Spatial Responses to Climate Across Trophic Levels: 
Modeling Plants, Prey, and Predators in the Western United States 

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Study area & partners

- 4 species
- 7 states
- 11 ecoregions
- 19 partners
  - Universities
  - Federal agencies
  - State agencies
  - Nonprofit organizations
  - Industry
Land-use changes
An ecosystem in flux

- **Climate**
  - Less precipitation
  - Earlier snowmelt
  - Longer growing seasons
  - More severe droughts

- **Land use**
  - Oil & gas drilling
  - (Sub-)urbanization
  - Agricultural expansion
  - Solar & wind farms

➢ *Habitat loss & fragmentation*
**Goal:** combine satellite imagery with *in situ* data to inform natural resource management

*How do climate changes propagate through ecosystems?*

- **Satellite observations**
- **Plant phenology**
- **Animal locations**
- **Habitat & demography**
Plant productivity & phenology: NDVI
MODIS Surface Reflectance
(daily, 500 m)
*coarse spatial x fine temporal scale*
Information loss with pixel size

Extracting plant-specific phenologies from mixed pixels

Mixed pixel Reflectance

UnMixing

Land-Cover Specific Reflectance

Land-Cover Specific NDVI

Evergreen-grass savannah

Plant productivity predicts herbivore abundance

$R^2 = 0.58$

Stoner et al. in prep.
Plant phenology predicts herbivore reproduction

Where can we grow deer in the future?

Plant phenology predicts herbivore survival

**Adult females**

```
Survival
0  0.2  0.4  0.6  0.8  1.0
0  2  4  6  8  10  12
```

- Green: High EOS NDVI
- Blue: Average EOS NDVI
- Red: Low EOS NDVI

**Fawns**

```
Survival
0  0.2  0.4  0.6  0.8  1.0
0  2  4  6  8  10  12
```

- Green: High TMAX, Long SHGS
- Blue: Mean TMAX, Average SHGS
- Red: Low TMAX, Short SHGS


…”Where can we grow deer in the future?”
Plant productivity predicts carnivore abundance

$R^2 = 0.60$

$R^2 = 0.58$

Stoner et al. in prep.
Conclusions

Ecological
- Climate changes propagate through ecosystems
  - Vegetation: productivity & phenology
  - Herbivores: abundance, demography & behavior
  - Carnivores: abundance

Technical
- Consistent, long-term records are key
  - Vegetation composition & structure
    - Landsat, lidar, radar
  - Plant phenology
    - MODIS & VIIRS
  - Plant chemistry / hyperspectral

Practical
- Managers need monitoring & forecasts
  - Gradual adoption of satellite data
  - Matching with GPS & population data
  - Strong need to grow research into satellite-based monitoring systems
Looking forward

- Economic impacts of wildlife
  - Wildlife-based economies
    - $150 billion / yr
    - > 600,000 jobs
    - ~ 1% of GDP
  - Agricultural & property damage
    - $5 billion / yr
  - Game species are conservation umbrellas

- The realities of land management
  - Agencies need to monitor and predict
  - Budgets not keeping pace with costs
  - Managers need systematic data and tools
    - Research
    - Monitoring
    - Communication