Restoration of Riversidean Sage Scrub

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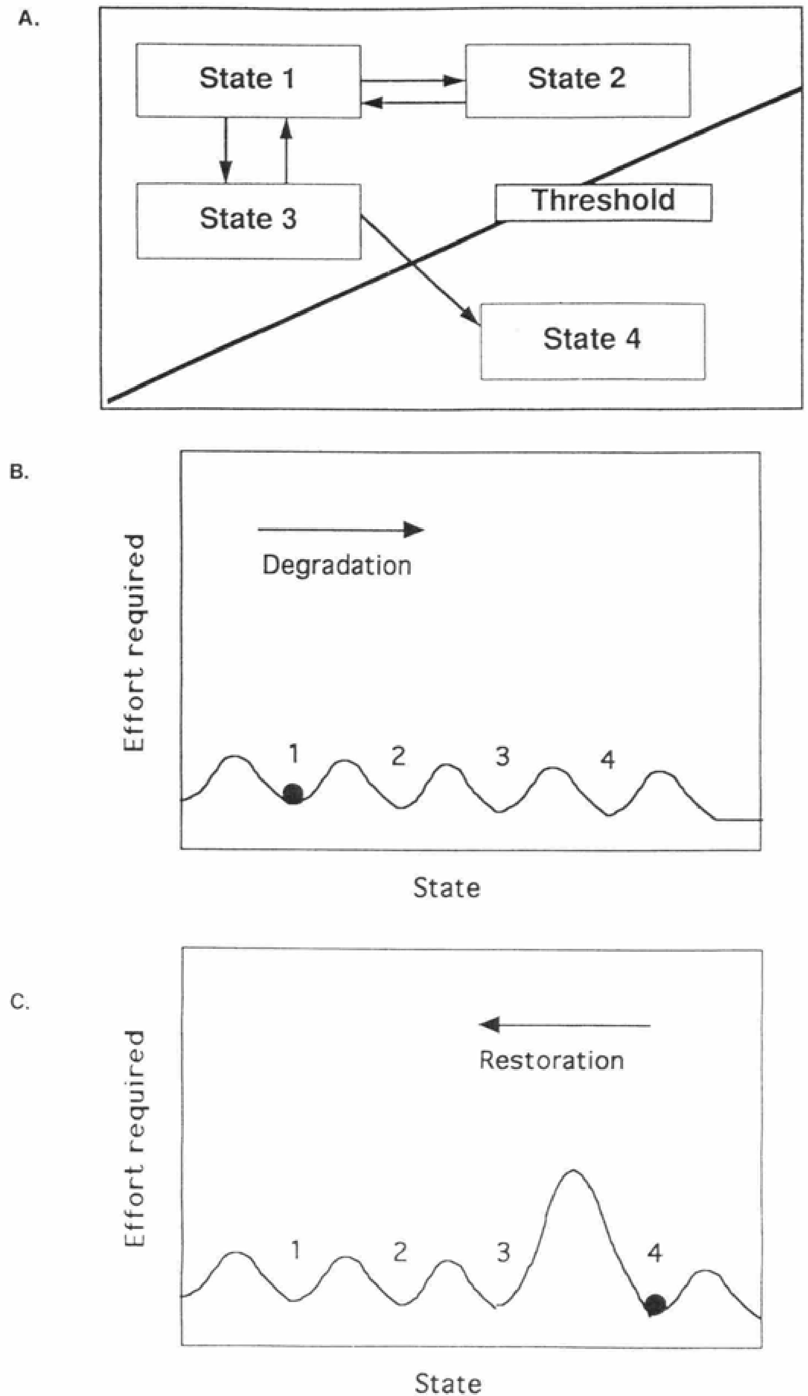
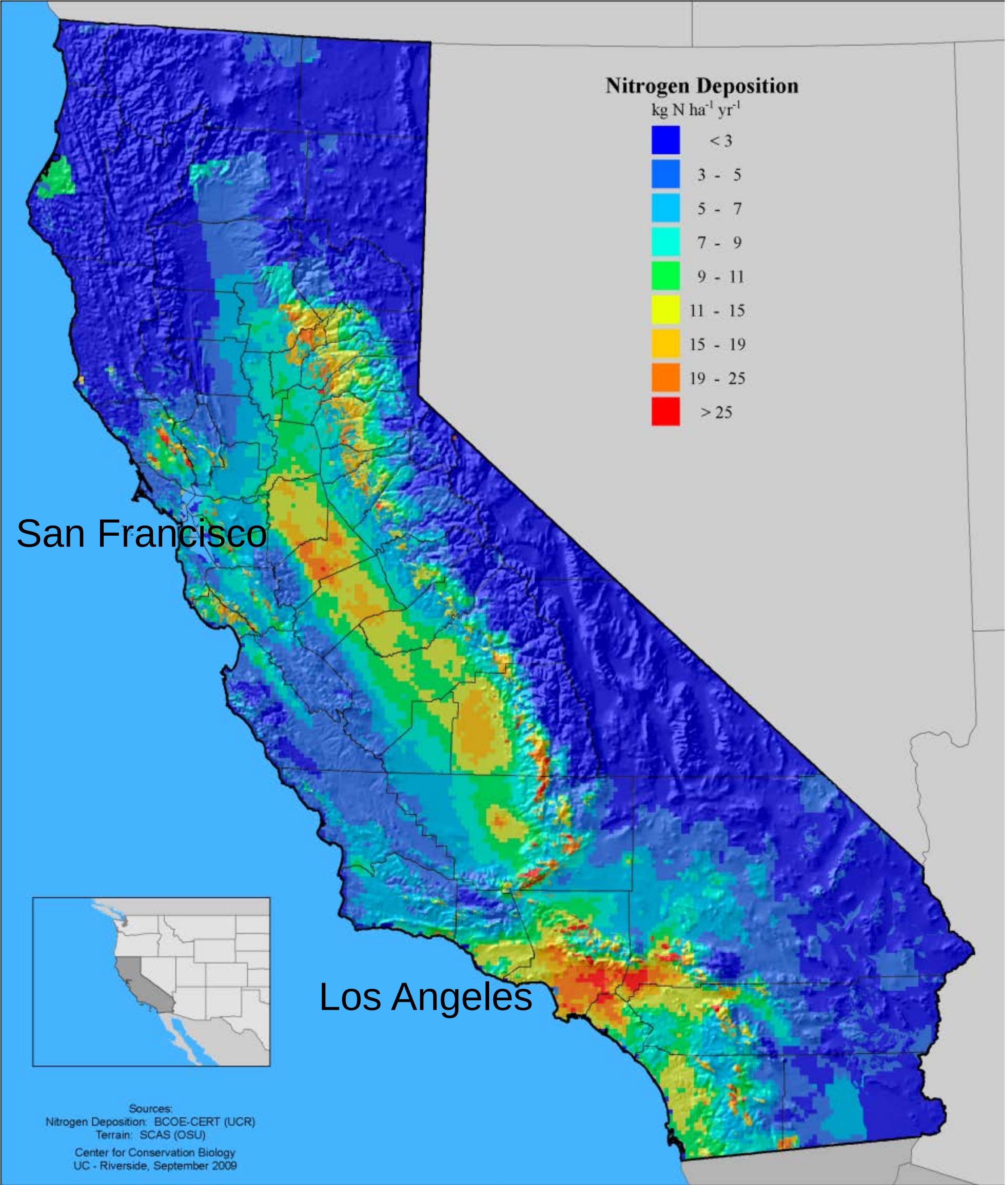
Objectives

- Assess potential for long-term restoration success of Riversidean sage scrub (or inland SS) invaded by exotic annual grasses and forbs, under anthropogenic nitrogen deposition, and subject to frequent fire
- Approaches include reducing N inputs below critical loads (assessing critical loads of N), mulch for N immobilization, grazing, dethatching, mowing, herbicide, solarization, fire, and seeding with native species.
- Inability to control exotic species reinvasion, restore diversity of native forbs results in novel ecosystems

Alternate stable states of ecosystems
(Hobbs & Norton 1996)
require restoration.

When natural successional processes and restoration success are limited, results in novel ecosystems (Hobbs et al. 2009)





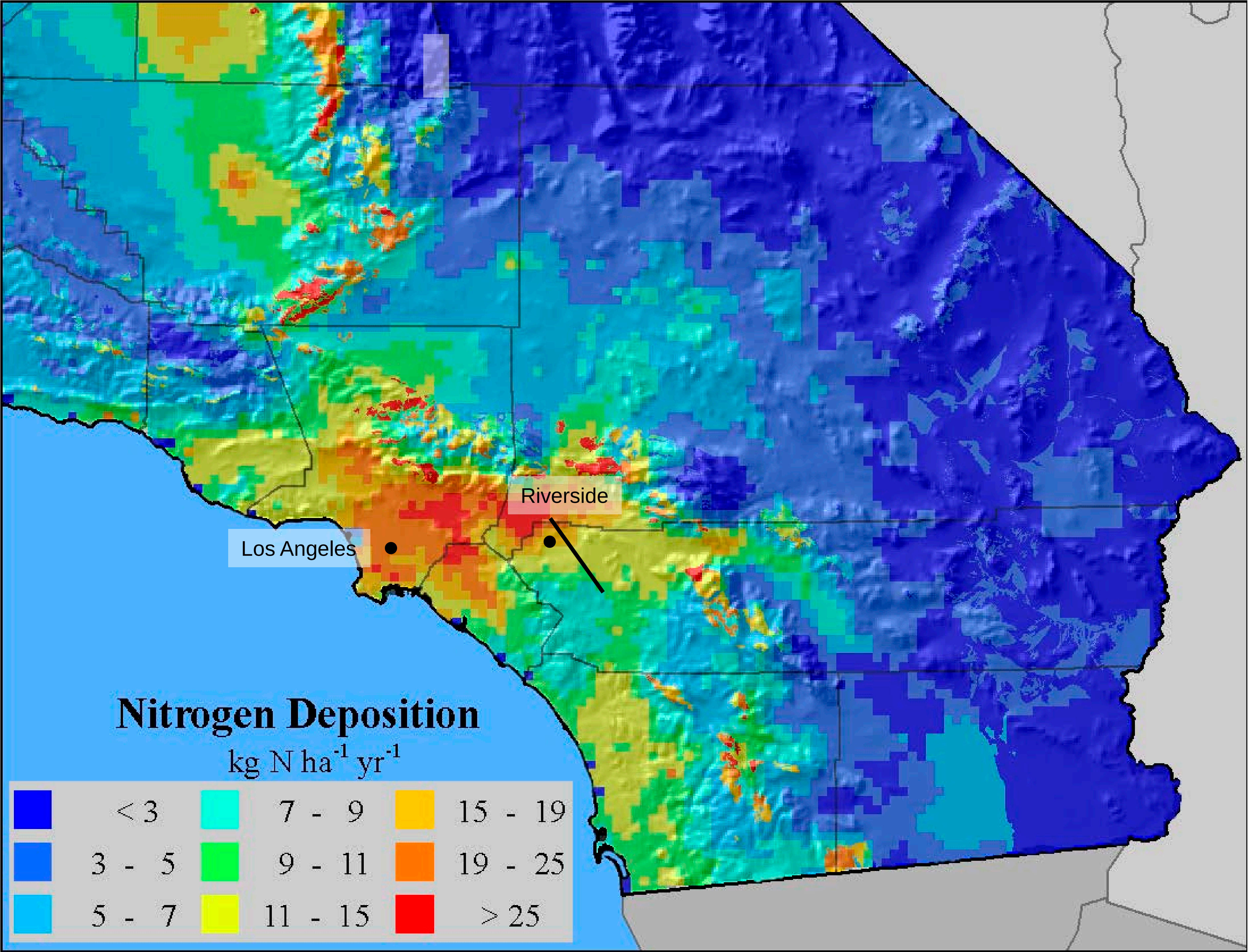
N deposition in California

Community Multiscale Air Quality (CMAQ) Model Output (Tonnesen et al. 2007)

Nitrogen deposition is up to 30 kg N ha^{-1}yr^{-1} in the Los Angeles air basin.

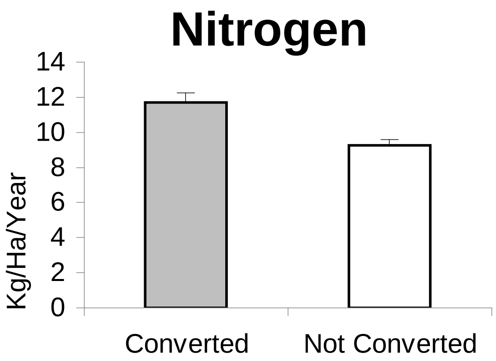
Most is dry deposition that falls during the dry summer.

View from Riverside west to Los Angeles


Riverside
Los Angeles
Nitrogen Deposition
kg N ha-1 yr-1
< 3
3 - 5
5 - 7
7 - 9
9 - 11
11 - 15
15 - 19
19 - 25
> 25

Nitrogen Critical Load

- A critical load for nitrogen is that amount of N deposition above which there are negative impacts on an ecosystem
- Impacts may be measured as changes in
  - organisms (e.g., loss of native species, increase in invasive species)
  - soils (e.g., decreased pH, elevated N),
  - biogeocycling rates (e.g., increased N in run-off, mineralization, frequent fire).

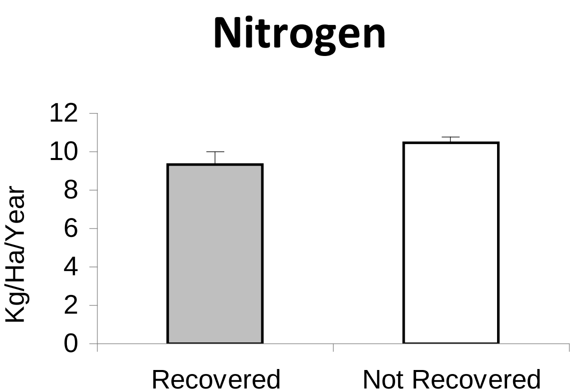


35% of RSS converted to exotic grassland

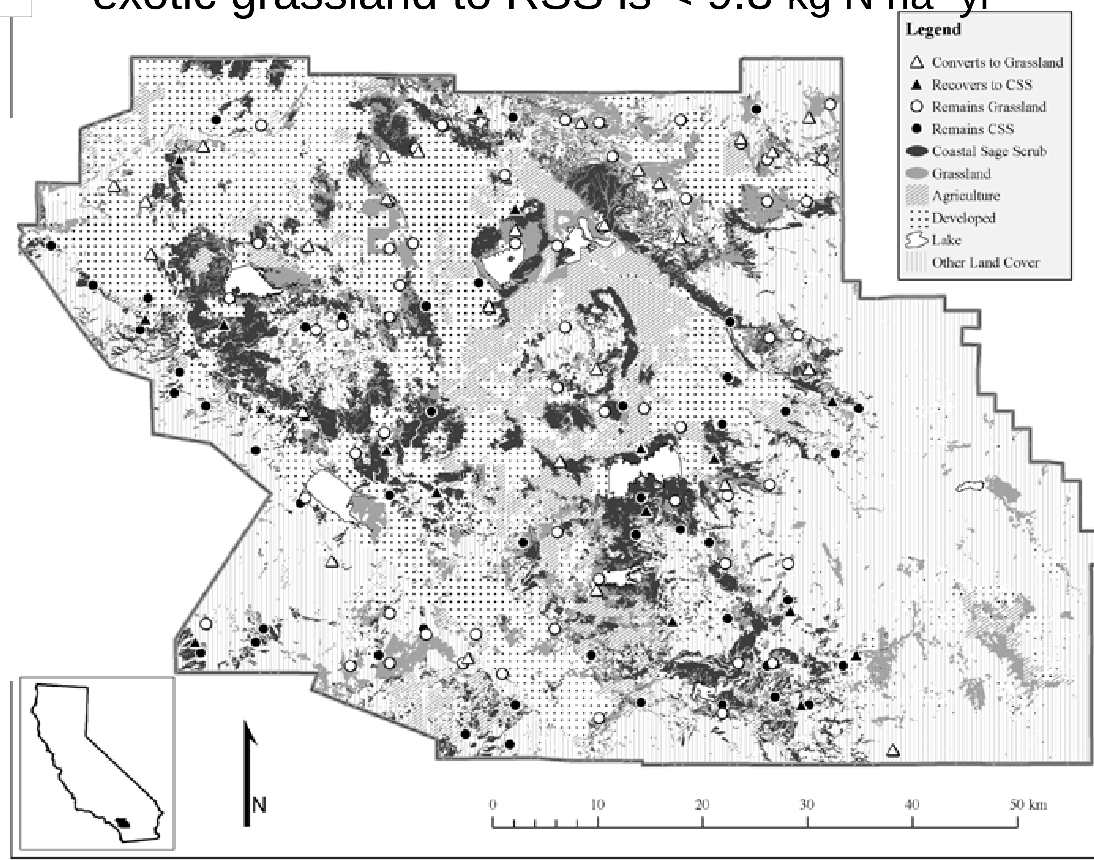
Comparison of 1930 VTM with 2009 Google Earth vegetation of western Riverside County (most recent fire 2003 to allow recovery):

Critical load of N deposition for conversion of RSS to exotic grassland is > 9.3 kg N $ha^{-1}yr^{-1}$

Critical load of N deposition for recovery of exotic grassland to RSS is < 9.3 kg N $ha^{-1}yr^{-1}$



23% of exotic grassland recovered to RSS



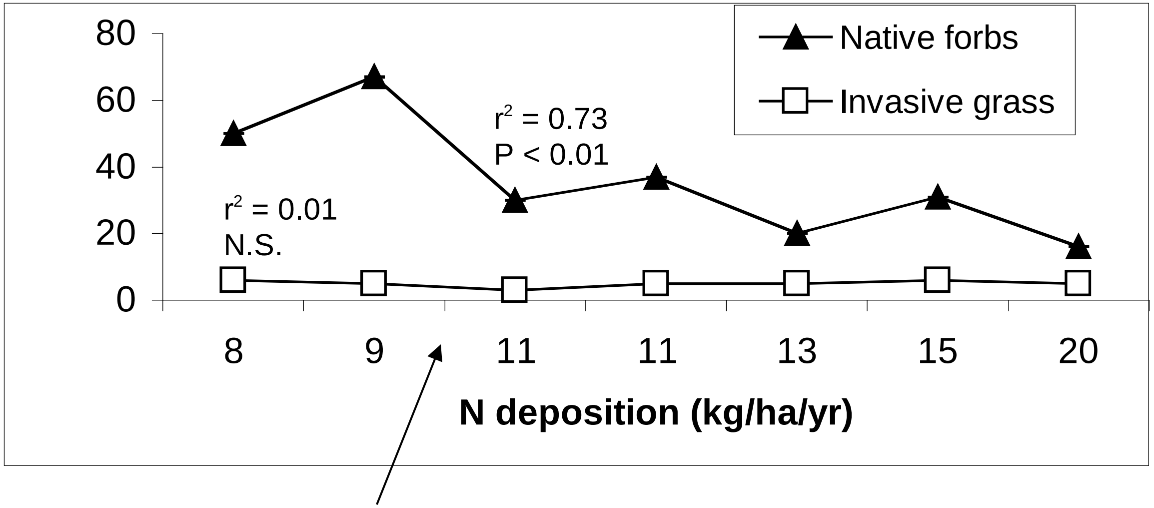
Diversity assessment on a N deposition gradient in coastal sage scrub (CSS):

High N deposition (20 kg N $ha^{-1}yr^{-1}$) dominated by exotic annual grasses from Mediterranean (*Bromus* spp., *Avena* spp., *Hordeum* spp.)

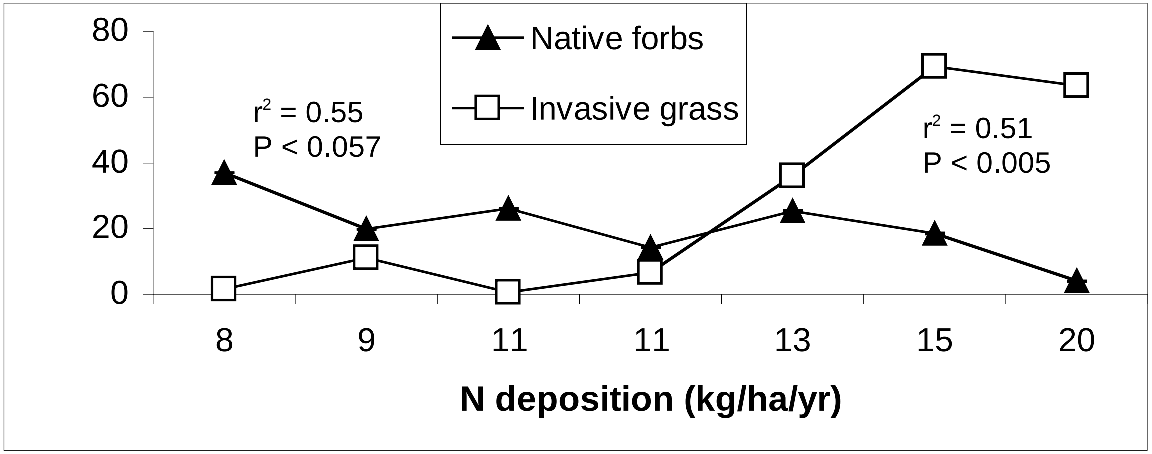
Low N deposition (8.7 kg N $ha^{-1}yr^{-1}$) dominated by native forbs and shrubs

Critical Load of N in RSS based on loss of native forb richness is between 9 and 11 kg N/ha/yr

Richness



Cover

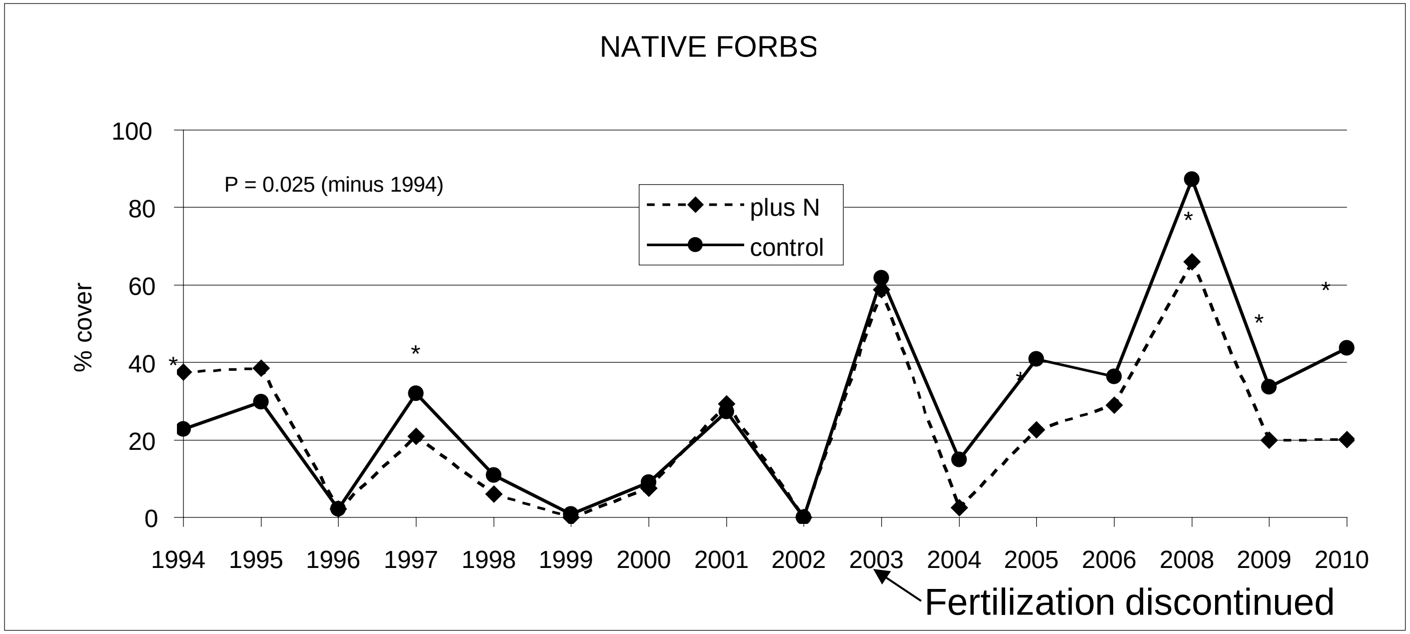


Seedbank of exotic grassland, native coastal sage scrub with grass understory, and from adjacent burned and unburned sites in RSS (Cox and Allen 2008).

	Average Seedlings per m^2			
Species	**Grassland**	**Shrubland**	**Unburned**	**Burned**
Exotic Grasses	7261	3932	7339	147
Exotic Forbs	4714	1126	1440	969
Native Forbs	407	800	211	121
Native shrubs	14	0.5	6.3	0

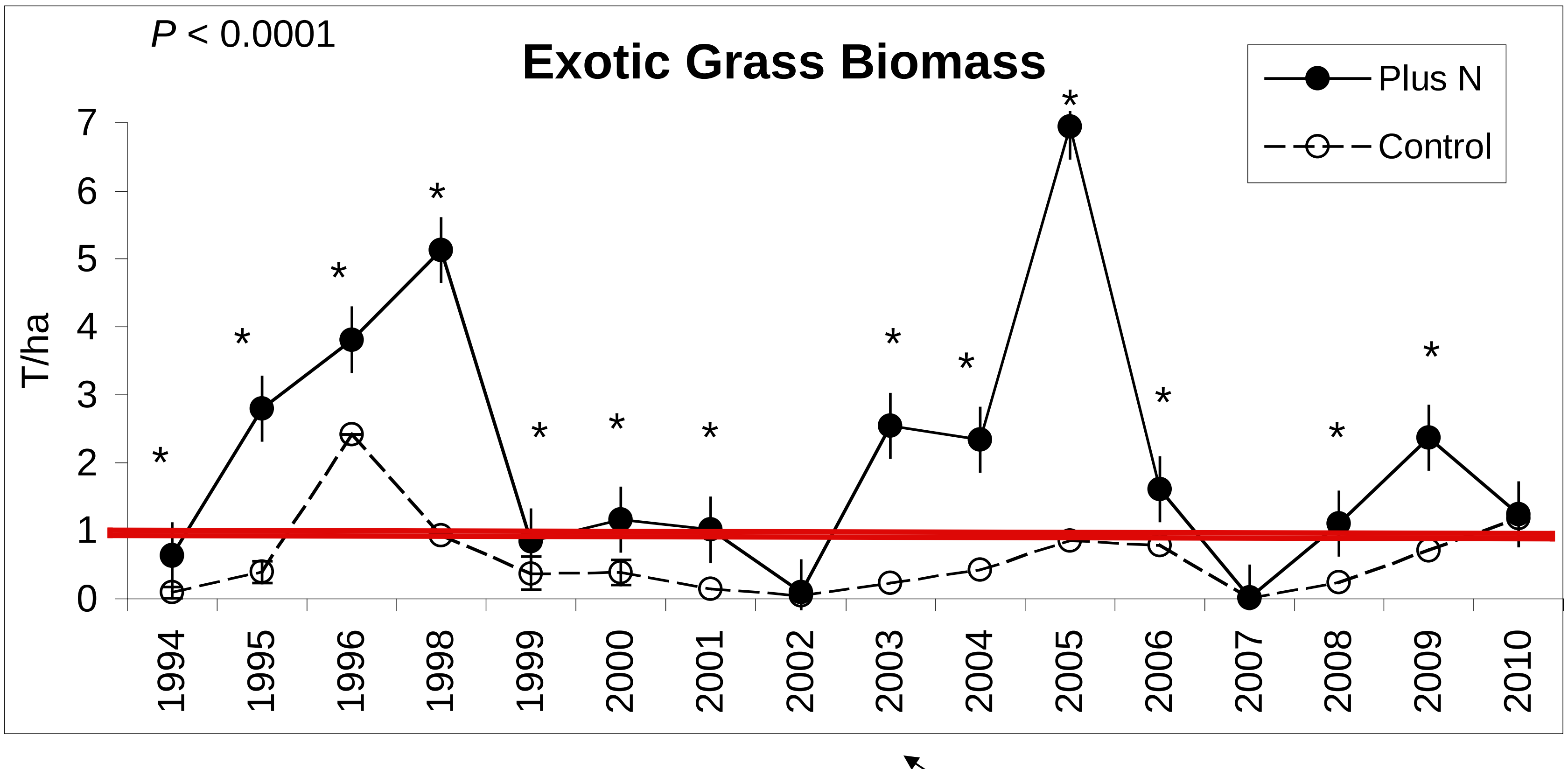
RSS vegetation was fertilized 1994-2000 with 60 kg N $ha^{-1}yr^{-1}$ as NH_4NO_3 following the 1993 wildfire in an area of low N deposition

% cover of native forbs (69 spp.) for 16 seasons following the 1993 fire, plus N fertilization and control



P is repeated measures probability,
* is *P* < 0.05 by year.

Biomass of exotic grass in control and plus-N treatment. The threshold for fire is 1.0 T/ha of fine grass fuel (red line). Grass biomass is below threshold in control plots in most years.



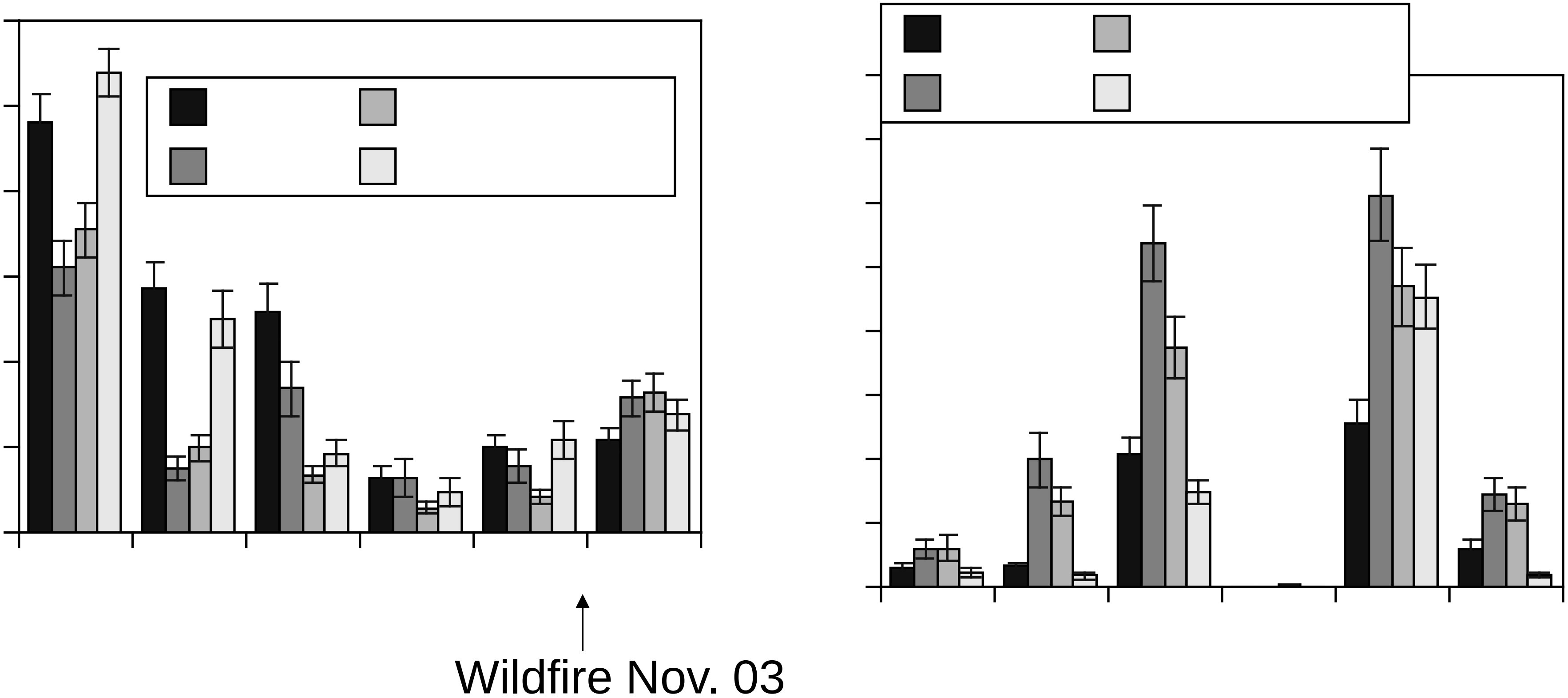
Fertilization discontinued

Restoration of coastal sage scrub in former grazing land at Lopez Canyon, Shipley Reserve, with exotic annual grass invasion (*Bromus* spp.).

Sheep grazing to control exotic grass

200/ha, 2 days, Mar/Apr 1999, 2000, 2001

Fusilade application, dethatching treatment to remove standing litter



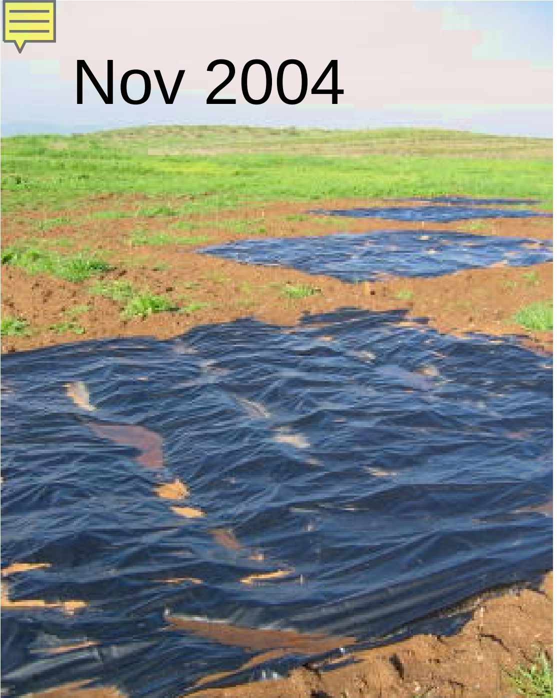
Exotic grass and exotic forb cover after two years of Fusilade application (1999, 2000) and 3 years of sheep grazing (1999, 2000, 2001).

Native forb response to herbicide still significant after four years, but cover lower than exotic grass

(Allen et al. 2005)

Solarization, herbicide, mowing in abandoned agricultural land

Seeded with native forbs and shrubs Jan. 05

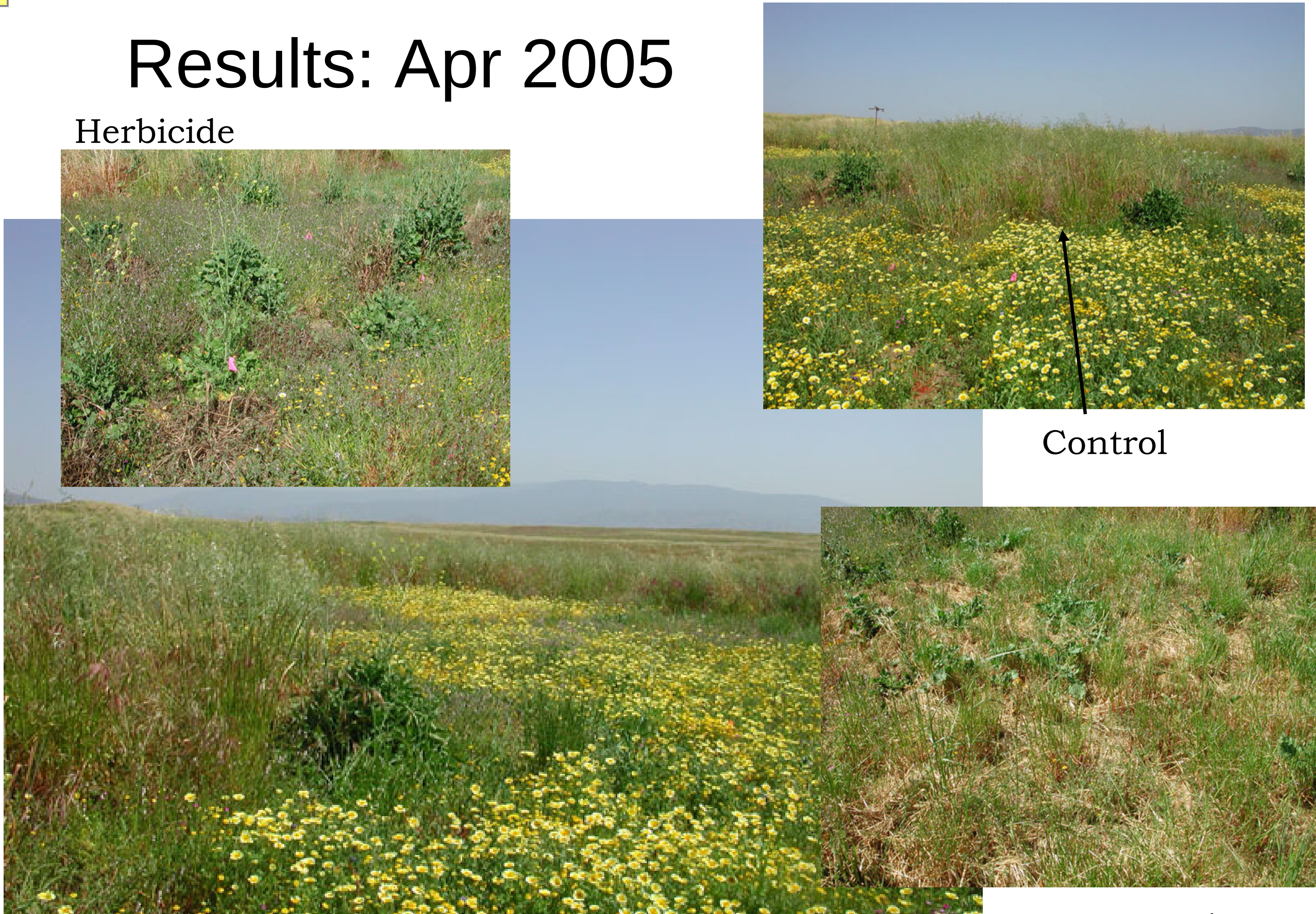


Mowed Feb, Mar

Fusilade Feb. 05

Herbicide
Damage
Mar. 05

Results: Apr 2005



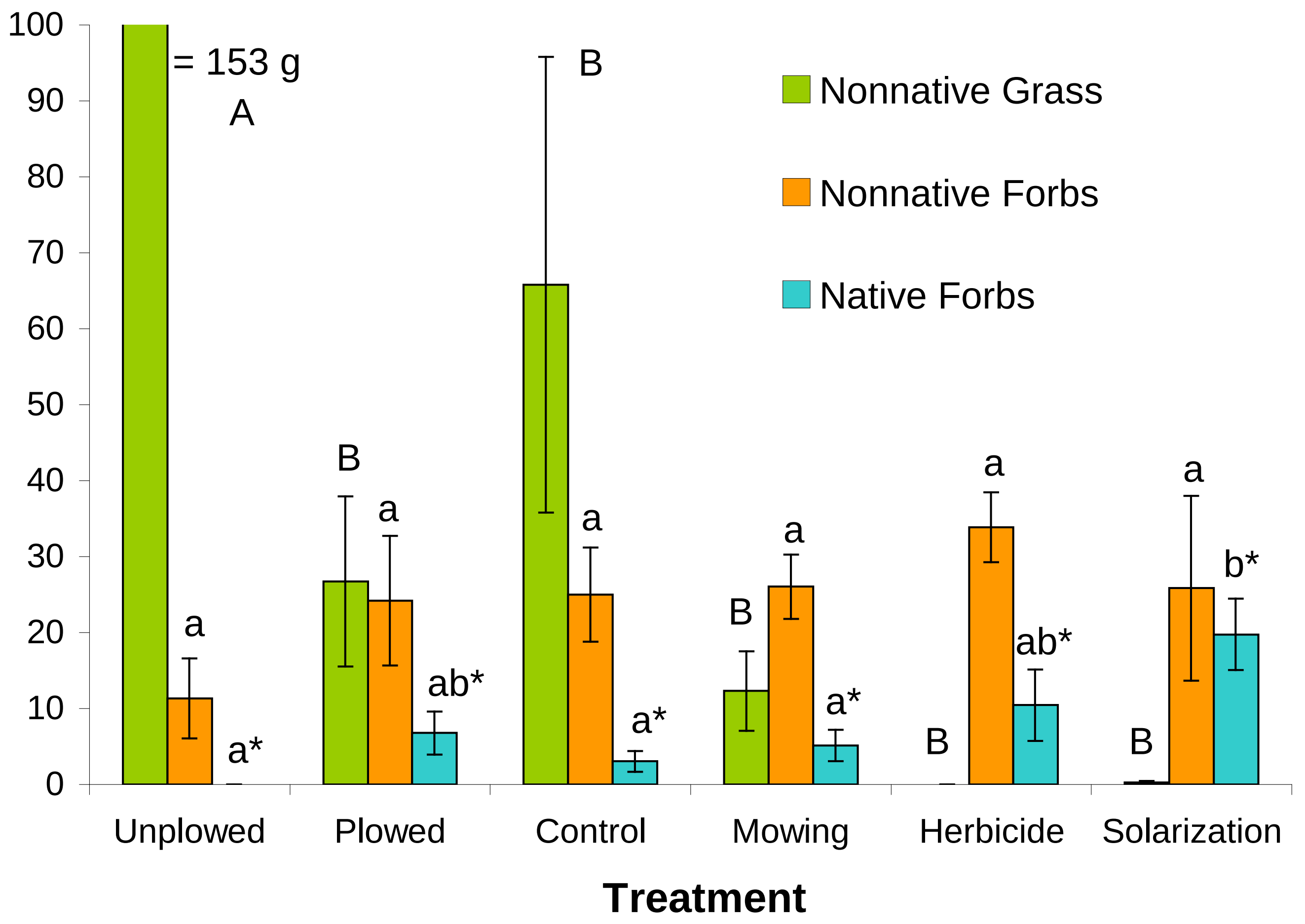
Herbicide

Control

Solarized

Mowed

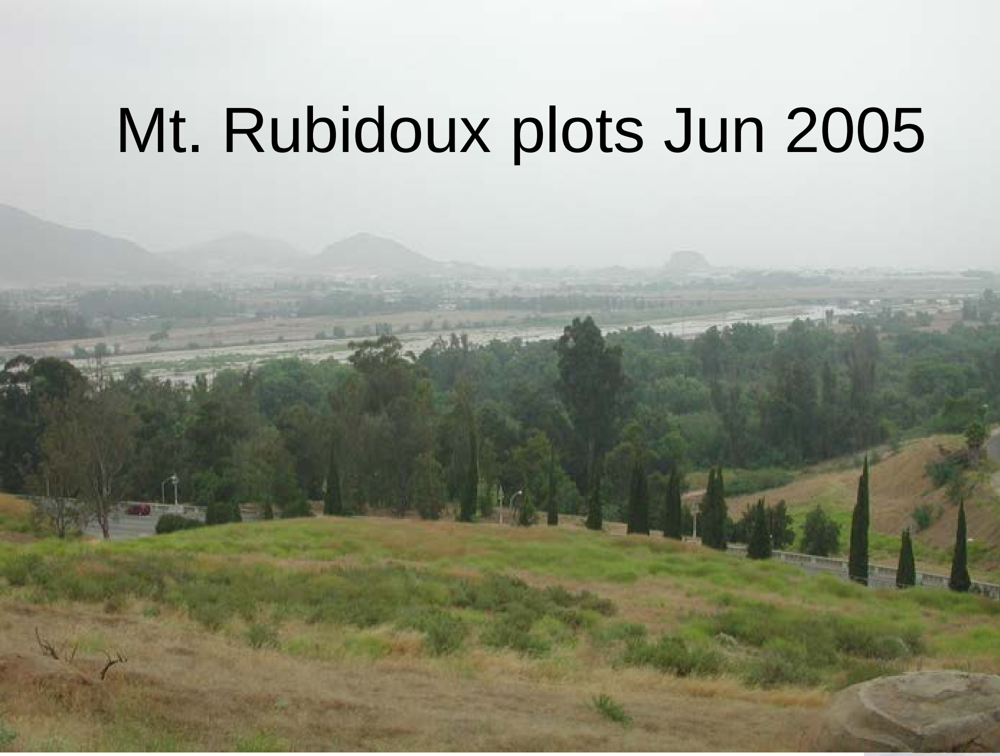
Results (Marushia & Allen 2010)



Solarization is most successful for establishing seeded native forbs

RSS Restoration at Mt. Rubidoux, 5/1998 following fire that burned exotic grass but not shrubs. Successful treatments to establish shrubs were Fusilade and hand cultivation to remove exotic grass. (Cione et al. 2002)

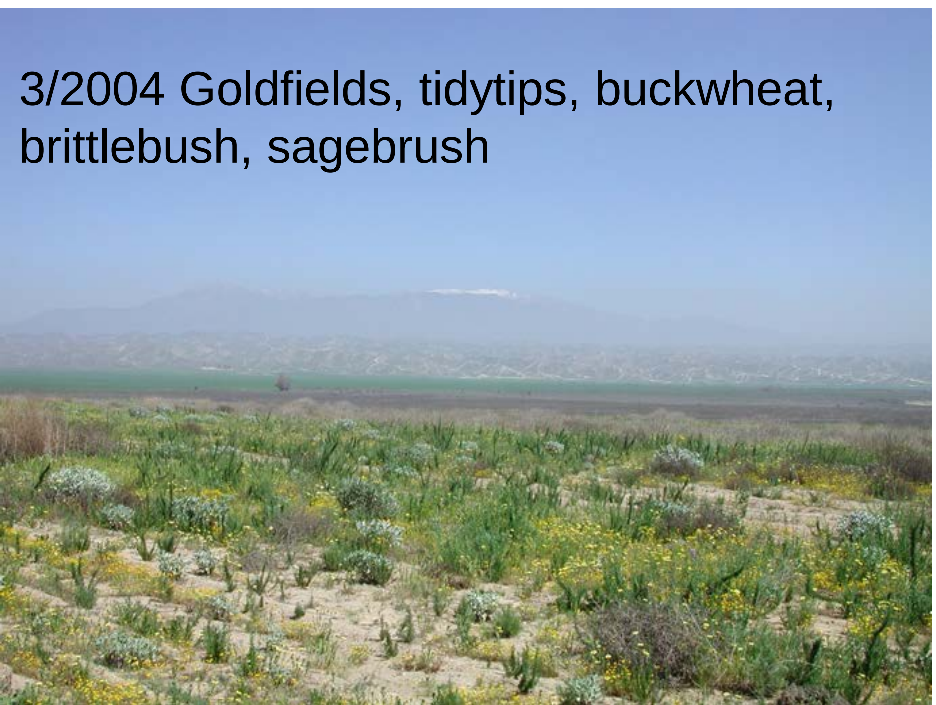
Mt. Rubidoux plots Jun 2005



Fire Oct. 2008

Post-fire May 2009
Plots are dominated by exotic grasses and shrubs have not recovered

Restored RSS in abandoned farmland, ~ 50 acres at San Jacinto Wildlife Area



Conclusions

1. Restoration attempts to control exotic species, whether by N immobilization, grazing, herbicide, mowing, or solarization are variably successful, and often temporary because exotic species recolonize.
2. For successful restoration, N deposition must be reduced to control productivity of exotic grasses and forbs.
3. Riversidean sage scrub is most often dominated by an understory of exotic grasses and forbs throughout its range, even with management to reduce exotic species. This may be considered a novel ecosystem that must be maintained to conserve sensitive native species.

1). Restoration of soil high in N. Use of mulch to immobilize soil N. Replant with *Artemisia californica* in

disturbed soil at Santa Margarita Ecological Reserve

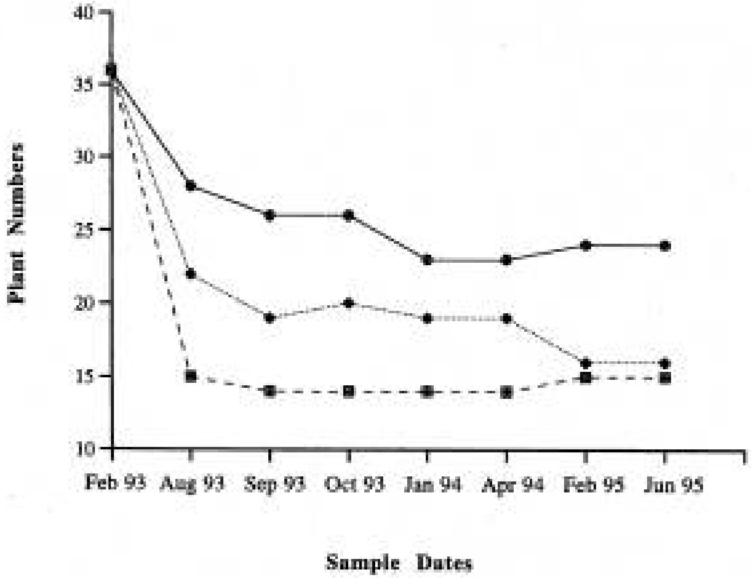


Figure 1. Survival rates for seedlings planted under control (dashed line), straw-amended (dotted line), and bark-amended (solid line) treatments.

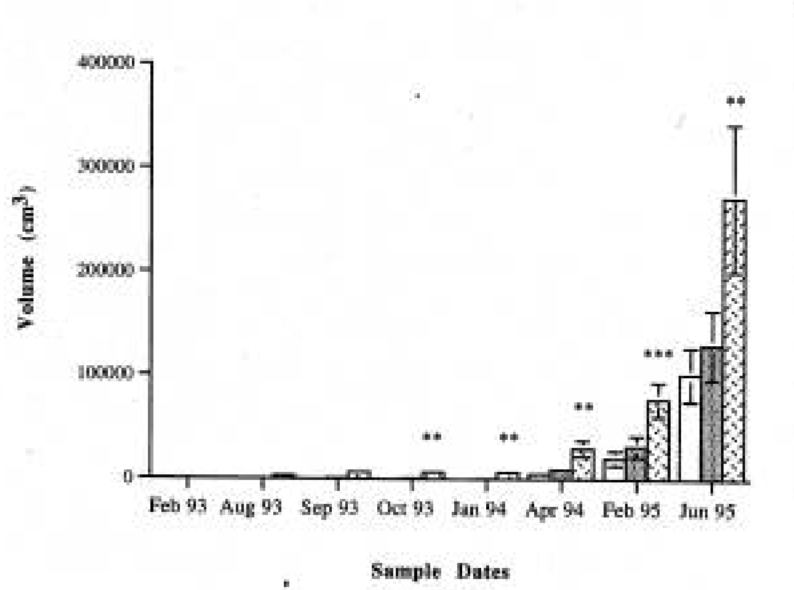


Figure 2. Plant volume under control (plain), straw-amended (stipuled), and bark-amended (cross-hatched) treatments. Significant difference at $p \leq 0.05$ represented by two asterisks; significant difference at $p \leq 0.01$ represented by three asterisks.

Artemisia californica survival and growth were highest in bark mulch, second in straw mulch, and lowest in unmulched plots (from Zink and Allen 1998).

N immobilization was greatest with bark mulch, reducing competitive grasses.