Ecological Remote Sensing of Invasion By Perennial Pepperweed

Margaret E. Andrew & Susan L. Ustin

Center for Spatial Technologies and Remote Sensing
Department of Land, Air, & Water Resources
University of California Davis

Outline

1. Introduction to *Lepidium*
2. Mapping *Lepidium* distribution with hyperspectral remote sensing
3. Modeling potential *Lepidium* distribution
4. Monitoring *Lepidium* spread
5. Detecting and explaining *Lepidium* phenological variation

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Lepidium latifolium

- Dramatically spread across the western US over the past decade.
- Invades wetland & riparian areas; tolerates salinity.
- Displaces natives; forms monocultures.
- May alter biogeochemical cycles.
- Spreads vegetatively; produces seeds prolifically.

Lepidium latifolium

- Cal-IPC A-list exotic pest plants
- CDFA B-list noxious weed

- Understanding the habitat requirements, spread characteristics, and phenology of *Lepidium* can inform management in space and time.

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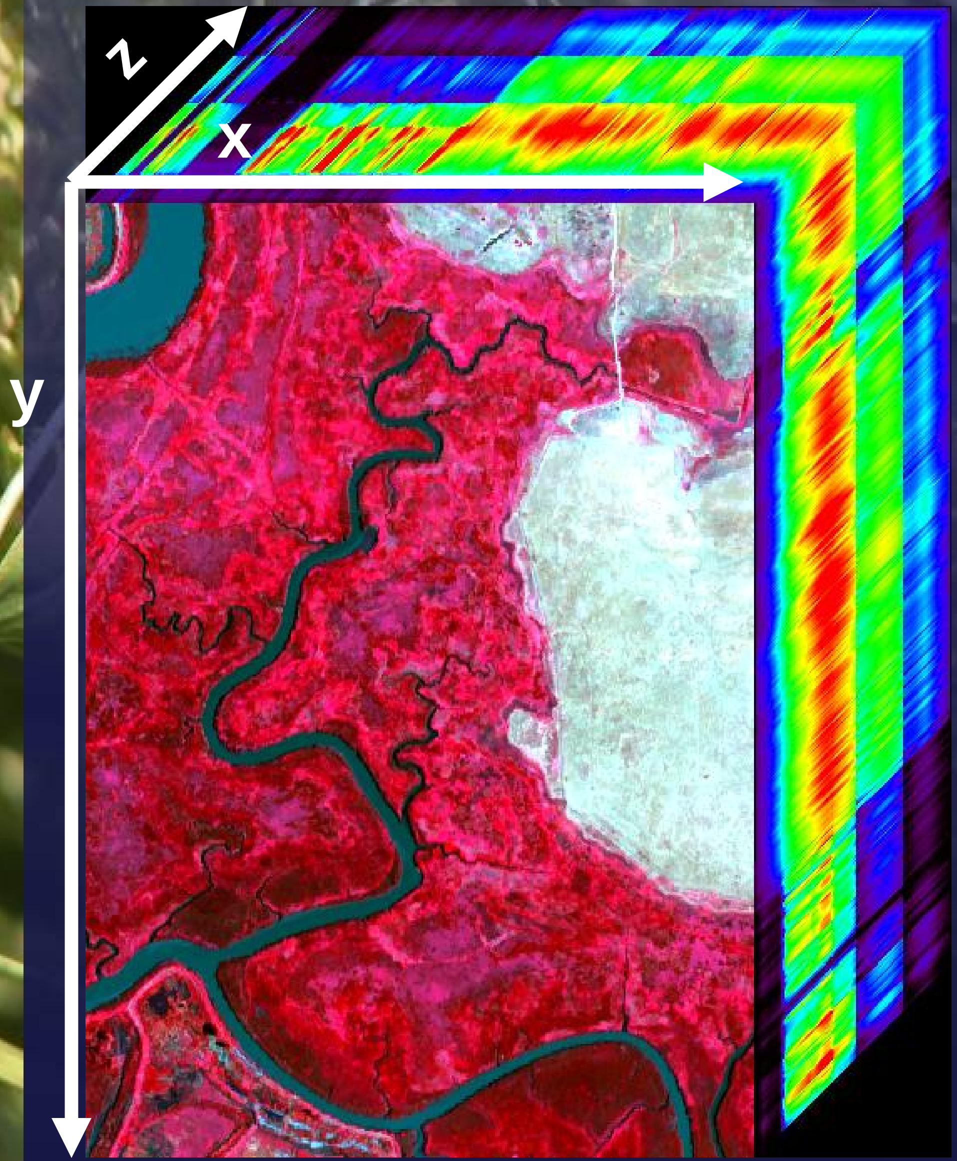
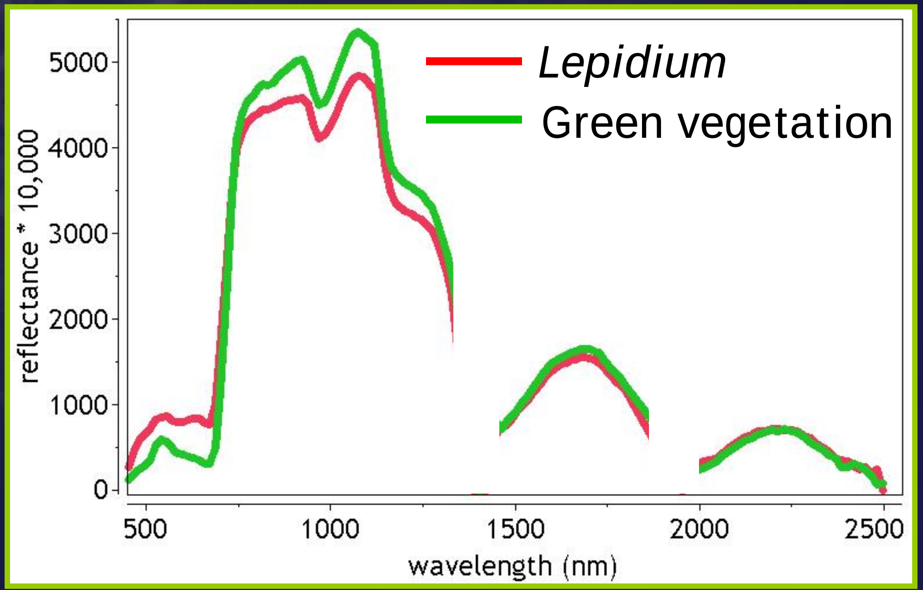
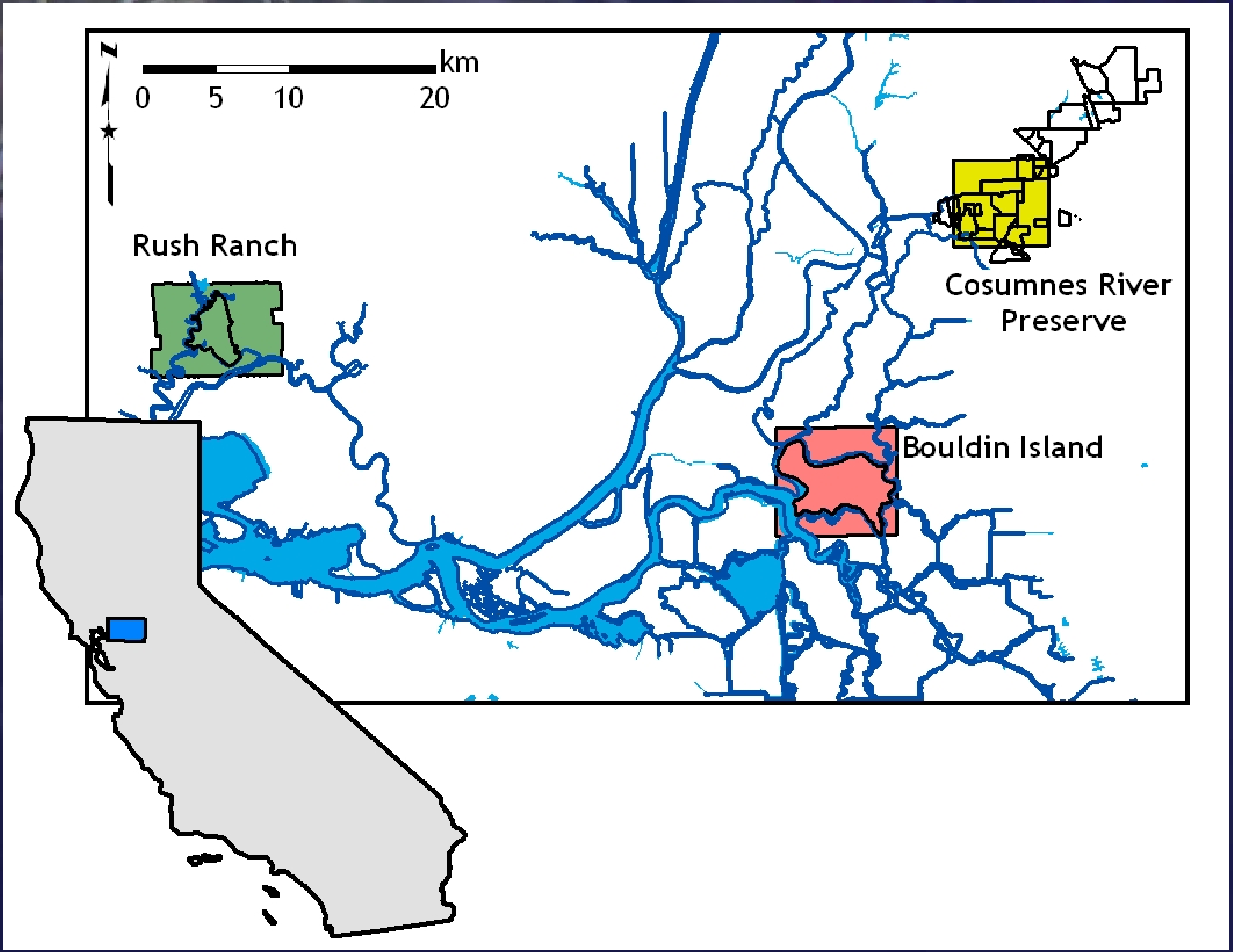
Hyperspectral Image Data



- HyMap airborne hyperspectral image data:
  - Spectral resolution - 128 15-20nm bands in the visible and reflected IR
  - Spatial resolution - 3m

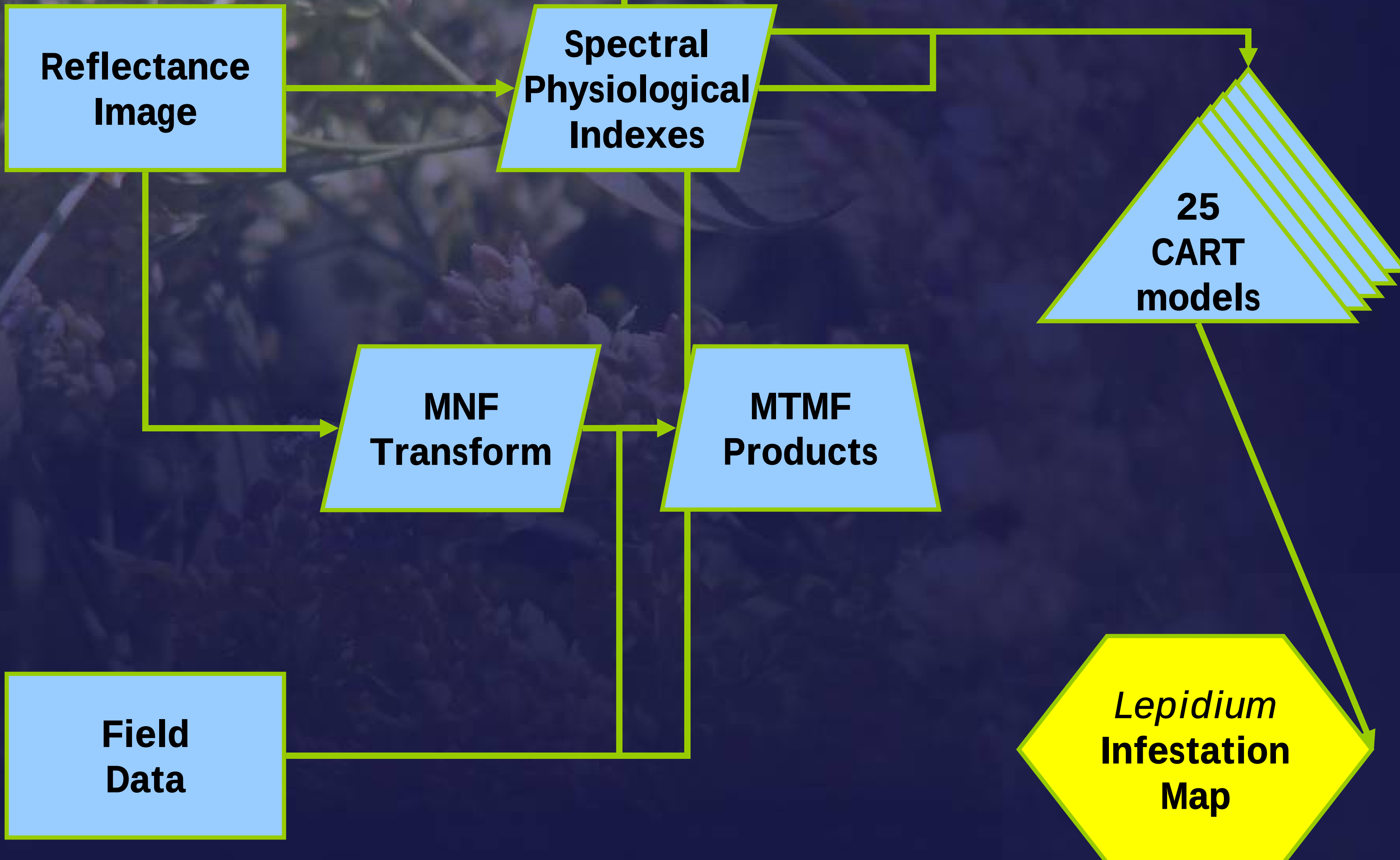


Study Sites



N
km
0
5
10
20
Rush Ranch
Cosumnes River
Preserve
Bouldin Island

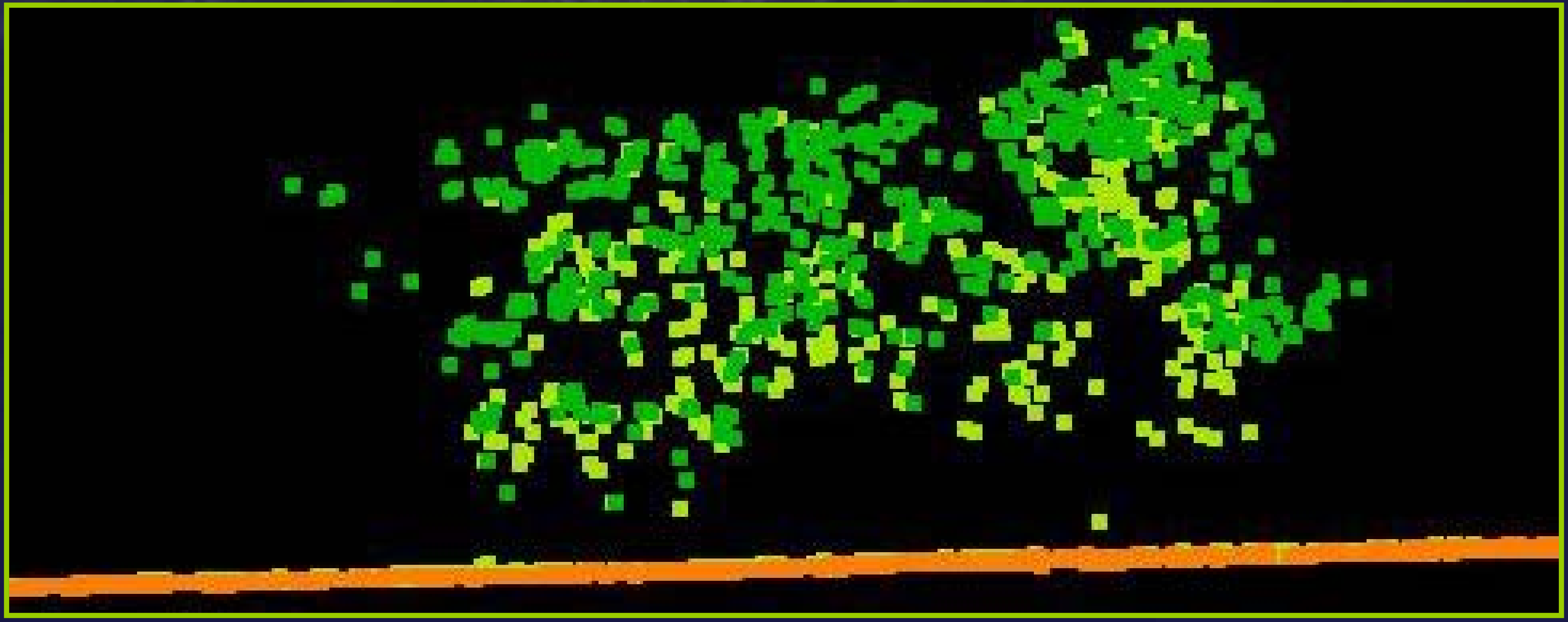
Hyperspectral *Lepidium* Detection



Andrew & Ustin, *In Press*

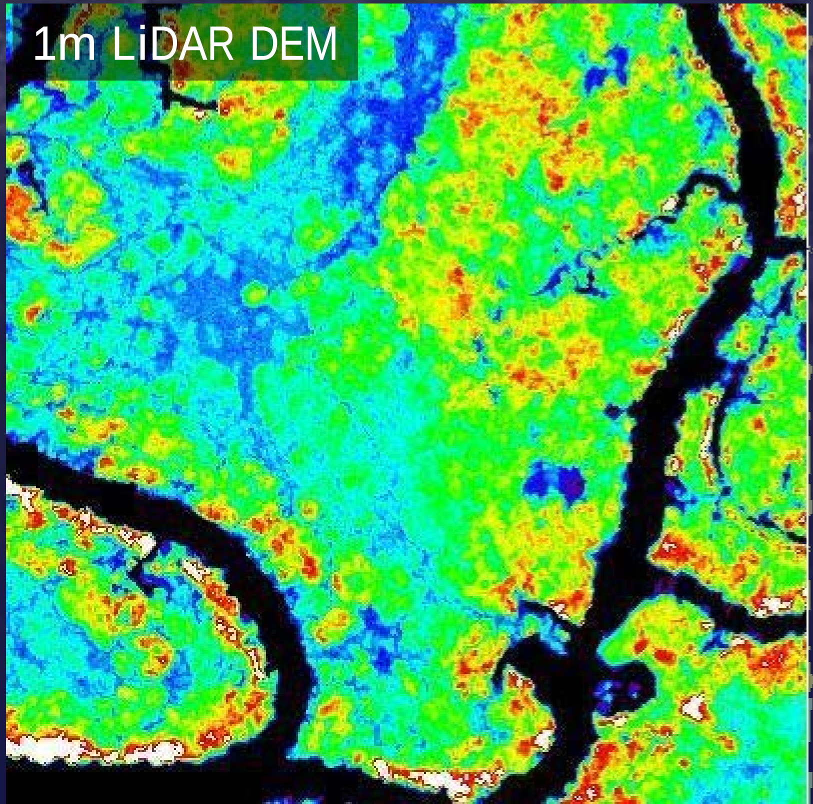
LiDAR

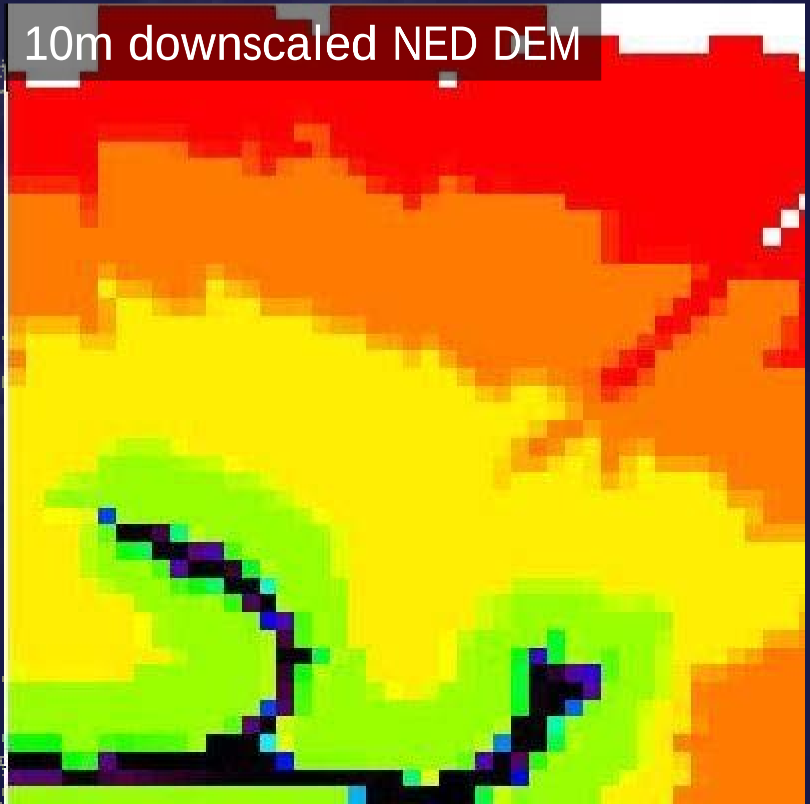
- Light Detection and Ranging
- Active sensor
  - Emits pulses of EMR
  - Calculates surface height from time of pulse return
- Uses
  - High-resolution DEM
  - Channel detection
  - Vegetation height
  - Vegetation structure
  - Etc.



LiDAR

- Benefits of high-resolution LiDAR DEM:
  - Only spatial elevation products available that adequately capture fine-scaled topography that is ecologically very important in wetlands.





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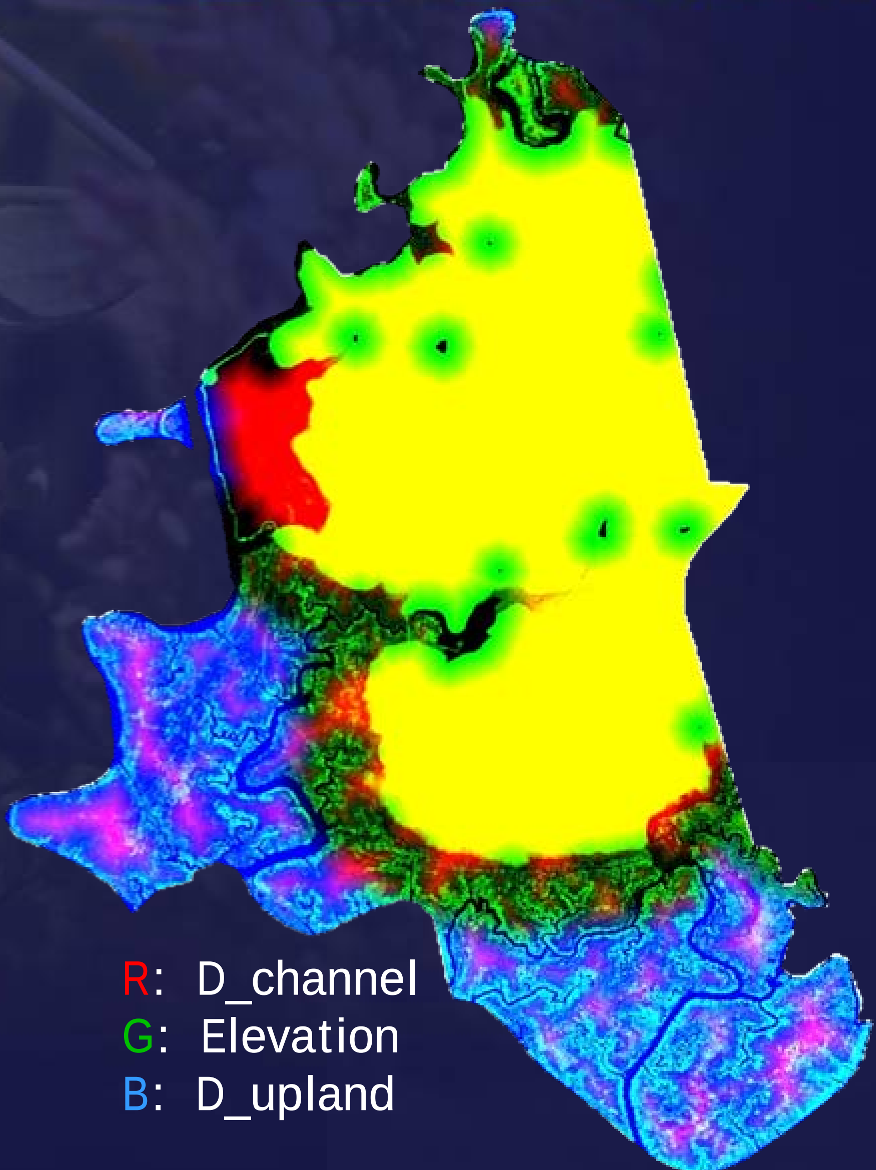
Potential *Lepidium* Distribution

- 12.6 ha current distribution
- 219 ha potential distribution
- 25% of Rush Ranch invasible
- Only 5% of suitable habitat is currently occupied
- Omission = 13.6%

Potential *Lepidium* Distribution

Variable Importance

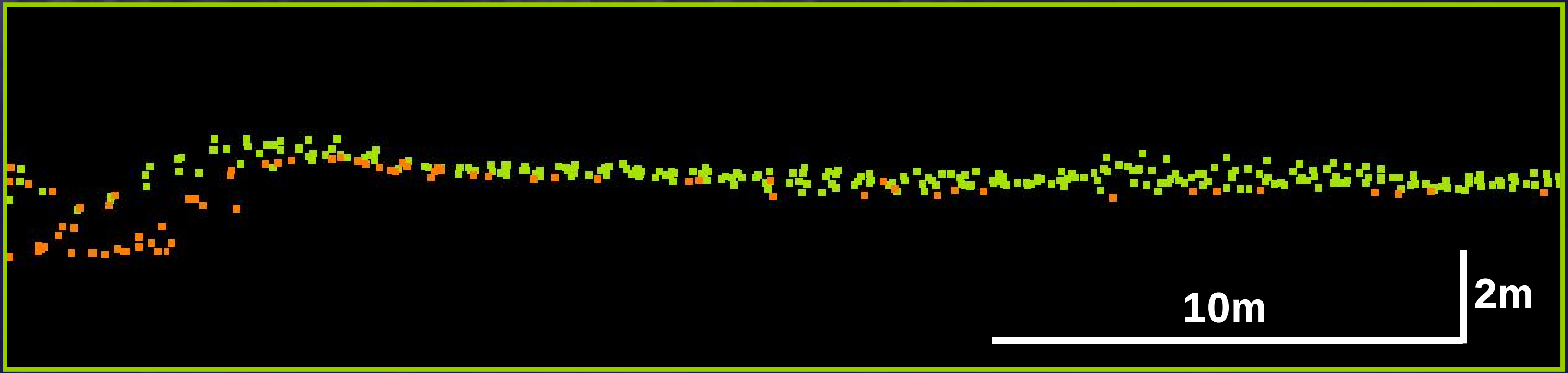
Distance to upland	**44%**
Distance to channel	**26%**
Elevation	9%
Aspect	3%
Slope	2%
Profile convexity	1%
Plan convexity	1%
Longitudinal convexity	1%
Cross-sectional convexity	1%
Minimum curvature	1%
Maximum curvature	1%



Potential *Lepidium* Distribution

- Distance to channel includes relevant topographical information, especially relative elevation.

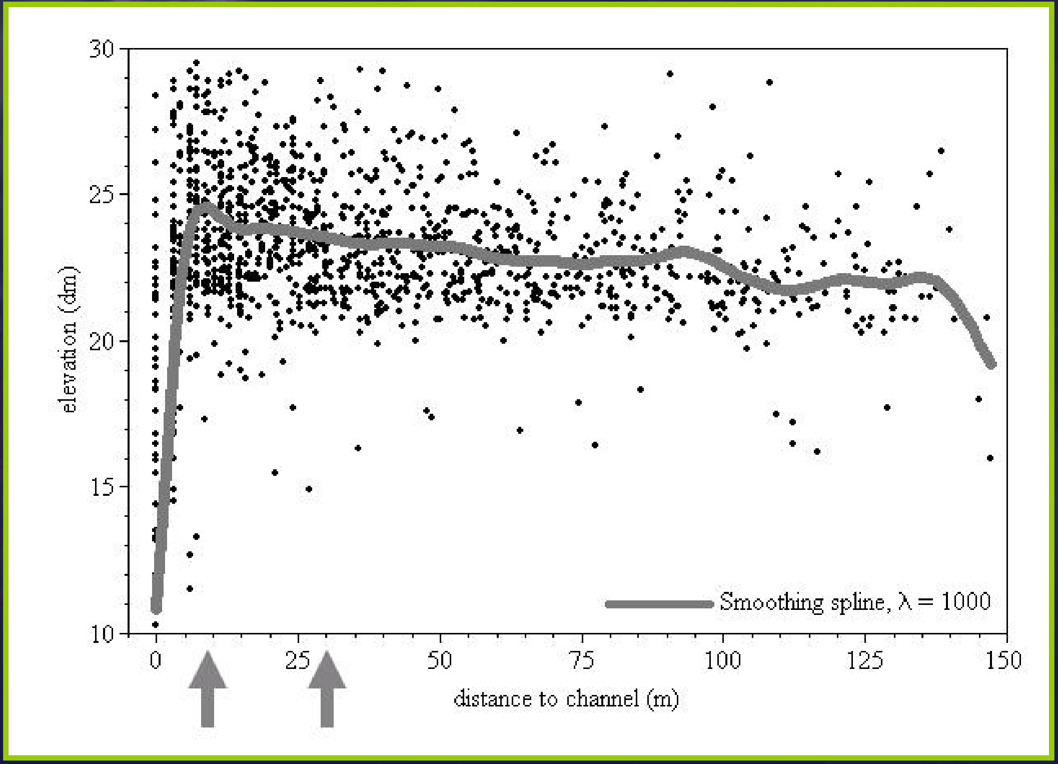
Sample LiDAR returns of a channel cross-section.



Potential *Lepidium* Distribution

- Distance to channel includes relevant topographical information, especially relative elevation.

Marsh-wide relationship between distance to channel and elevation:



$R^2 = 0.49$

Distribution Modeling - Conclusions

- There is the potential for considerable spread of *Lepidium* at Rush Ranch.
- *Lepidium* selects habitats that minimize the stress associated with wetlands.
  - Marshland-upland margin – increased terrestrial influence.
  - Along channels – relatively high ground → avoid inundation and anoxia stress.

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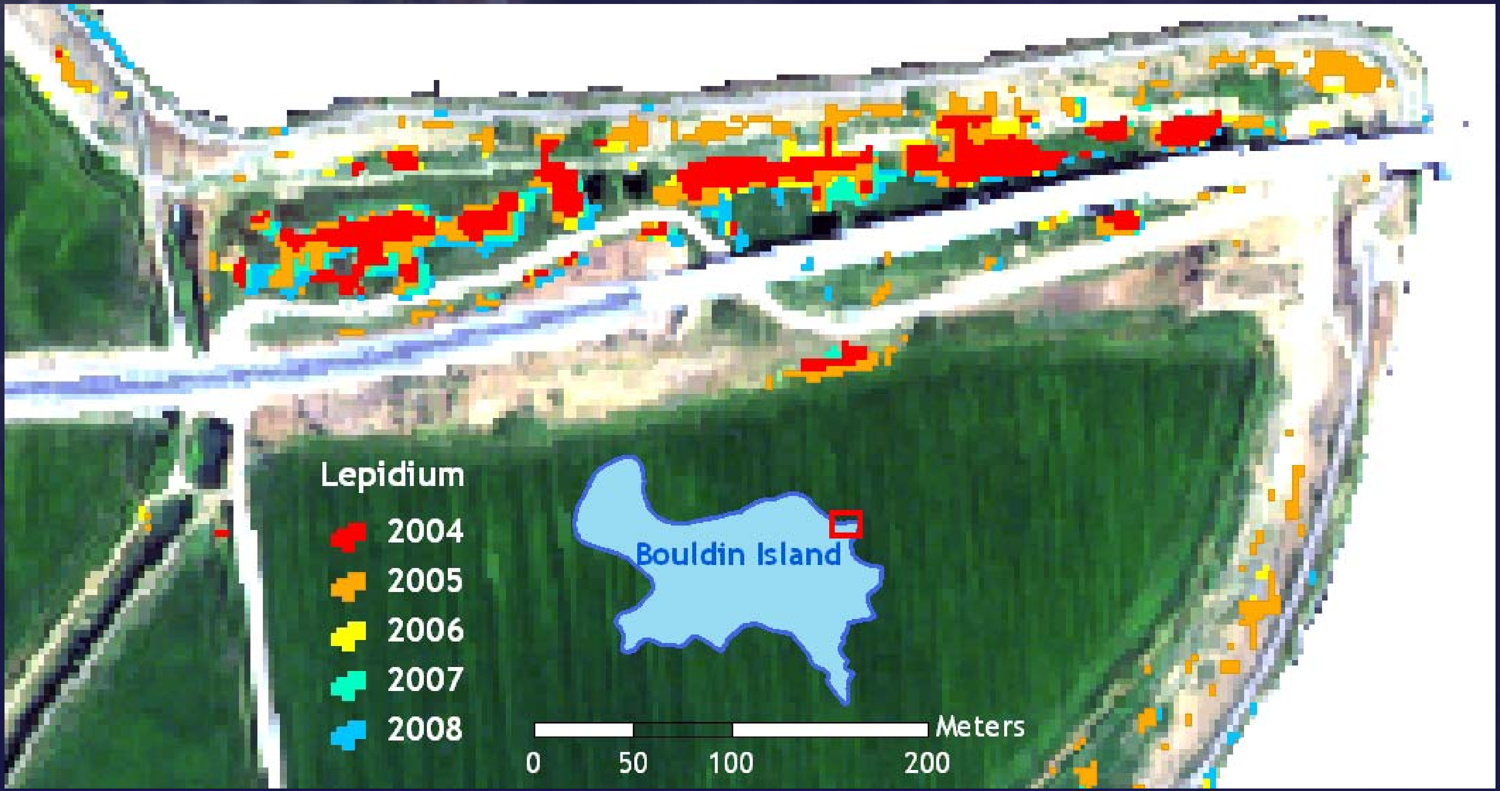
Lepidium Spread – Bridge Site

- Increased 2.6x in 5 years.
- Dispersal distances

2004-2005: 15 ± 18m, max = 78m
2005-2006: 5 ± 5m, max = 25m
2006-2007: 6 ± 3m, max = 20m
2007-2008: 5 ± 4m, max = 31m



Lepidium Spread – Western Mesic Site

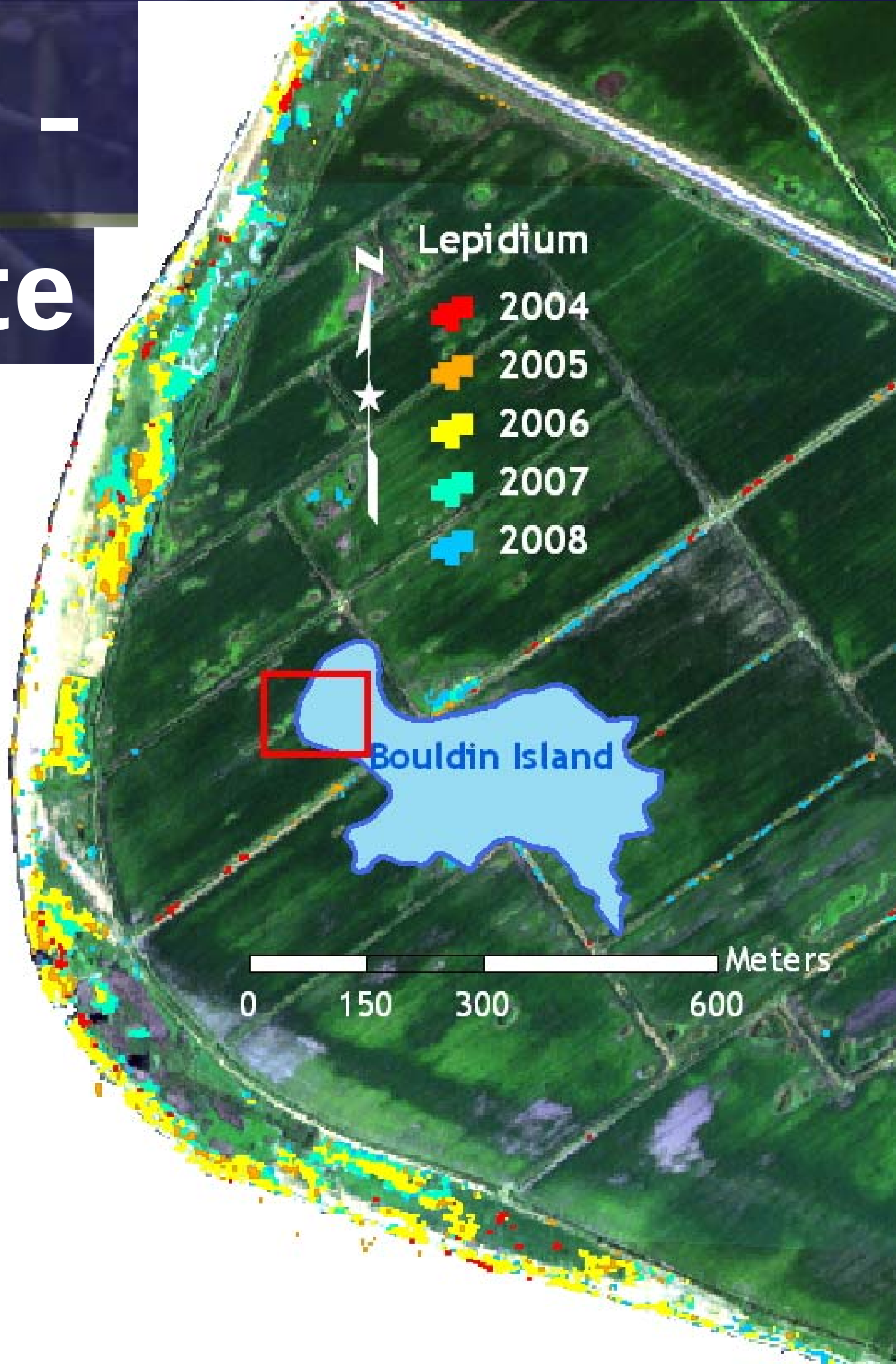
- 30-fold increase in area.
- <u>Dispersal distances</u>

2004-2005: 53 ± 46m
max = 215m

2005-2006: 16 ± 15m
max = 123m

2006-2007: 11 ± 11m
max = 71m

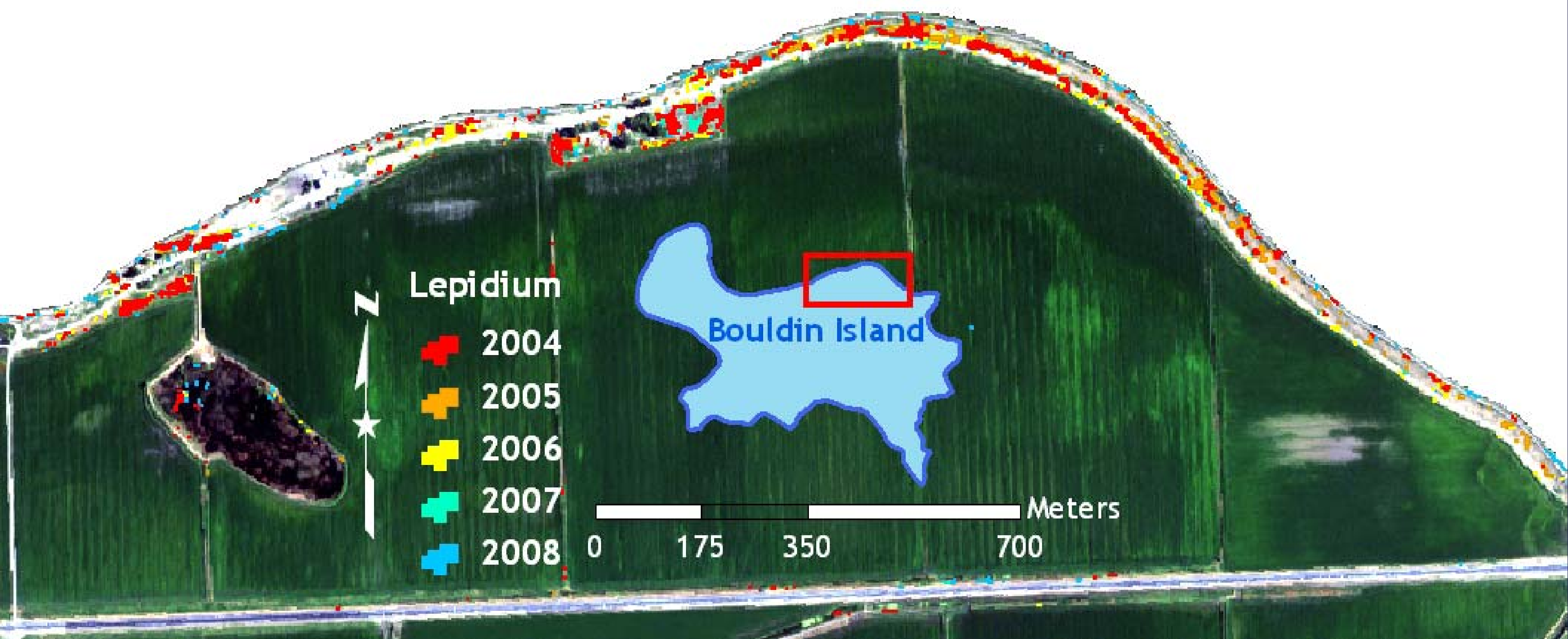
2007-2008: 5 ± 5
max = 57m



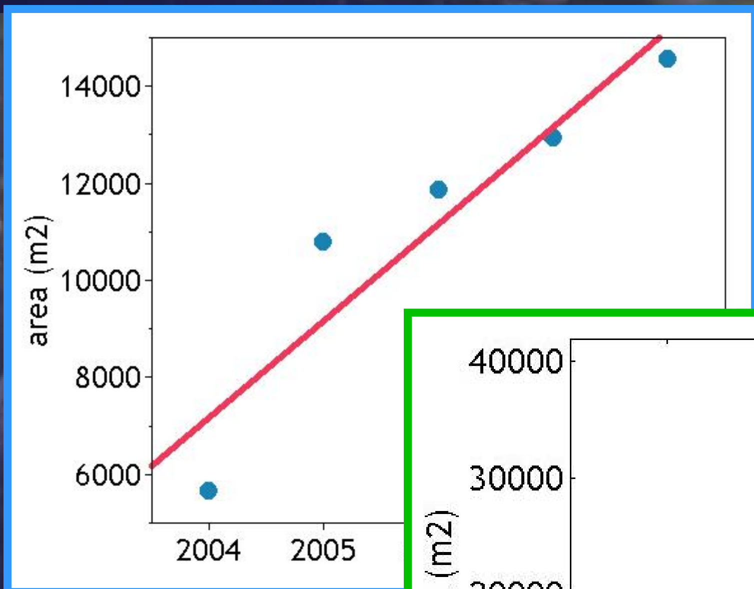
Lepidium Spread - Levee Site

- Doubled in area.
- <u>Dispersal distances</u>

2004-2005: 8 ± 8m, max = 43m
2005-2006: 17 ± 19m, max = 123m
2006-2007: 9 ± 8m, max = 51m
2007-2008: 14 ± 11m, max = 57m

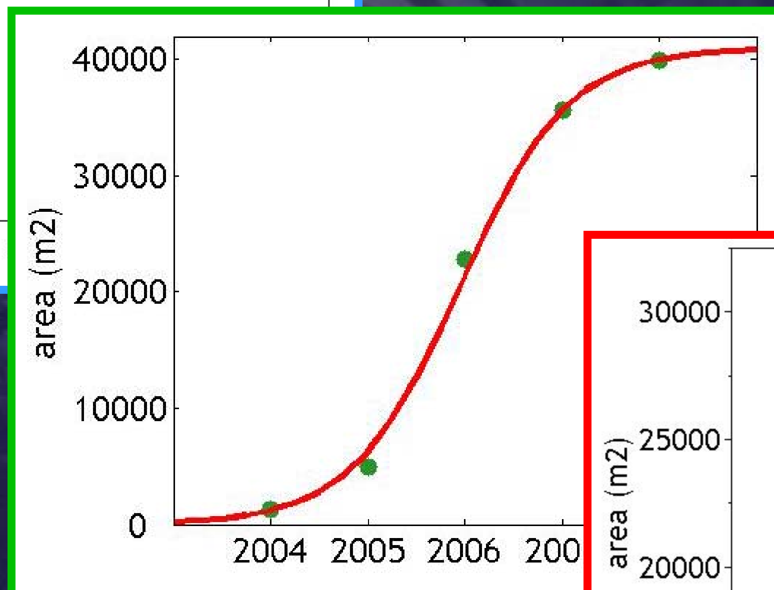


Spatial Variation in Spread



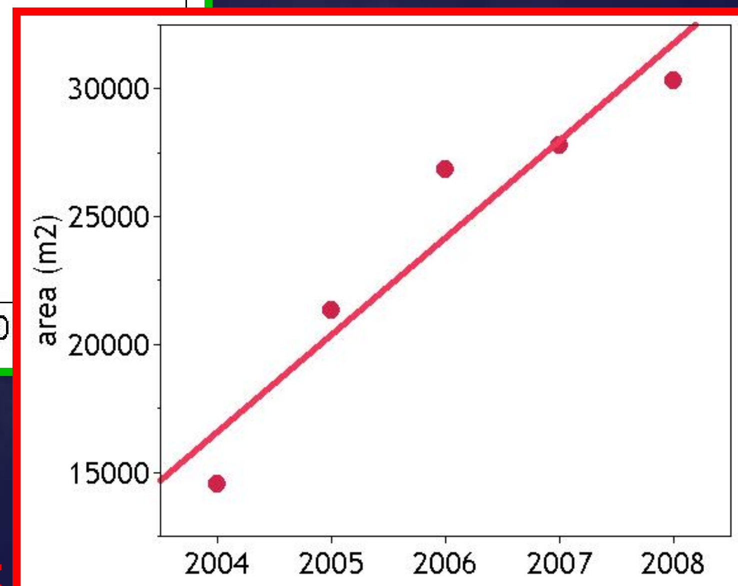
Bridge

>> Linear spread,
+ 2000m²/year



Western Mesic

>> Logistic growth increased 380-460% in exponential stage

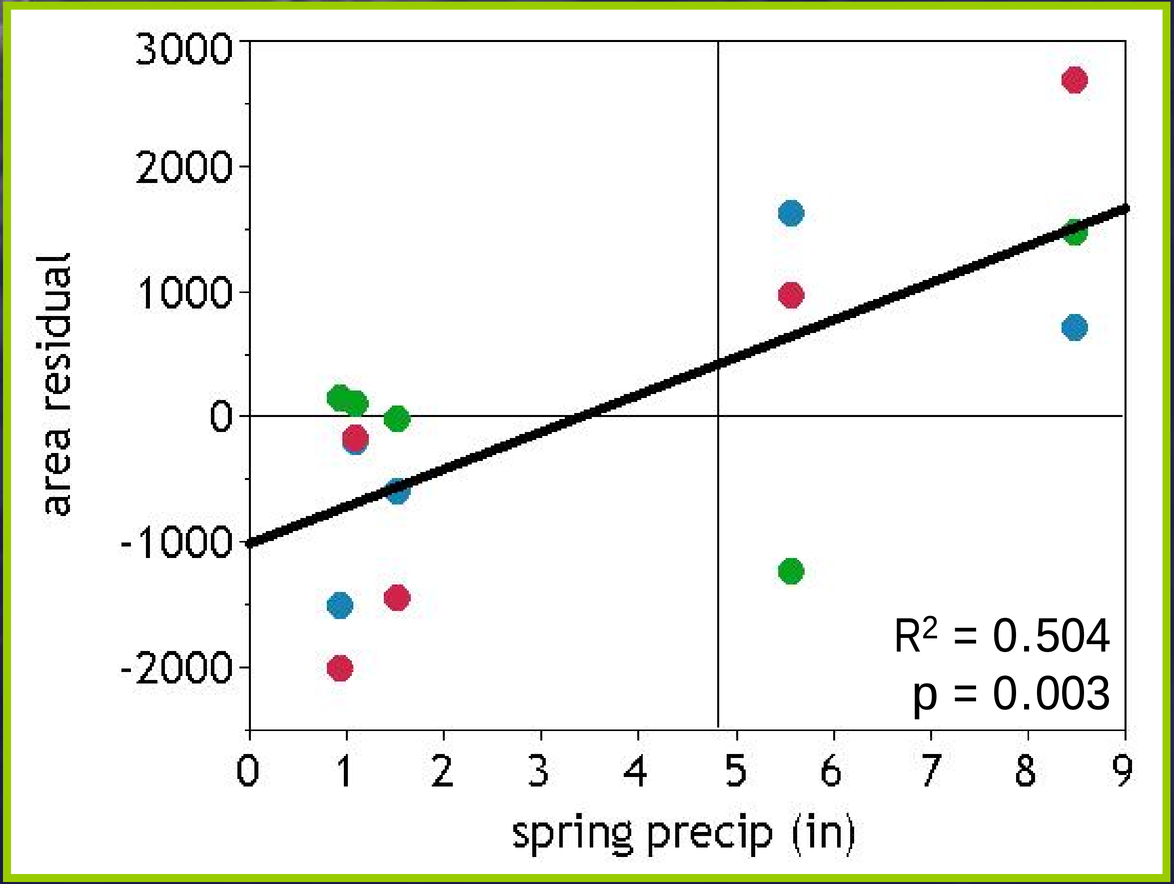


Levee

Linear spread, <<
+ 4000m²/year

Annual Variation in Spread

- Greater spread in wet springs



- Importance of long time series

Conclusions – Monitoring Spread

- *Lepidium* spreads extremely quickly when colonizing a site.
- Eradication should focus on satellite populations.
- *Lepidium* spreads steadily at established sites.
- *Lepidium* spread may be influenced by annual precipitation.

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Identification of phenologic stages Rush Ranch

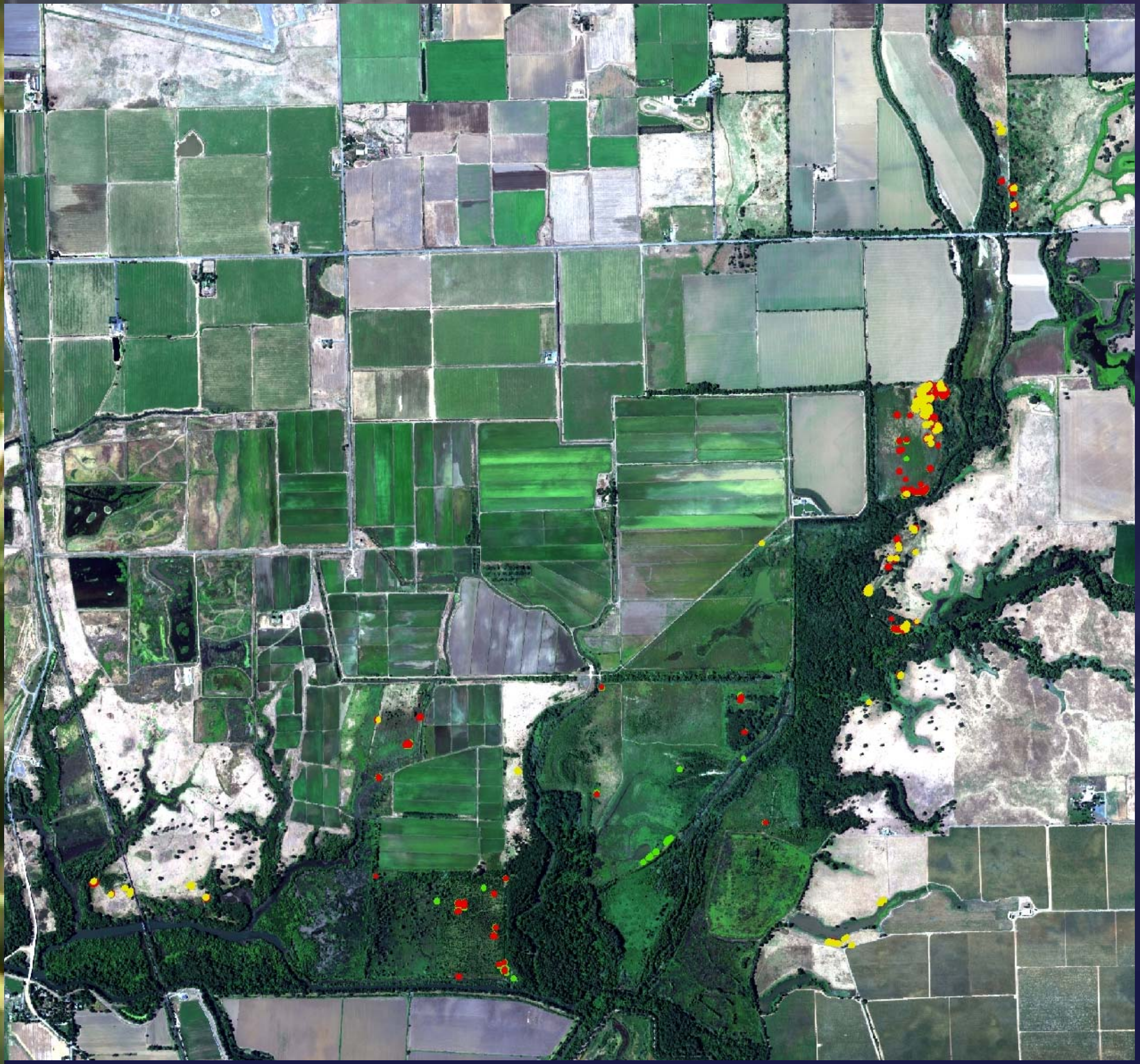
June 2006

Early flowering

Peak flowering

Fruiting

Identification of phenologic stages Cosumnes River Preserve



June 2005

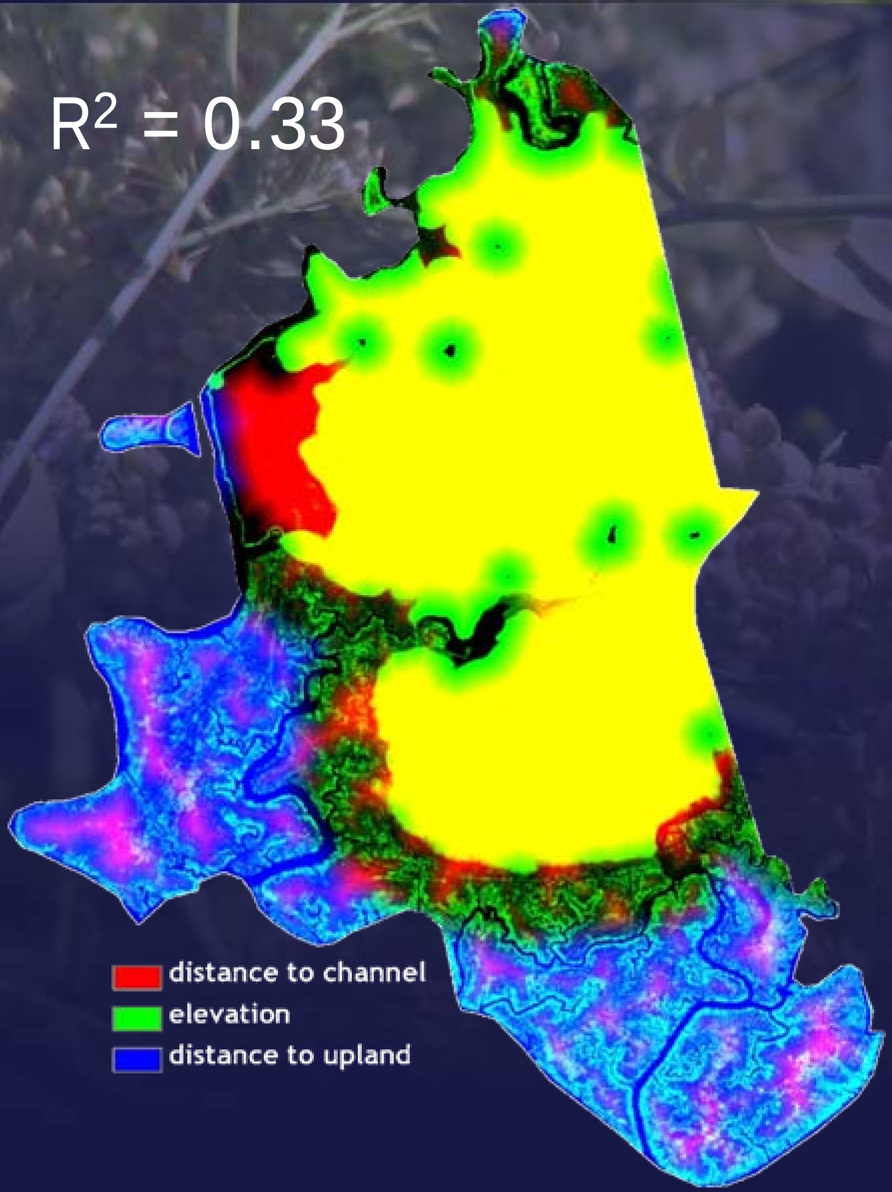
Vegetative

Flowering

Senescent

Environmental controls of phenology Rush Ranch

$R^2 = 0.33$

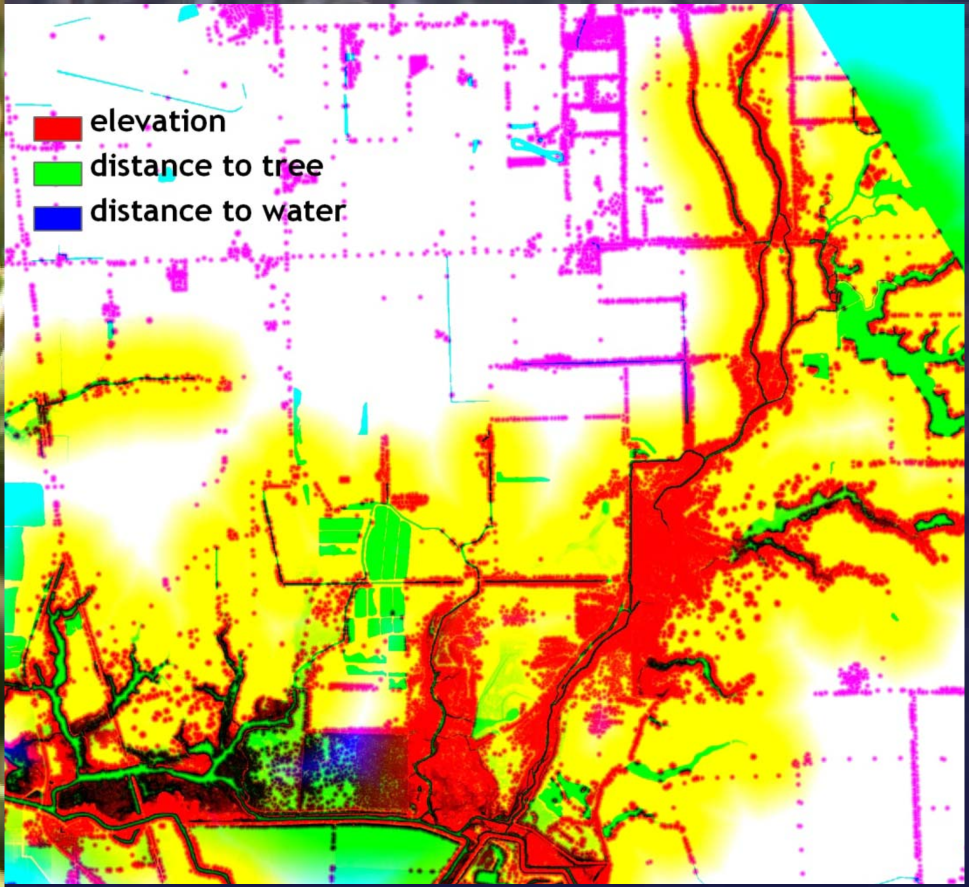


Significant terms:

- distance to channel
- slope
- longitudinal convexity
- distance to upland
- eastness
- profile convexity
- distance to edge
- d_channel * d_upland
- d_channel * d_edge
- elevation * slope
- slope * minimum curvature
- plan convexity * d_edge
- longitudinal convexity * eastness
- d_upland * eastness
- profile convexity * eastness

Environmental controls of phenology Cosumnes River Preserve

$R^2 = 0.56$



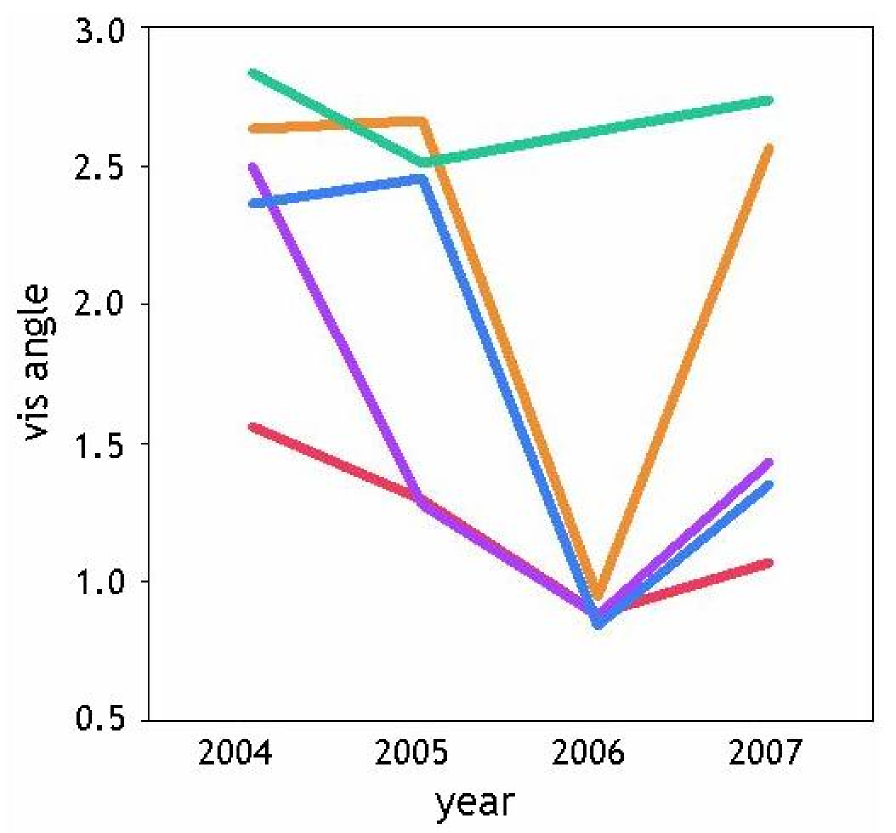
Significant terms:

- elevation
- slope
- maximum curvature
- distance to tree
- elevation *distance to tree
- elevation*maximum curvature
- distance to edge

Environmental controls of phenology

- At both sites, more advanced phenology associated with:
  - Interior of patches (intraspecific competition)
  - Lower convexities
  - Shallower slopes
  - Higher elevations (drier)

Interannual phenologic variation Cosumnes River Preserve



	2004	2005	2006	2007
1	Veg – flower	Veg	Veg	Veg
2	Flower	Veg	Veg	Veg
3	Flower	Fruit	Veg	Veg
4	Flower	Fruit-senesce	Veg	Flower
5	Fruit	Fruit-Senesce	Fruit	Fruit-senesce

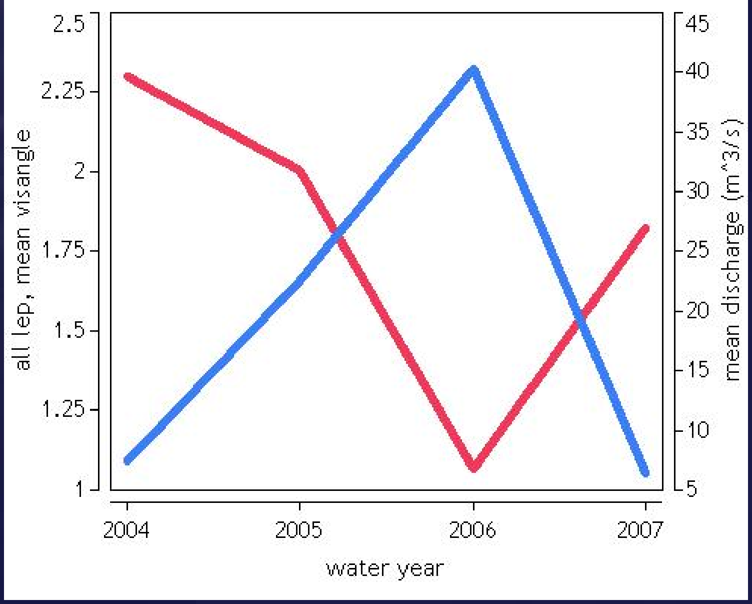
Interpretations confirmed by inspecting mean spectra.

- 5 phenological trends identified ($p < 0.0001$, repeated measures MANOVA).

Interannual phenologic variation Cosumnes River Preserve

- All trajectories except 3 were strongly related to hydrological variables.
  - Total/springtime precipitation (P1, P2)
  - Water year/springtime mean discharge of Cosumnes River (D1, D2)
  - N days (water year/springtime) with sufficient discharge to inundate floodplain (F1, F2)

R^2	P1	P2	D1	D2	F1	F2
1	.15	.50	.54	.53	.34	.27
2	.32	.64	.57	.59	.59	.57
3	.01	.19	.27	.25	.06	.02
4	.31	.58	.72	.69	.37	.26
5	.70	.80	.68	.71	.89	.92
All	.25	.62	.70	.68	.42	.33



Conclusions - Phenology

- *Lepidium* exhibits substantial spatial and interannual variation in phenology.
- 33-56% of the spatial variation is explained by environmental variables.
  - Unexplained variation? Missing variables (e.g., soils data)? Genetic?
- Interannual variation is strongly related to weather/hydrology but also to specific site conditions.

Phenology Relevance

- Practical:
  - Phenology influences detection. Both field and image surveys most successfully detect flowering *Lepidium*.
  - Effectiveness of control varies with phenology.
  - These results can inform management scheduling.
- Ecological:
  - Variation in phenology (either plastic or genetic) may contribute to invasion success and habitat breadth.
  - Summer-active phenology of *Lepidium* may contribute to invasiveness in Mediterranean climates.

Conclusions

- Remote sensing provides accurate, rapidly repeatable maps of *Lepidium*.
- Uses of remotely sensed *Lepidium* maps:
  - Inform management
  - Drive predictive distribution modeling
  - Monitor spread – estimate population parameters and their spatial & temporal variability
  - Detect and explain phenological variation
  - Etc.

Acknowledgements

- Calfed Science Fellows Program
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