An Adaptive Management Approach to Recovering BUOW Populations and Restoring A Grassland Ecosystem (studies of holes in the ground)

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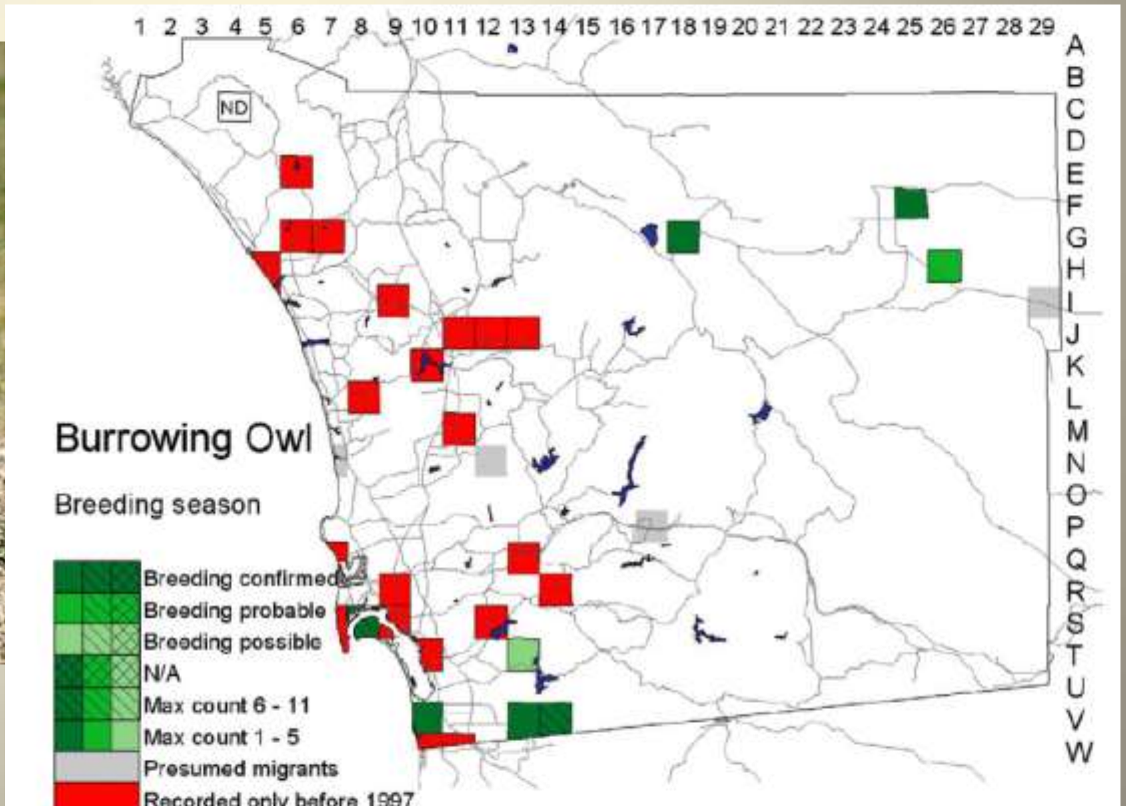
Status of Burrowing Owl Populations

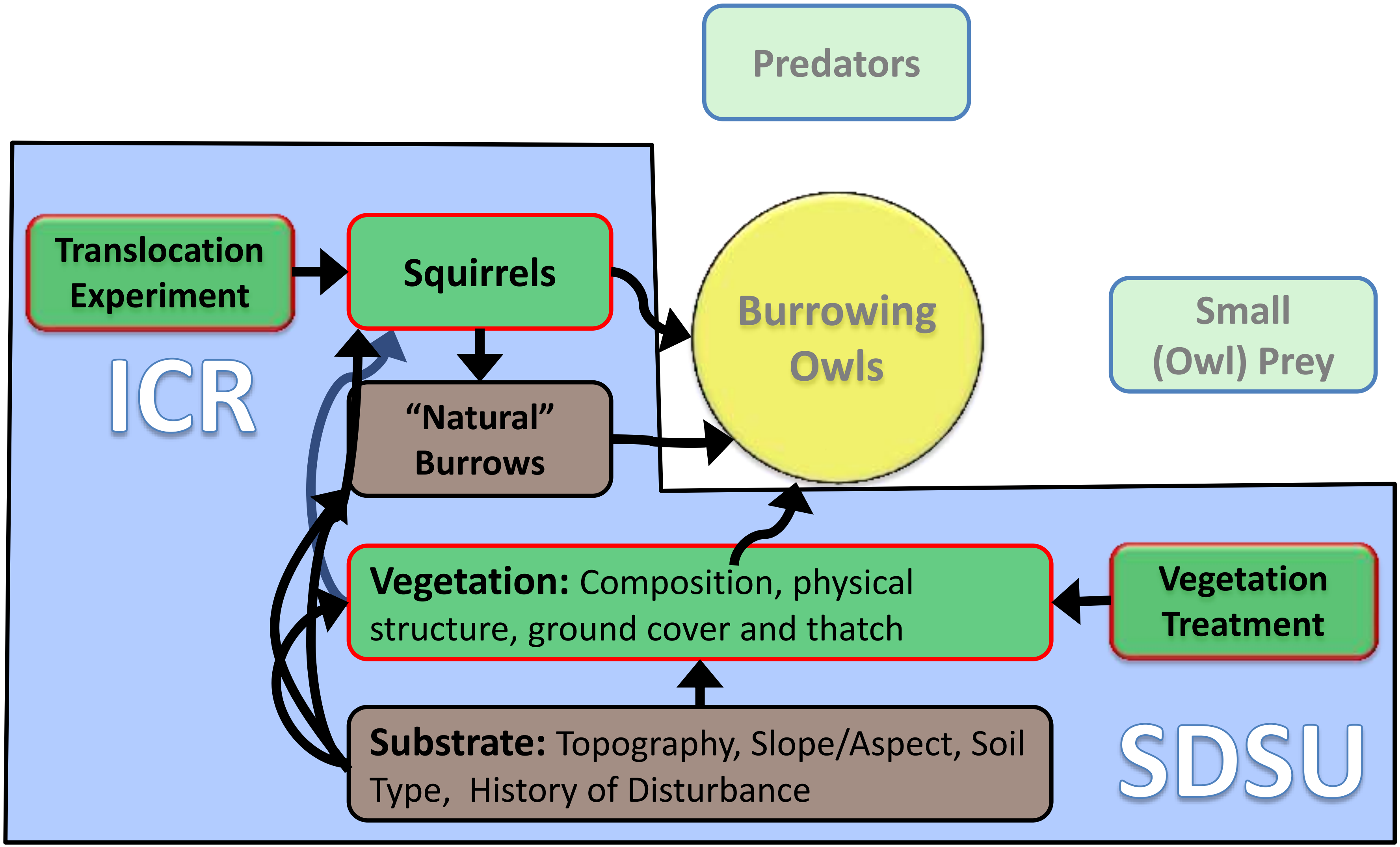


San Diego County Bird Atlas, 2004

Project Background

- Adaptive management approach
- Project Objectives
  - Reestablishing California Ground Squirrels
  - Understanding squirrel and BUOW habitat
  - Burrowing Owl ecology & population regulation
  - Develop management protocols

Conceptual Model for Management Experiment



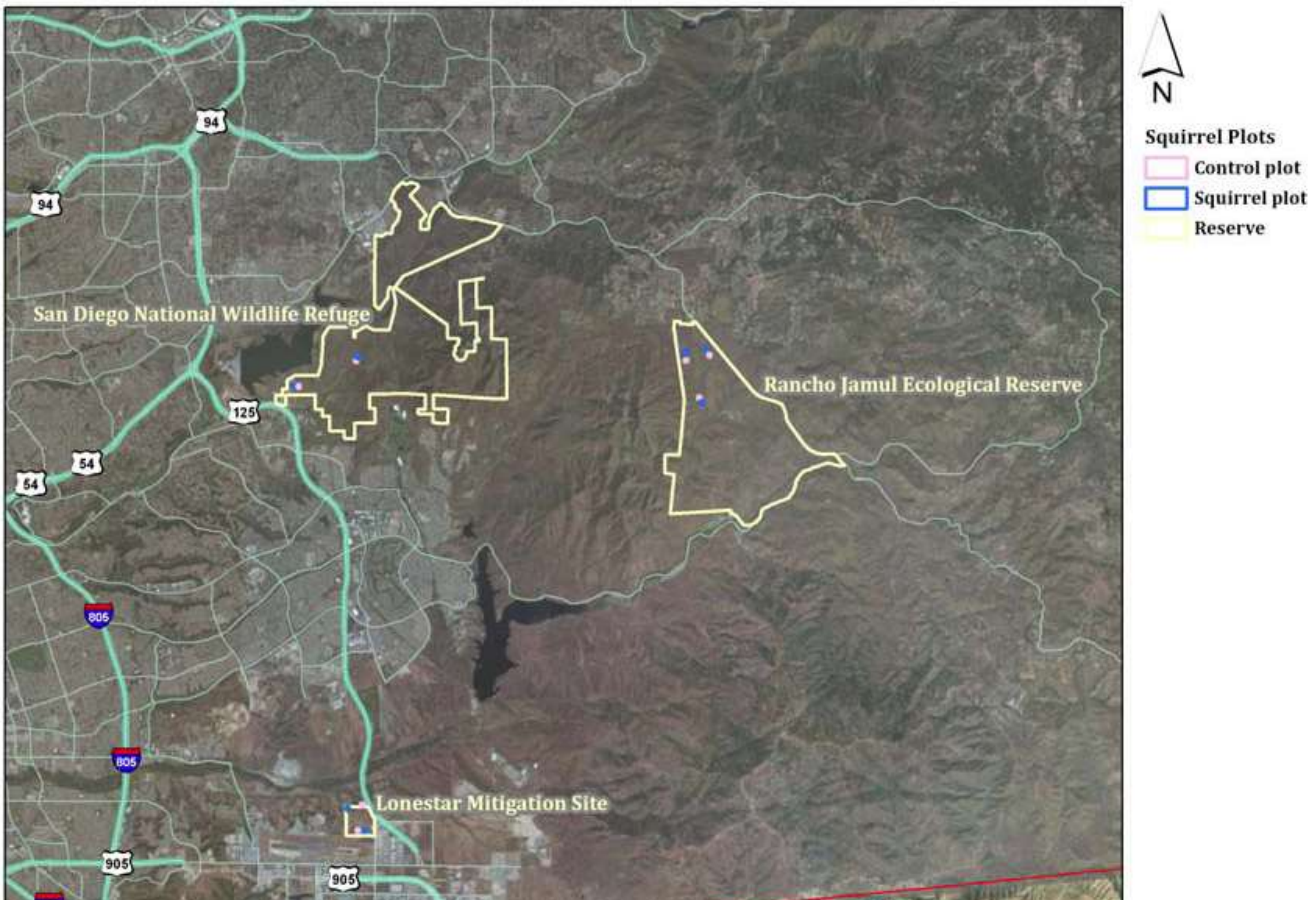
Burrowing owls: build it & they will come

Our vision

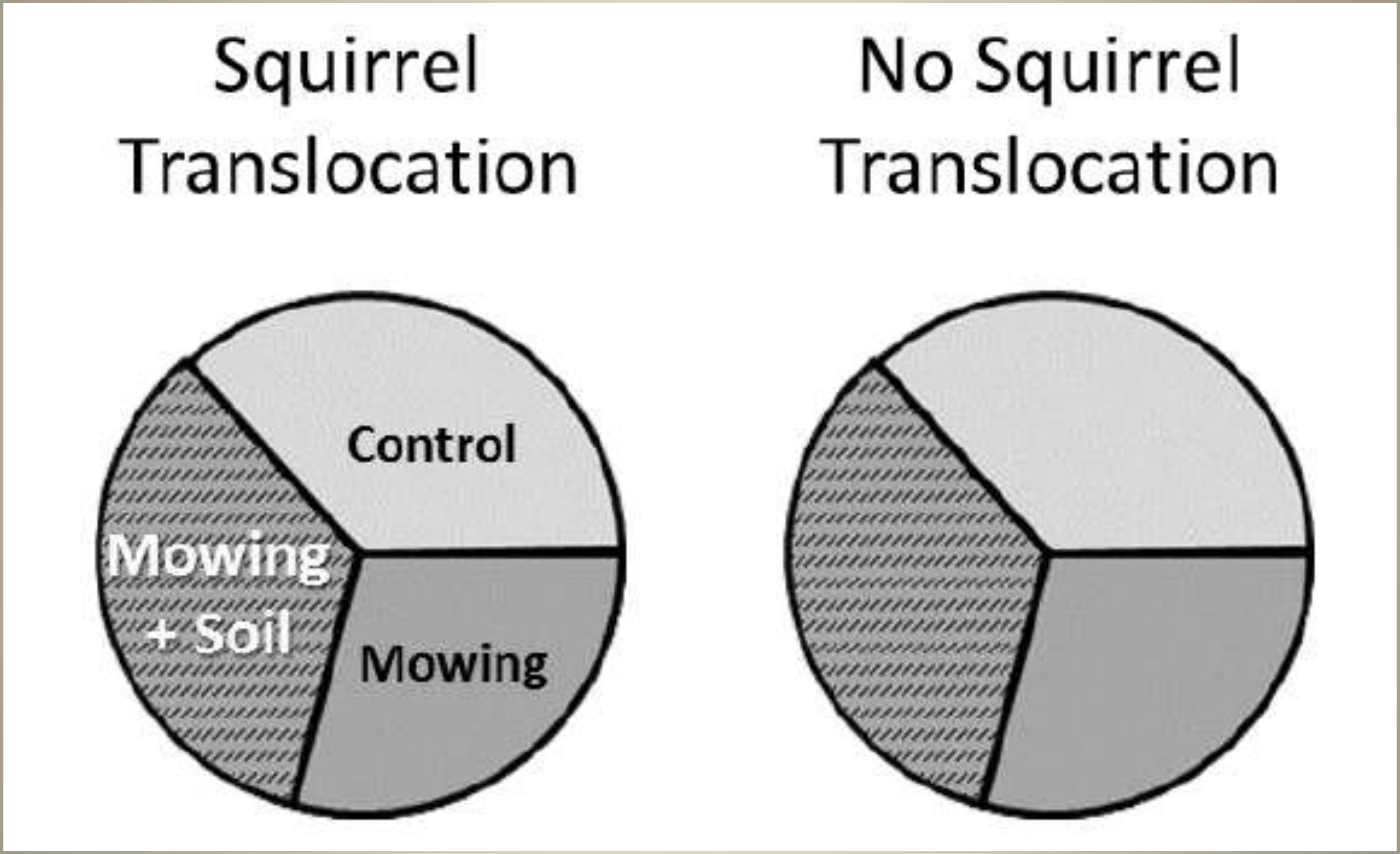
Bring in the ecosystem engineers: a translocation program

Capture pests… release ecosystem engineers

Restoration sites



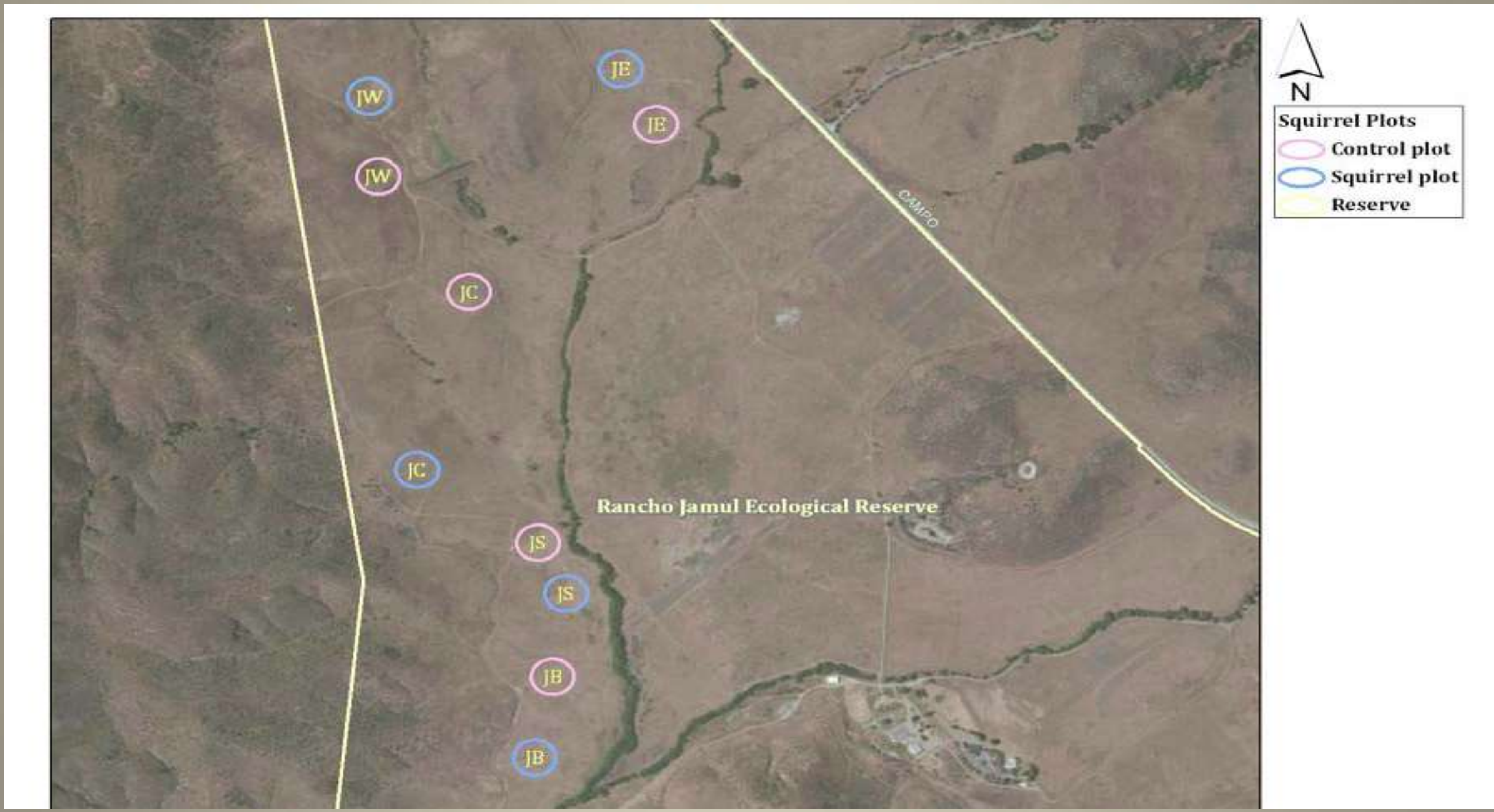
Experimental Design



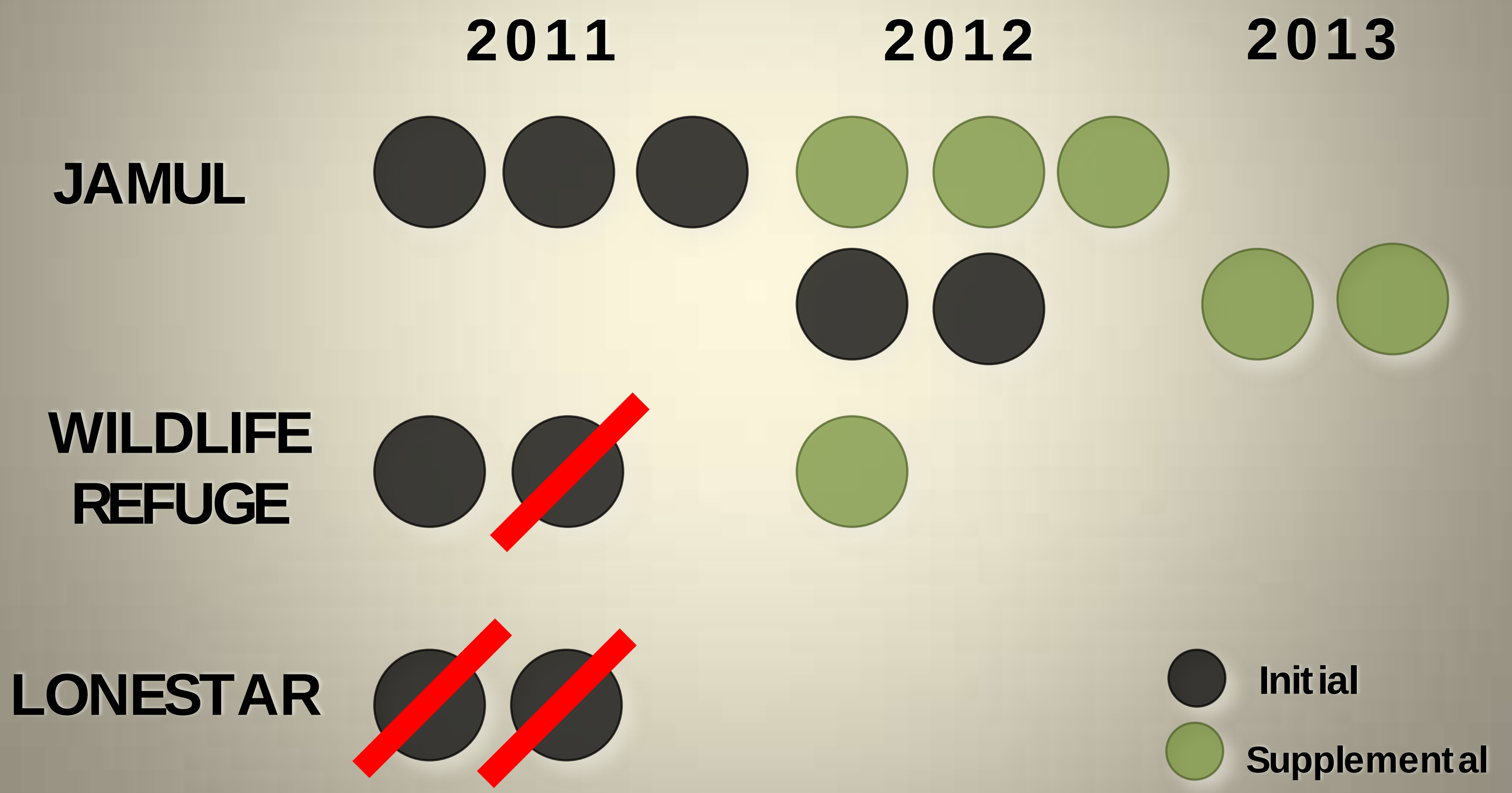
*Translocation plots received 45-50 squirrels

Vegetation manipulations

Experimental Plots



Experimental replicates



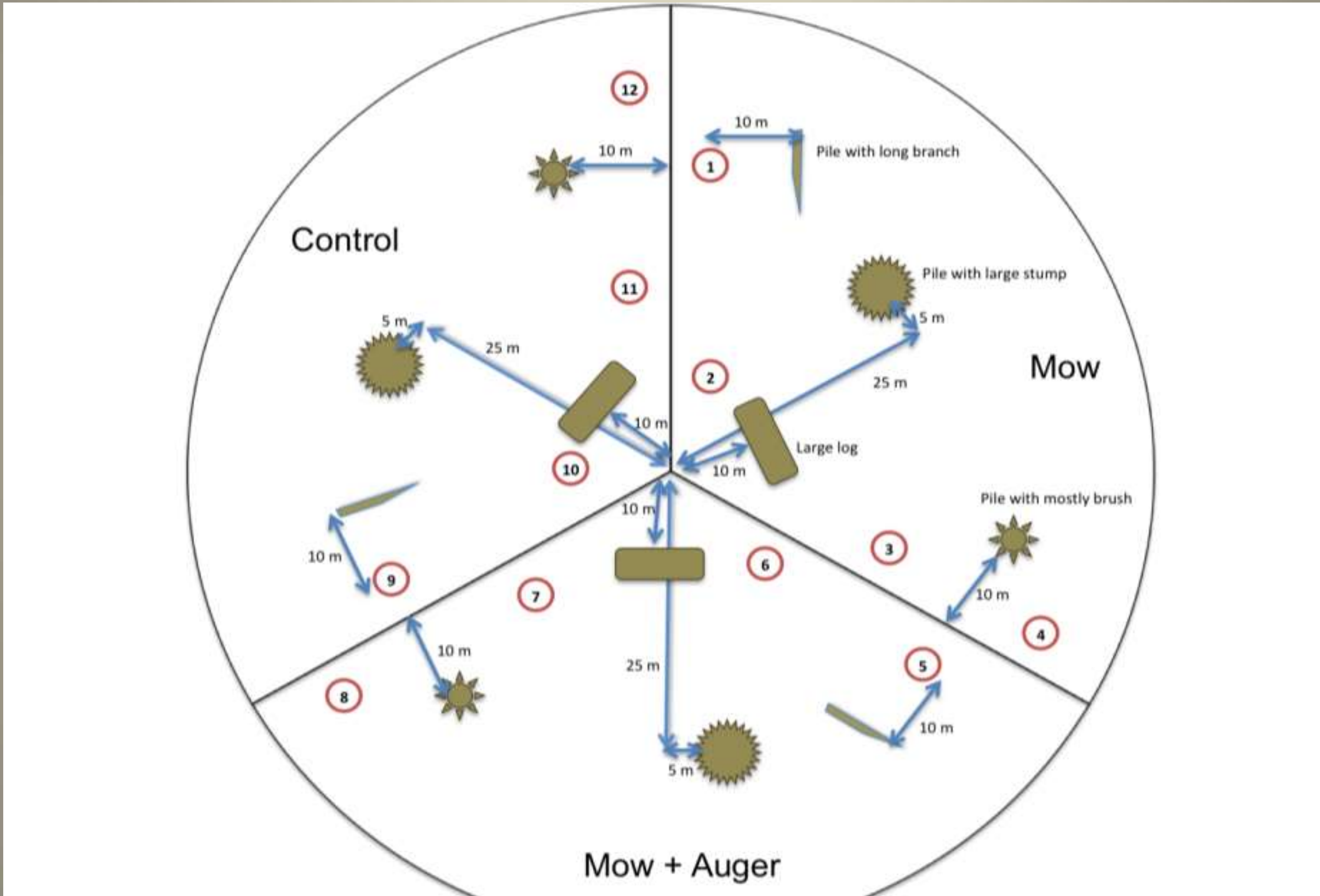
Adaptive management implications for supplemental translocations

- Cover
- Season
- Social familiarity

Soft release protocols

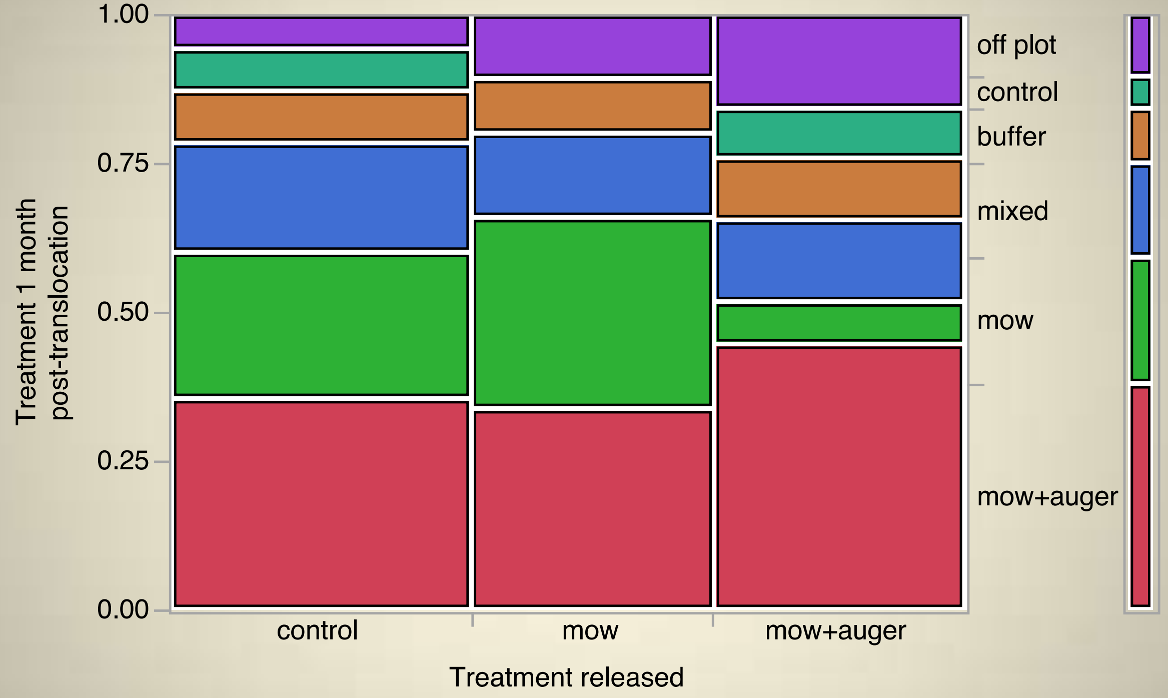
- Habitat enhancement
- On-site acclimation
- Supplemental food (water) for 3 months
- Familiar release group
- Cover added

Experimental Plot Manipulations: Supplemental Translocations

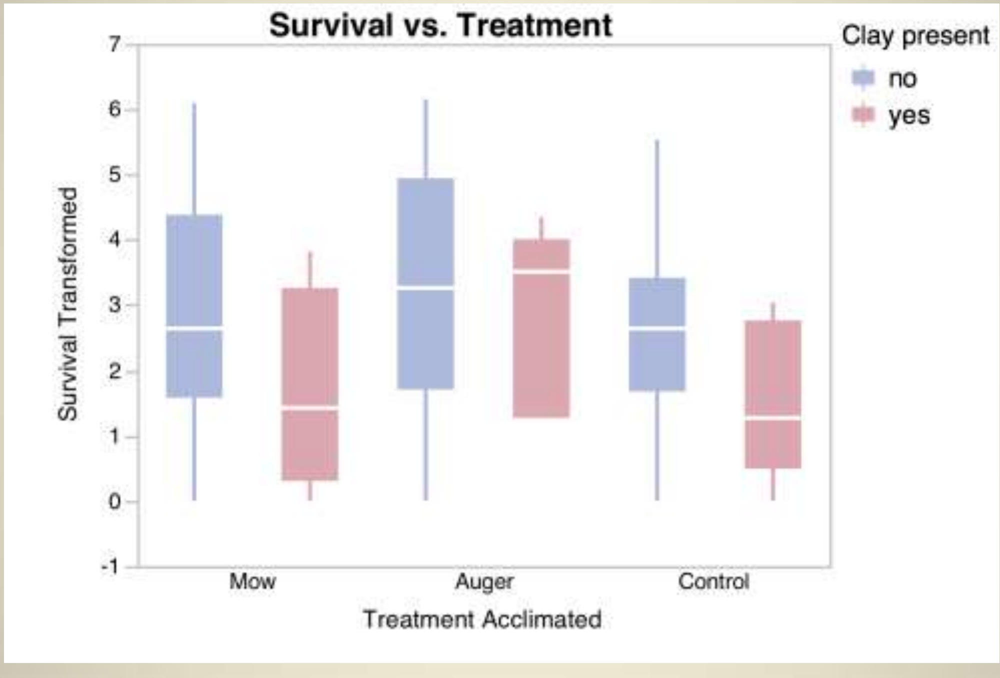


Post-release monitoring

Treatment effects on settlement decisions

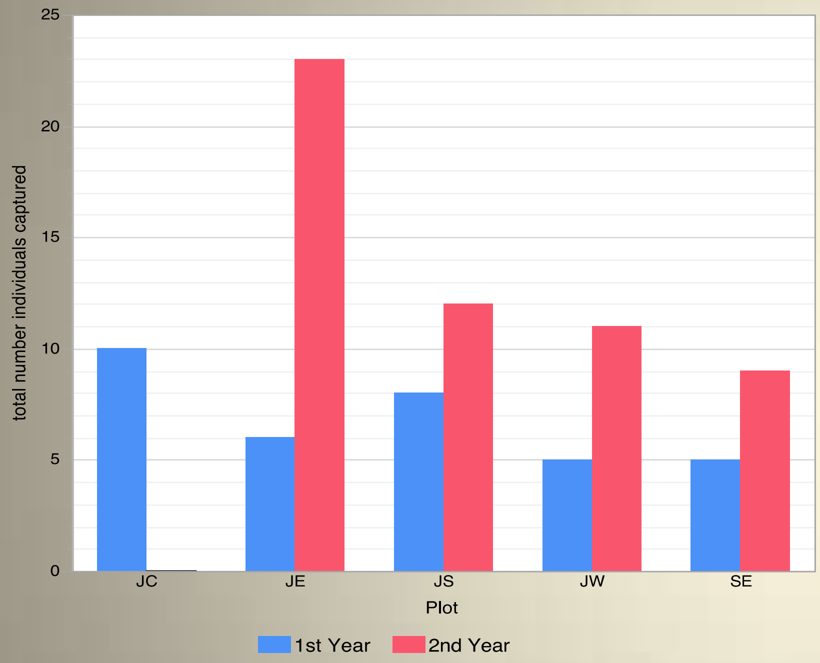


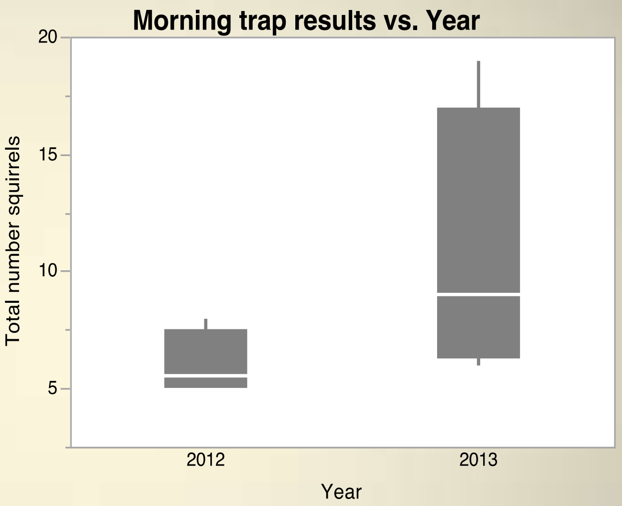
Treatment effects on survival



*None, they dispersed out of less favorable control treatment

Long-term monitoring of translocation outcomes: comparing initial to supplemental* translocation strategies





P<0.01

*Supplemental modifications:

- Residents
- Cover
- Season
- Social familiarity

Minimum survival from trapping 1-month post-release

What explains the high mortality rate?Insights from radiotracked squirrels

Long-term monitoring of translocation outcomes: minimum survival one year post-release

- After first year only:
  - Sweetwater
    SE = 5
  - Jamul 2011
    JE = 6
    JW = 6
    JS = 7
  - Jamul 2012
    JB = 0
    JC = 9

Cohort	SE	JE	JW	JS	JB	JC
Trans	2	2	2	2	0	6
F1	3	4	2	3	0	2
Recruit	0	0	1	2	0	1
Unknown	0	0	1	0	0	0

Reproduction resulting from translocation: juveniles trapped on site 2012 & 2013

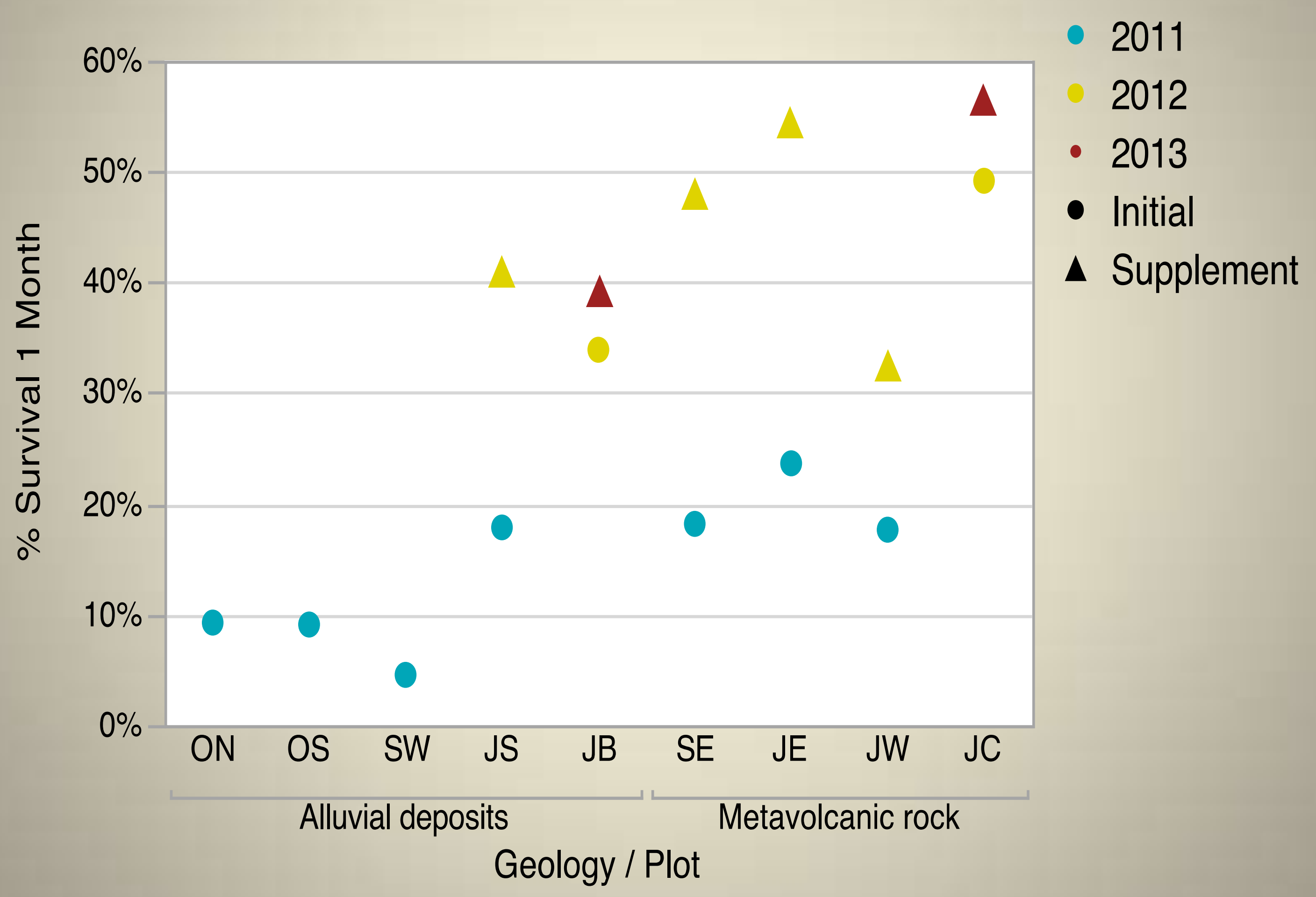
Trans.	SE	JE	JW	JS	JB	JC	
Initial	4	4	4	4	0	3	19
Supplement	2	11	9	5	NA	NA	27+
	6	15	13	9	0	3	46

*These are minimum numbers, not estimates

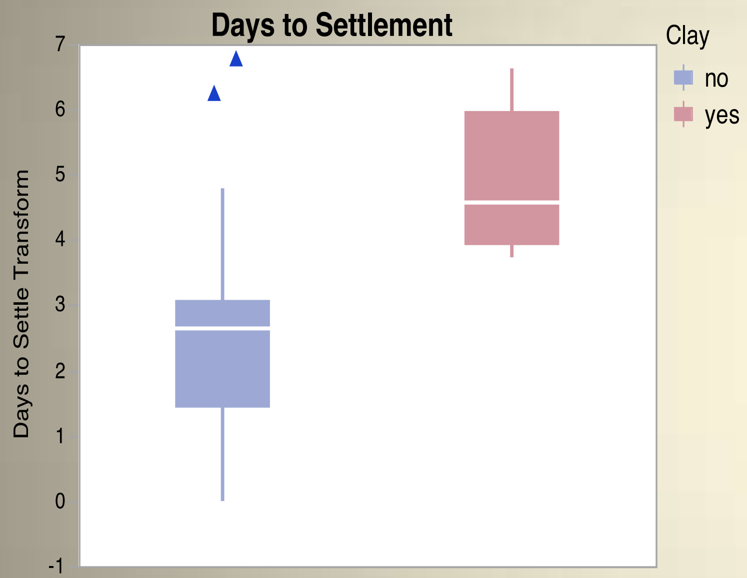
Squirrel establishment

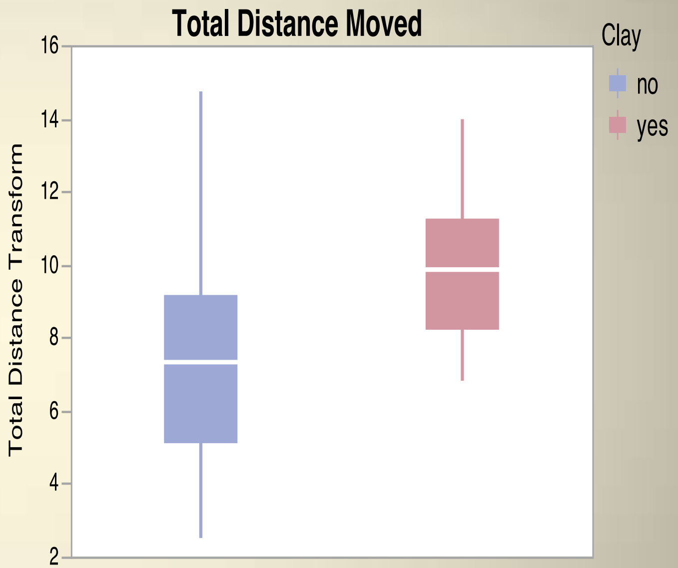
One year later the successful plots had ~15-20 squirrels each following supplemental translocations used to bolster the populations
(*est. populations from morning trapping, evening trapping, camera trapping, radiotelemetry, observations)

Do soil characteristics explain site-level effects?



Should they stay or should they go?

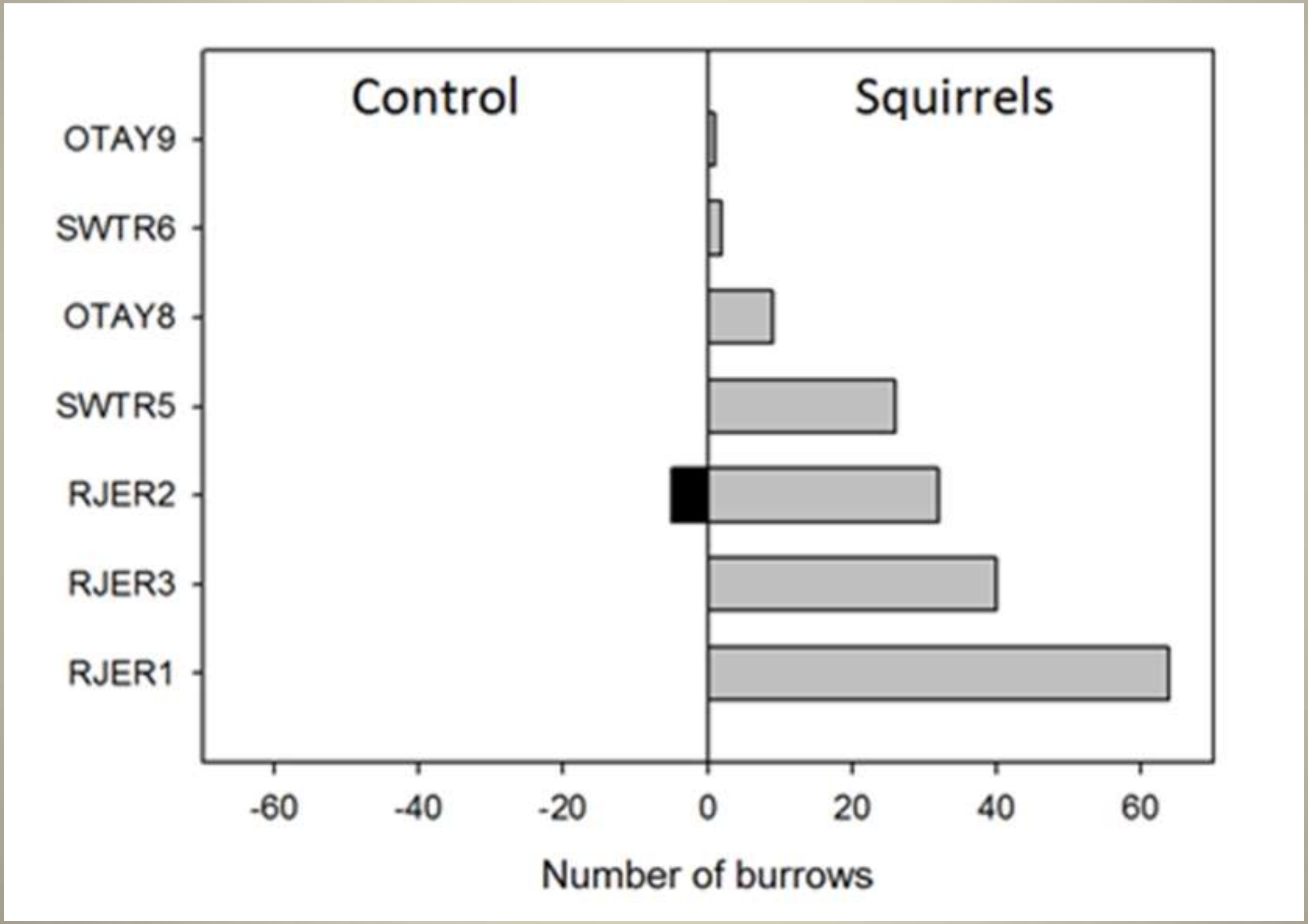




Clay present → longer to settle
(F=13.2, $p<0.001$, $R^2=0.22$)

Clay present → settled further from release site
(F=4.3, p=0.04, $R^2=0.08$)

Ecosystem engineering effects



Results at 1 year

Ecosystem engineering effects

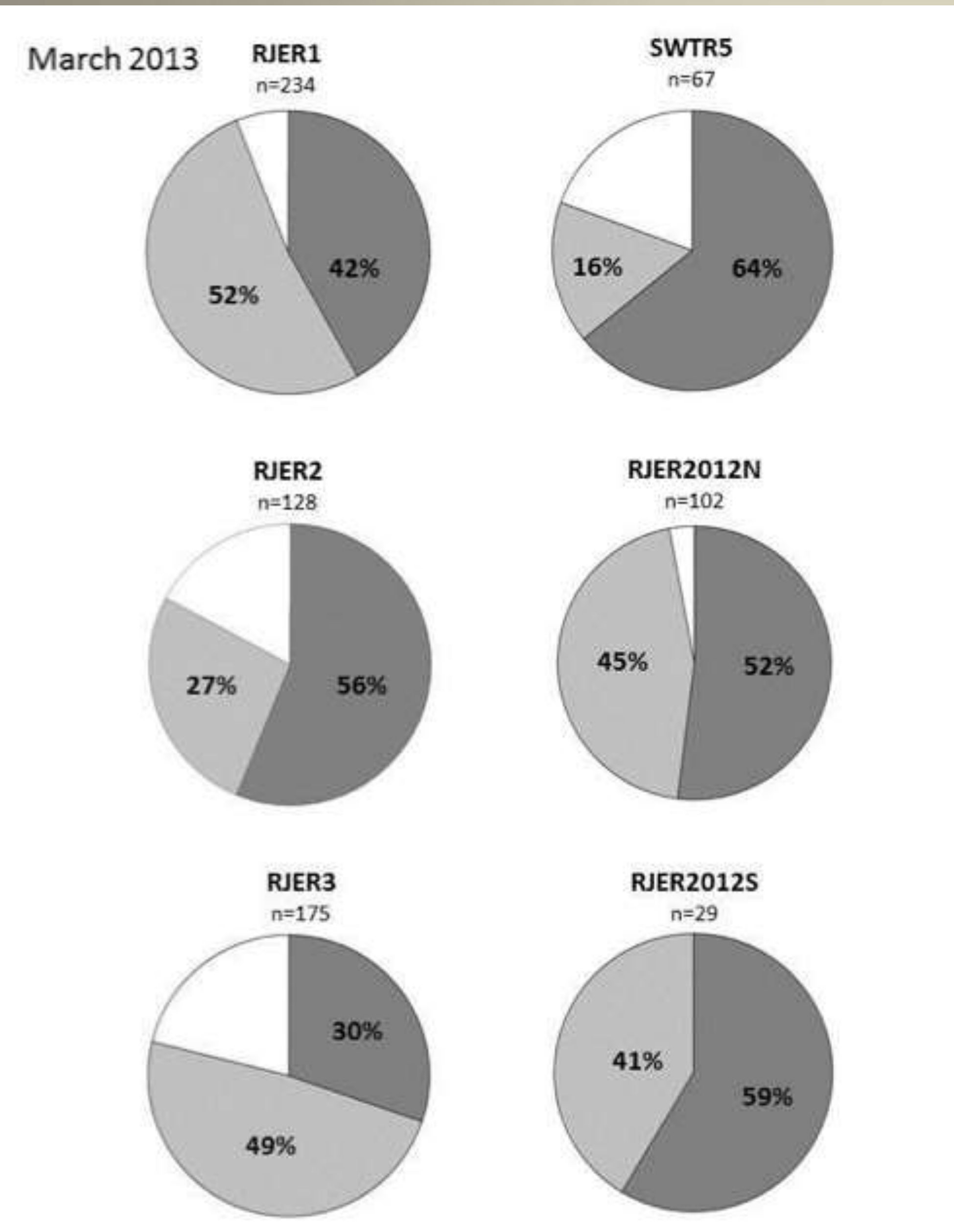
SAN DIEGO STATE UNIVERSITY

March 2013		
Control	Translocate	Total
4	106	110
2	29	31
12	234	246
8	128	136
24	175	199
2	68	70
52	**740**	**792**

Results at 2 years

Extensive burrow engineering effects even when CAGS survivorship was low

Treatment Effects



Percentage of Burrows in Each Plot Treatment (March 2013)

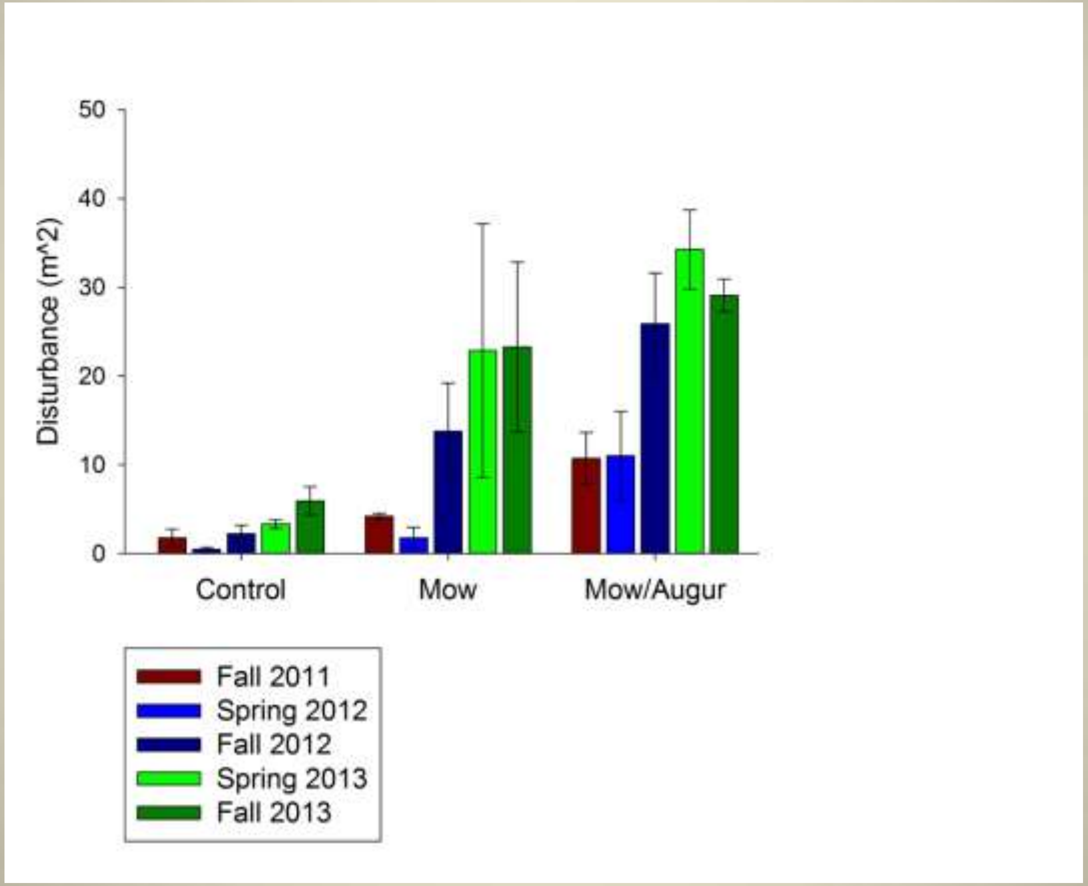
Mowing is important…
Augering not so much

Mowing +Translocation Needed!!

Percentage (%) of burrows in each plot by treatment

- Control
- Mowing
- Mowing and auguring

Ecosystem engineering: ground disturbance



Effects of squirrels on translocation plots

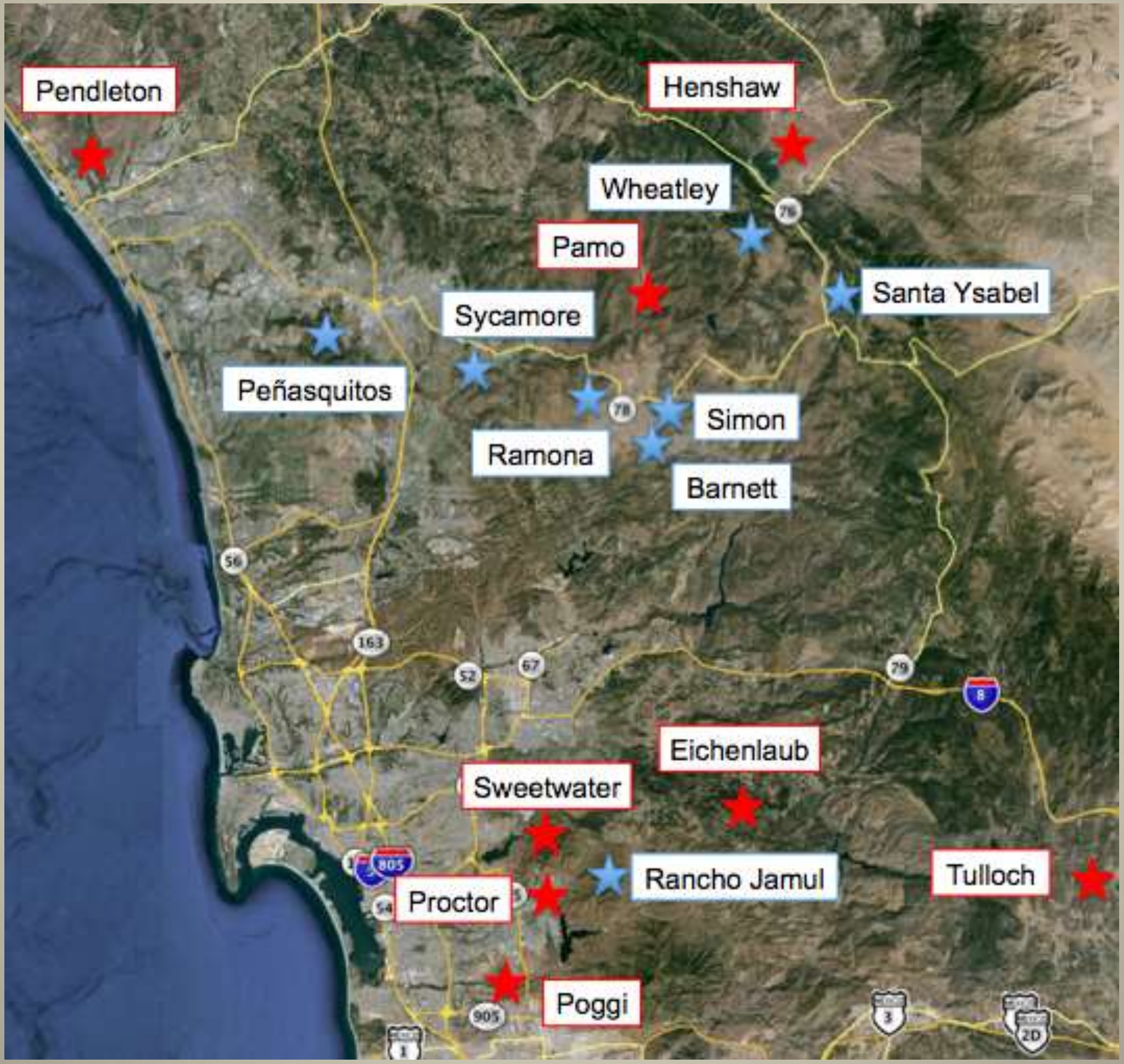
Lessons learned

- Improved protocols through adaptive management
  - Add brush piles, extend feeding, improved monitoring
- High survival rates are not needed to have successful ecosystem engineering effects
  - Burrows present & increasing
- Remains unknown: long-term persistence of squirrel colony over time to maintain burrows

What ecological variables predict squirrel presence?

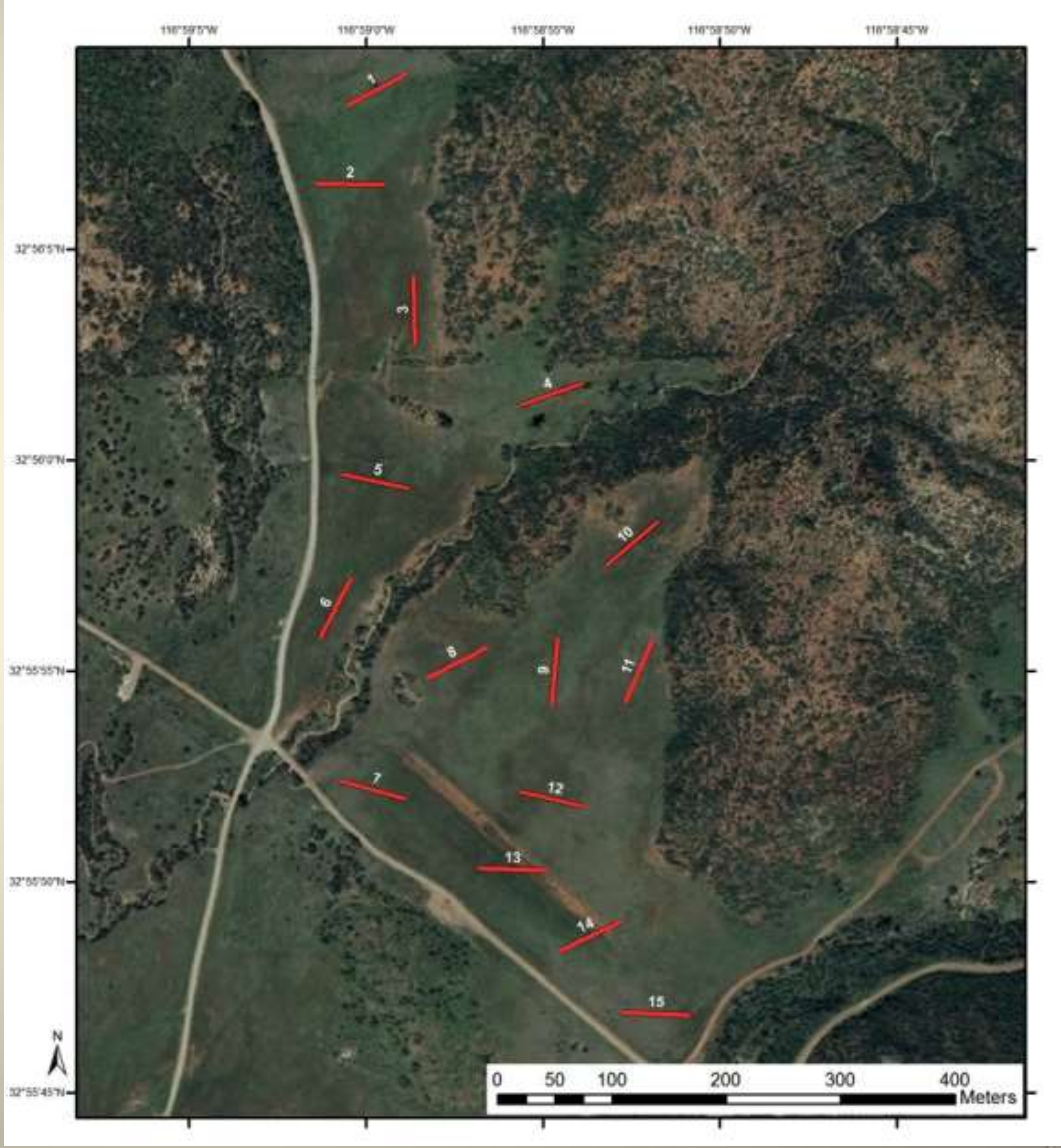
Building a habitat suitability model

CAGS habitat survey sites



Transect Site Selection

- Grassland habitats
- Random transects generated through ArcGIS
- 15 per site
- N= 90 presence plots, 138 absence



- GPS plot center
- Community type
- Dominant species - grass, forb, shrub
- Nearest elevated structures
- Is burrow active?
- Burrow protection
- # and distance of other CAGS and/or burrows sighted from transect
- Predators
- Site history (if known)
- Soil cores (3 per transect)
- Vegetation type and height
    - Forb/Grass/Shrub
    - Exotic/Native
    - Annual/Perennial


Sample Collection
PENDLETON TRANS 7 CORE 1 DATE 7/10
PENDLETON TRANS 7 CORE 2 DATE 7/10
PENDLETON TRANS 7 CORE 3 DATE 7/10
Drying, % Gravel, Bulk Density
Soil Texture

Habitat Variables Associated with Squirrel Burrow Presence

- Site effects strong ($p = 0.001$)
  - Known burn history increase presence ($p = 0.067$)
  - Known graze history increase presence ($p = 0.058$)
- Soil and vegetation
  - Best model included % sand (negatively correlated to % clay and silt) and percent vegetative cover
  - Exotic vegetation negatively associated with squirrel presence ($p<0.05$)
- Conclusion: squirrels associated with soil texture that affords digging, open native vegetation, and sites with a history of burning/grazing
- Model predicts only Jamul East suitable for squirrels

*Results from logistic regression

And now, the owls



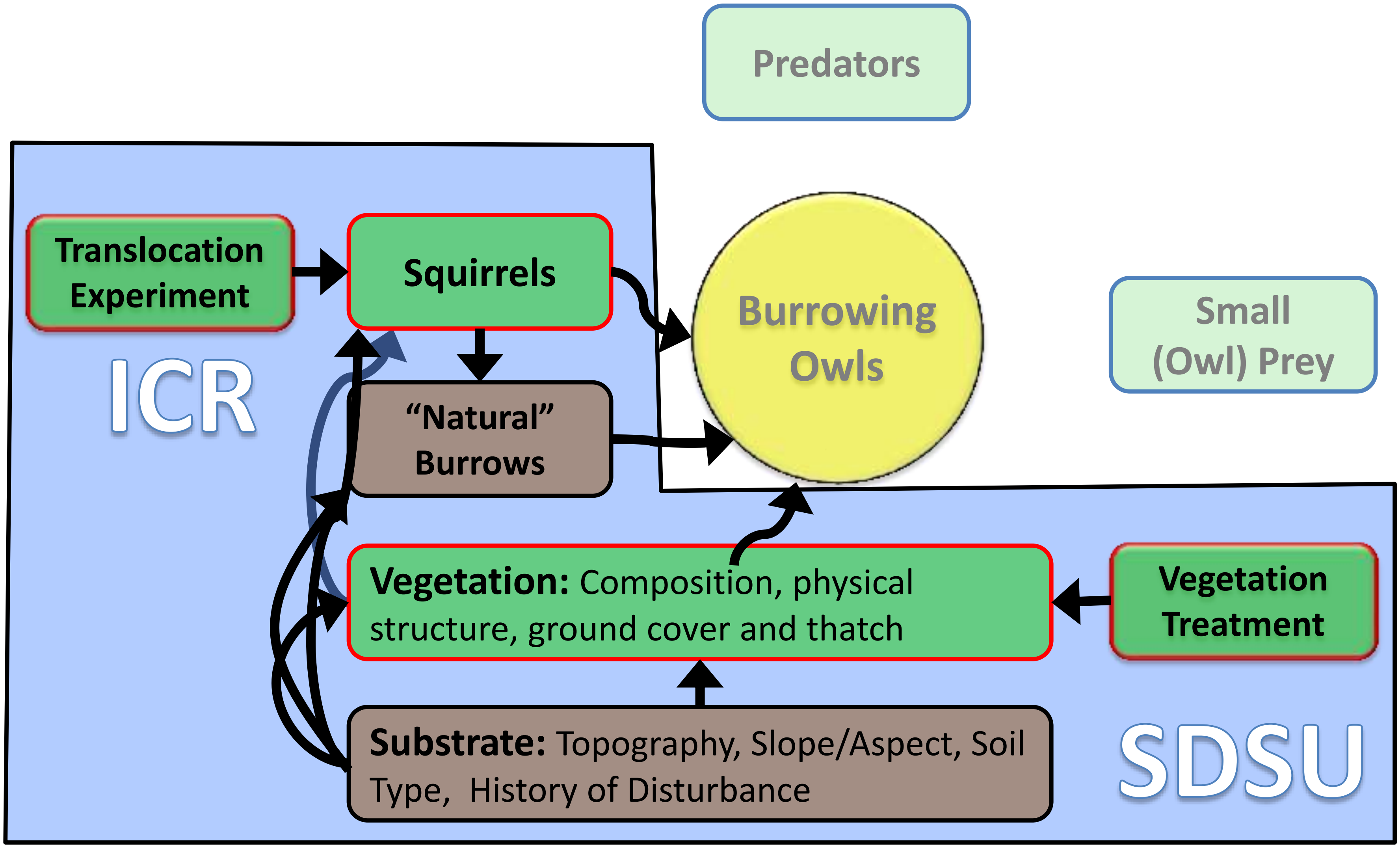


Burrowing Owl Nesting and Foraging Ecology





Conceptual Model for Management Experiment



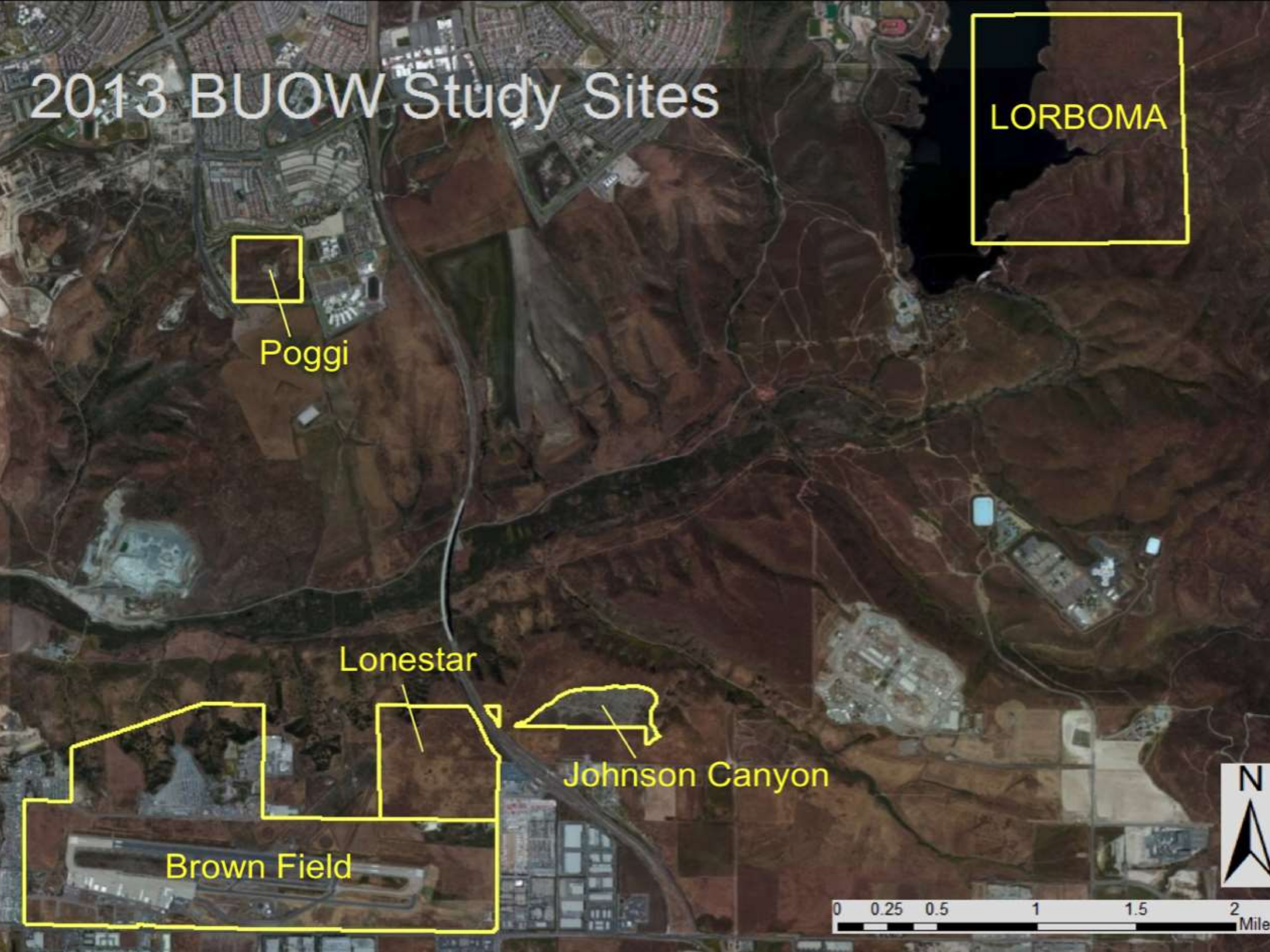
Burrowing Owl Monitoring (2013)

- Active Breeding Burrows (18)
  - 9 Natural (CA ground squirrel) burrows
  - 9 Artificial burrows
- Observations, Camera Trapping, & Banding
  - Weekly visits to burrows; opportunistic banding
- Goals – BUOW ecology
  - Reproductive rates, nest success, survivorship, prey provisioning, predation

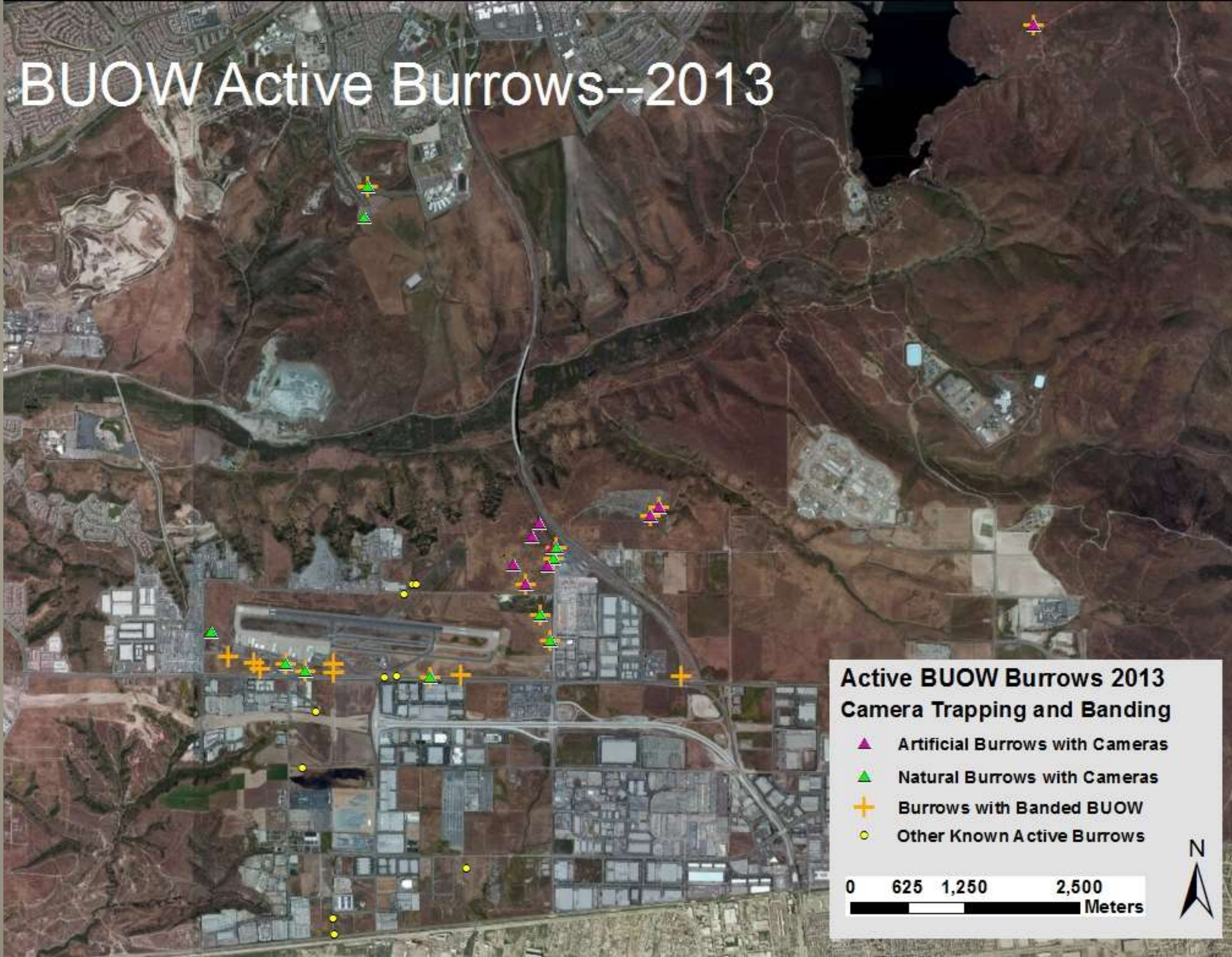
Methods

Active Breeding Burrows

- Database records (eBird, CNDDB, CA DFW)
- Observations
- Camera Trapping (at a subset)
- Banding


2013 BUOW Study Sites
LORBOMA
Poggi
Lonestar
Johnson Canyon
Brown Field
N
0 0.25 0.5 1 1.5 2
Mile

BUOW Active Burrows--2013



Camera Trapping

- 1-2 camera traps per burrow
  - Reconyx® Hyperfire PC900 ($650)
  - Bushnell® TropyCam HD 119437 ($170)
- 3 pictures/trigger (motion-activated), 30-second quiet period

Banding

- Trapped at active burrows using one-way door traps and bow nets
- Banded with USGS bands and green Acraft bands
- Blood sample taken from brachial vein and frozen for later DNA extraction
- Standard morphometric measures and photos of plumage



Camera Trap (& Banding) Data

- Frequency of prey deliveries and types of prey
- Frequency of predation events and types of predators
- Human disturbances
- Reproductive success
- Survivorship of marked individuals
- Maximum number of adults and juveniles per day
- Other wildlife at/near burrows

Camera Trap Photo Processing

Keywords for tagging photos

Adobe® Bridge

Invertebrate Prey

Herp Prey


Snake
Bushnell BUOW B15 68°F20°C 05-06-2013 17:32:50


Patchnose Snake
Bushnell BUOW B16 86°F30°C 06-22-2013 11:31:42


2013-05-12 5:55:54 PM M 1/3 99°F
Lizard
BUOW R11


2013-05-07 4:22:06 AM M 1/3 57°F
Frog
RCNX3

Mammal Prey


2013-04-13 11:11:42 AM M 1/3 77°F
Rabbit
BUOW R12


2013-05-29 11:31:31 PM M 2/3 57°F
Kangaroo Rat
BUOW R15


2013-04-25 2:29:00 AM M 1/3 54°F
Mouse/Vole
RCNX4


2013-05-12 4:11:52 PM M 2/3 101°F
CA Ground Squirrel
BUOW R2

Bird Prey


Passerine
Bushnell M BUOW B10 88°F31°C
05-19-2013 10:36:59


PM M 2/3 81°F
Kestrel
RCNX2
RECONYX

Predation Events

Potential Predators

Other Interesting Observations

Camera trap data processing

- Data
  - 1,860,224 total photos collected
  - 1,520,917 photos processed
  - ~1 TB worth of photo data
- 9 volunteers, ~10 hours training per volunteer
- Processing time: ~40 hours/week for 4 months
- Quality Control: ~10 hours/burrow

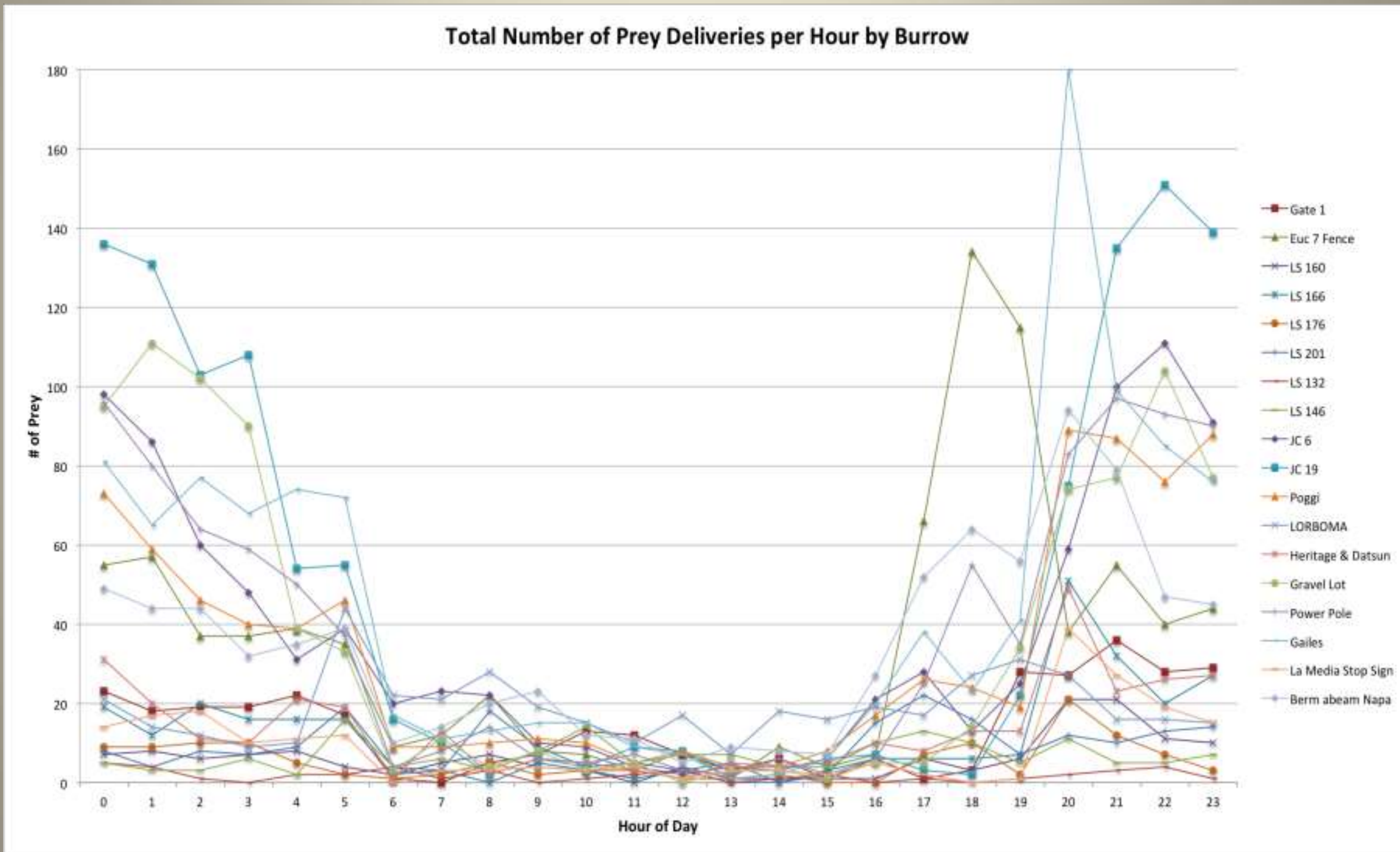
Reproduction and offspring survival

Burrow	Estimated First Egg Date[1]	Estimated Hatch Date[2]	First Chick Emergence Date[3]	# Chicks at 1st Emergence	Max # chicks (Date)	Estimated Fledging Date	# Juveniles Fledged
Gate 1	Mar 20	Apr 19	May 3	1	5 (May 7)	Jun 3	0
Euc 7 fence	Mar 18	Apr 17	May 1	2	8 (May 4*)	Jun 1	2
LS 160 (A)	Apr 13	May 13	May 27	2	2 (May 27 & 28)	Jun 27	0
LS 166 (A)	Apr 25	none hatched	none	none	0 (no eggs hatched)	n/a	n/a
LS 176 (A)	Apr 19	May 19	Jun 2	3	3 (June 2-9)	Jul 3	2
LS 201 (A)	May 8	Jun 3	none	none	1 (June 4**)	Jul 18	0
LS 132 (A)	Apr 13	May 13	May 27	3	3 (May 27)	Jun 27	0
LS 146 (A)	Apr 23	May 23	Jun 6	1	1 (June 6)	Jul 7	0
JC 6 (A)	Mar 21	Apr 20	May 4	1	5 (May 8-21)	Jun 4	4
JC 19 (A)	Mar 7	Apr 6	Apr 20	1	7 (May 6, 7, 9, 11)	May 21	4
Poggi	Apr 23	May 23	Jun 6	1	6 (June 9)	Jul 7	2
LORBOMA (A)	Apr 3	May 3	May 17	2	7 (May 21-22)	Jun 17	2
Heritage and Datsun	Apr 1	May 1	May 15	2	4 (May 17-23)	Jun 15	0
Gravel Lot	Mar 25	Apr 24	May 8	1	7 (May 16 & 18)	Jun 8	4
Power Pole	Mar 20	Apr 19	May 3	5†	7 (May 4-5)	Jun 3	2
Gailes	Apr 3	May 3	May 17	2	8 (May 22)	Jun 17	5
La Media Stop Sign	no data	no data	none	none	0	n/a	n/a
Berm Abeam Napa	Apr 10	May 10	May 24	2	5 (May 26-28)	Jun 24	0

Prey delivery data

Site	Burrow	Camera Type	Total # Prey Deliveries	Birds (%)	Inverts (%)	Herps (%)	Mammals (%)	Unknown (%)	BUOW (#)
Lonestar	Gate 1	Reconyx	331	1	66	2	6	24	2
	Euc 7 Fence	Reconyx	847	0	26	0	2	72	4
	LS 160 (A)	Bushnell	147	0	67	3	10	21	0
	LS 166 (A)	Bushnell	279	3	68	3	8	17	0
	LS 176 (A)[1]	Bushnell	122	0	64	2	5	30	0
	LS 201 (A)	Bushnell	211	<1	83	<1	5	11	0
	LS 132 (A)	Bushnell	43	0	49	0	5	47	0
	LS 146 (A)	Bushnell	162	11	51	9	4	25	0
Johnson Canyon	JC 6 (A)	Both	911	<1	41	<1	1	57	0
	JC 19 (A)	Reconyx	1187	<1	47	<1	5	48	0
Poggi	Poggi[1]	Both	642	<1	66	2	17	16	2
LORBOMA	LORBOMA (A)[1]	Both	415	<1	70	1	18	10	2
Brown Field	Heritage and Datsun	Reconyx	321	<1	44	1	25	29	0
	Gravel Lot[2]	Reconyx	901	0	51	<1	4	45	0
	Power Pole[1]	Reconyx	911	<1	70	1	1	28	0
	Gailes[1]	Both	979	<1	73	<1	12	15	1
	La Media Stop Sign[2]	Reconyx	210	<1	63	4	11	21	0
	Berm abeam Napa	Reconyx	832	<1	49	2	5	44	0

Activity cycles



Sources of juvenile mortality

Site	Burrow	Mortality event
Lonestar	Gate 1	Infanticide
		Infanticide
		Cooper's hawk
	Euc 7 Fence	Infanticide
		Infanticide
		Infanticide
		Likely Infanticide
Johnson Canyon	JC 6 (A)	Likely Infanticide
Poggi	Poggi	Infanticide
		Possible Siblicide
LORBOMA	LORBOMA (A)	Infanticide
		Infanticide
Brown Field	Heritage and Datsun	long-tailed weasel
	Power Pole	California king snake
		common raven
		common raven
	Gailes	Infanticide
		Cooper's hawk
	Berm abeam Napa	Likely Starvation

Banding: Preliminary Results

		Family	Adults			
			Female	Male	Juveniles	Total per Family
Natural	1	BF: Cul-du-sac	1		3	4
	2	BF: Gailes			6	6
	3	BF: Gravel Lot	1		4	5
	4	BF: Berm abeam Napa			2	2
	5	BF: Pipes Driveway	1	1	1	3
	6	BF: Power Pole	1		2	3
	7	BF: Old Schoolhouse			5	5
	8	BF: Sikorsky Hydrant			3	3
	9	BF: Tripad Fence			4	4
	10	BF: Tripad North			2	2
	11	PO: Poggi	1	1	4	6
	12	LS: Euc 7 Fence	1*		3	4
	13	OM: SR-125 Exit			1	1
Artificial	14	JC: JC 19			2	2
	15	JC: JC 6			4	4
	16	LO: LORBOMA			3	3
	17	LS: LS 176	1*	1	2	4
		Totals	7	3	51	61

- Building encounter histories of banded birds for survival analysis
- Able to document individuals changing nest burrows in season & dispersal of several juveniles
- 5/51 juveniles, 4/10 resighted in 2014

More burrow studies

Goal: understand how variation in microclimate, microhabitat, & landscape features influence burrow outcomes

Artificial vs. natural burrows

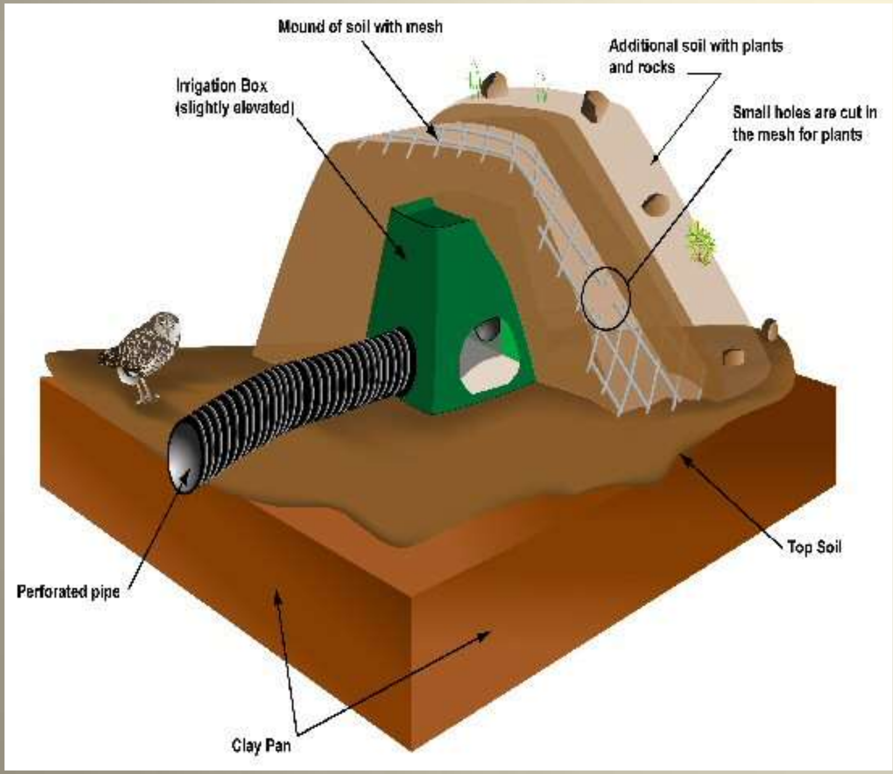
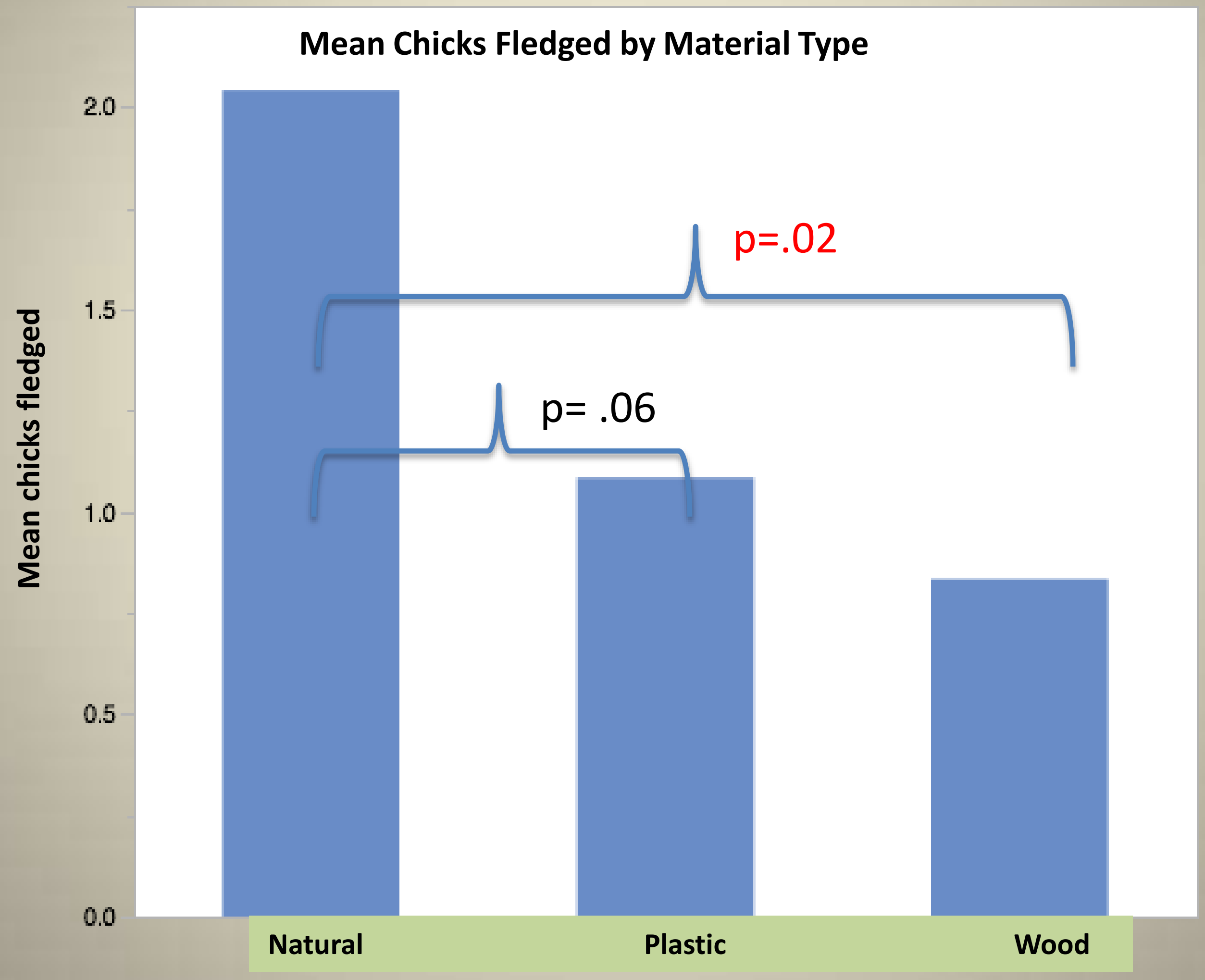


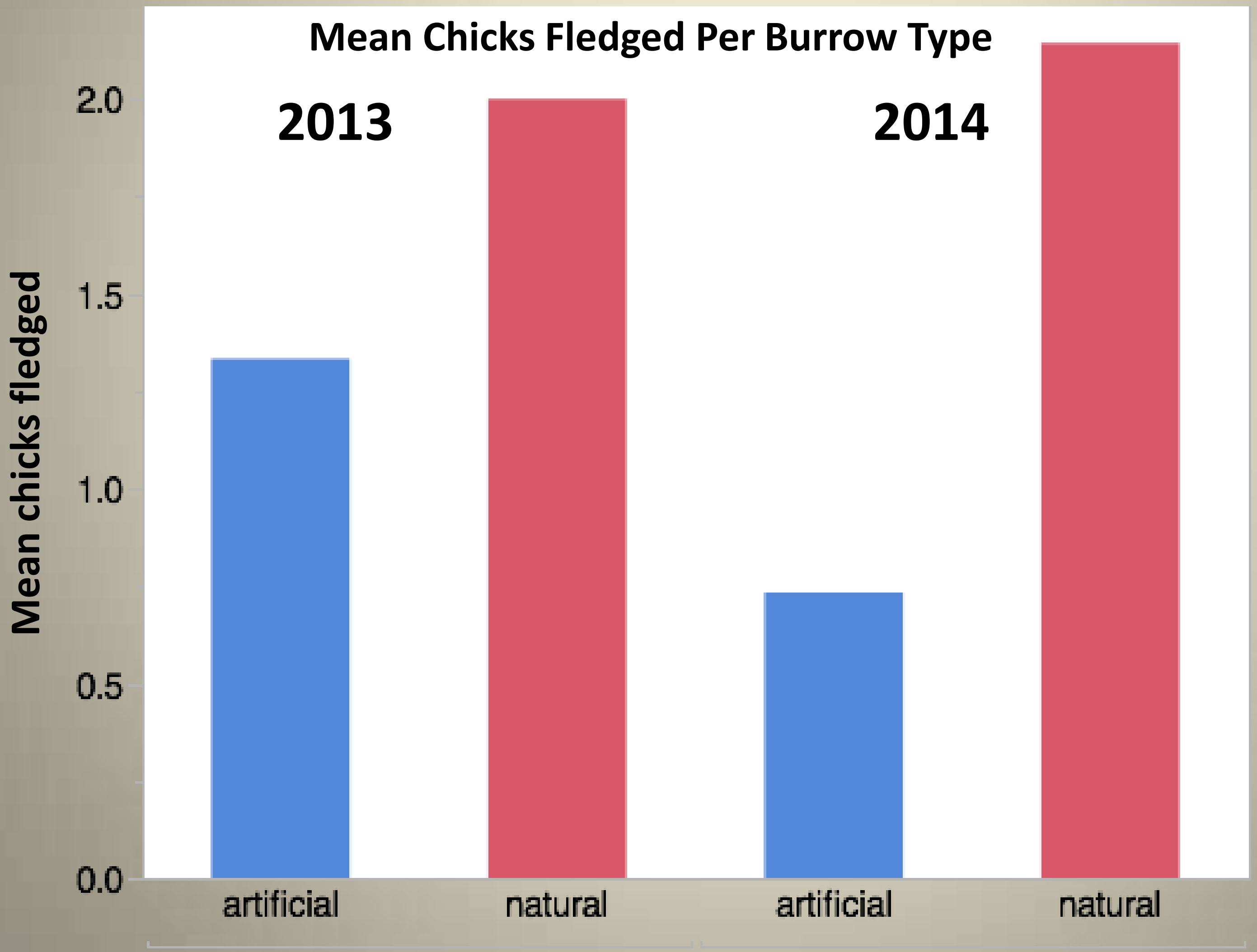
Photo by CalTrans

Evaluate differences between 3 burrow types

Burrow type matters



Inter-annual variability



- Natural burrows
- Artificial burrows

But what are the ecological factors driving these fitness effects?



Microhabitat, soil, microclimate, prey availability, (foraging) landscape features?

Methodologies

iButtons: data loggers

Soil sample analysis

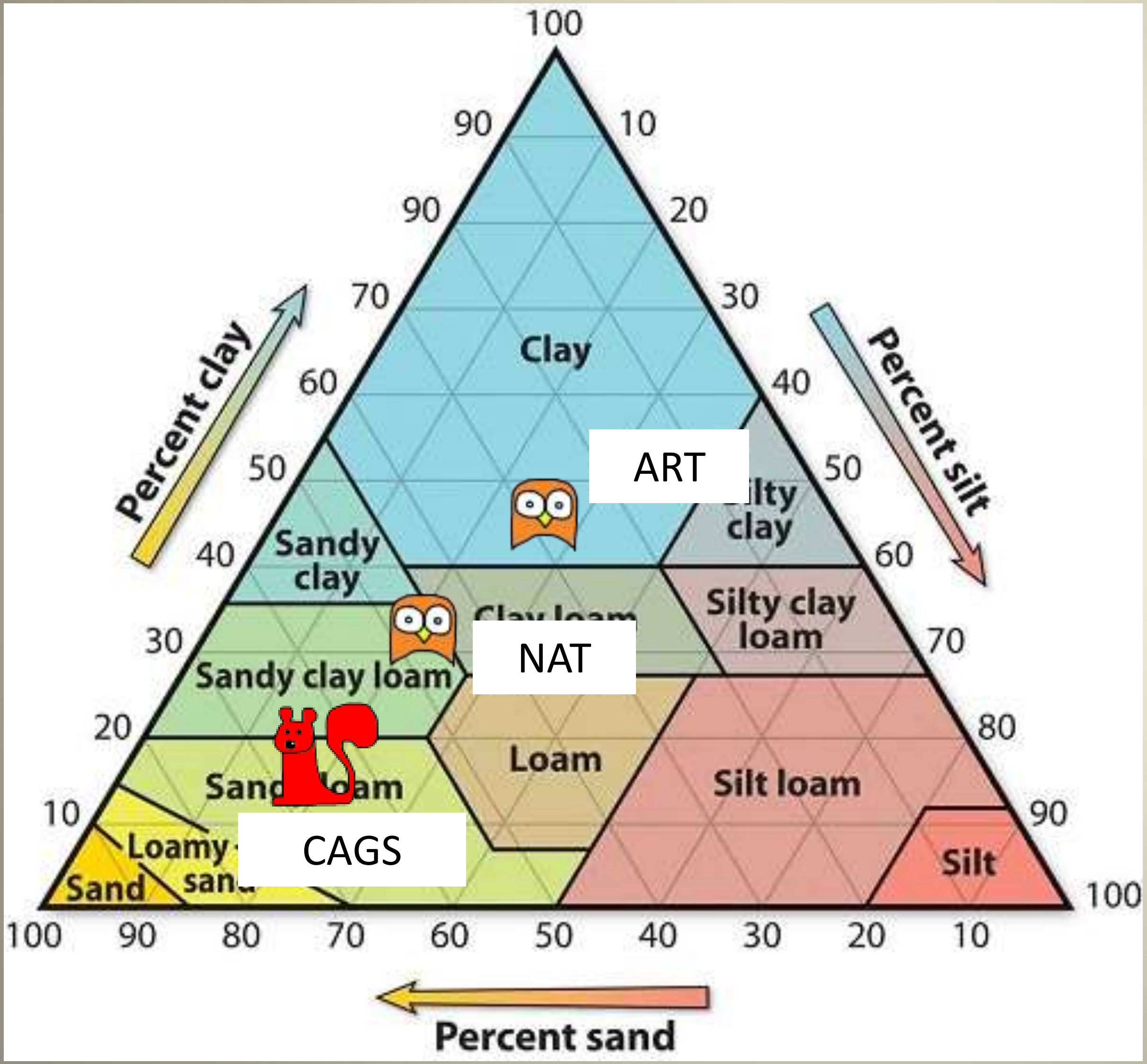
Vegetation surveys, substrate surveys, burrow and nearby habitat , camera traps

http://www.alphamach.com/product/ibutton-23/

Comparing habitat characteristics at natural and artificial BUOW burrows

- 45 active nests (19 natural, 26 artificial) across 6 sites (monitored with camera traps)
- Same habitat variables collected as CAGS plots
- Total BUOW soil samples = 147

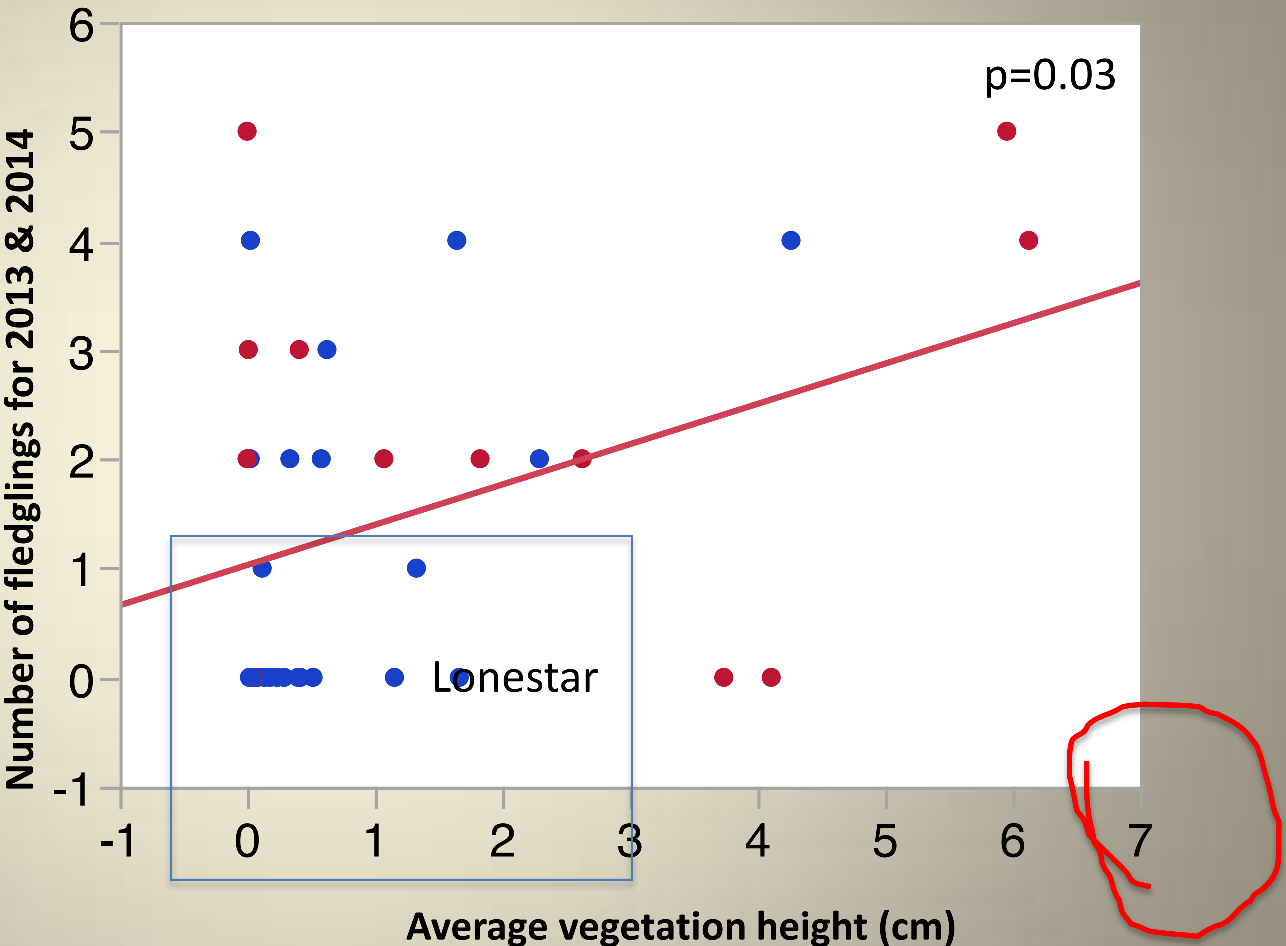
Soil texture differentiates burrow types



- CAGS and BUOW (natural burrows) have similar/ overlapping soil type
- Artificial BUOW burrows are being placed in sites with higher % clay and lower % sand.

Vegetation height affects fitness

- Natural burrows
- Artificial burrows

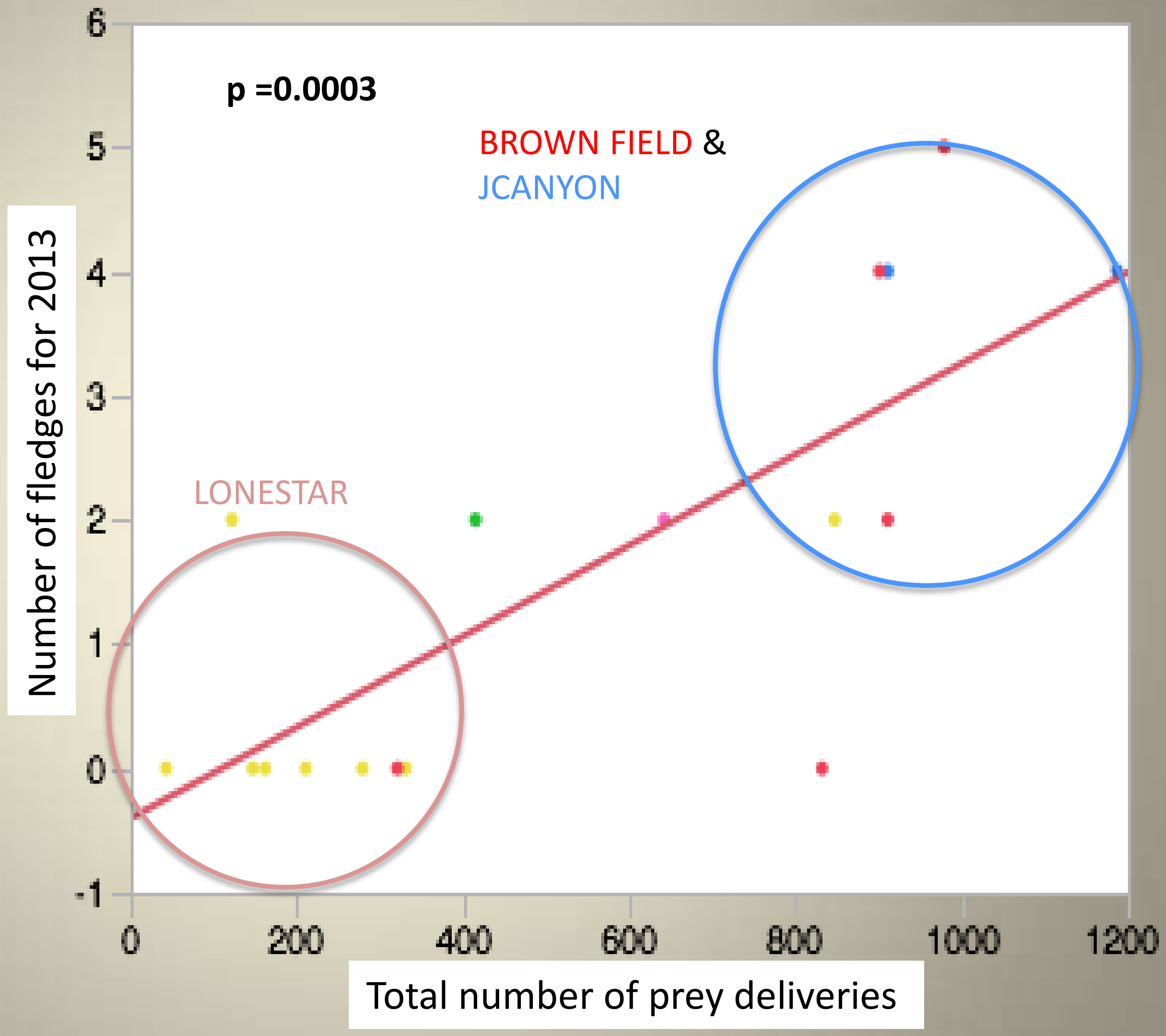


Low variation in veg height data: if too tall, fitness affects may be reversed


LONESTAR


JOHNSON CANYON

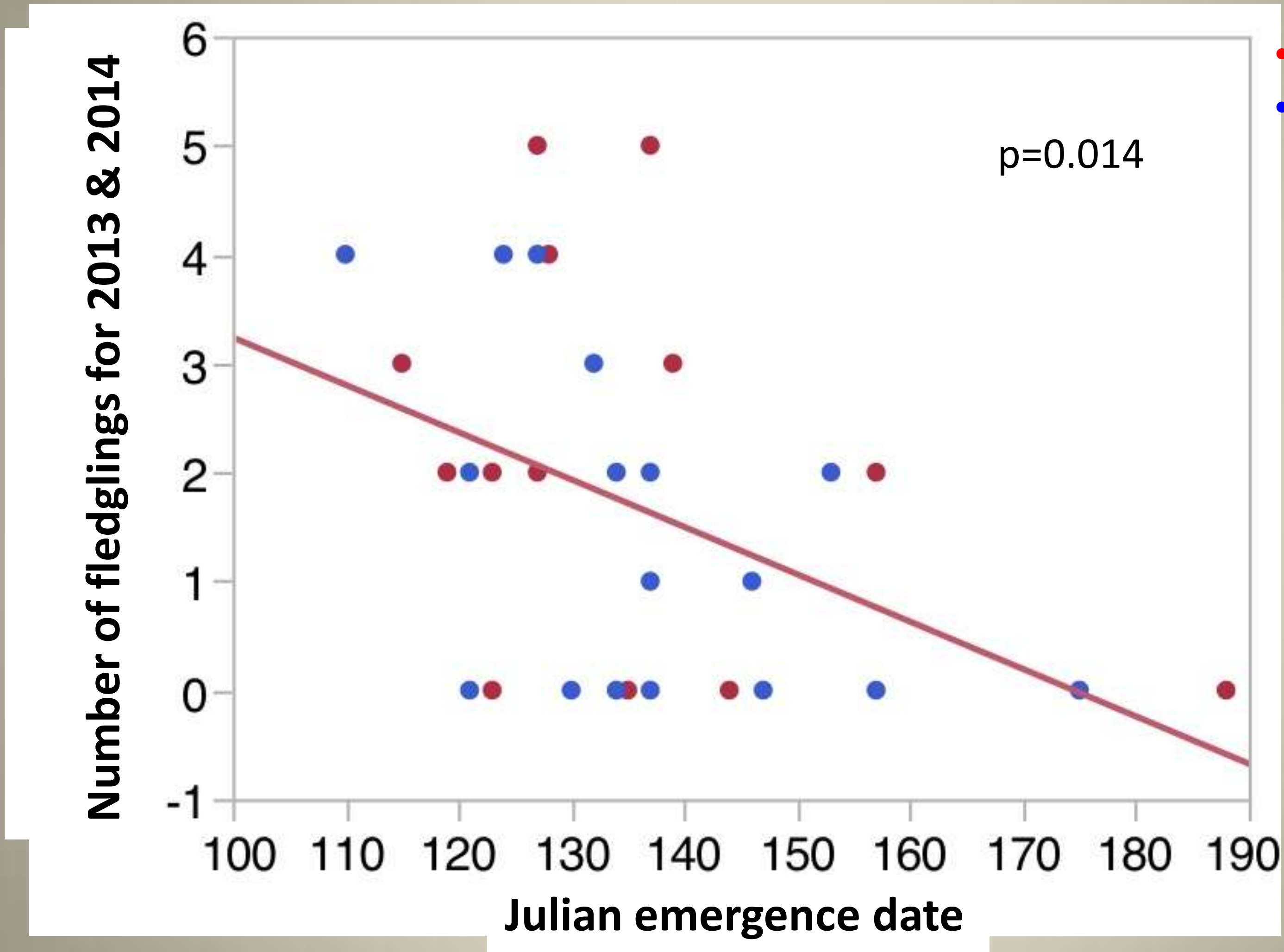
Prey delivery affects fitness



Hot off the press: spatial ecology

Daily foraging movements restricted to small area around burrows

Emergence date influence fitness

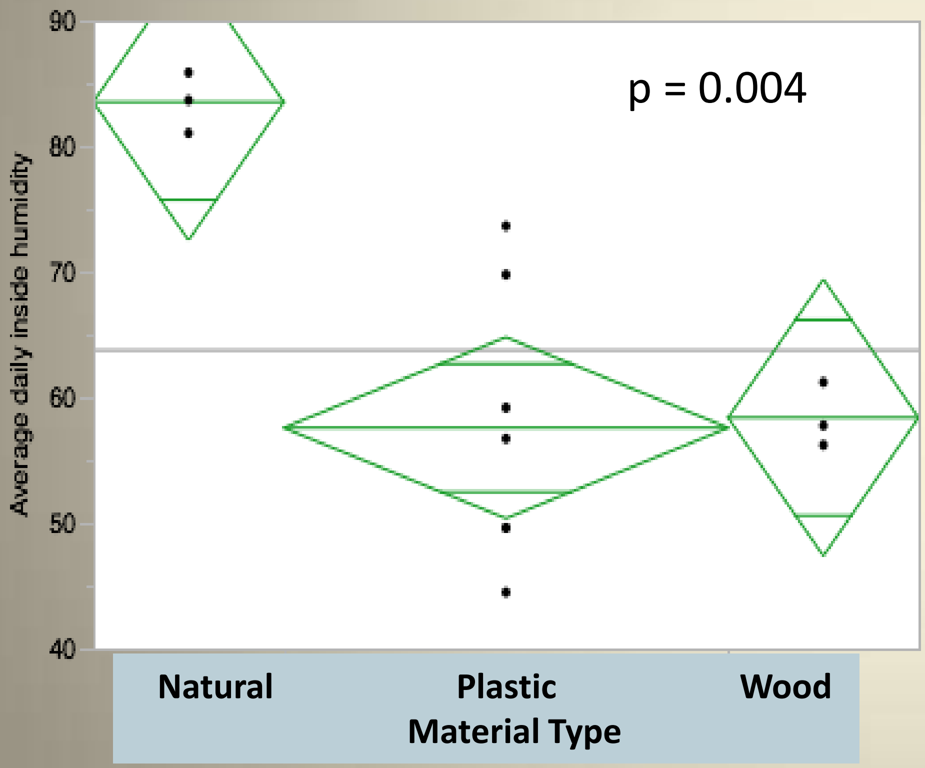


•Natural burrows
•Artificial burrows

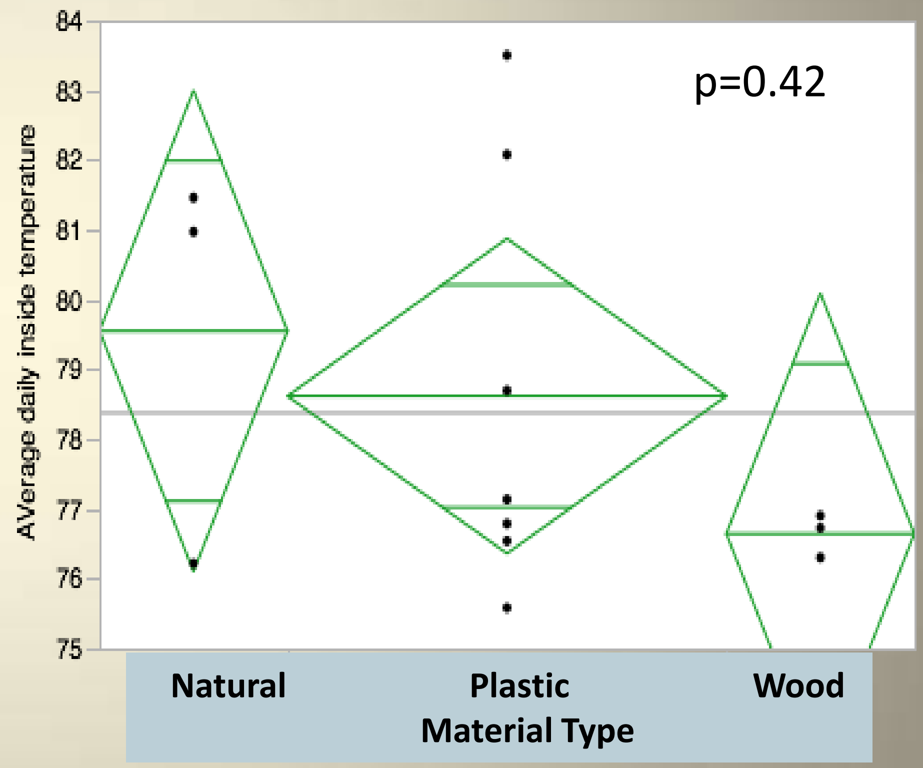
The early bird gets the fitness: implications for climate change?

Microclimate inside the burrow

ANOVA of Average Daily Inside Humidity

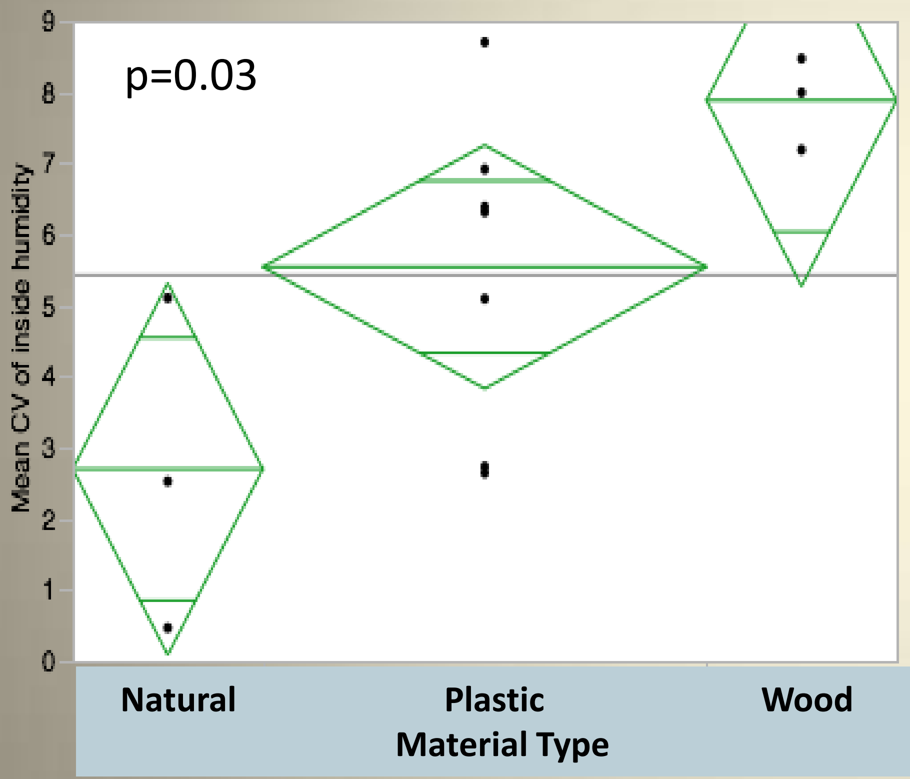


ANOVA of Average Daily Inside Temperature

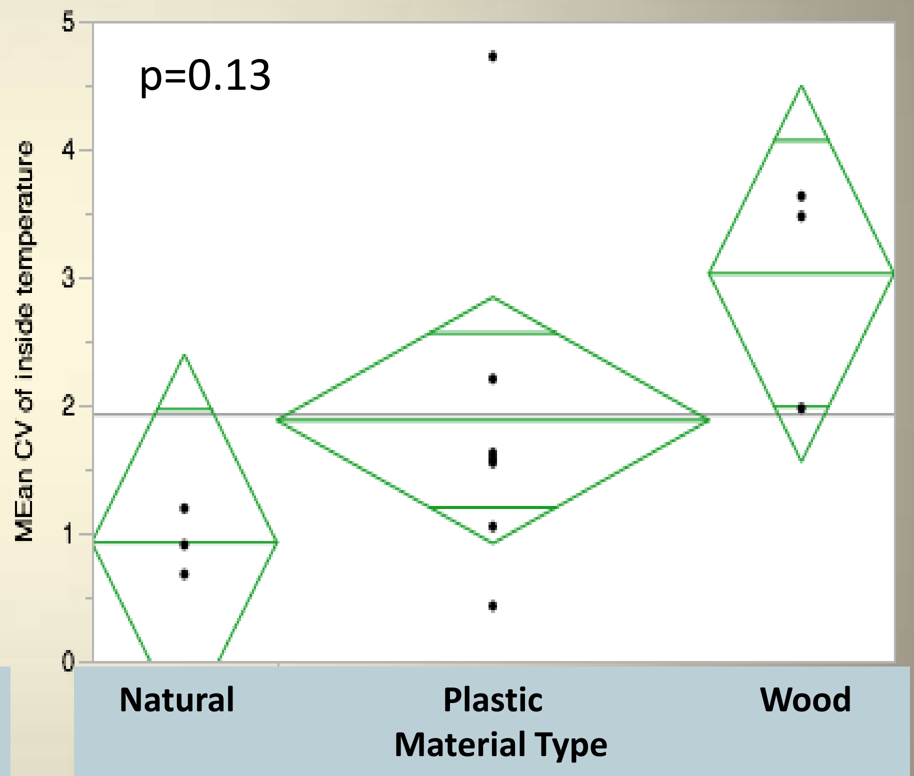


Microclimate variation inside the burrow

ANOVA of Mean Variation of Daily Inside Humidity



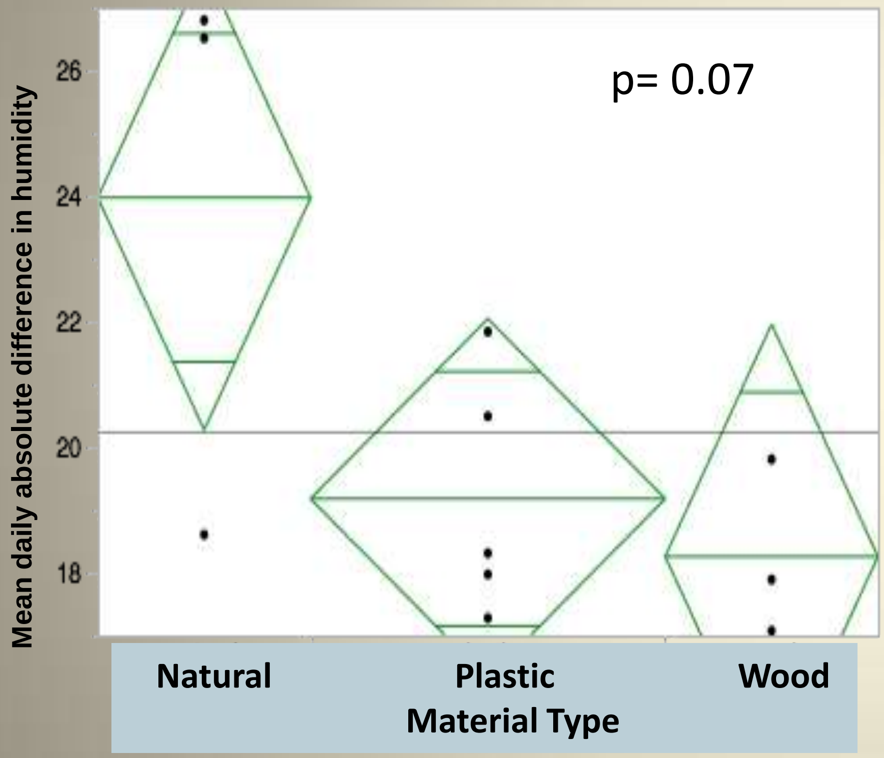
ANOVA of Mean Variation of Daily Inside Temperature



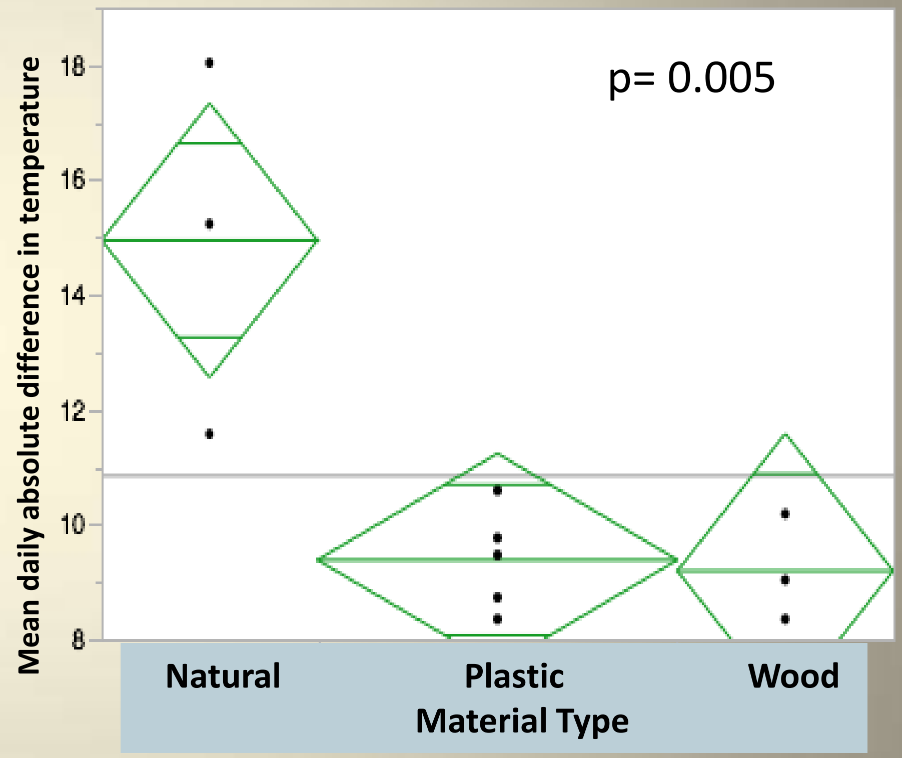
Natural burrows buffer against extreme temperature fluctuations

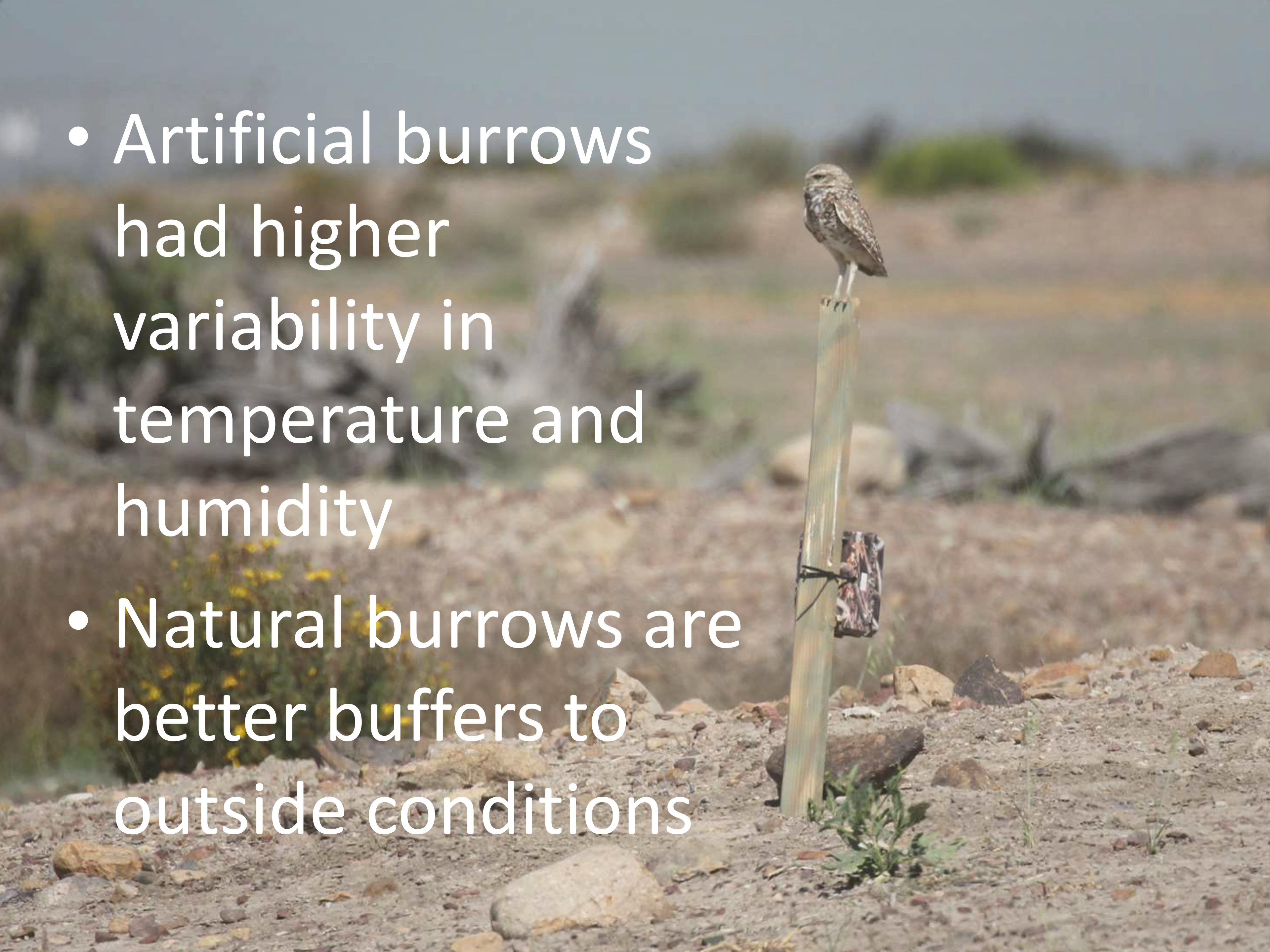
Buffering Effect of Burrow Types

ANOVA of mean daily differences between the outside and inside humidity



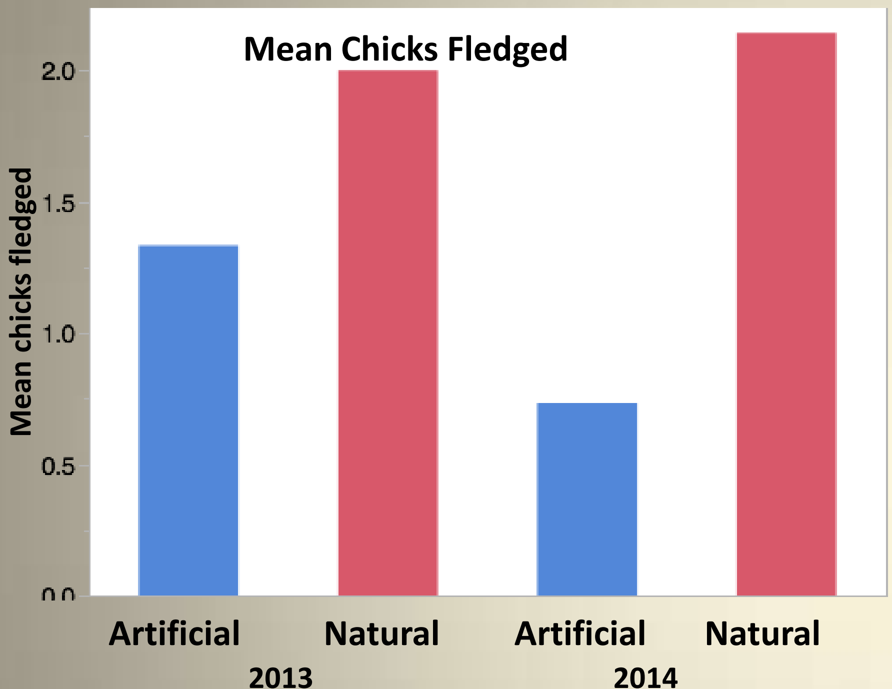
ANOVA of mean daily differences between the outside and inside temperature





- Artificial burrows had higher variability in temperature and humidity
- Natural burrows are better buffers to outside conditions

Natural Burrows Are Best



- Natural burrows are more productive
- Have a better buffering effect

<u>Manage for squirrels!</u>

Considerations when placing artificial burrows

- Vegetation: structure and prey availability
- Nearby disturbance → Future GIS research
- Possibility of ecological traps

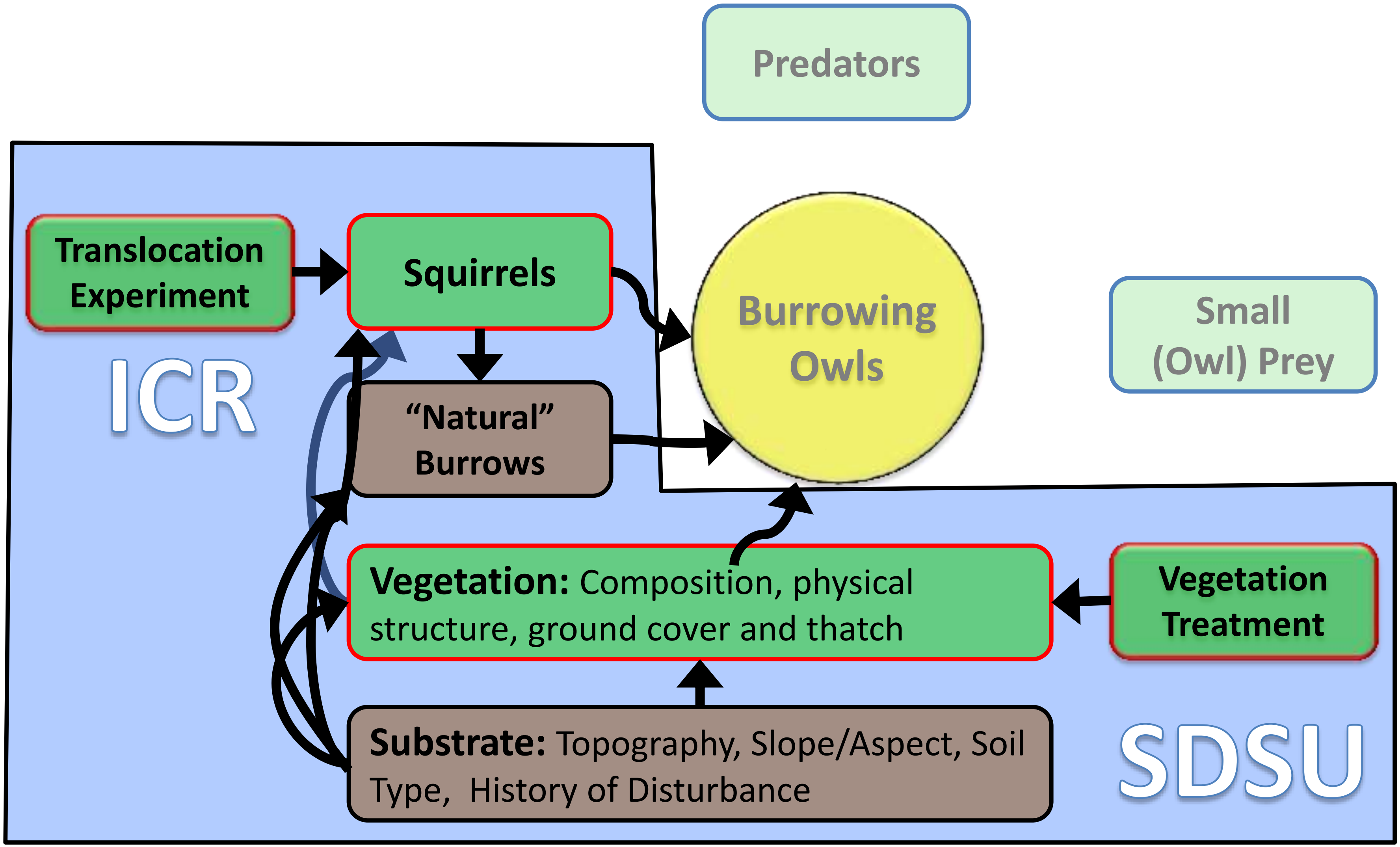
Management Implications

- Better understanding of local population drivers and threats
- Identifying sites for protection or restoration for BUOW
- Prioritization for fossorial mammal re-establishment
- CAGS translocation protocols
- Site selection for successful CAGS establishment or translocation
- Site selection for artificial burrow installment

Squirrels and owls living together

- The beginnings of a conservation toolkit for managing the species

Conceptual Model for Management Experiment



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