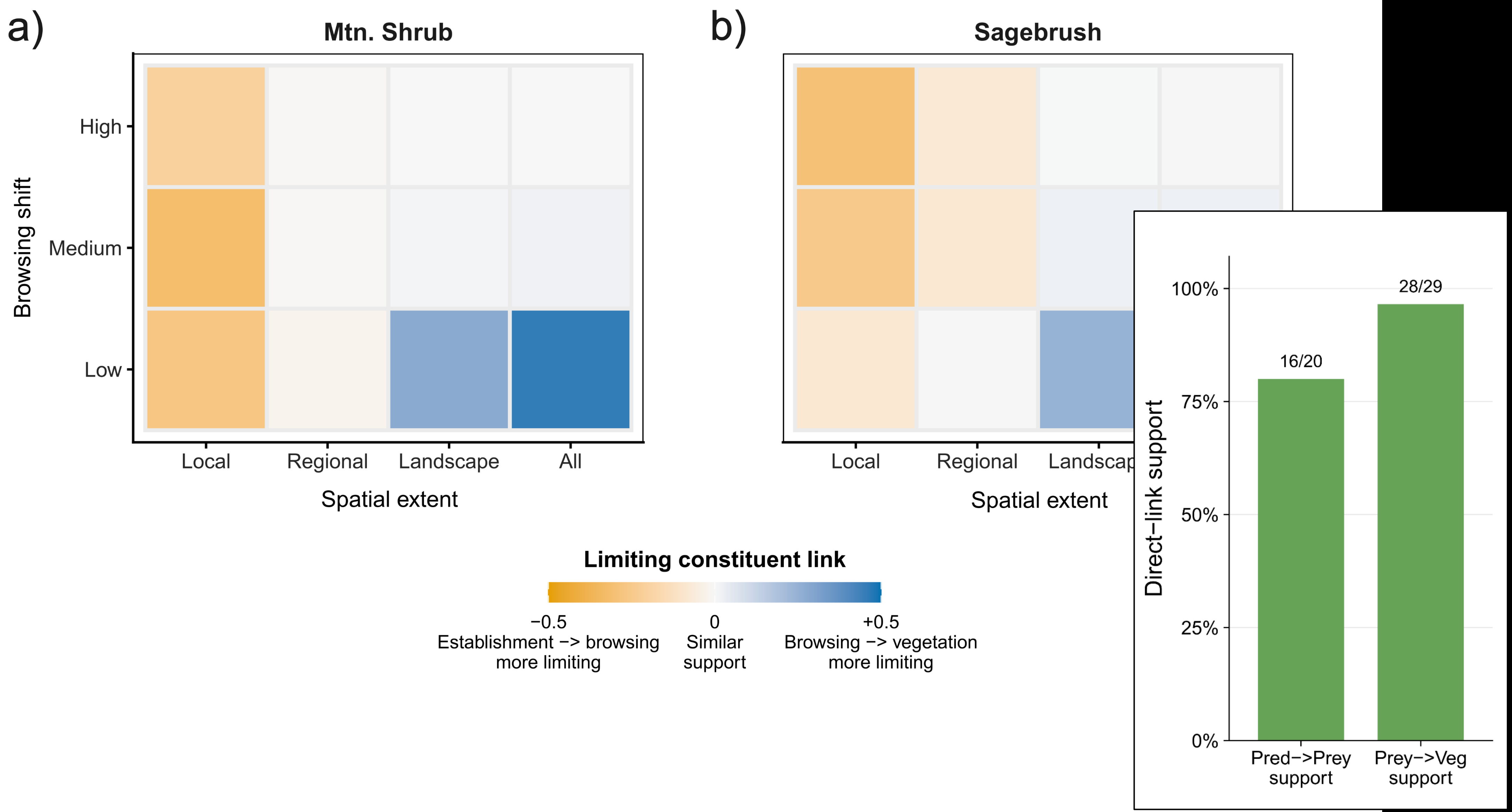


Mtn. Shrub
Type I Error
Local(10%)
Regional(30%)
Landscape(60%)
All(100%)
(a) Paired T Test
(b) Mixed-effects model
(c) Mechanistic Test
Indirect: Predator → vegetation
Indirect: Predator → vegetation
Indirect: Predator → vegetation
Direct: Predator → prey
Prey → vegetation
Detection
Sample size
0%
25%
50%
75%
100%
30
60
100
130
Browsing shift
low (-0.1)
med (-0.3)
high (-0.5)

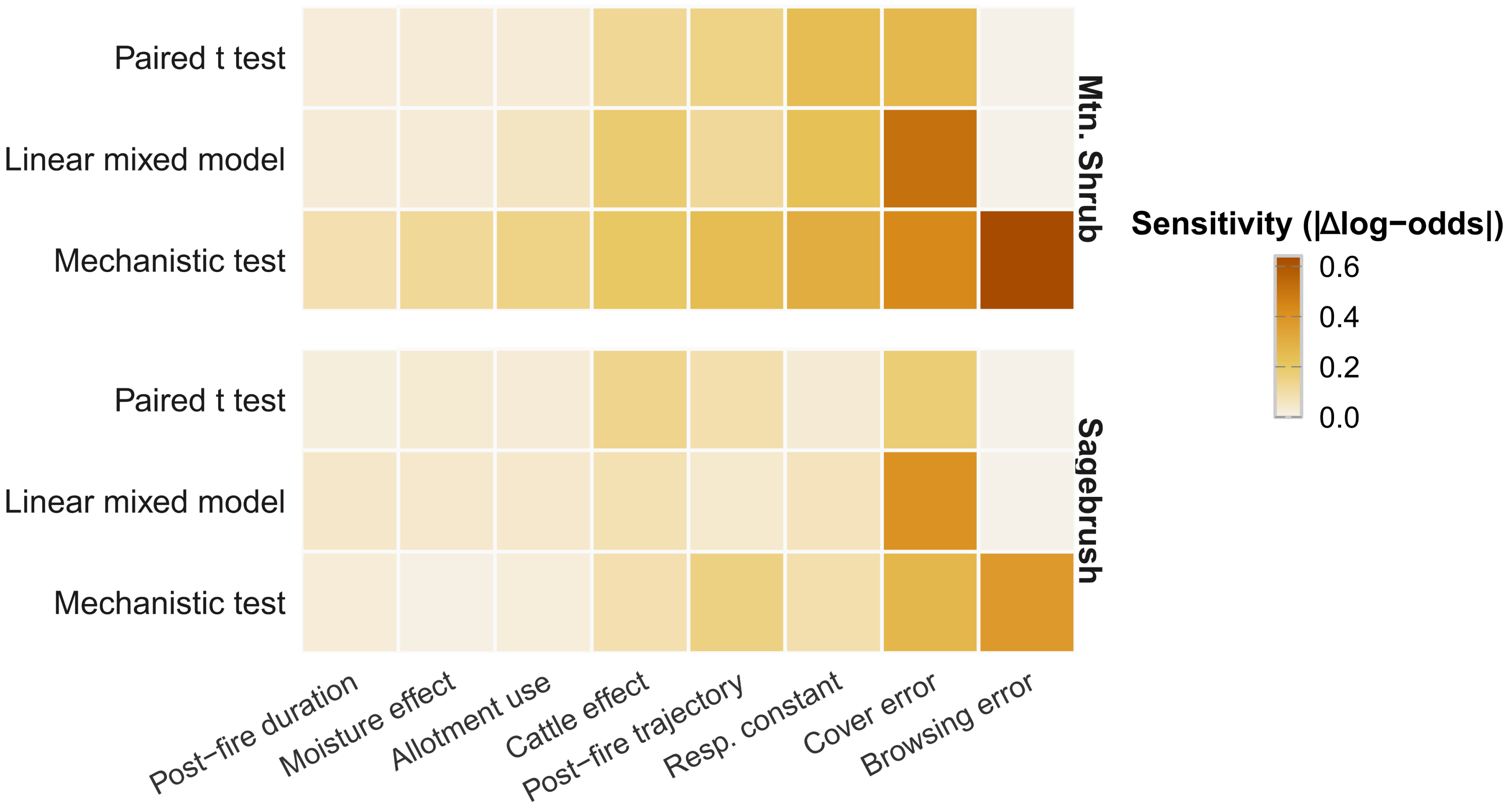
Mechanistic test (full pathway evidence)



Mechanistic test (full pathway evidence)



Model sensitivity



Conclusions

- Disparate findings reflect both ecological context-dependence and differences due to evidentiary standards and study design

Conclusions

- Disparate findings reflect both ecological context-dependence and differences due to evidentiary standards and study design
- Evaluating the full pathway (two direct links + one indirect link) provides strong Type I error control

Conclusions

- Disparate findings reflect both ecological context-dependence and differences due to evidentiary standards and study design

- Evaluating the full pathway (two direct links + one indirect link) provides strong Type I error control
    - This occurs without a loss of statistical power when top-down effects are strong enough to produce meaningful vegetation change

Conclusions

- Disparate findings reflect both ecological context-dependence and differences due to evidentiary standards and study design

- Evaluating the full pathway (two direct links + one indirect link) provides strong Type I error control
  - This occurs without a loss of statistical power when top-down effects are strong enough to produce meaningful vegetation change

- The detection bottleneck shifts upstream or downstream based on the strength and representation of top-down effects

Conclusions

- Disparate findings reflect both ecological context-dependence and differences due to evidentiary standards and study design

- Evaluating the full pathway (two direct links + one indirect link) provides strong Type I error control
  - This occurs without a loss of statistical power when top-down effects are strong enough to produce meaningful vegetation change

- The detection bottleneck shifts upstream or downstream based on the strength and representation of top-down effects

- Increasing measurement precision can pay substantial dividends for detection probability

Acknowledgements

Colorado State University

Brian Gerber
Kim Samsel

Colorado Parks and Wildlife

Ellen Brandell
Danielle Johnston
Andy Holland
Lauren Brandt
Lyndsey Aguilar

NASA DEVELOP team

Nick Young
Truman Anarella
Sheyla Galeano
Erin Burke
Ashley Banuelos
Scott Mohan