

Long-term restoration of riparian understory species over large spatial scales

**Karen D. Holl, Jessica E. Hammond, Charles D. McClain,
Prairie L. Moore, and David M. Wood**
UC Santa Cruz and CSU Chico



Is forest recovery more strongly affected by processes at local or landscape scales?

- Scale at which ecosystem processes are regulated?
- Is it more important where we restore or how we restore?
- How do these processes change as succession proceeds?

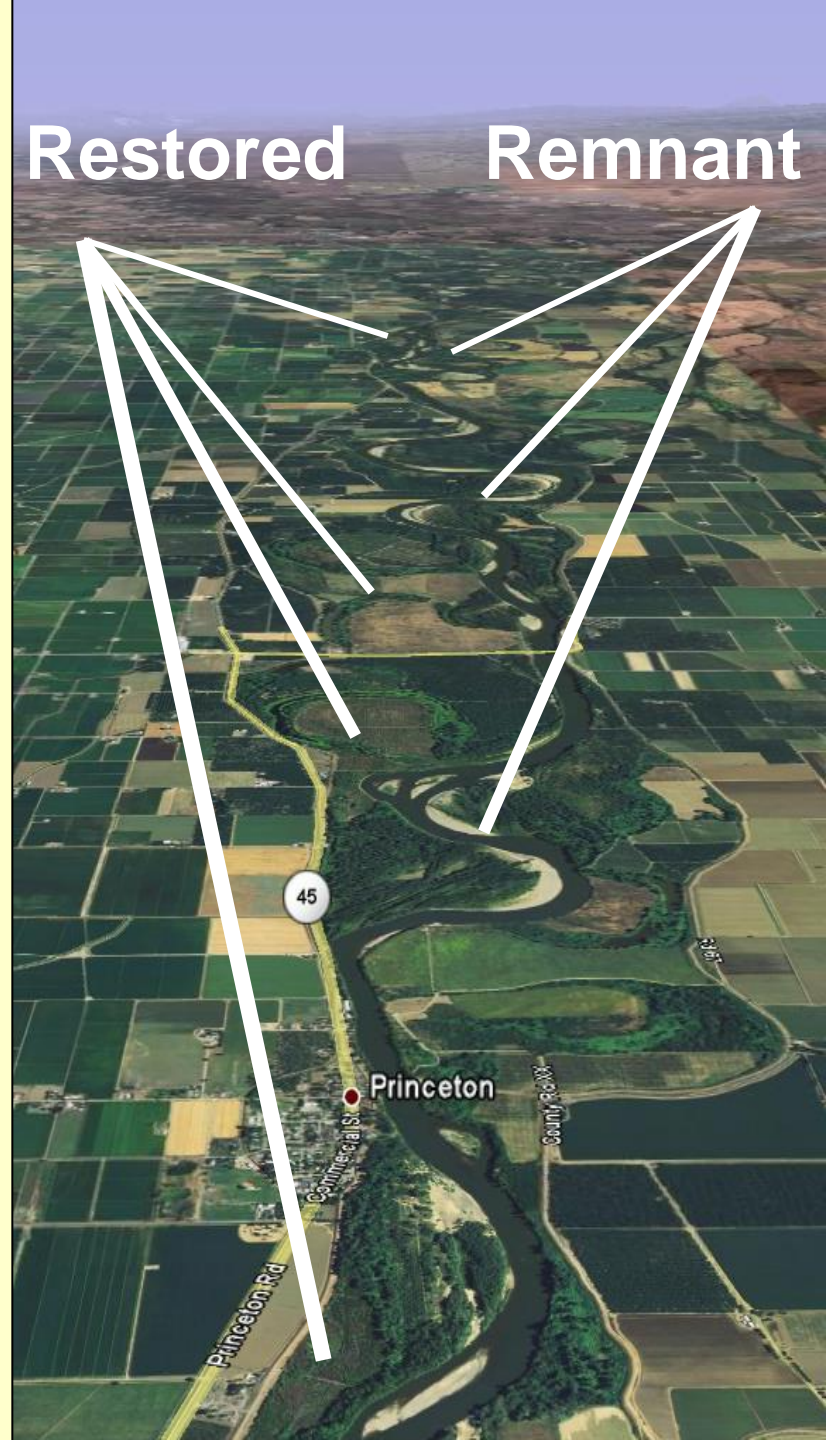


SACRAMENTO RIVER

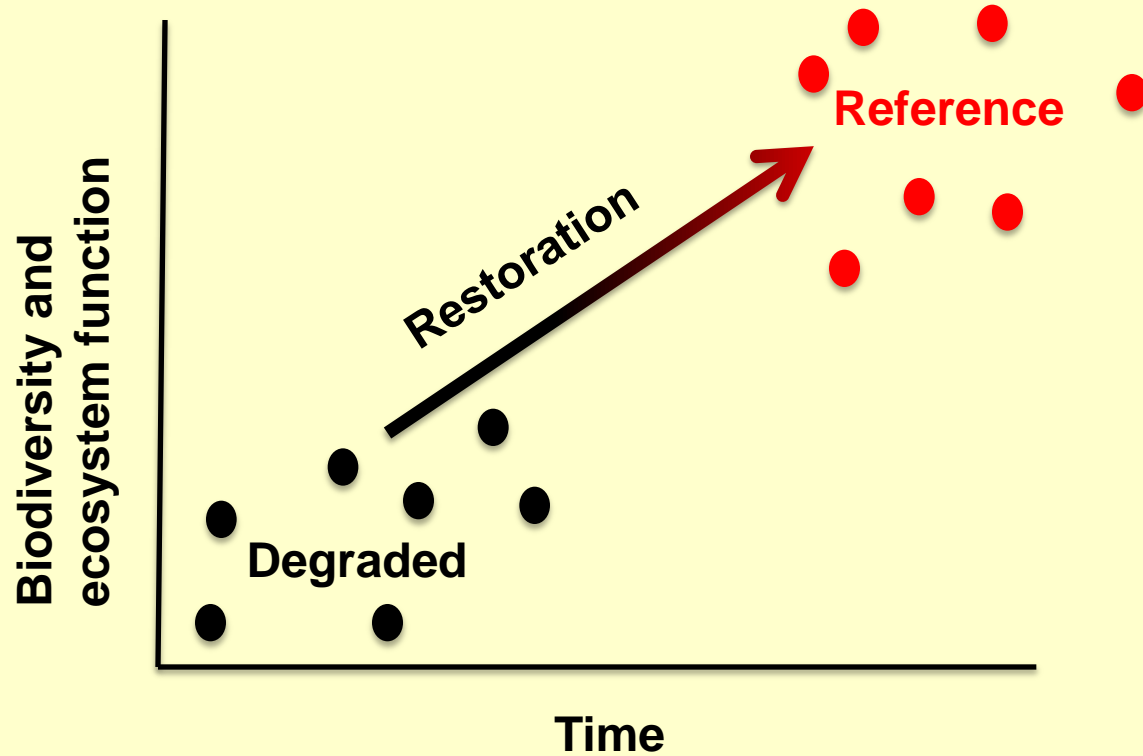
Large-scale of restoration allows asking these questions in a real world setting

Opportunity to do replicated manipulative experiments to inform both basic ecological questions and restoration efforts

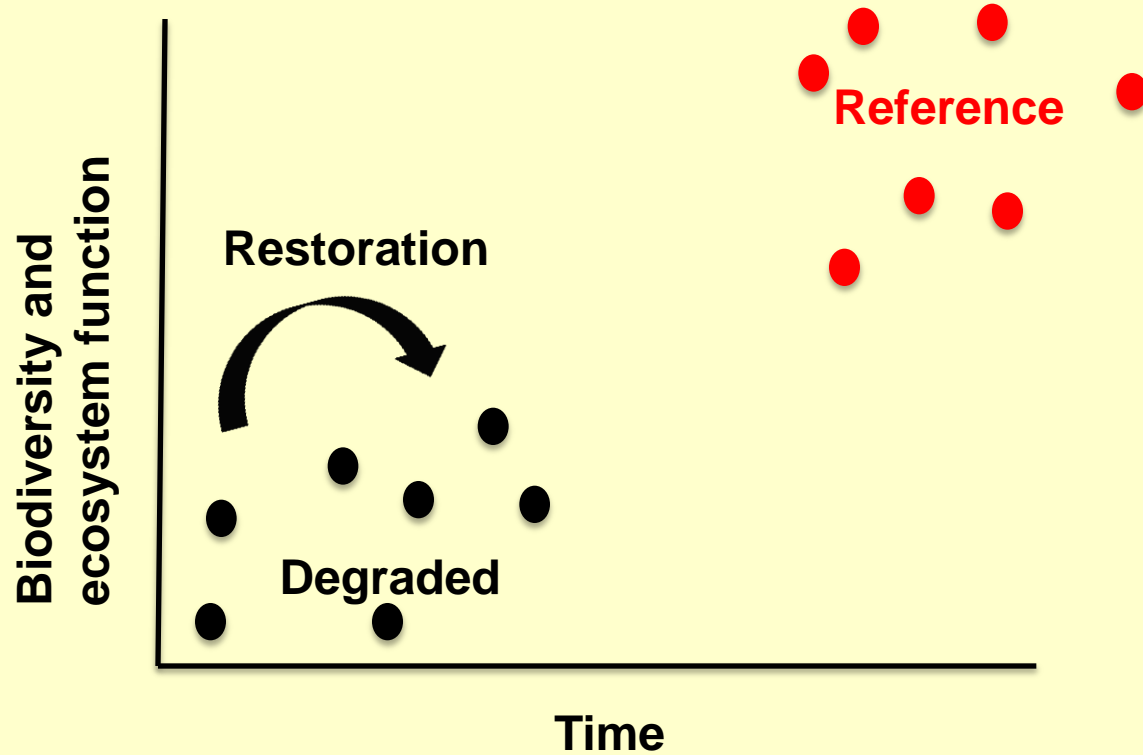
Restoration efforts over 25 yr



Successional Models

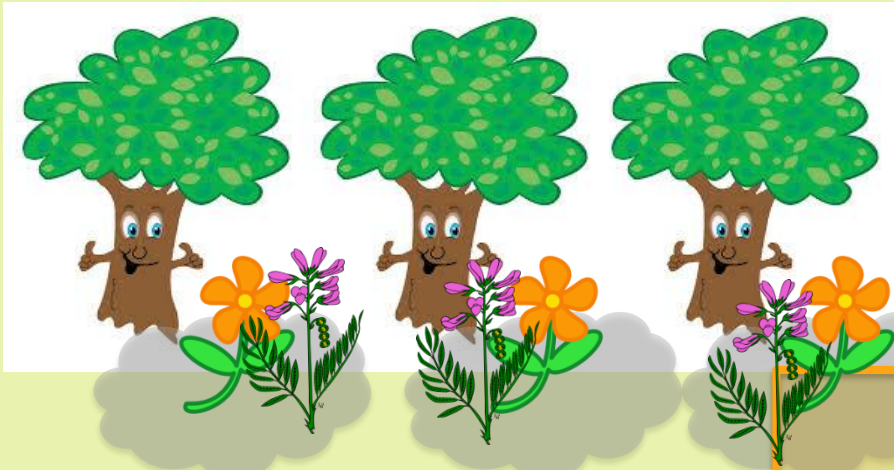


Successional Models



Successional Models

Relay Floristics



Initial Floristics



Advancements in Restoration

1. Woody species only (1989-1996)
2. Understory seedling (1997-2002)
3. Direct seeding of understory (2003-present)



Aristolochia californica



Carex barbarae



Vitis californica



Common understory species



Artemisia douglasiana



Euthamia occidentalis



Rubus ursinus



Clematis ligusticifolia

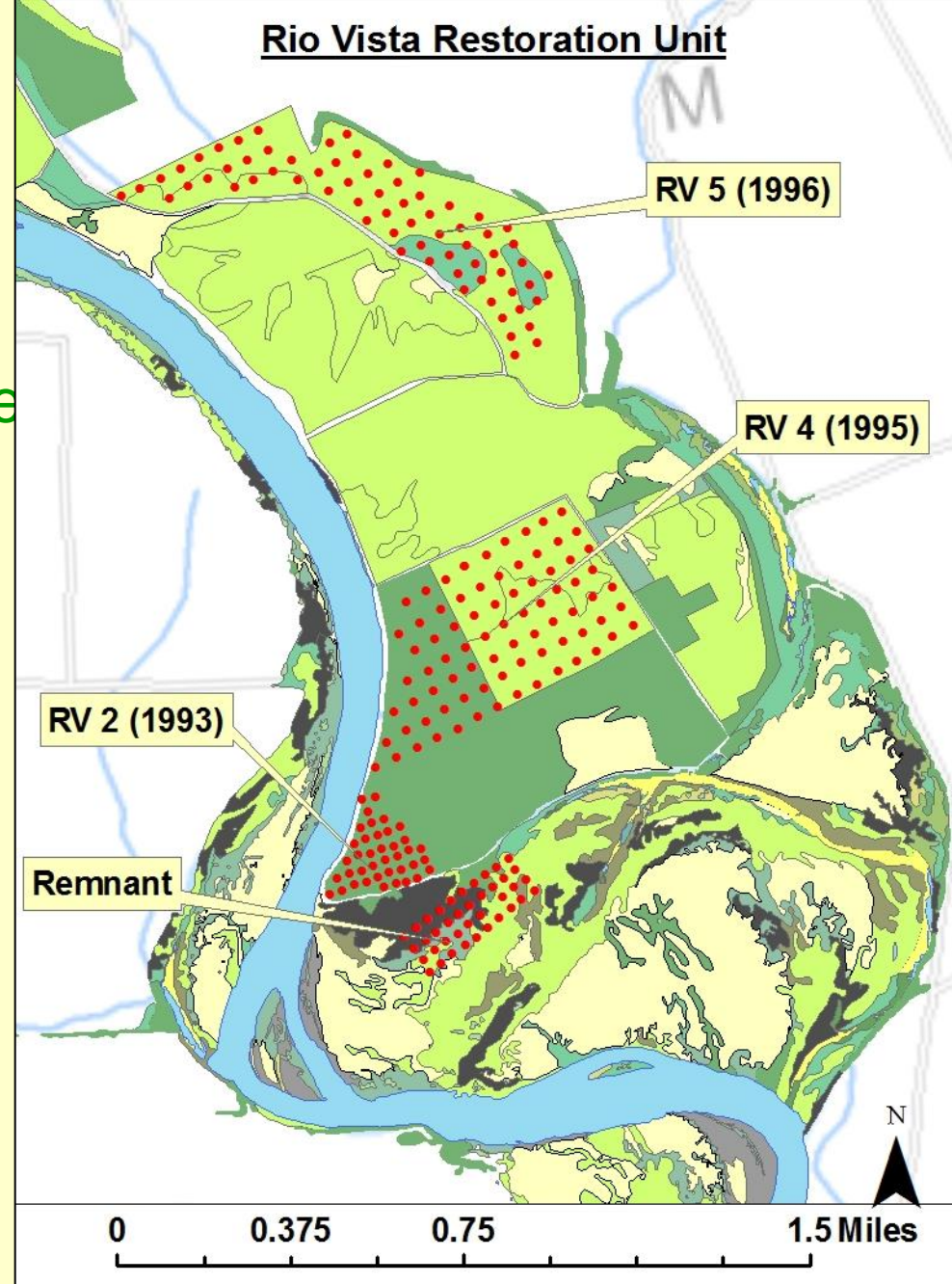
Questions

1. Is vegetation species composition in restored sites meeting restoration targets and becoming more similar to reference forest over time?
2. Is cover of native understory species increasing over time? What factors at the landscape and local scale enhance native cover?
3. Does restoring forests with seeded or planted understory succeed in restoring higher and more diverse native cover?

Methods - Survey

Sampled understory vegetation and overstory cover in:

- 15 sites restored 1989-96 in both 2001 and 2007, 20 more sites in 2007
- 10 remnant forests
- 1×1 m quadrats
- 20-80 per site
- 40-80 m apart

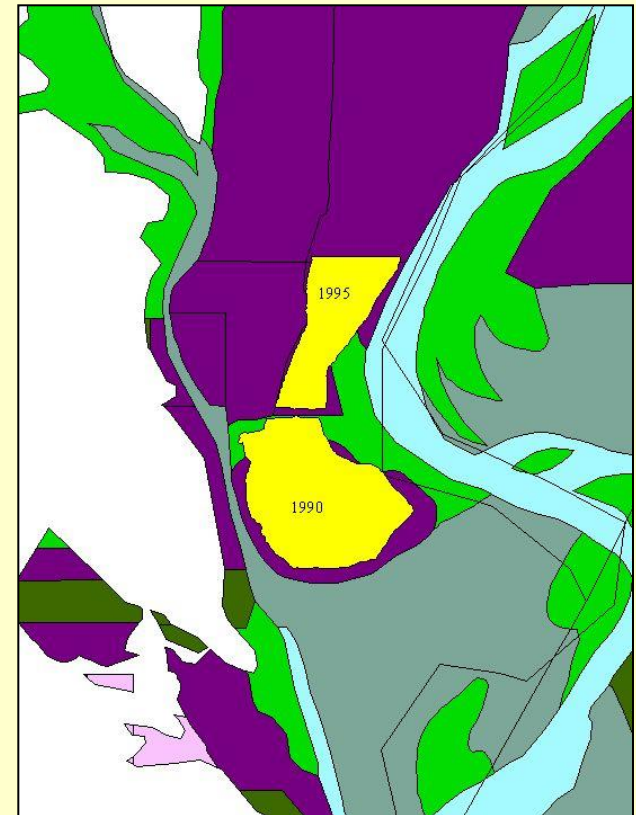


SPATIAL ANALYSES

Local variables – soil texture, overstory cover, other species

Site variables – past land use, time since planting, patch size

Landscape variables –
distance to river,
elevation on the floodplain,
distance to remnant forest,
amount of remnant forest surrounding
at 100, 500, 1000 m



RESULTS – Comparison of sites surveyed in 2001 & 2007

- Overstory cover increases over time

	2001	2007	Reference	F	<i>p</i>
Overstory cover	29.2 ± 4.4 ^a	59.6 ± 5.7 ^b	78.8 ± 2.5 ^c	25.5	<0.0001
Relative native cover	20.7 ± 4.0 ^a	32.3 ± 6.4 ^a	65.2 ± 5.5 ^b	15.3	<0.0001
Rel. nat. cover (no <i>Galium</i>)	14.7 ± 3.3 ^a	17.0 ± 4.0 ^a	45.4 ± 6.2 ^b	11.9	<0.0001
Native richness per site	4.7 ± 0.5 ^a	6.5 ± 0.5 ^b	10.1 ± 0.6 ^c	26.6	<0.0001
Relative exotic cover	78.6 ± 4.4 ^a	66.7 ± 6.5 ^a	34.2 ± 5.4 ^b	15.0	<0.0001
<i>Rubus discolor</i>	0.9 ± 0.5 ^a	8.1 ± 2.4 ^b	6.9 ± 2.0 ^b	8.4	0.0011

McClain et al. 2011 *Restoration Ecology* 19:280-289.

RESULTS – Comparison of sites surveyed in 2001 & 2007

- Natives colonize slowly

- native species richness increased over time, but native frequency and cover did not
- dominated by *Galium aparine*

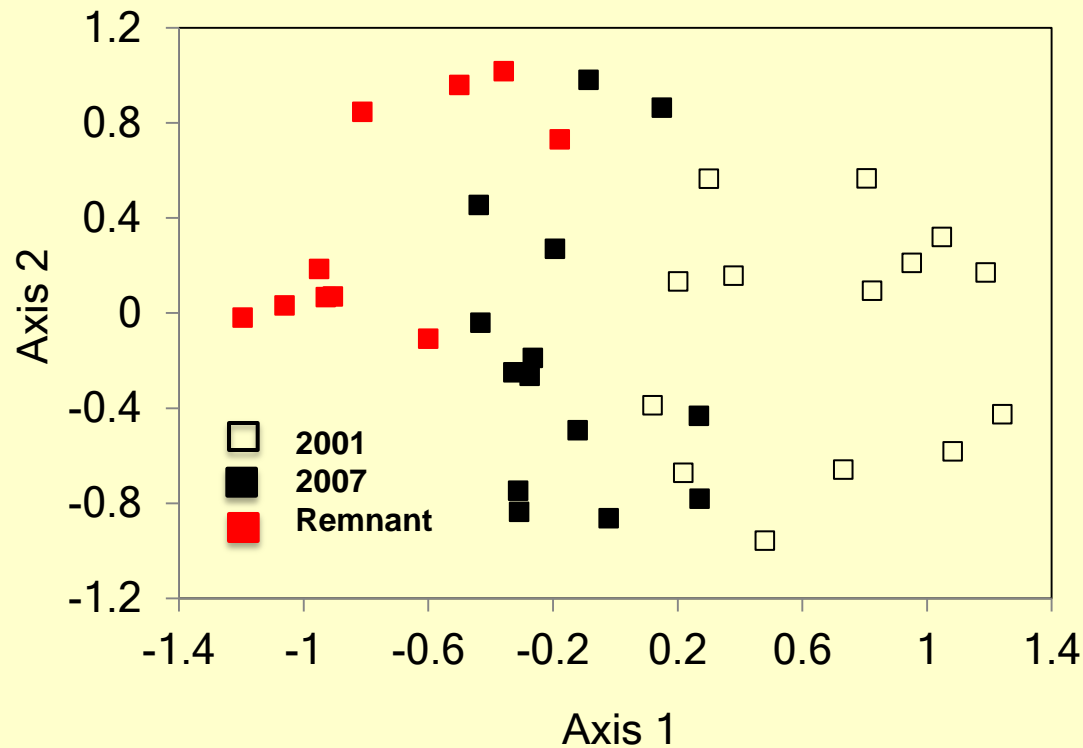
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RESULTS – Comparison of sites surveyed in 2001 & 2007

- Exotic cover decreases slightly and shifts from light demanding to shade tolerant exotics

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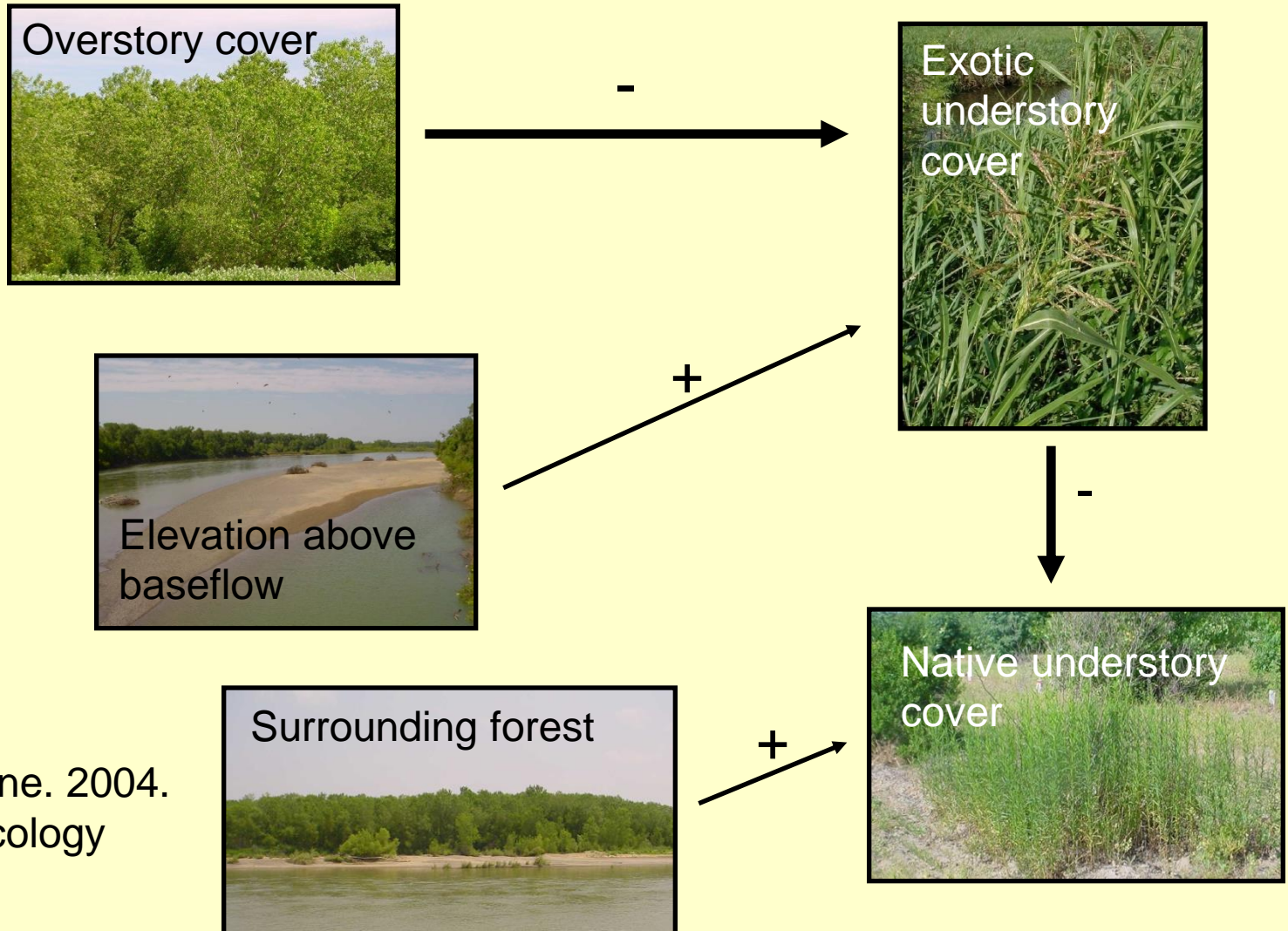
Successional Models



Species composition in restore sites is approaching that of forest



PAST RESULTS – Factors affecting native establishment



Holl and Crone. 2004.
J. Applied Ecology
41:922-933.

SPATIAL RESULTS – 2007 survey

Variable	Significant factors (r ²)	Comments
Exotic cover	(–) overstory cover (0.51) (*) past land use (0.25)	> in former orchards
Native cover	(–) exotic cover (0.32) (–) distance to river (0.17)	
<i>Galium aparine</i>	(–) exotic cover (0.30)	59% of native cover
Wind-dispersed	(+) %forest 1000 m (0.29)	primarily <i>Art doug</i>
Gravity-dispersed	(+) site age (0.35) (–) distance to river (0.15)	
Animal-dispersed	(*) past land use (0.48)	> in fallow lands

MANIPULATIVE STUDY – EXPERIMENTAL DESIGN

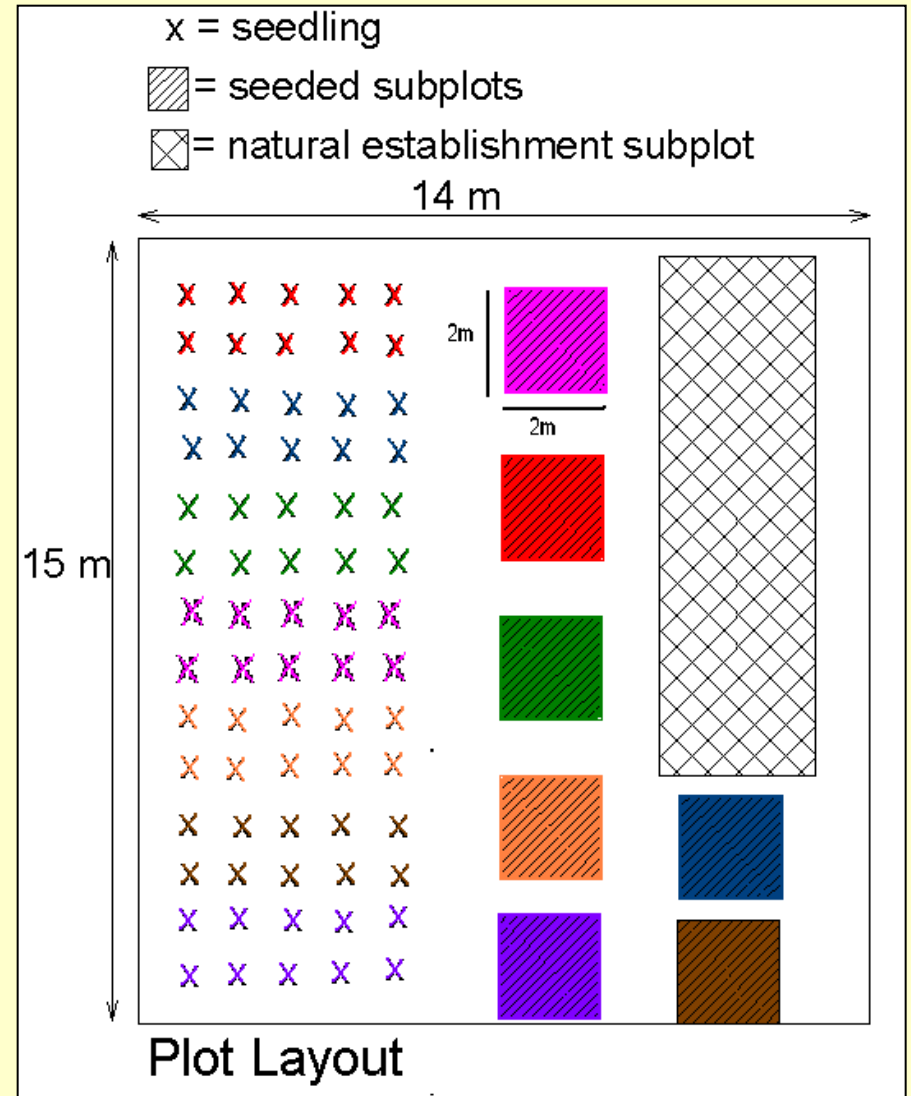
- 6 sites – 3 restored recently and 3 restored >7 yr.
Factorial design – overstory cover removal, grass cover control, near (<50 m) and far (>250 m) from forest edge



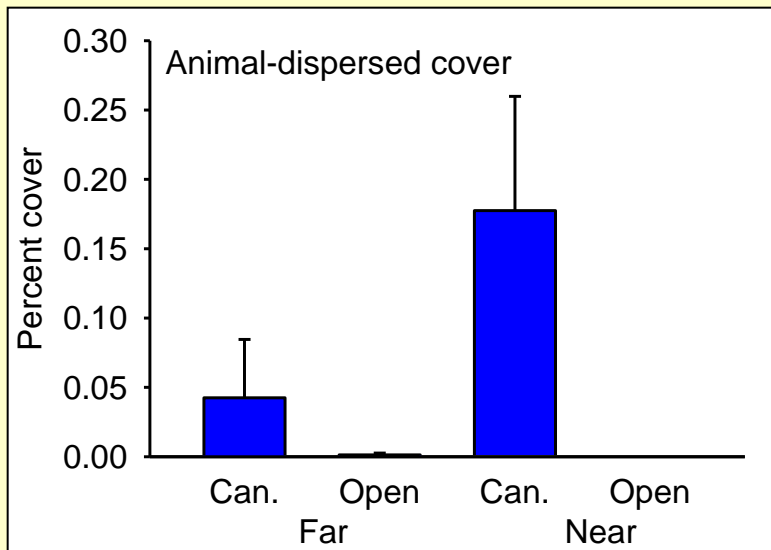
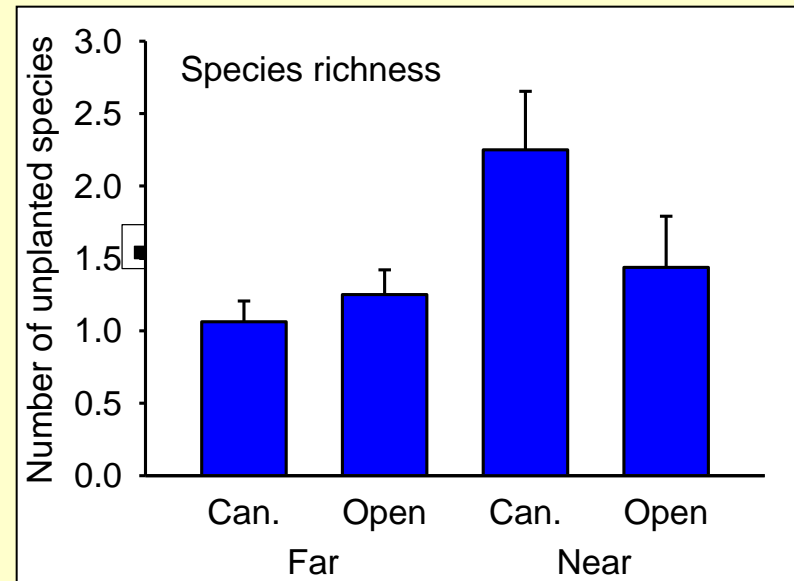
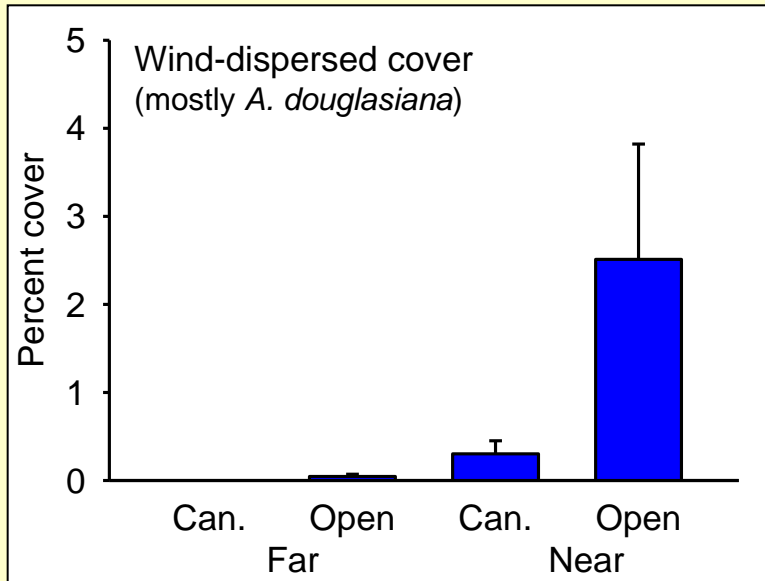
Moore et al. 2011. SF Estuary and Watershed Science 9.

MANIPULATIVE STUDY – EXPERIMENTAL DESIGN

- Planted and seeded 7 native understory herb and shrub species in Dec. 2005.
- Monitored survival and cover in May and Sept. 2006-2008
- Monitored natural recruitment for 3 yr.



NAT. RECRUITMENT – DISTANCE & CANOPY EFFECTS



Both distance
and overstory
cover effects

CONCLUSIONS

- Both local and landscape factors affect recovery. In this system local factors more important, but varies by dispersal guilds and physiological tolerance of species.
- To restore understory need to plant species, particularly when farther from seed sources.
- Need longer term data about successional trajectories.



FUTURE WORK

- Spring 2014 - repeat understory survey
 - 15 sites restored before 1996 (third survey)
 - 15 sites restored 1996-2003 (second survey)
 - 15 sites restored more recently (understory planted and seeded)
 - Remnant sites - not static



QUESTIONS

- Is there a lag time in native understory cover establishment?
- Does the importance of proximity to forest increase during succession?
- Do recent forest restoration efforts create communities more similar to the surrounding forests?



Acknowledgements

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