Welcome to the Conservation Lecture Series

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- Watch videos of past lectures

Questions? Contact
margaret.mantor@wildlife.ca.gov

Lectures in April

- **Cactus Wren, Dr. Kristine Preston**

  April 17, 1:00-3:00, San Diego
- **Alameda Striped Racer, Karen Swaim**

  April 24, 1:00-3:00, Sacramento
- **California Tiger Salamander, Dr. Chris Searcy**

  April 28, 1:00-3:00, Sacramento
- **Shasta Crayfish, Dr. Maria Ellis**

  April 29, 10:00-11:30, Redding

California's native and nonnative red foxes

photo by K. Aubry, USFS

photo by B. Sacks

photo by A. Rich, USFS

Benjamin N. Sacks

Mammalian Ecology and Conservation Unit

Center for Veterinary Genetics

Dept. Population Health and Reproduction

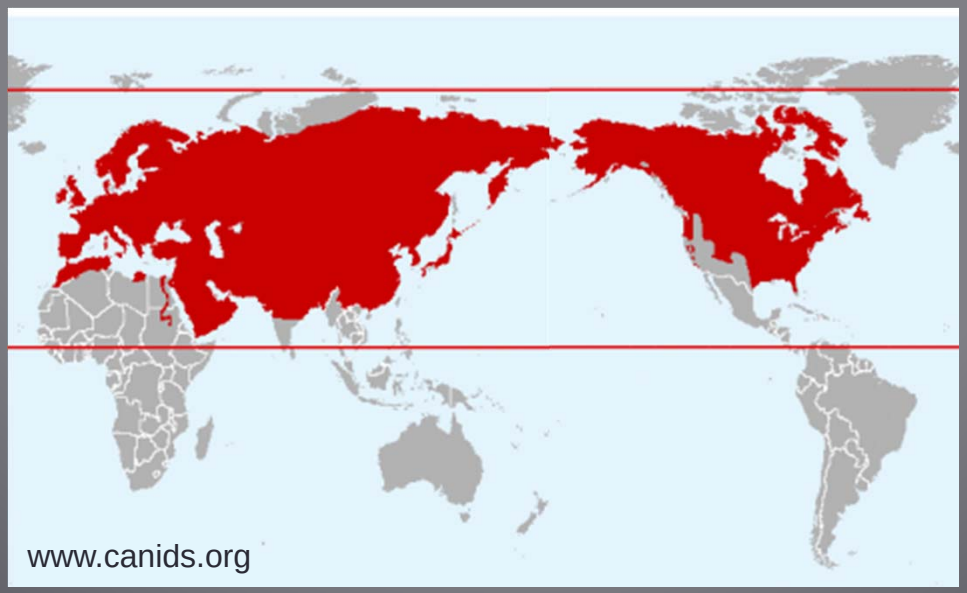
UC DAVIS VETERINARY MEDICINE

Overview

- Biogeography
- California's 3 red foxes
- Population trends and status
- Sacramento Valley red fox research
- Sierra Nevada red fox research

Biogeography and taxonomy

- Evolved in Africa and Eurasia
- Fossil record: arrival in North America 0.5–0.3 MYA
- Until 1959, was considered *Vulpes fulva* in NA
- Currently considered conspecific with Eurasian *V. vulpes*



DNA as a tool

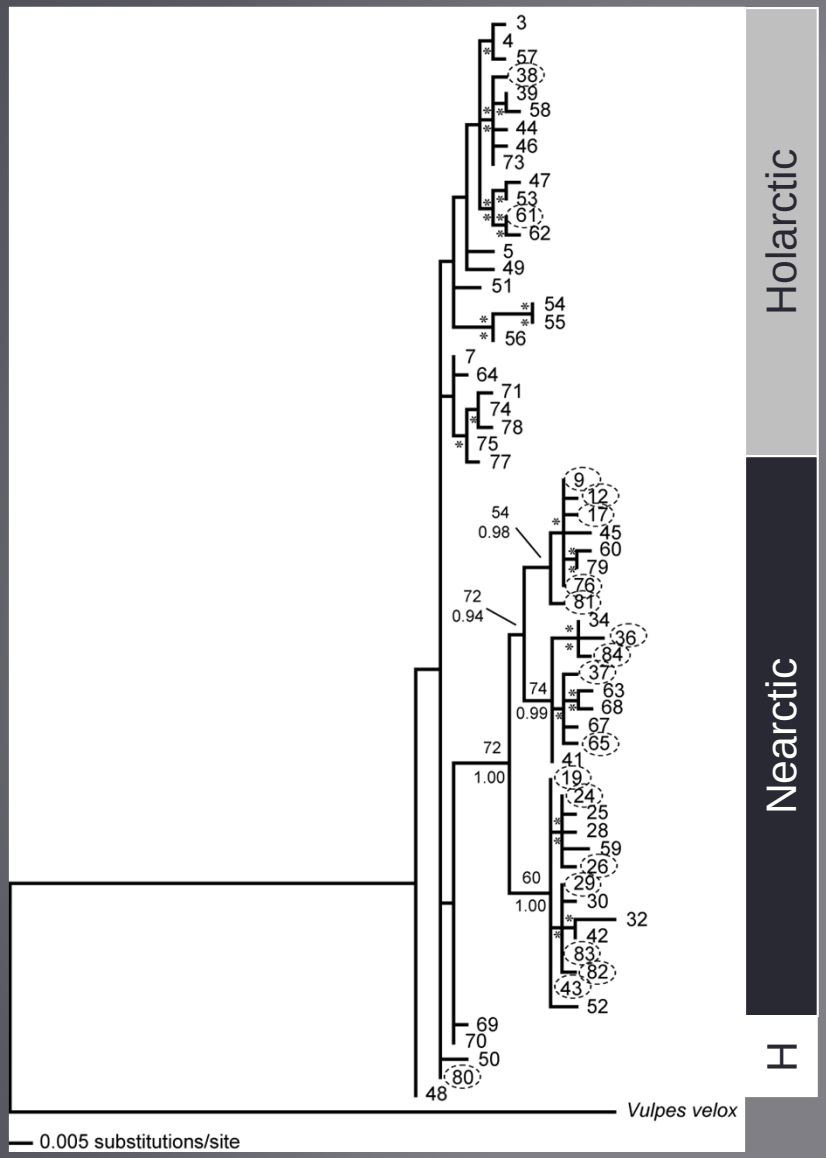
Mitochondrial

- Cytoplasmic
- Maternal inheritance
- 16,000+ base-pairs
- 100% inherited together
- Mutations accumulate over time (molecular clock)
- Great for reconstructing ancestry (maternal evolutionary trees)
- but can be misleading…

Nuclear

- Nucleus (chromosomes)
- Biparental inheritance
- ~3 billion base-pairs (x2)
- Randomly inherited genes
- Each gene has different ancestral history
- Statistical averaging necessary (species trees)
- Great for population assignment, parentage, individual fingerprints, etc.

Mitochondrial tree



Eurasia and
NW North America

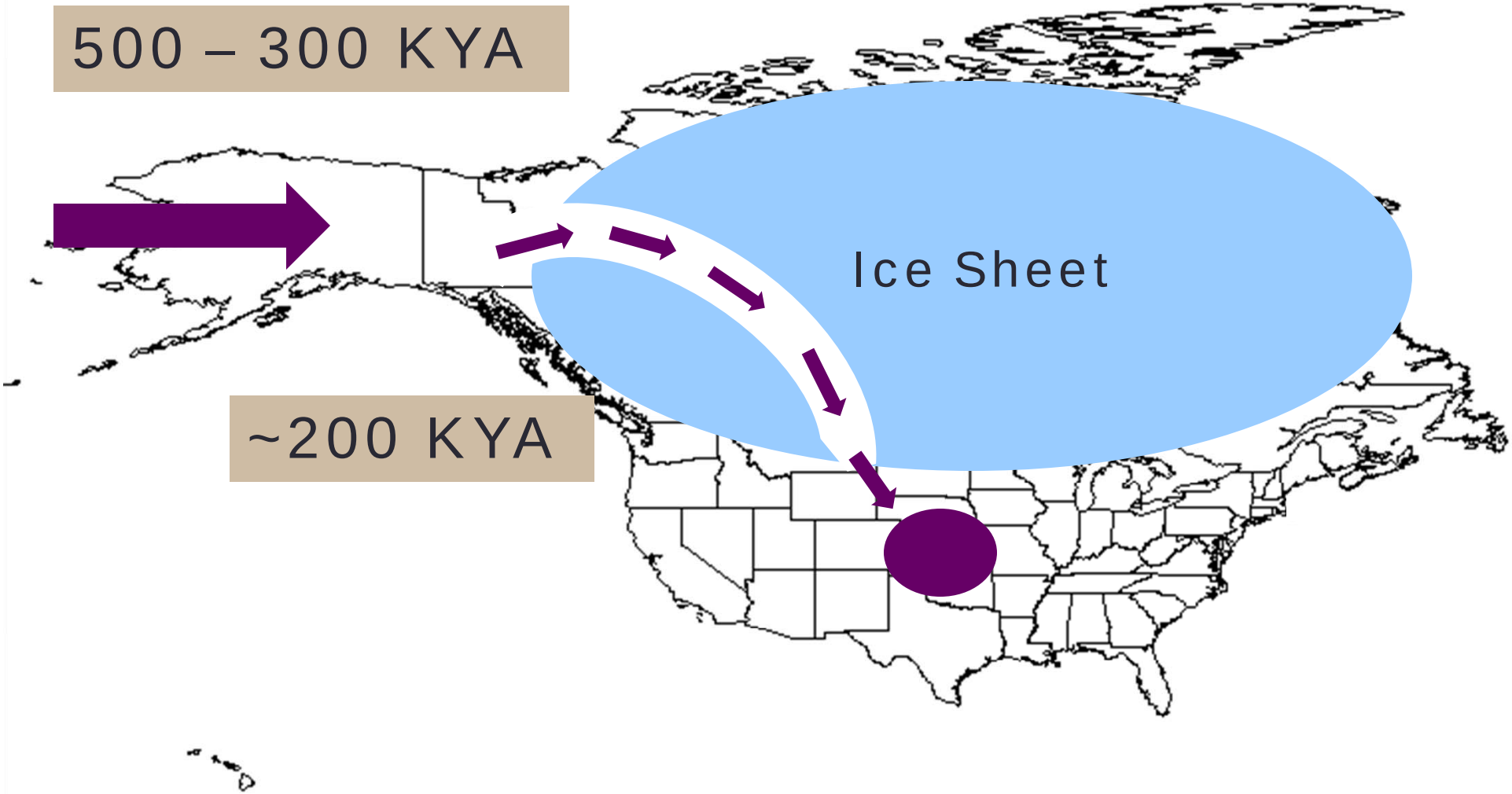
North America Only

Clades separated by
300,000 years

Aubry et al. 2009

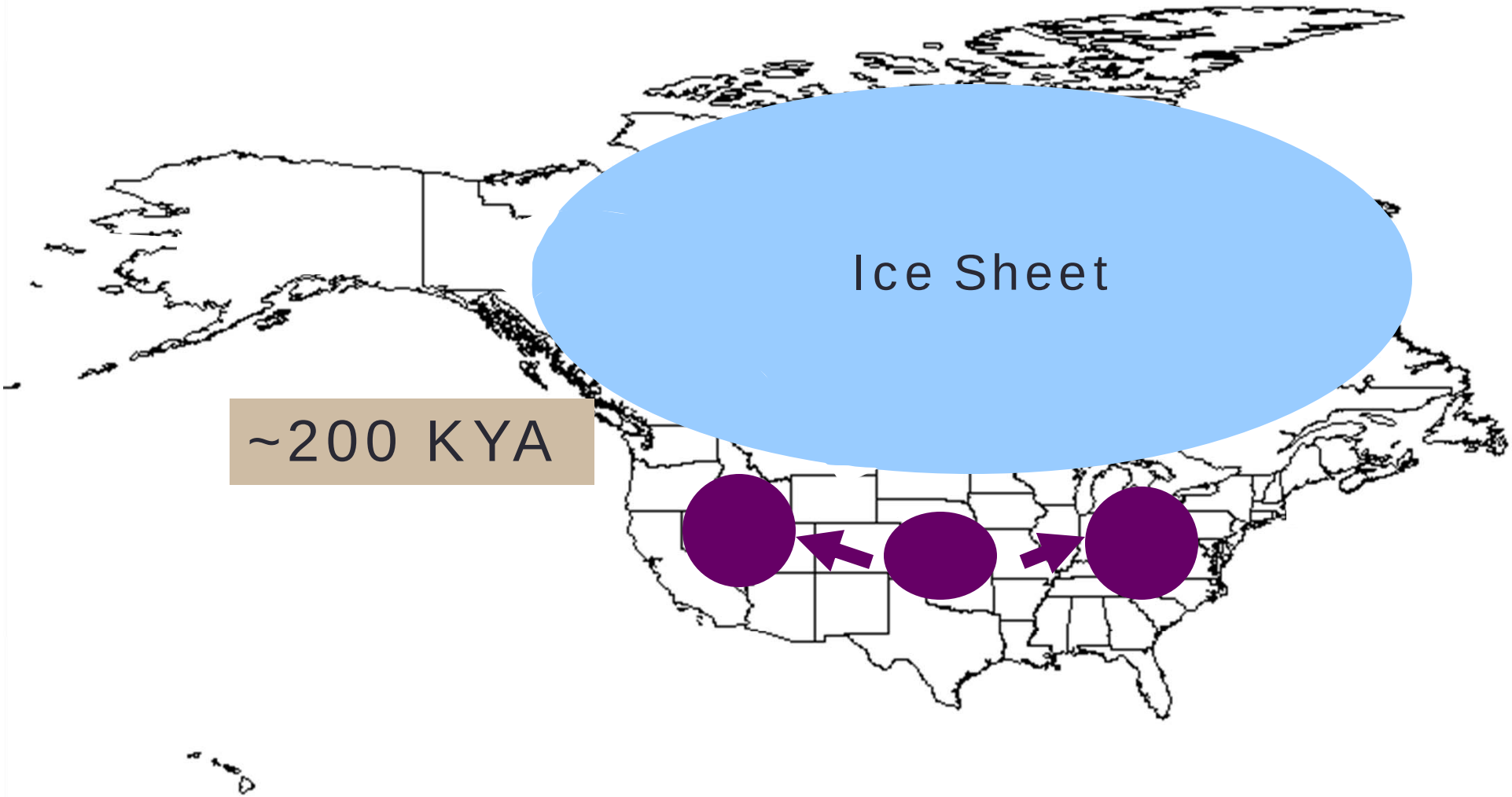
(slide by Marcelle Moore)

Native Red Foxes



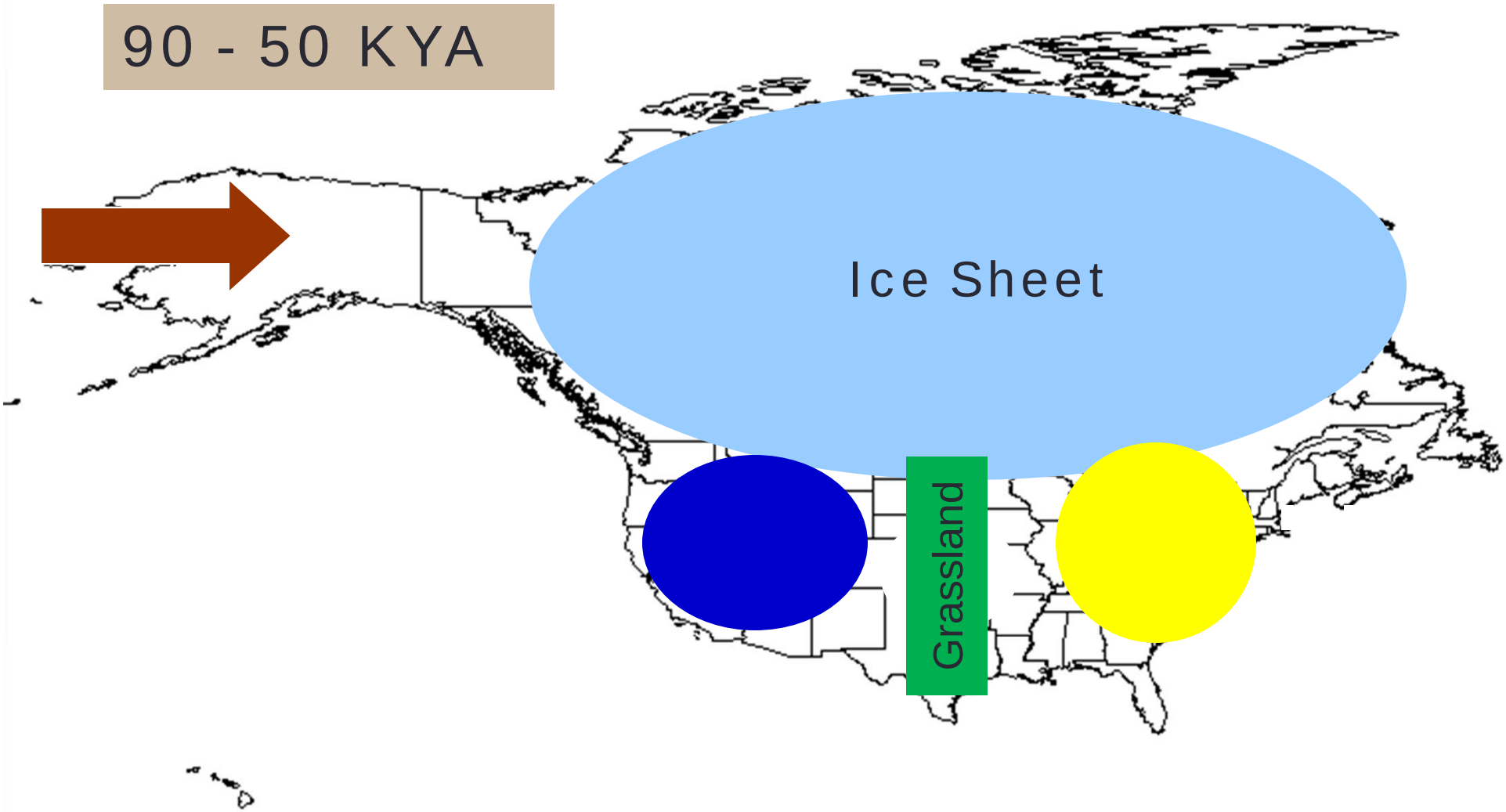
(slide by Marcelle Moore)

Native Red Foxes



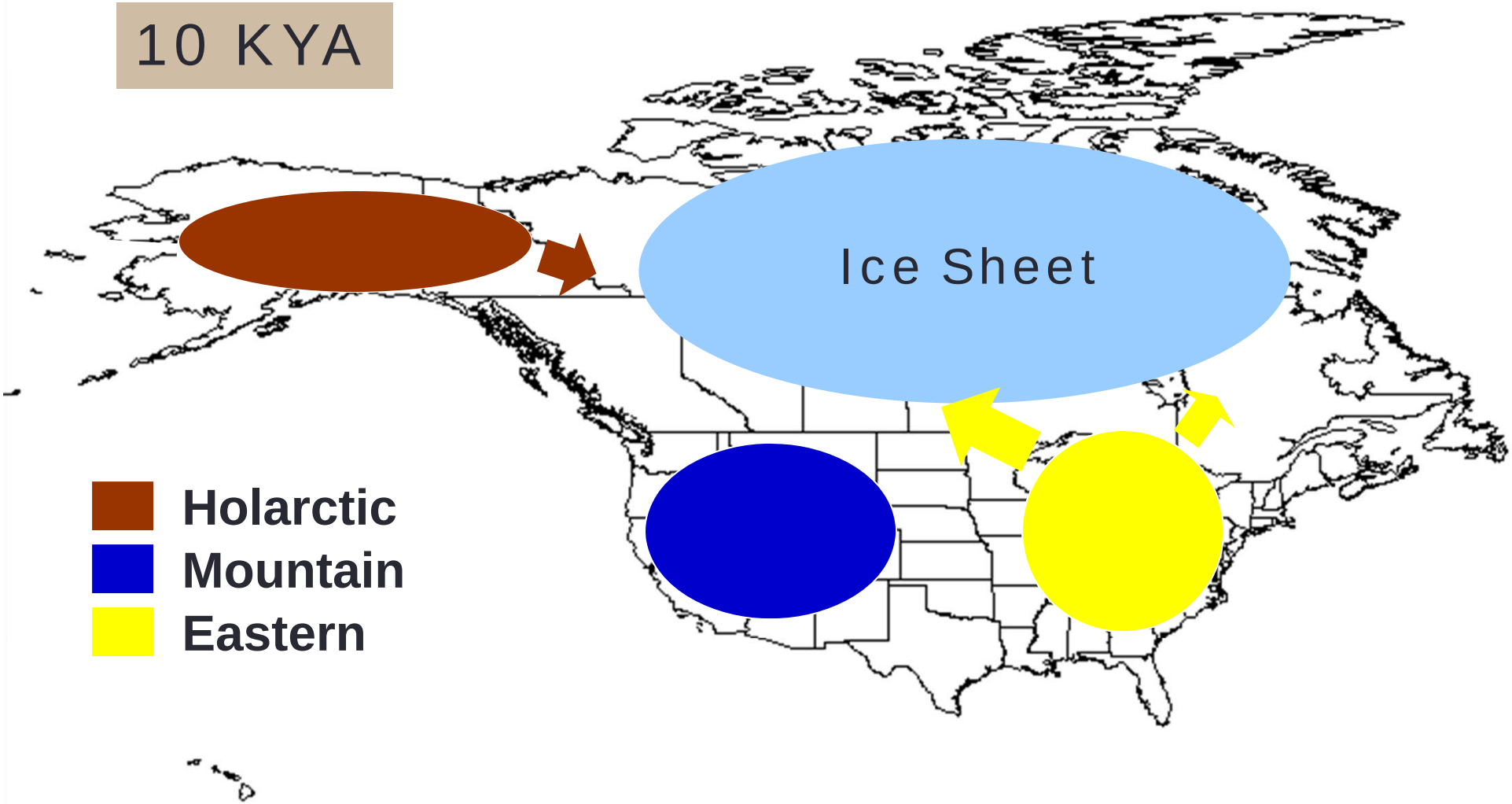
(slide by Marcelle Moore)

Native Red Foxes

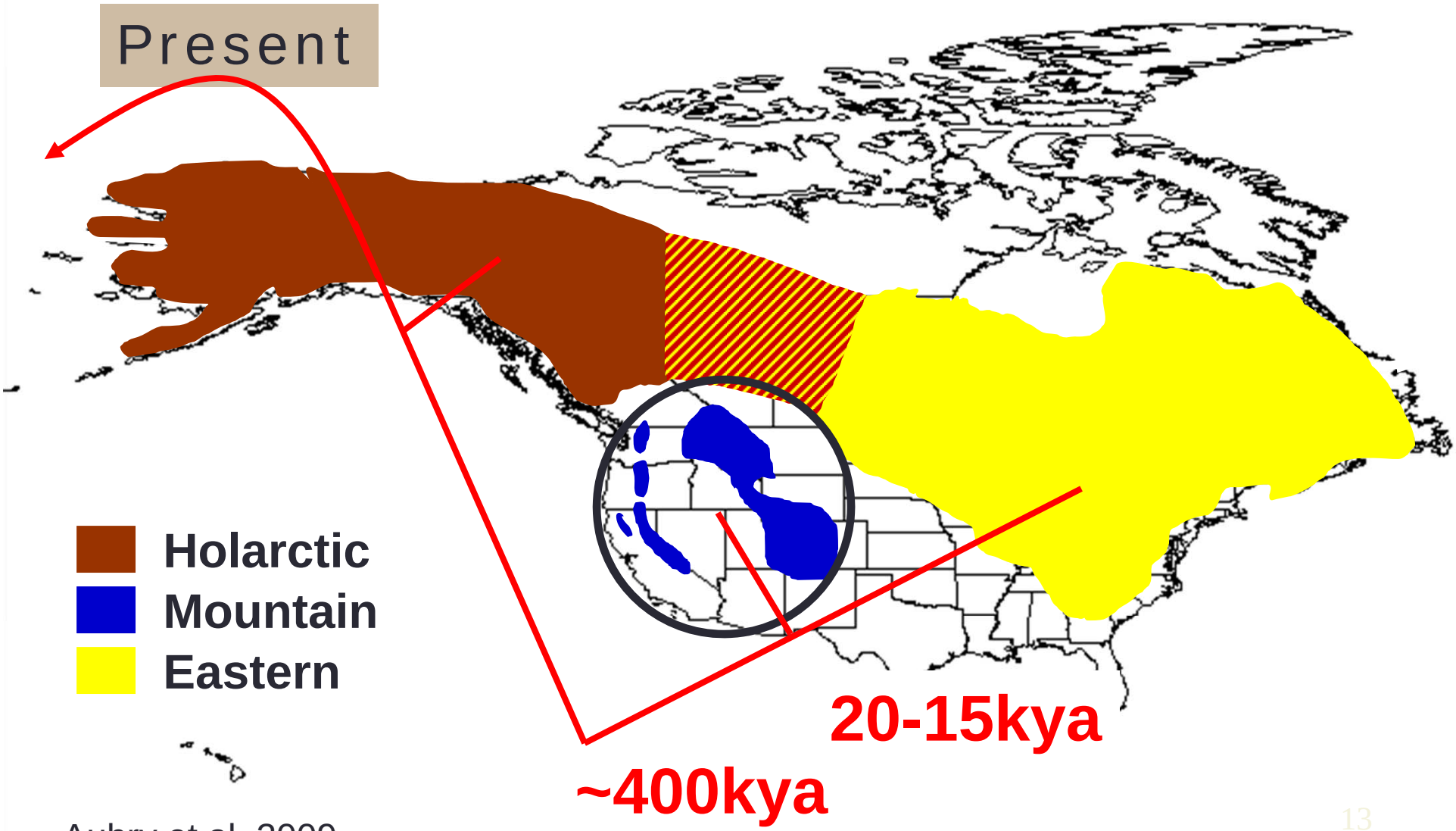


(slide by Marcelle Moore)

Native Red Foxes

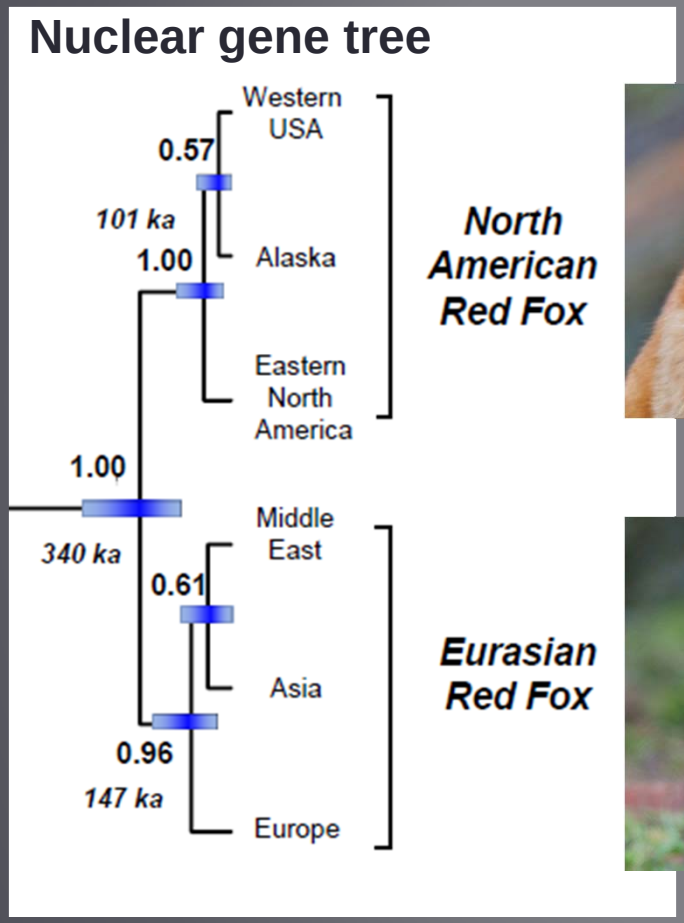


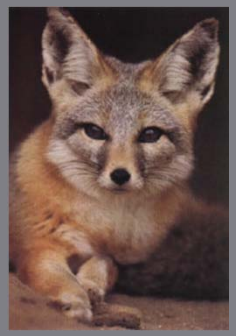
Native Red Foxes



Aubry et al. 2009

North American red foxes could be distinct species from Eurasian/African ones





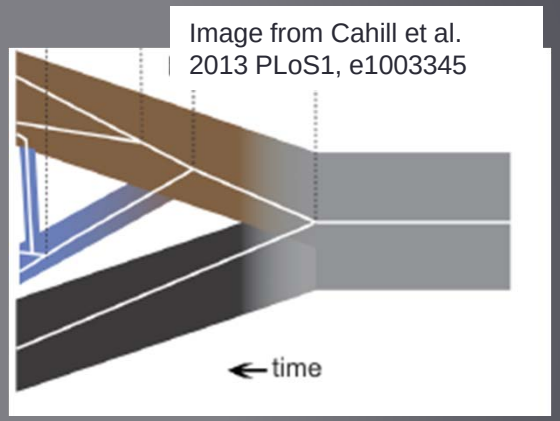


Image from Cahill et al. 2013 PLoS1, e1003345

Statham et al. in review

California's 3 red foxes

photo by B. Sacks, Sacramento Valley red fox, Yolo County

photo by A. Rich, USFS, Sierra Nevada red fox, Tuolumne Countly

photo by Jim Wiley, San Francisco Bay area non-native

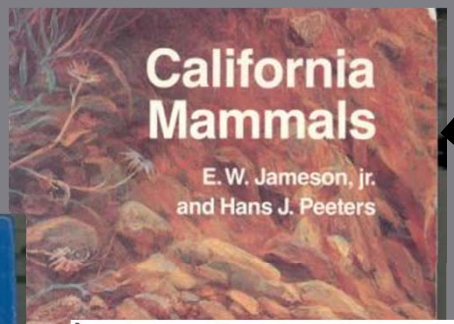
Sacramento Valley?

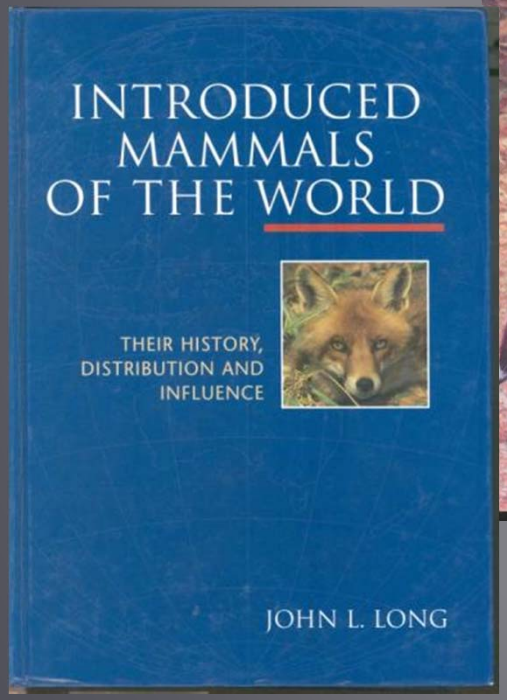
- Present since 1880
- VERY different habitat
- Origin?
- Roest: railway from east

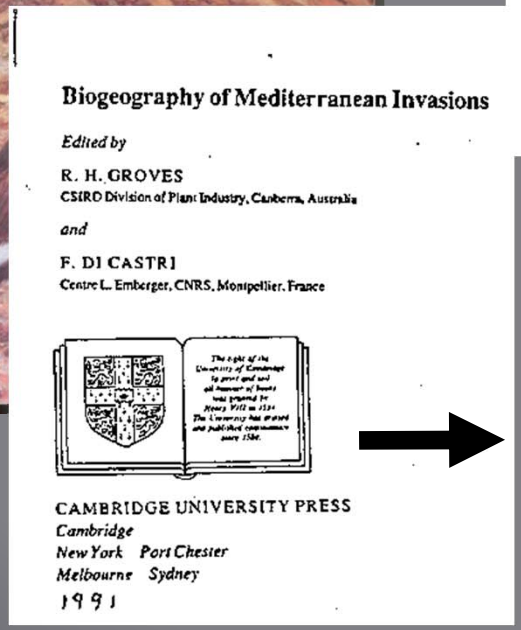
(*Range map approximate only; do not reference*)

Conventional wisdom

"Only the montane red fox is native to California. In the nineteenth century a population of the eastern red fox was introduced into the lowlands of the state."






Biogeography of Mediterranean Invasions

Edited by

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CSIRO Division of Plant Industry, Canberra, Australia

and

F. DI CASTRI
Centre L. Emberger, CNRS, Montpellier, France

CAMBRIDGE UNIVERSITY PRESS
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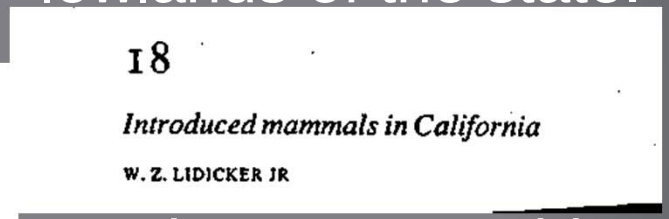
New York Port Chester
Melbourne Sydney
1991


18

Introduced mammals in California

W. Z. LIDICKER JR

"In about 1885…this species became established in the Sacramento Valley…almost certainly introduced from eastern North America…have now spread widely…"

Conventional view (1999)

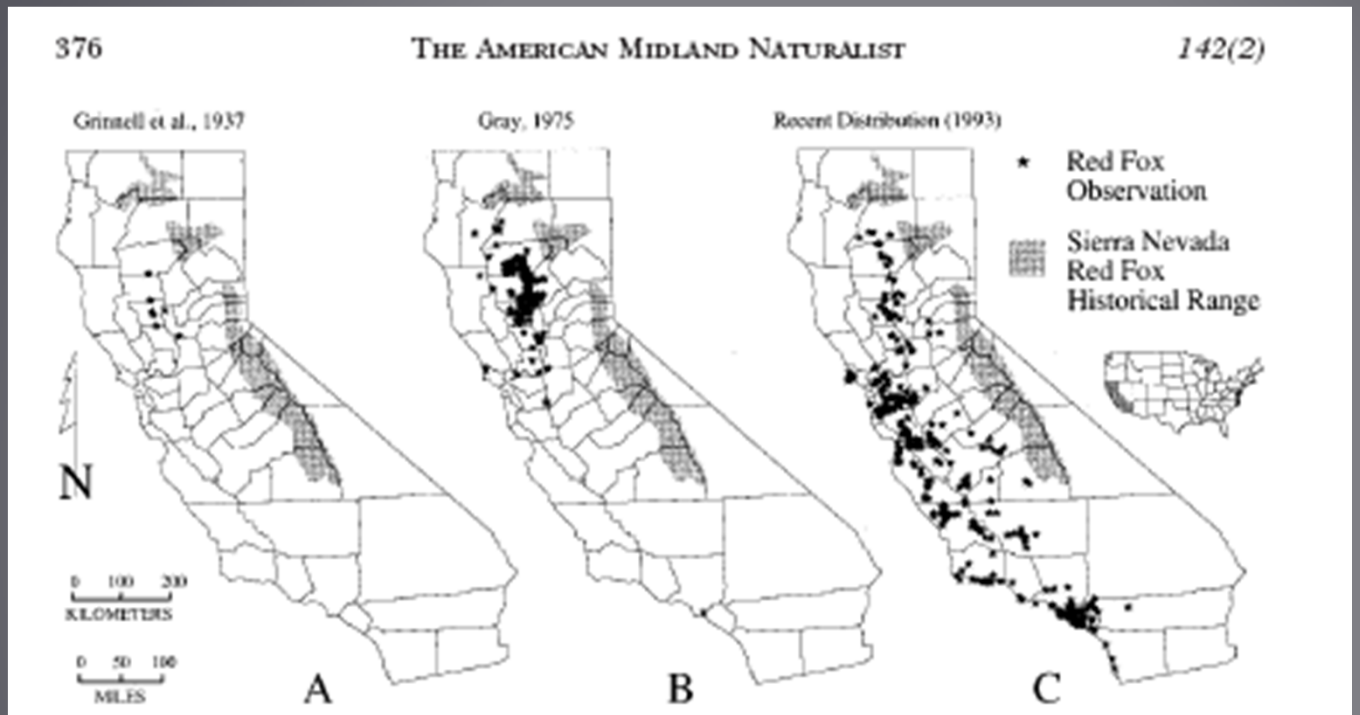
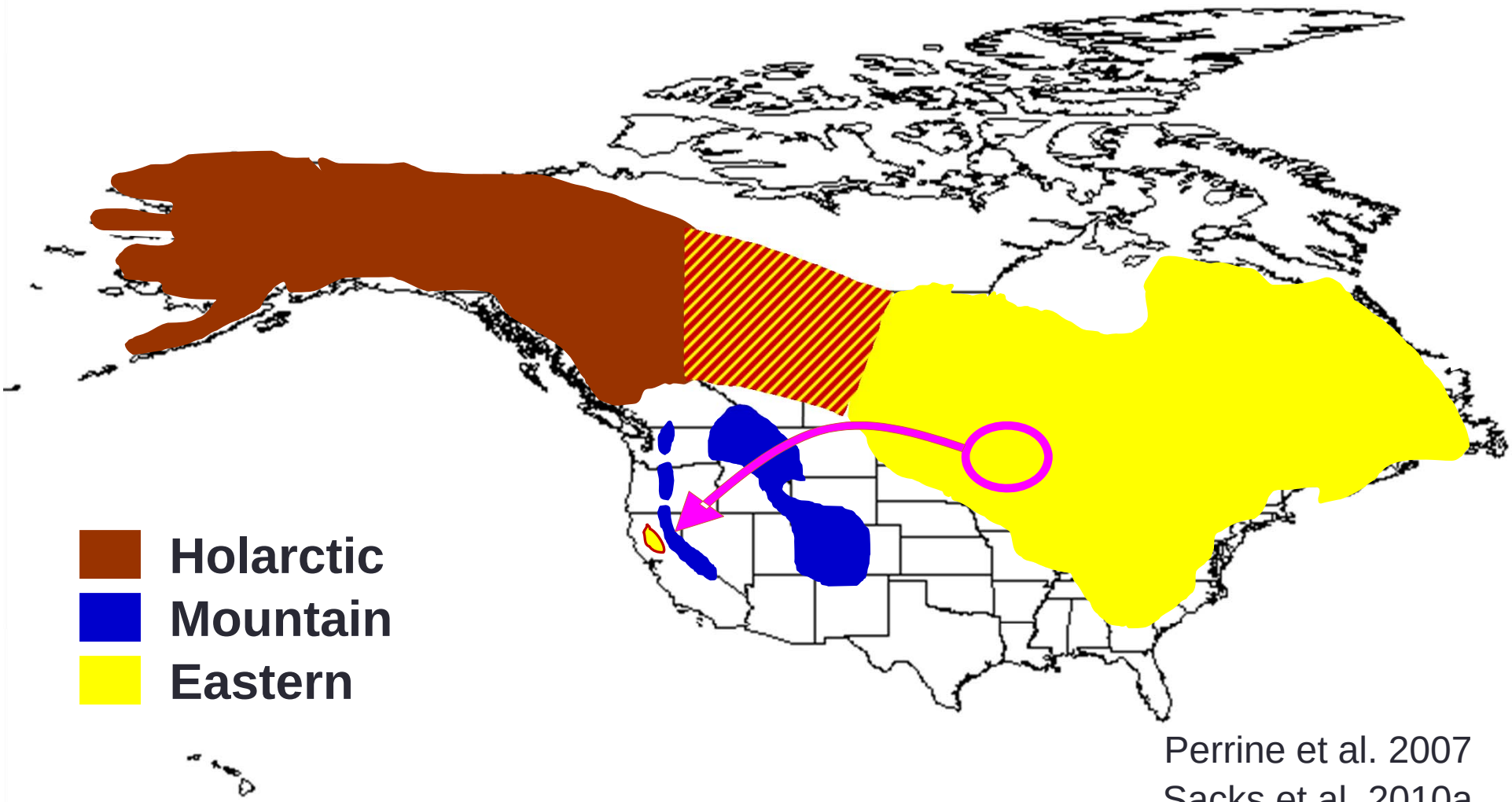


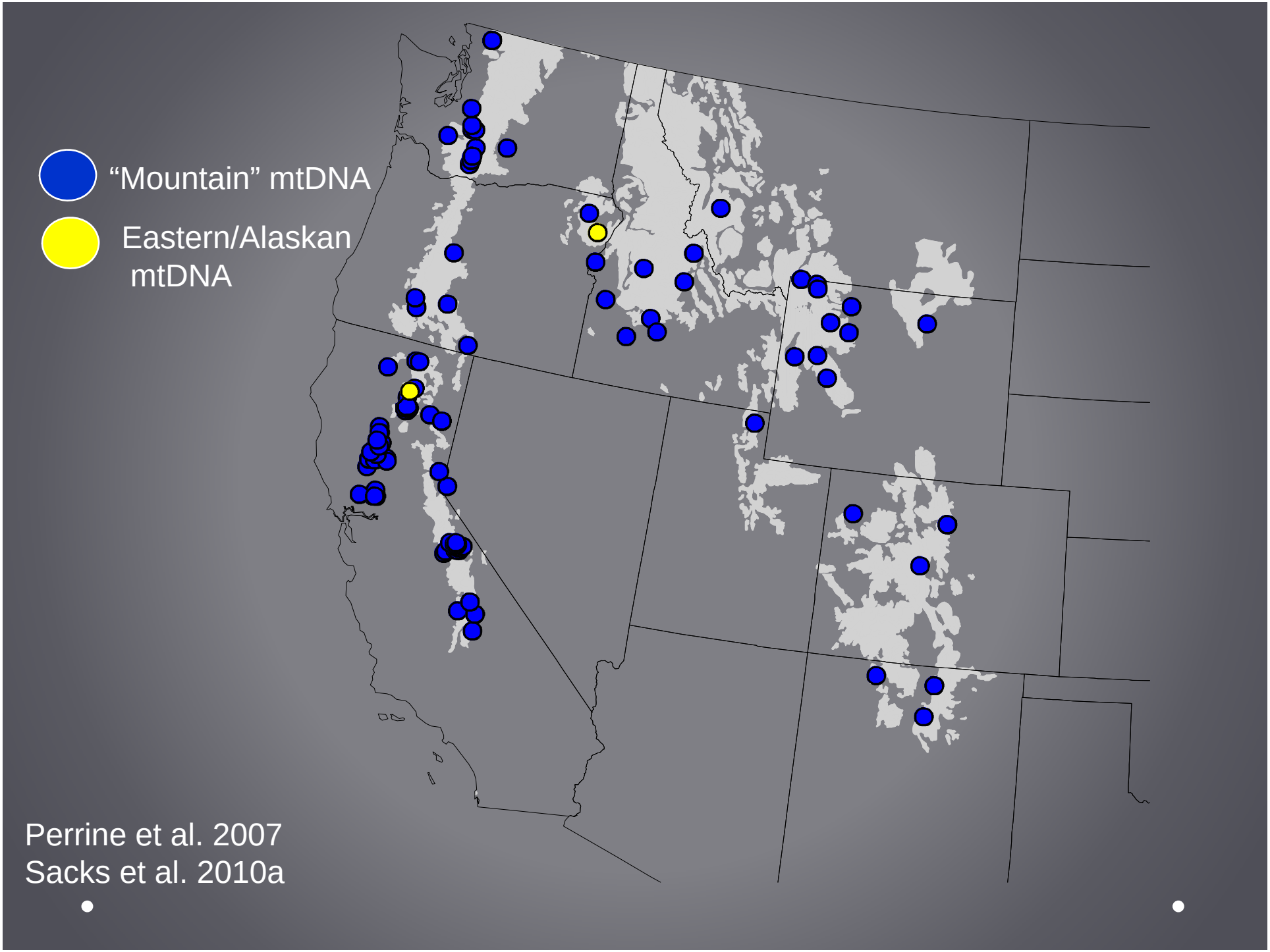
FIG. 2.—The range expansion of the nonnative red fox in California from A) Grinnell *et al.* (1937), B) Gray (1975) and C) the recent distribution (1993). The star in the southern portion of the Gray (1975) distribution represents a small satellite population of foxes in the City of Long Beach in Los Angeles County. The historical range of the Sierra Nevada red fox was described by Grinnell *et al.* (1937)

Lewis, J.C., K.L. Sallee, and R.T. Golightly, Jr. 1999. Introduction and range expansion of nonnative red foxes (*Vulpes vulpes*) in California. *American Midland Naturalist* 142:372-381.

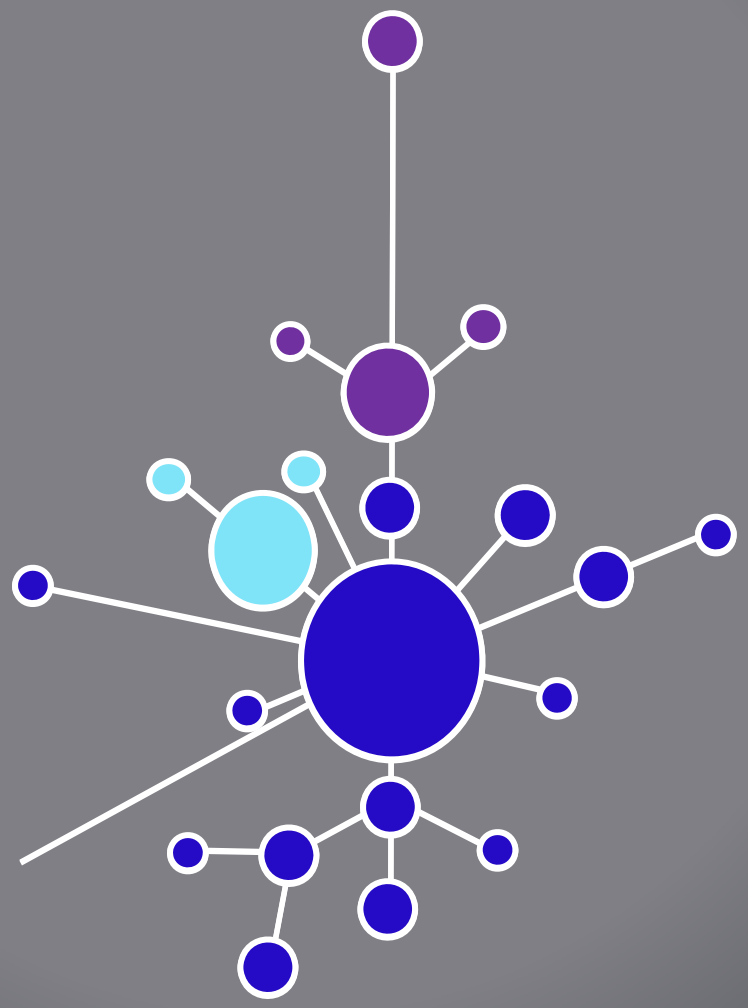


Perrine et al. 2007
Sacks et al. 2010a

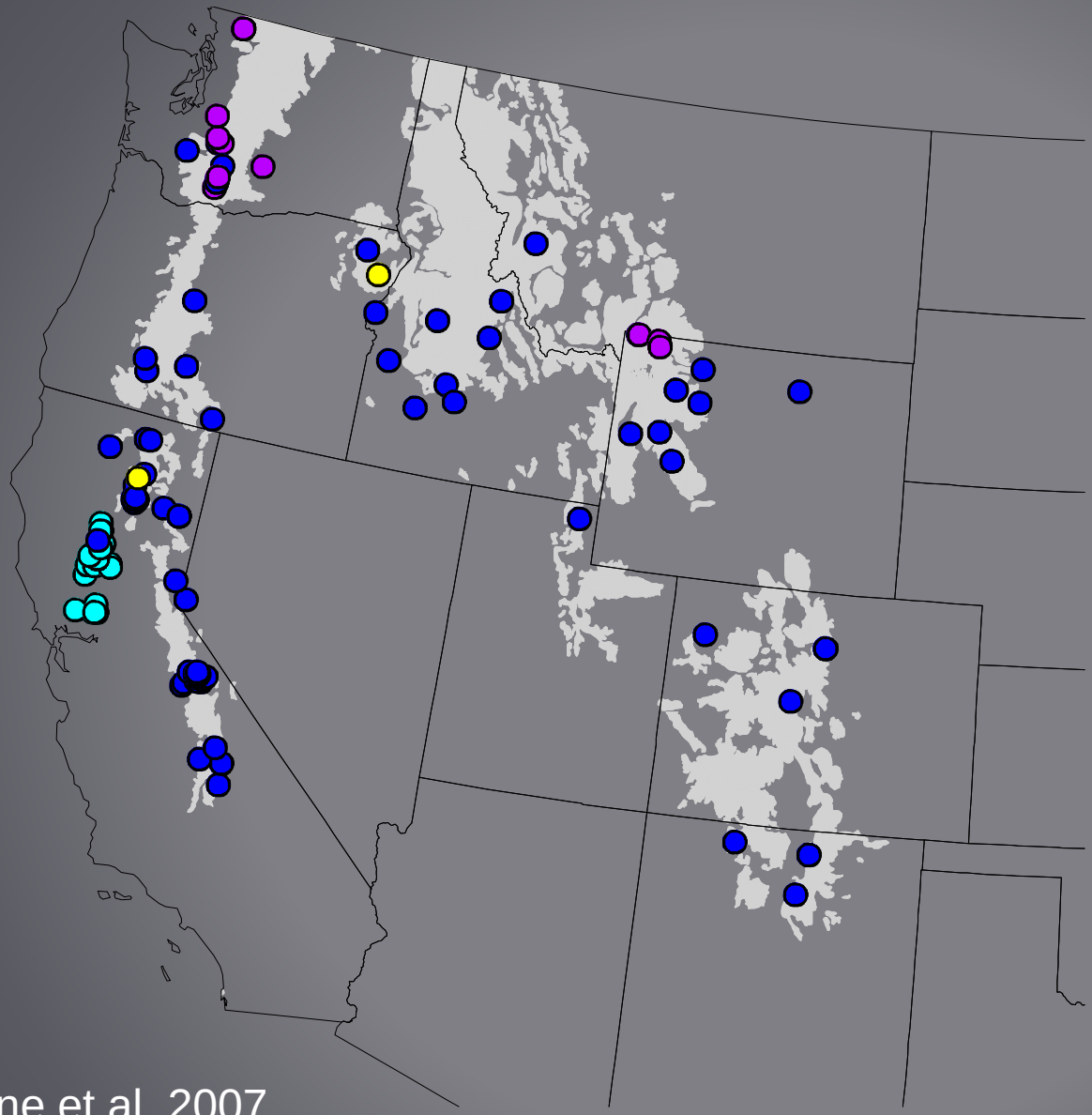
Historical (1850-1930) Modern (2000-2008)

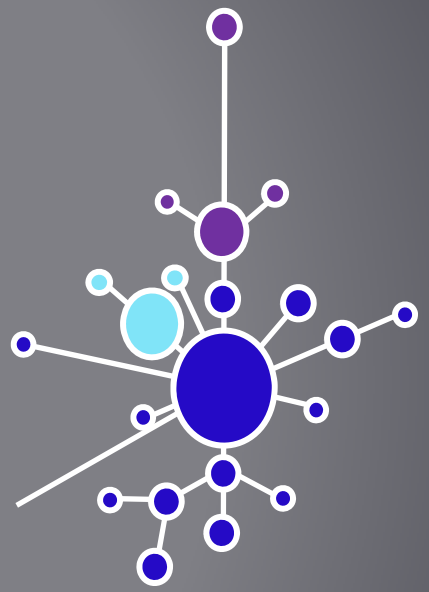

"Mountain" mtDNA
Eastern/Alaskan mtDNA
Perrine et al. 2007
Sacks et al. 2010a

“Mountain mtDNA”



Perrine et al. 2007
Sacks et al. 2010a





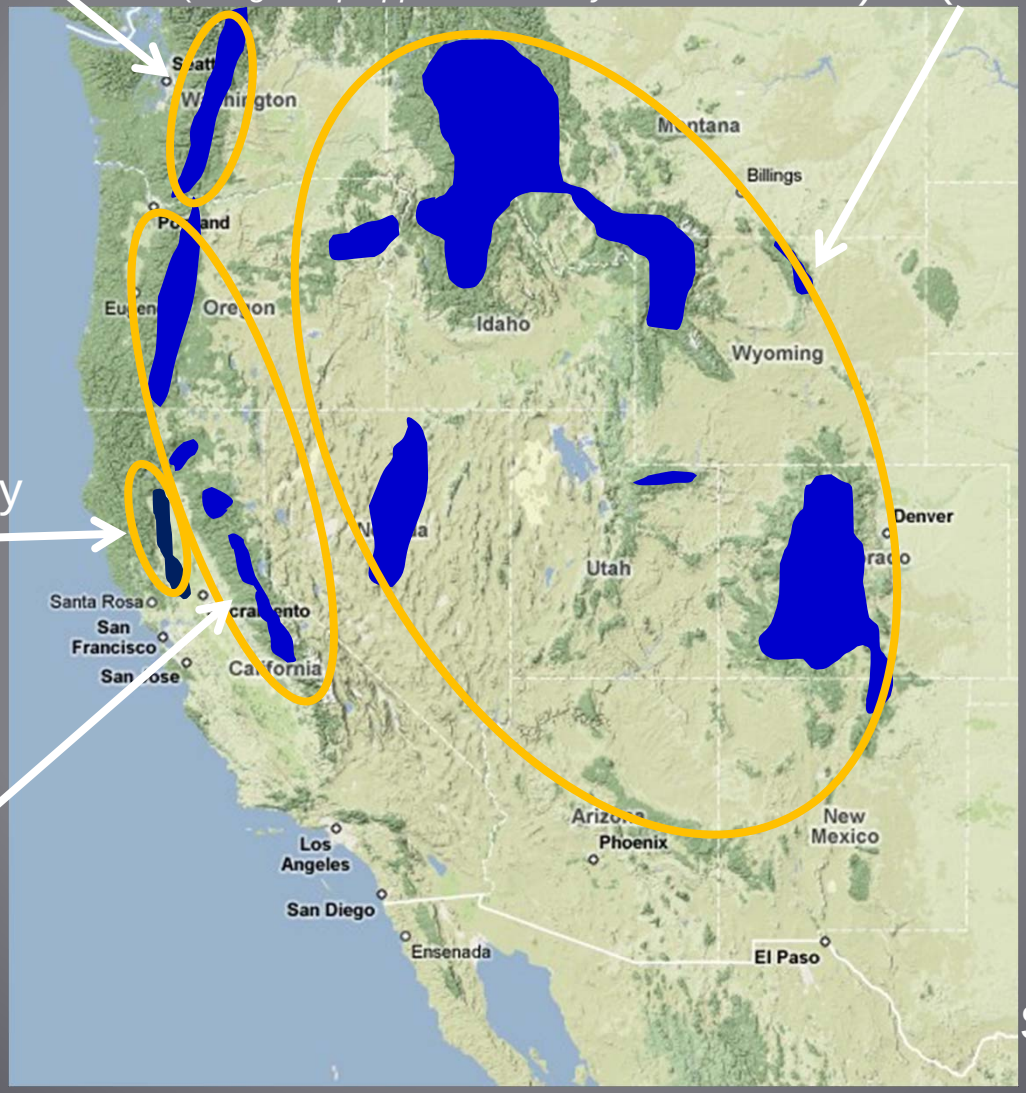
Perrine et al. 2007
Sacks et al. 2010a

Native subspecies of western red foxes

Washington Cascades red fox
(*V. v. cascadensis*)

(*Range map approximate only; do not reference*)

Rocky Mountain red fox
(*V. v. macroura*)



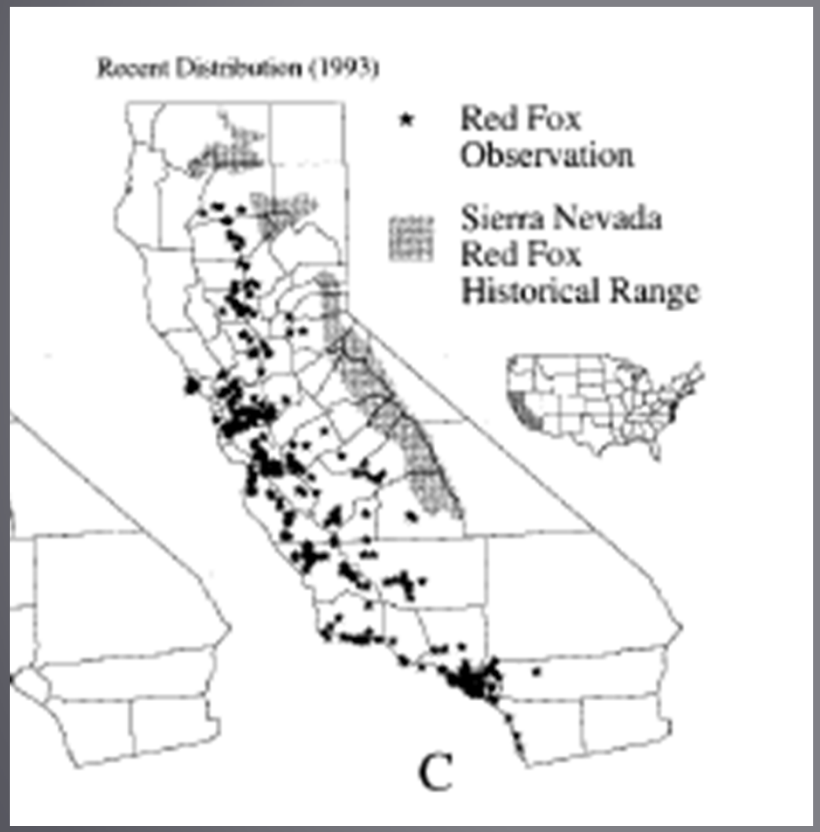
Sacramento Valley red fox
(*V. v. patwin*)

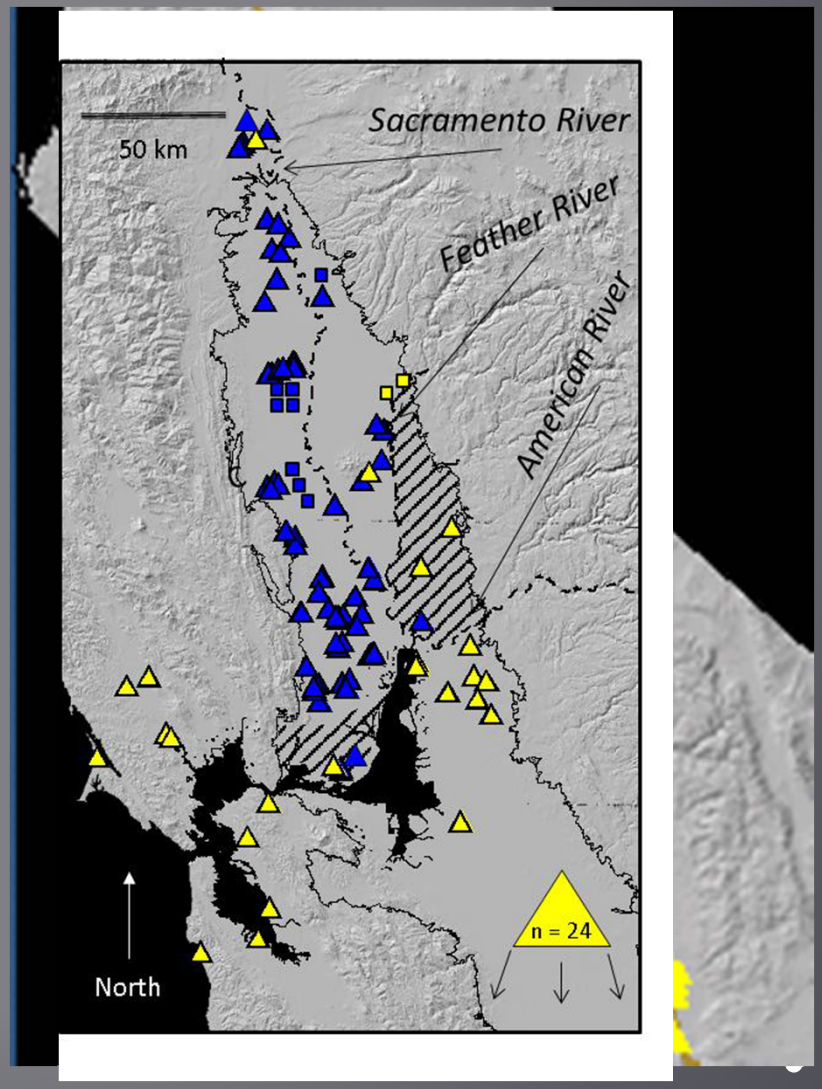
Sierra Nevada red fox
(*V. v. necator*)

Sacks et al. 2010a

Lowland red foxes revisited

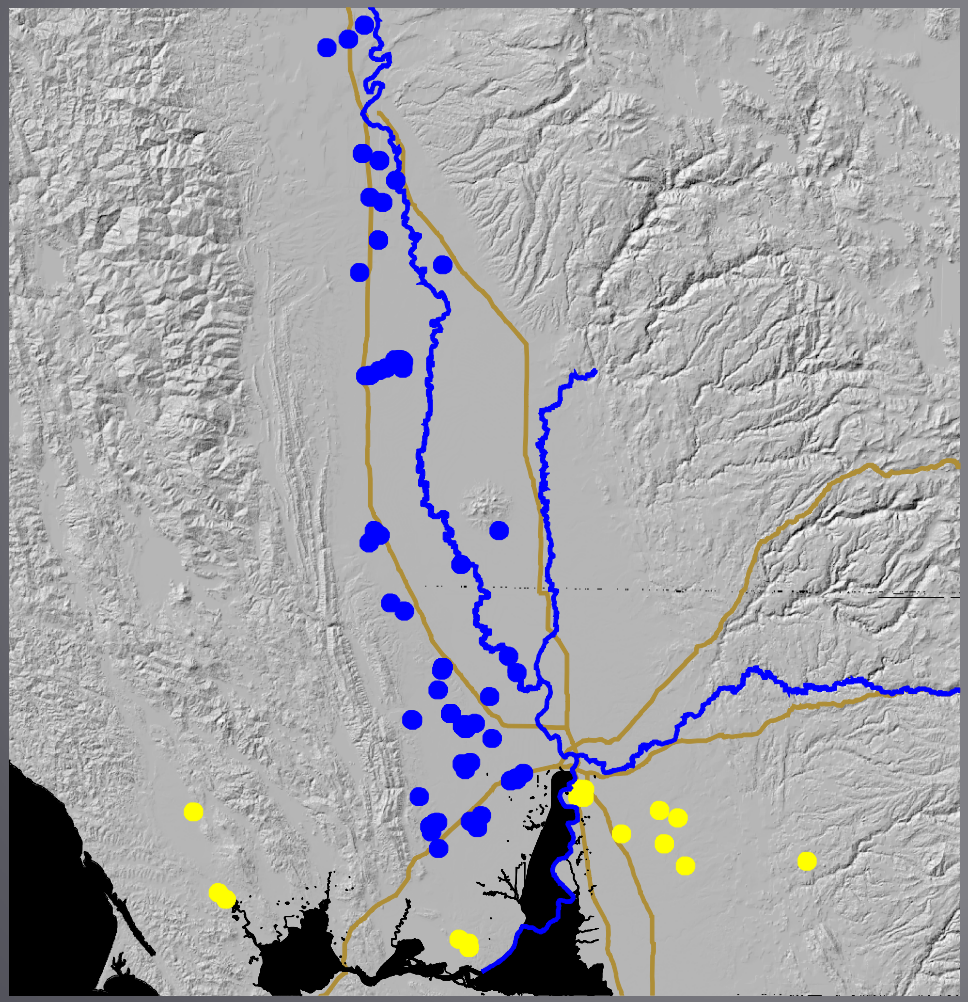
Lewis, J.C., K.L. Sallee, and R.T. Golightly, Jr. 1999..
American Midland Naturalist 142:372-381.





Moore 2009
Sacks et al. 2010b, 2011

Distribution of “pure” (>90%) foxes

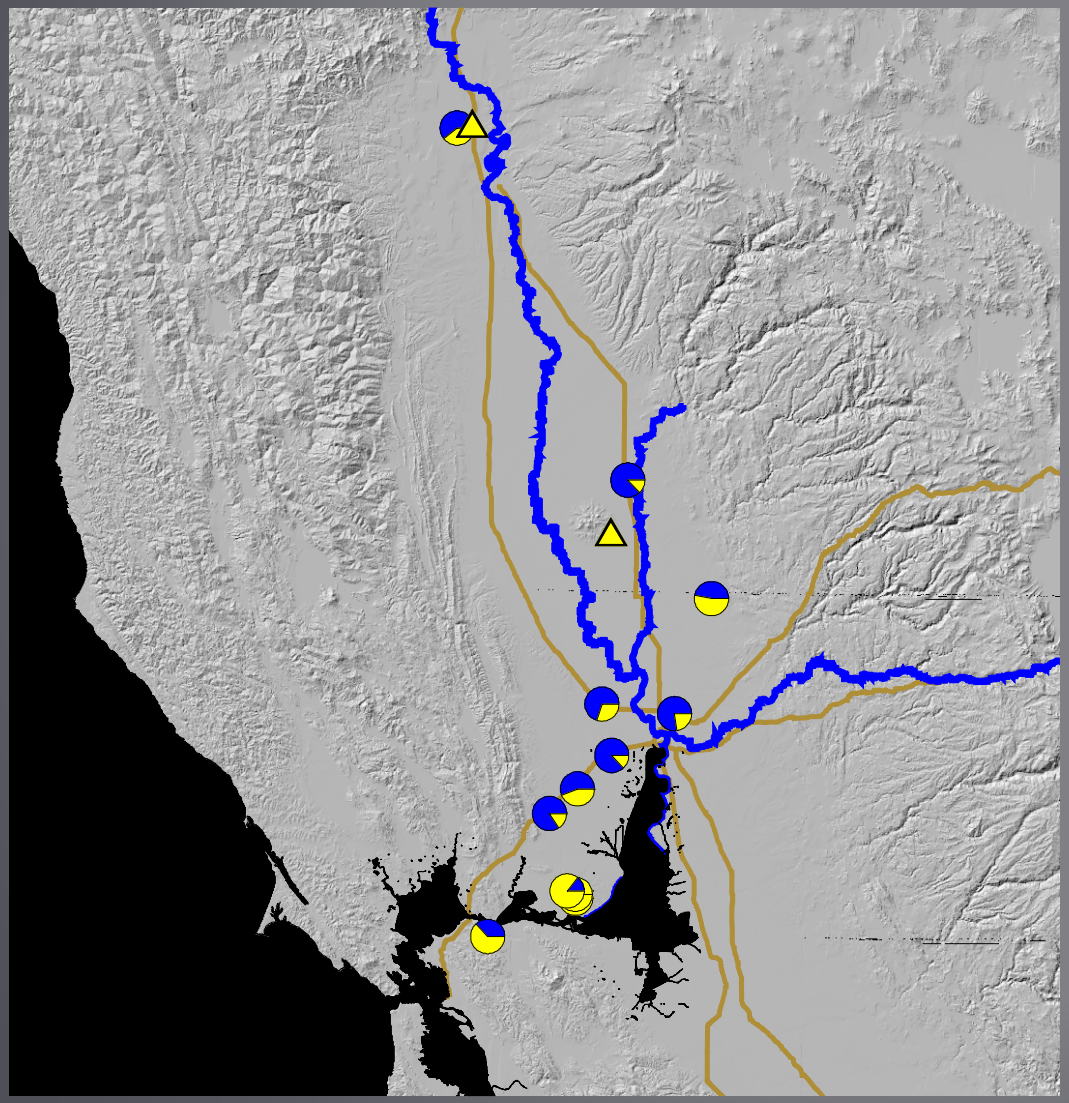


Native genome

Non-native genome

Moore 2009
Sacks et al. 2011

Distribution of hybrids



Native ancestry

Non-native ancestry

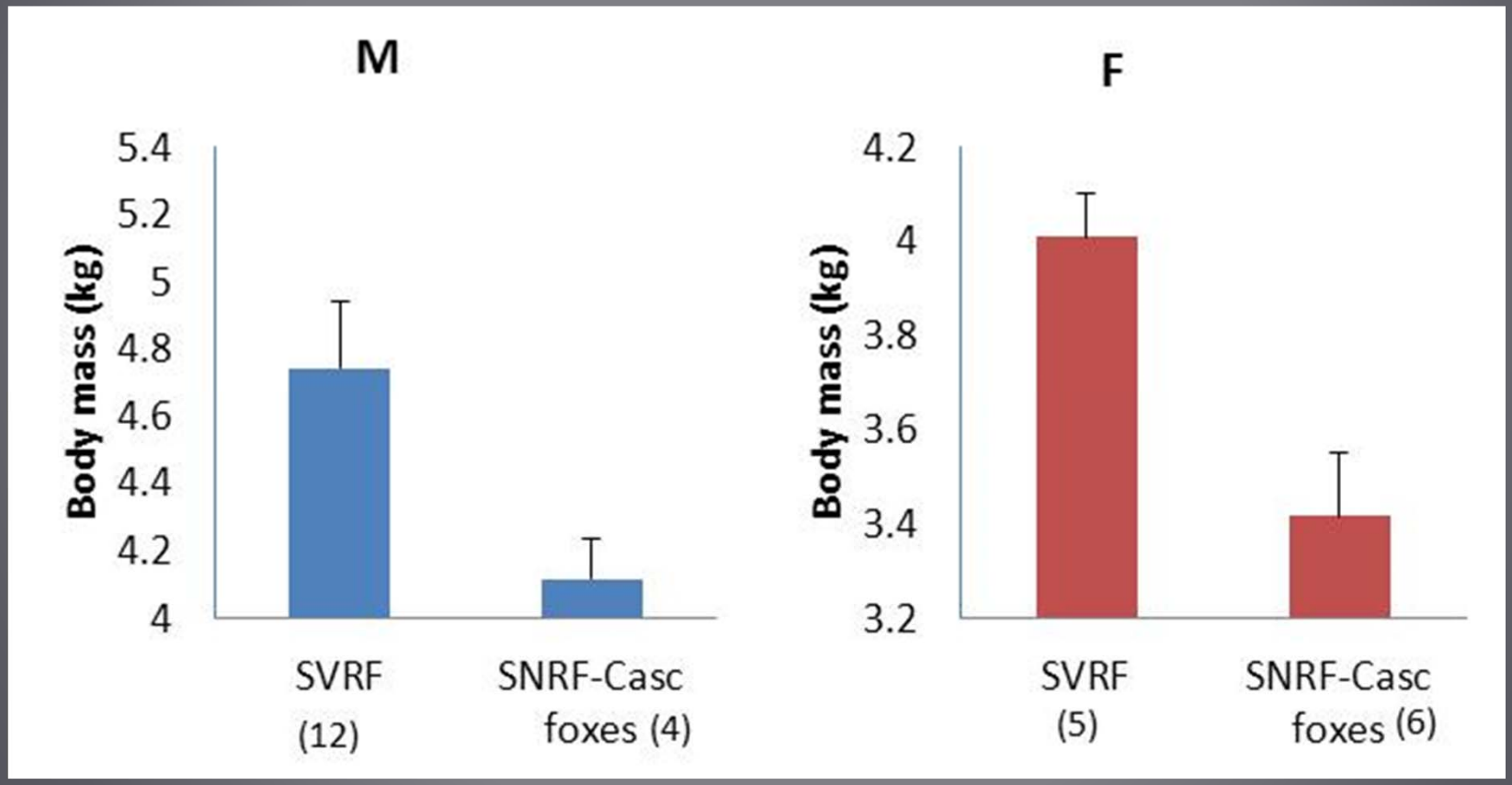
Moore 2009
Sacks et al. 2011

The two native California red foxes are not the same

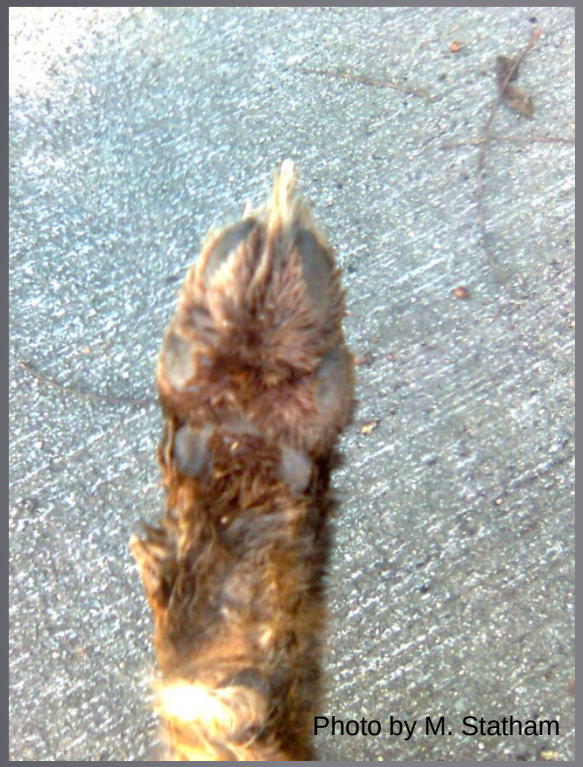
Photo: B. Sacks, Sacramento Valley RF, Yolo Cty, CA

Photo: B. Freund, Sierra Nevada RF, Oregon Cascades

SVRF foxes larger



Sacks et al. 2010b



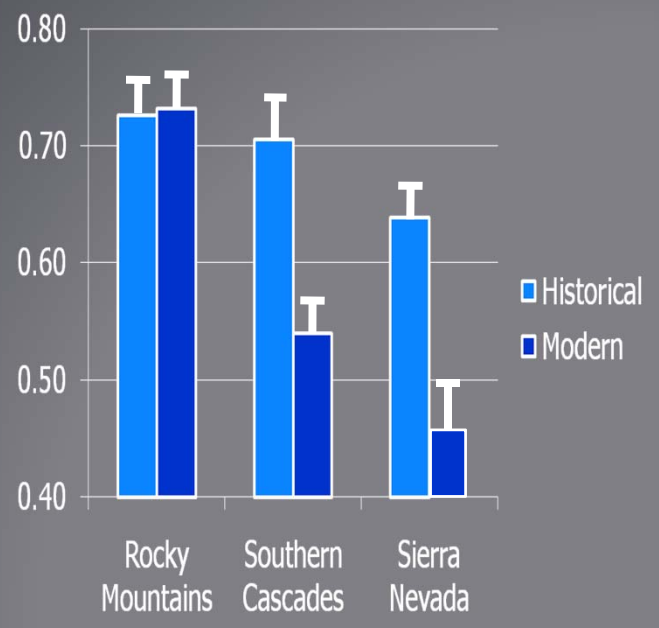
Sacramento Valley red fox
Jan 2011

Sierra Nevada red fox
Jan 2011

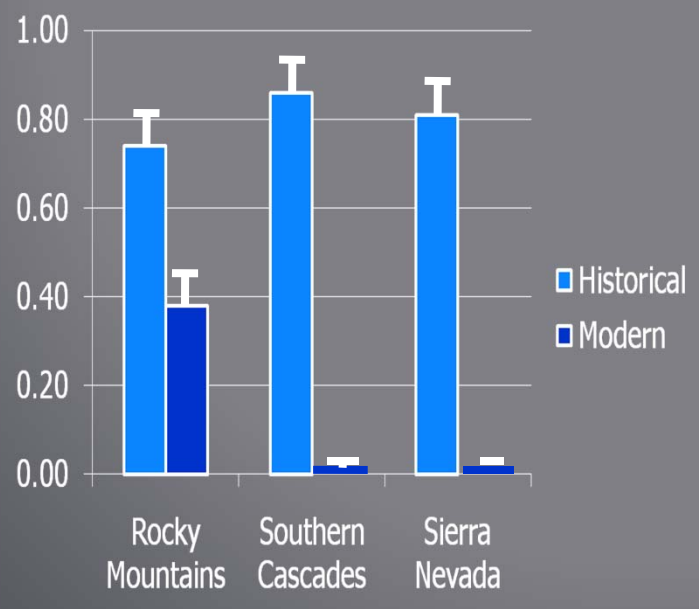
Population trends and status

Genetic diversity decline

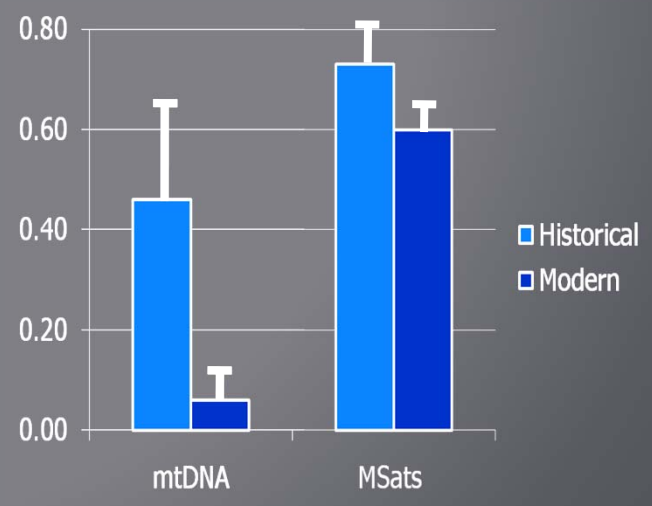
Genome wide



mtDNA



Sac Valley



How many Sacramento Valley red foxes today?

- Phase I: Develop species distribution model
  - Determine habitat use relative to availability
  - Apply Maxent approach to predictive modeling
  - Validate with independent data
- Phase II: Assess occupancy in predicted habitat
  - Select “random” subsample of model-predicted habitat to survey
  - Assess red fox presence
    - Baited camera traps
    - Scat searches
  - Factor in detection probability to estimate occupancy fraction
- Occupancy fraction * predicted habitat area/home range size = estimated number of breeding pairs

Phase I

THE DAVIS enterpr | SUNDAY, APRIL 29, 2007

Sports | UC Davis offensive lineman waits for second day of NFL Draft

You can help
Report fox sightings, or the locations of dens or road kills online at

UCD: Valley foxes are genetically distinct

he study is important because
ewhere in California are in-
ave so badly "hammered" en-
cies that some biologists have
to be culled.
nary evidence in the study
uggest an evolutionary rela-
en foxes here and the Sierra
, a rare subspecies at home

See FOXES, Page A11

The Sacramento Bee

REGIONAL DIGEST

UCD prof seeks help with red foxes

DAVIS – A University of California,

Students and Field/lab techs: Marcelle Moore, Karen Converse
PIs: BN Sacks/HU Wittmer/MJ Statham
CDFW cooperator: Armand Gonzales
Funding: USFWS/CDFW/UC Davis CPB/Sac State

Burrowing Owl

Yolo Audubon Society

Vol. 36 No. 9 May-June 2007

Rethinking the Red Fox in the Sacramento Valley

A biologis

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Native Red Foxes Living in Valley; Public's Help Sought

May 29, 2007

Contrary to onetime scientific opinion, red foxes living in the Sacramento Valley are not an artificially introduced species that threaten local ecosystems, according to a UC Davis researcher.

This adult red fox, a California native, was photographed hunting ground squirrels in a freshly disked field near Woodland, Calif. (Ben Sacks/UC Davis photo)

Ben Sacks, an expert in canine genetics and a researcher in the School of Veterinary Medicine, has new findings suggesting that these animals are natives, and close cousins to the native Sierra Nevada red fox.

In other low-elevation parts of the state, red foxes are indeed nonnative, invasive and threaten several endangered bird species. Some ecologists and biologists have called for the nonnative animals to be killed in these areas to preserve the delicate balance of those ecosystems.

Sacks, who has been studying the foxes for the past 10 years, is reaching out to the public for help in reporting all sightings of red foxes in the Sacramento Valley and in the high elevations of the Sierra Nevada and Cascades mountains. He is requesting that anyone who sees any evidence of red foxes in the area, either alive or dead (such as roadkill), tell him about it online.

"It's important that we collect public data as well as continue our own research," said Sacks. "Getting this well-rounded stream of information will help us learn more about how the Sacramento Valley red fox interacts with its local environment."

Specifically, Sacks and his team are interested in understanding how the Sacramento Valley foxes, whose ancestors evolved in cold mountainous climates, adapted to the warm flatlands of the valley.

Sacks and the School of Veterinary Medicine have set up a Web site where the public can report their sightings: http://foxsurvey.ucdavis.edu. The site also has helpful tips and photos for distinguishing red foxes from gray foxes and coyotes.

Additional information:

- Fox survey

Media contact(s):

- Ben Sacks, School of Veterinary Medicine, (530) 754-9088, bnsacks@ucdavis.edu
- Sylvia Wright, UC Davis News Service, (530) 752-7704, swright@ucdavis.edu

http://foxsurvey.ucdavis.edu/DataEntry.action

Sacramento Bee

UCDAVIS UNIVERSITY OF CALIFORNIA

Sacramento Valley **Fox Survey**

Home | Report a Sighting | Fox or Coyote? | Status

Contact: sacvalleyredfox@gmail.com

Red Fox Sighting Report

Please report road-kills immediately to Ben Sacks, 530-754-9088

Digital photos appreciated

Animal

Species

- ○ Red Fox
- ○ Gray Fox
- ○ Coyote
- ○ Other
- Confidence: Choose

Tail

- ○ Did Not See
- ○ White Tip
- ○ Black Tip

Ears

- ○ Did Not See
- ○ Backside Black Tip
- ○ Backside Orange Tip

Body

- ○ Mostly Orange
- ○ Mostly Gray

Date and Time

How Recently: Choose or Month/Year:

Time of Day:

Location

Description:
(distance and direction to nearest town/intersection)

County: Choose

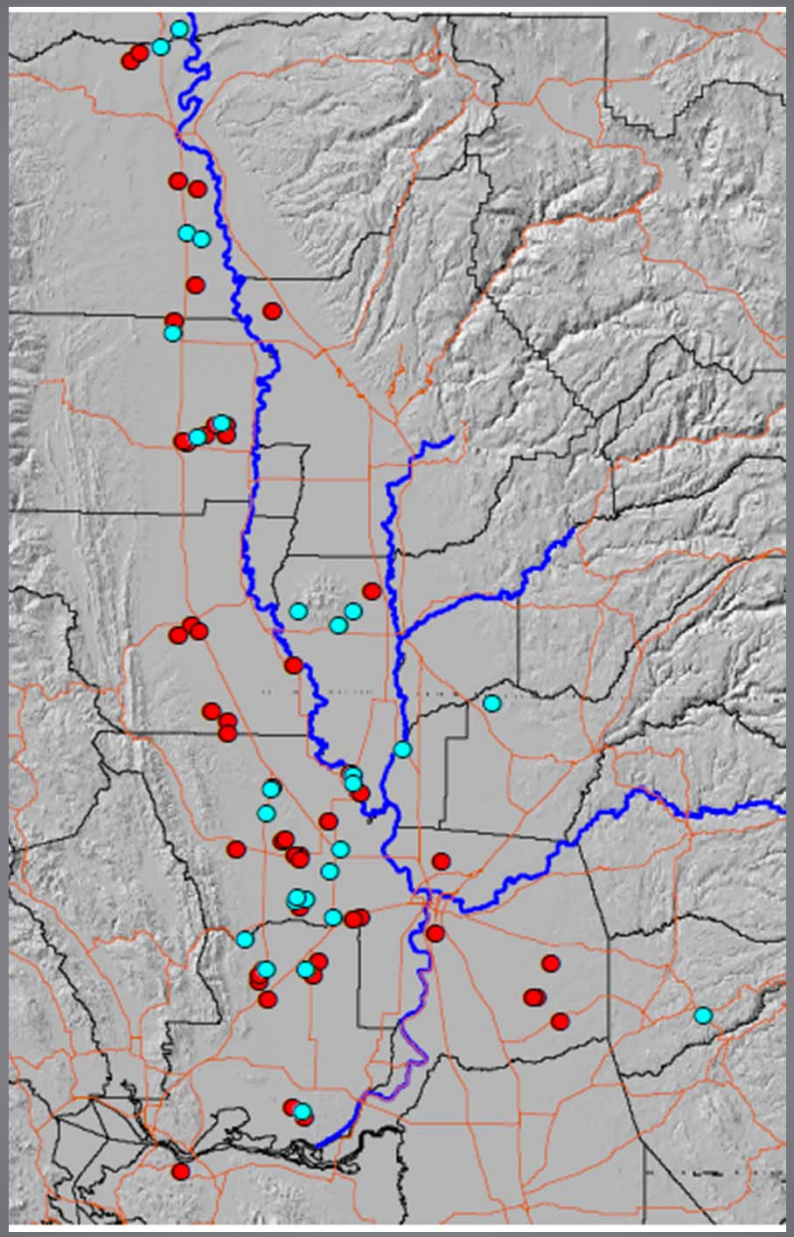
Click on the map to fill in coordinates.

Latitude:

Longitude:

Terrain: Choose

Search near sighting reports to confirm occurrence

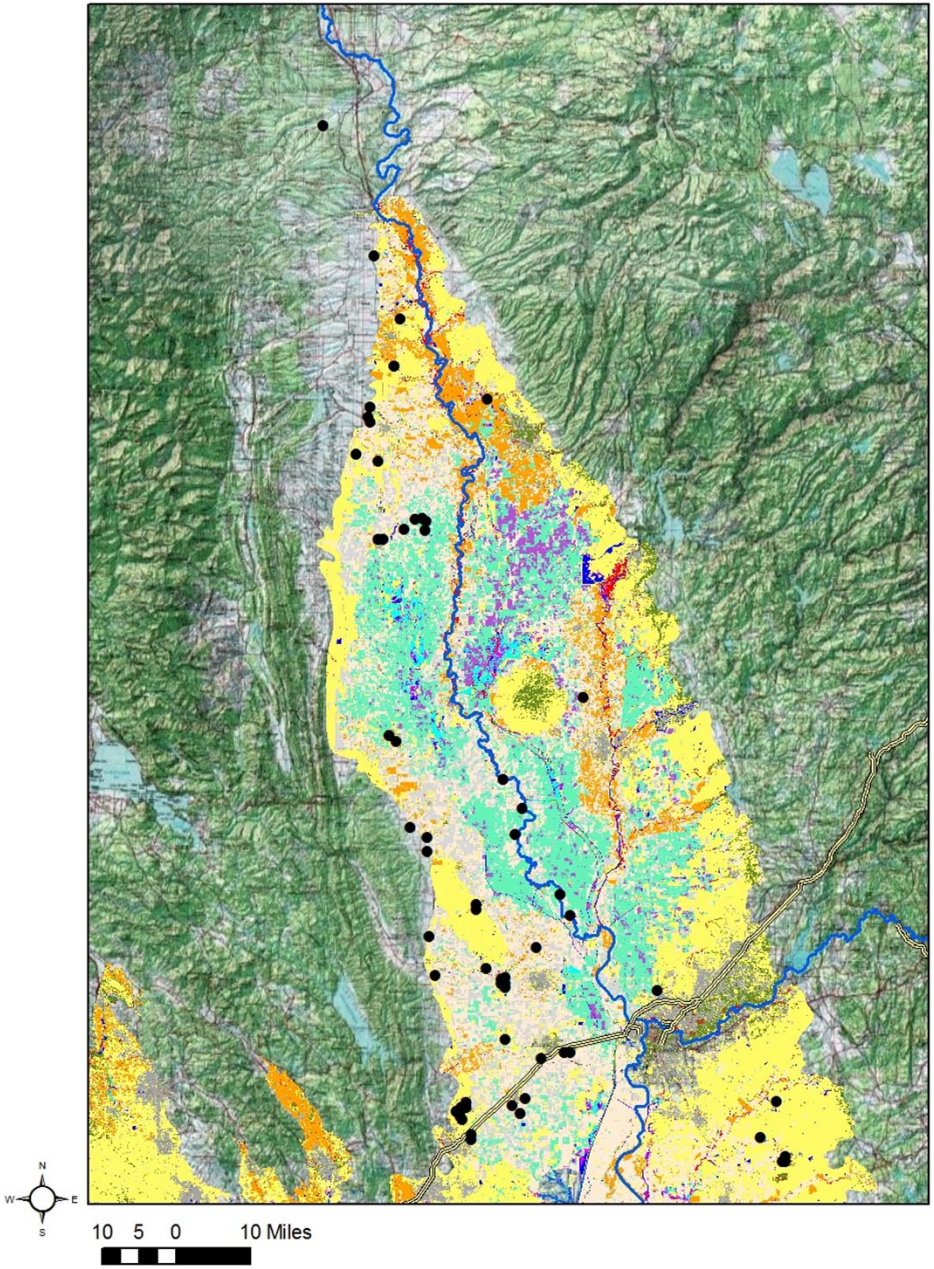


Road kills

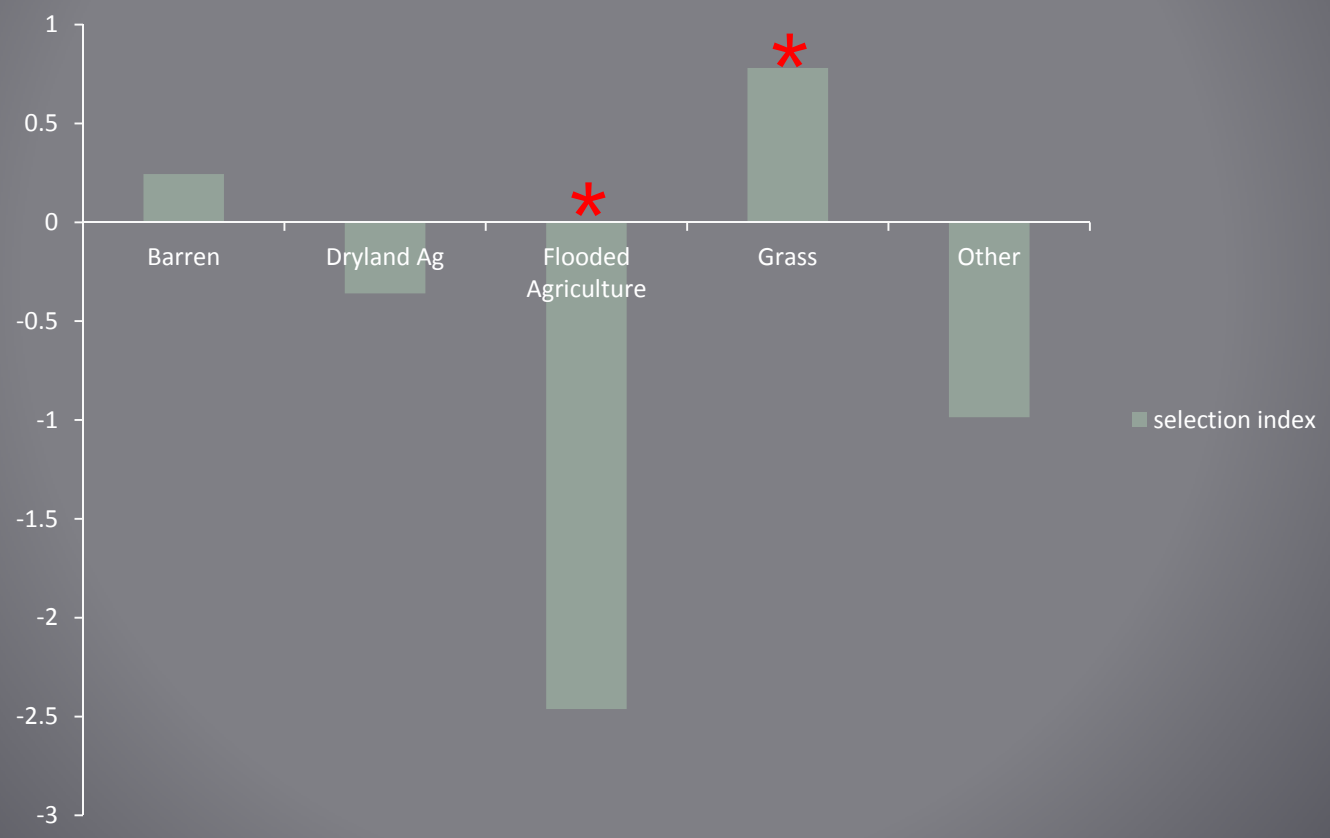
Den sites

Sacks et al. 2010b

Tuffly, M., and A. Kilgore. 1998. California Central Valley Wetlands and Riparian GIS Data Sets. California Department of Fish and Wildlife. http://www.dfg.ca.gov/biogeodata/gis/clearinghouse.asp>

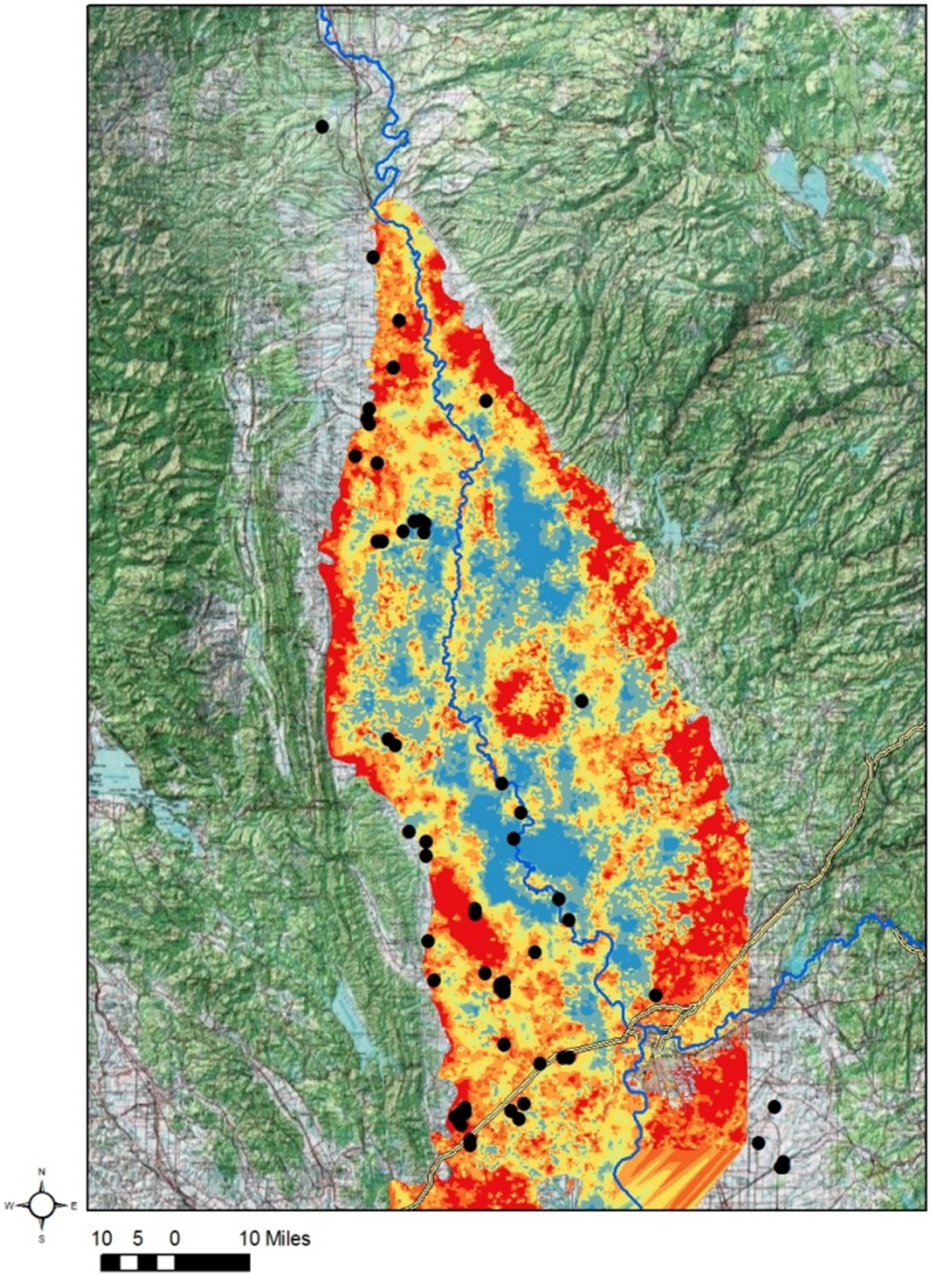


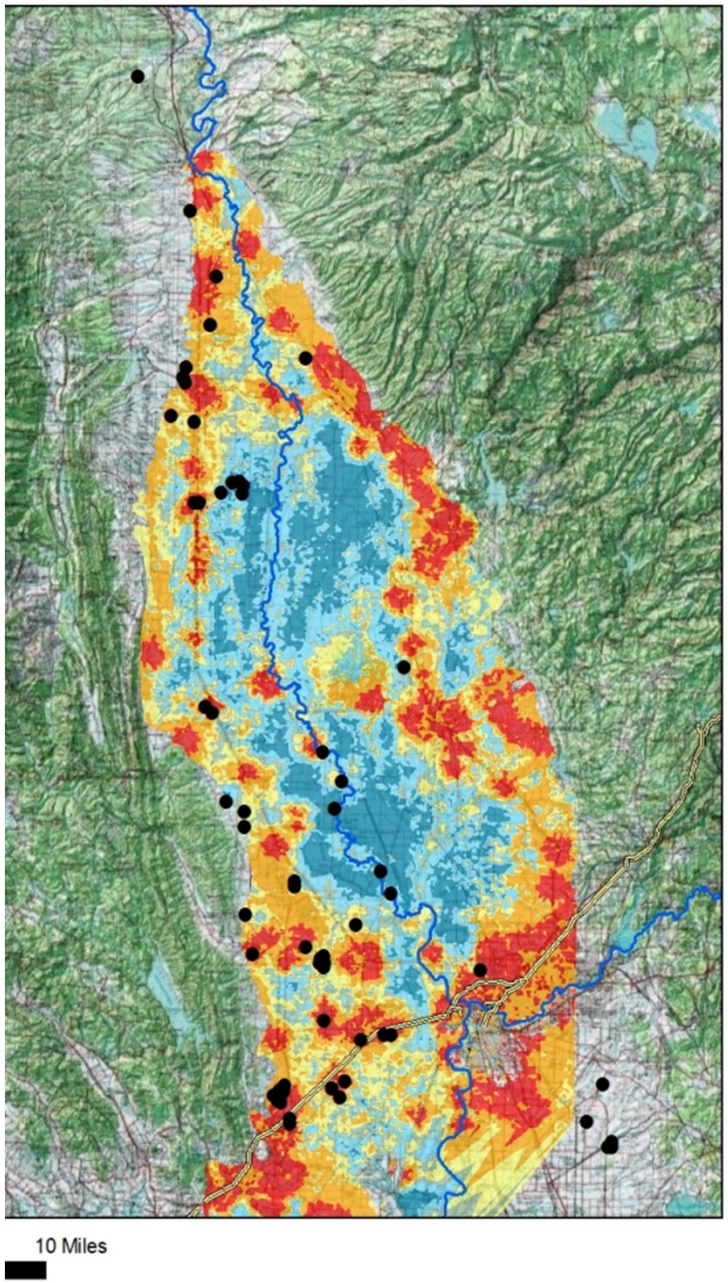
Selection index



Sacks et al. 2010b

Sacks et al., unpublished distribution models

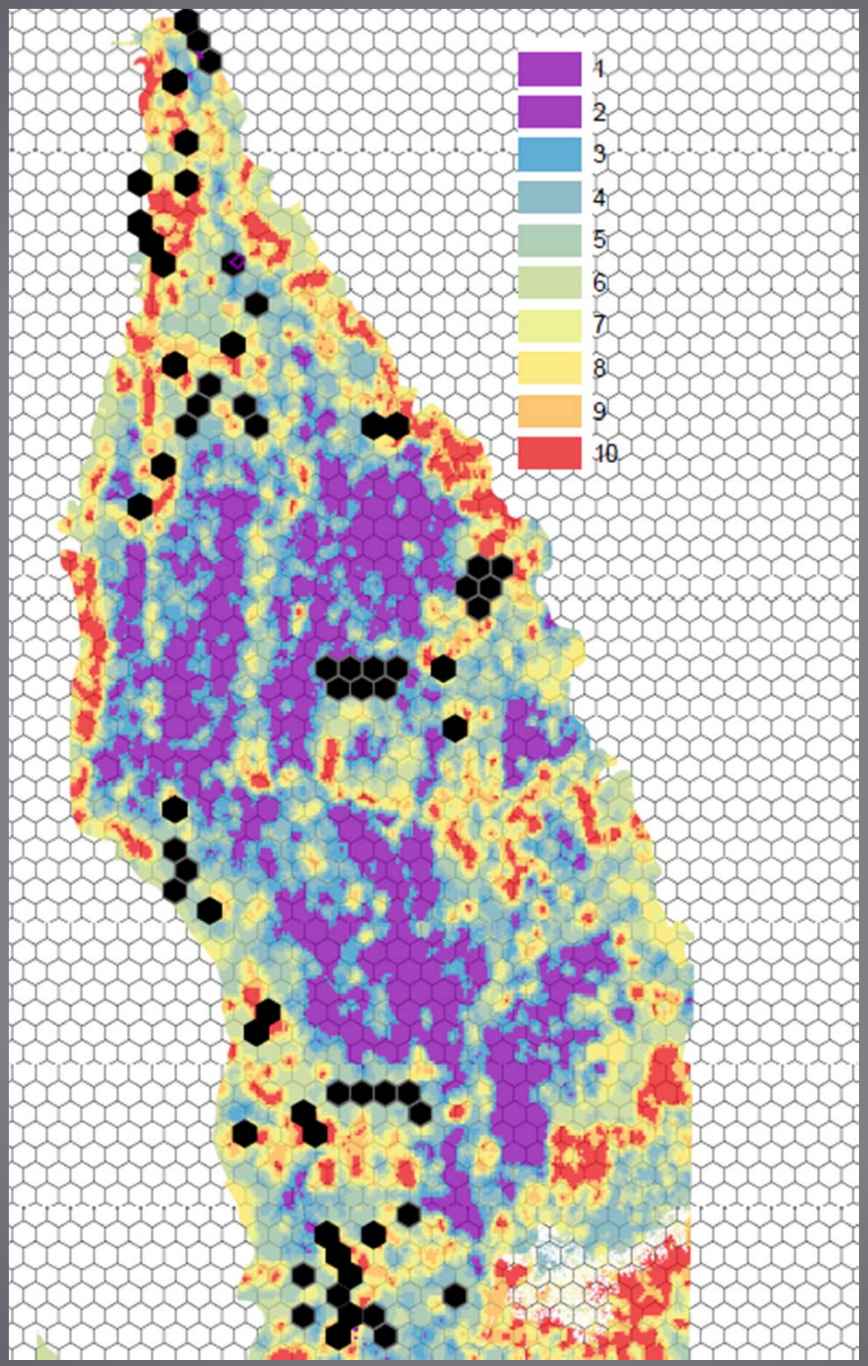




Phase II (in progress)

- Stratified based on model
- Selected hexes within strata at random
- Seek permission to survey on private land
- Survey
  - Baited camera traps
  - Scat collection and DNA analysis

*Project leader: **Kat Miles** (MS student)*
Field/lab techs: Preston Alden, Michelle Holtz, Zach Lounsberry
PI: BN Sacks
CDFW cooperators: D. Wright, C. Nguyen, S. Hemingway, K. Converse
Funding: USFWS/CDFW/UC Davis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47°F
H0898
RECONYX

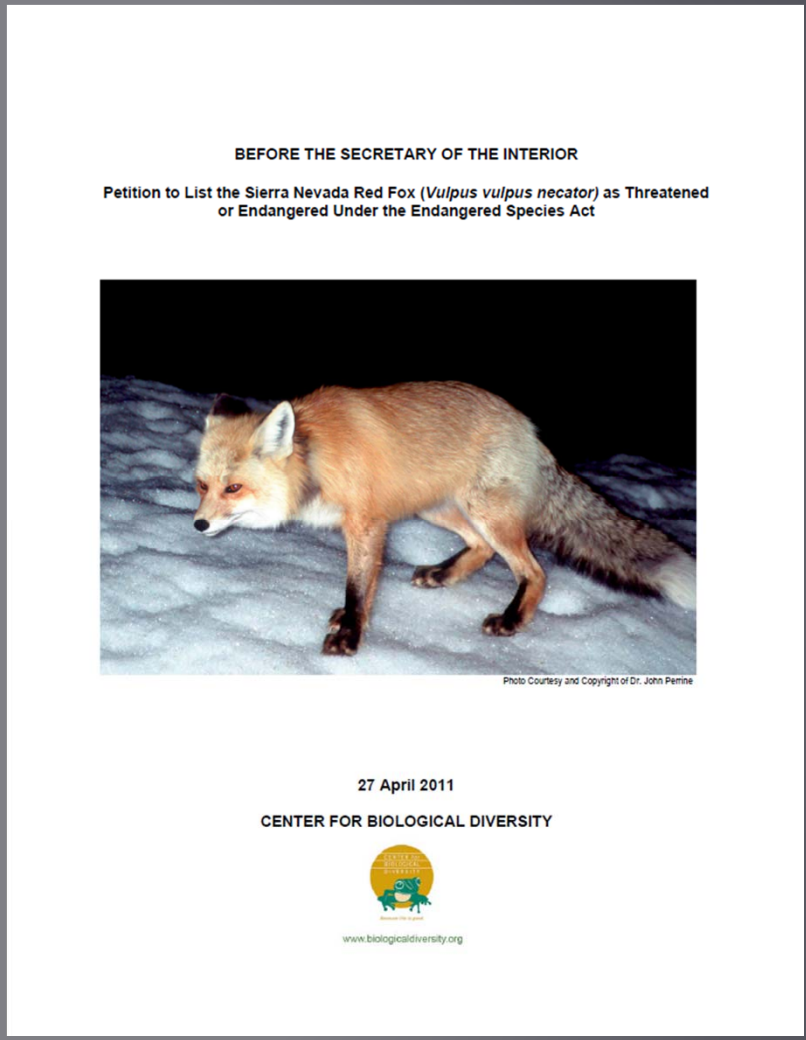
2013-04-21 4:15:01 AM M 1/3
54°F
H0890
RECONYX

Preliminary findings

- Presence detected in 3/3 positive control hexes
- Presence detected in 0/4 predicted-absence hexes
- Presence detected in 1/7 predicted-presence sites(!!)

Sierra Nevada red fox

- "Threatened" under California ESA 1980
- Petitioned for listing under the US ESA 2011
- Causes for decline unclear
  - Trapping?
  - Coyote encroachment?
  - Habitat transformation (fire, timber, livestock)?
  - Prey declines?
  - Climate change?
- Factors limiting recovery
  - Inbreeding depression?
  - Less frequent high-prey years?
  - Recreational/other uses, etc.?



BEFORE THE SECRETARY OF THE INTERIOR

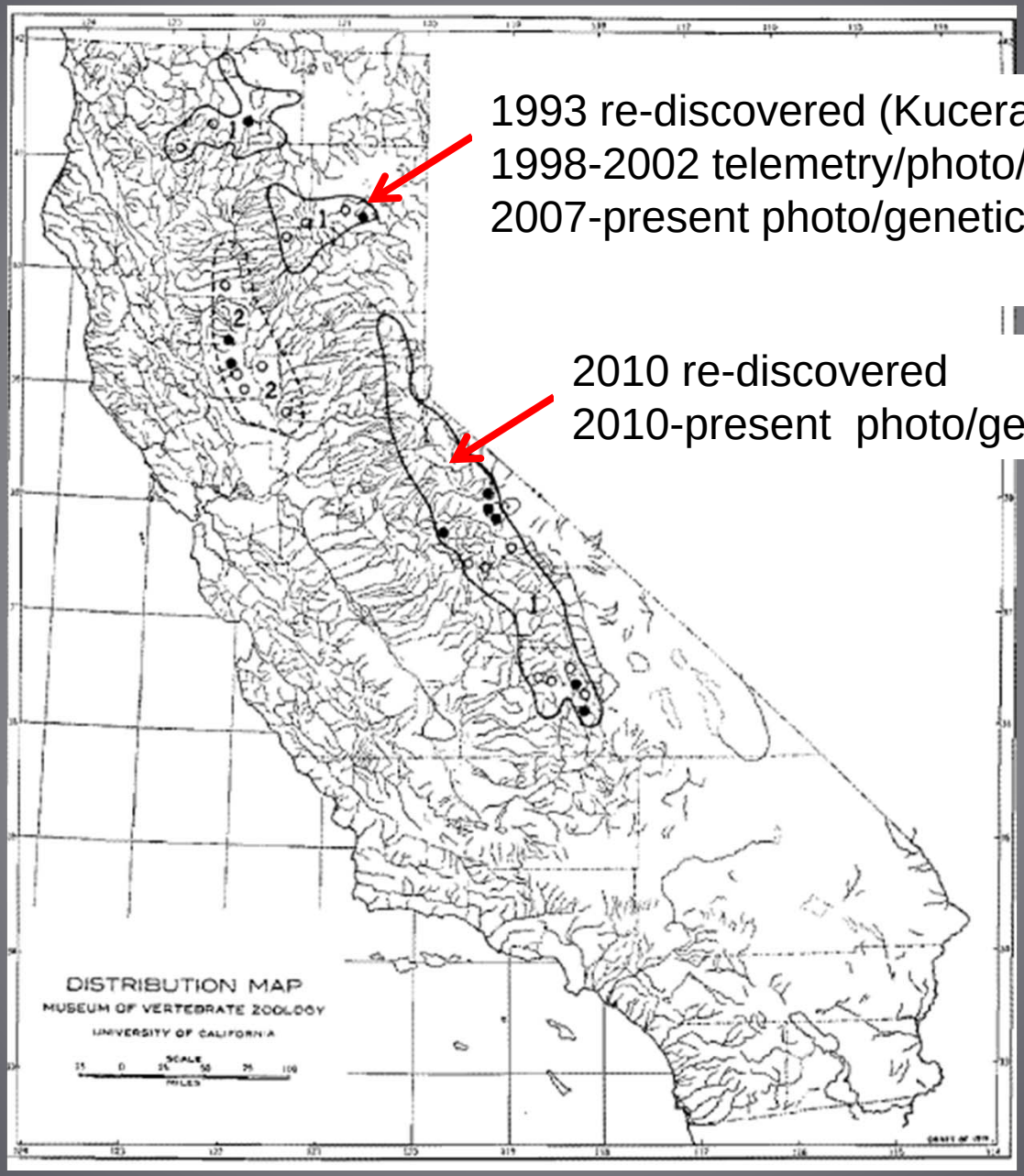
Petition to List the Sierra Nevada Red Fox (*Vulpus vulpus necator)* as Threatened or Endangered Under the Endangered Species Act

Photo Courtesy and Copyright of Dr. John Perrine

27 April 2011

CENTER FOR BIOLOGICAL DIVERSITY

www.biologicaldiversity.org


1993 re-discovered (Kucera)
1998-2002 telemetry/photo/genetics
2007-present photo/genetic monitoring
2010 re-discovered
2010-present photo/genetic monitoring
DISTRIBUTION MAP
MUSEUM OF VERTEBRATE ZOOLOGY
UNIVERSITY OF CALIFORNIA

Cuddeback

Cuddeback

Cuddeback

Cuddeback

Southern Sierra Nevada red fox working group

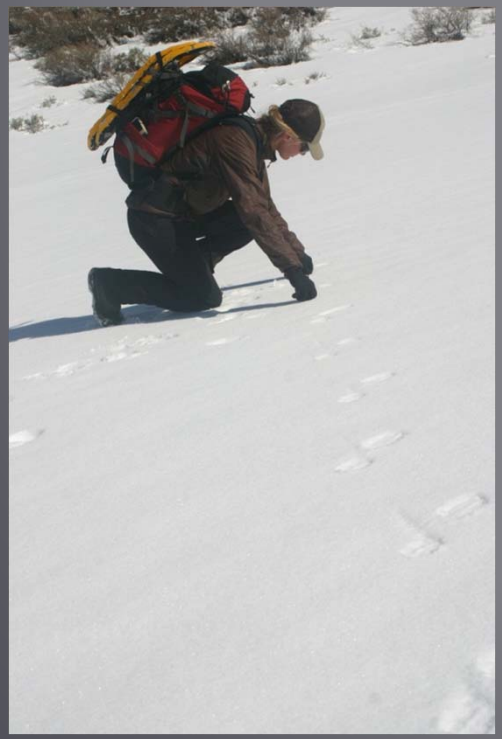
Two efforts initiated

- Broad survey (Chris Stermer, CDFW)
- Focal study of re-discovered population (UCD, CDFW, USFS)
  - Size, extent, status of population
  - Snowmobile impacts?
  - Marine training impacts?

FOCAL STUDY
*Project leader: **Cate Quinn** (PhD student)*
Field/lab techs: Preston Alden, David Wolfson, Kat Miles
PI: BN Sacks
CDFW collaborators: E. Burkett, C. Stermer
USDA-FS colaborators: A. Rich, S. Lisius, R. Mazur, J. Lowden
Funding: OHV/USDA-FS/USFWS/CDFW/UC Davis

Methods

- Telemetry
- Noninvasive
  - Remote cameras paired with hair snaggers (for DNA)
  - Scat collection (for DNA)
  - Snowtracking



Courtesy of P. Figura

Trapping winter 2014

SNRF 10
RECONYX

SNRF CAM3
RECONYX

SNRF CAM5
RECONYX

SNRF07
RECONYX

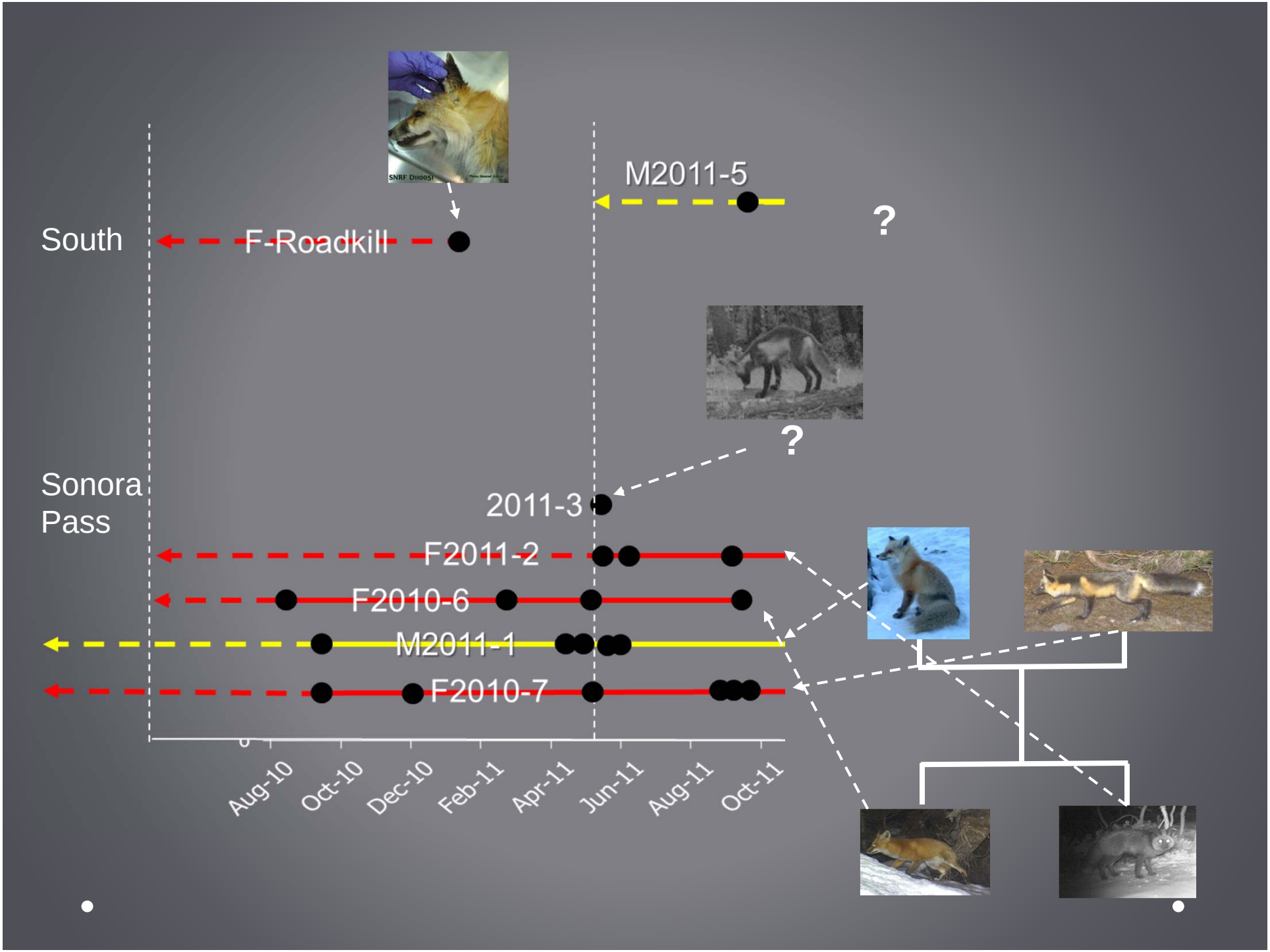
SNRF TRAP2
RECONYX

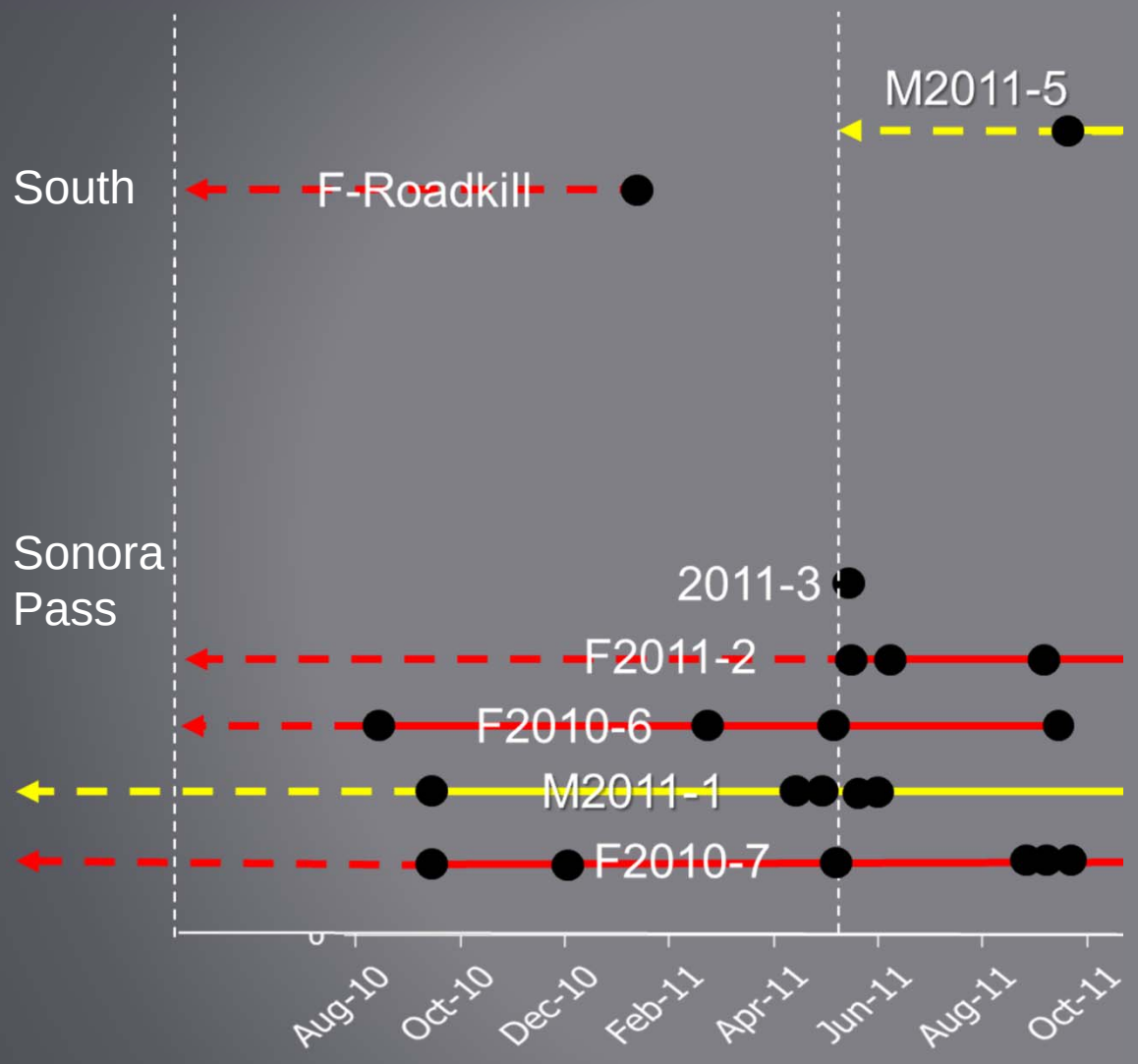
What next?

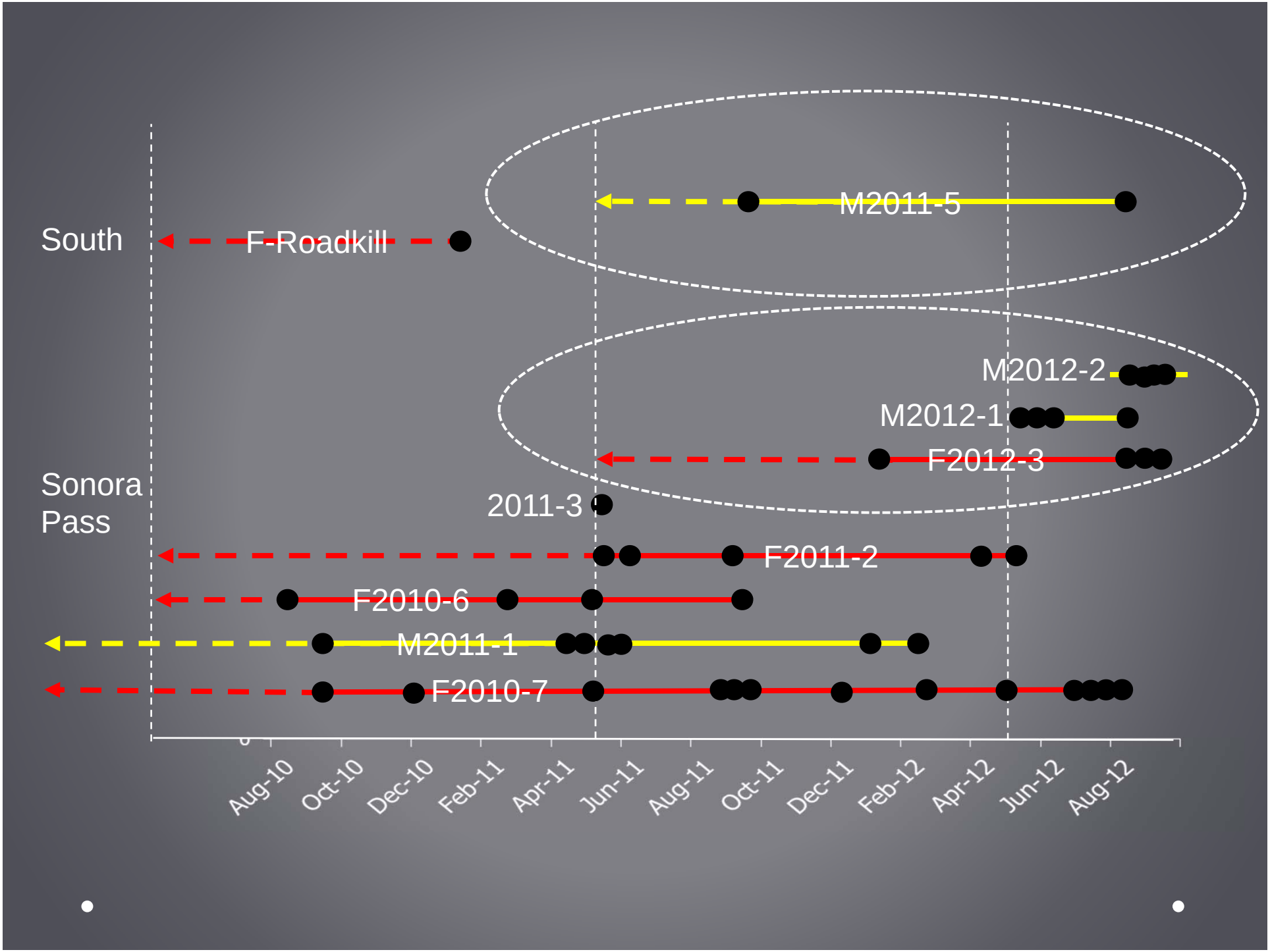
photo courtesy of Patrick Cross

Noninvasive genetic monitoring

- **Sources of DNA**
  - Hair (baited snaggers)
  - Scats (foot-searches)
  - Urine (Snow-tracking)
- **Analysis of DNA samples**
  - Mitochondrial
    - Identify species
    - Native/nonnative haplotypes
  - Nuclear microsatellites/sex markers
    - Compare to population database
    - Identify sex and individual
    - Familial relationships
- **Outcomes**
  - Individual timeline, longevity
  - Immigration/births
  - Home ranges


South
F-Roadkill
M2011-5
?
?
Sonora Pass
2011-3
F2011-2
F2010-6
M2011-1
F2010-7
Aug-10
Oct-10
Dec-10
Feb-11
Apr-11
Jun-11
Aug-11
Oct-11

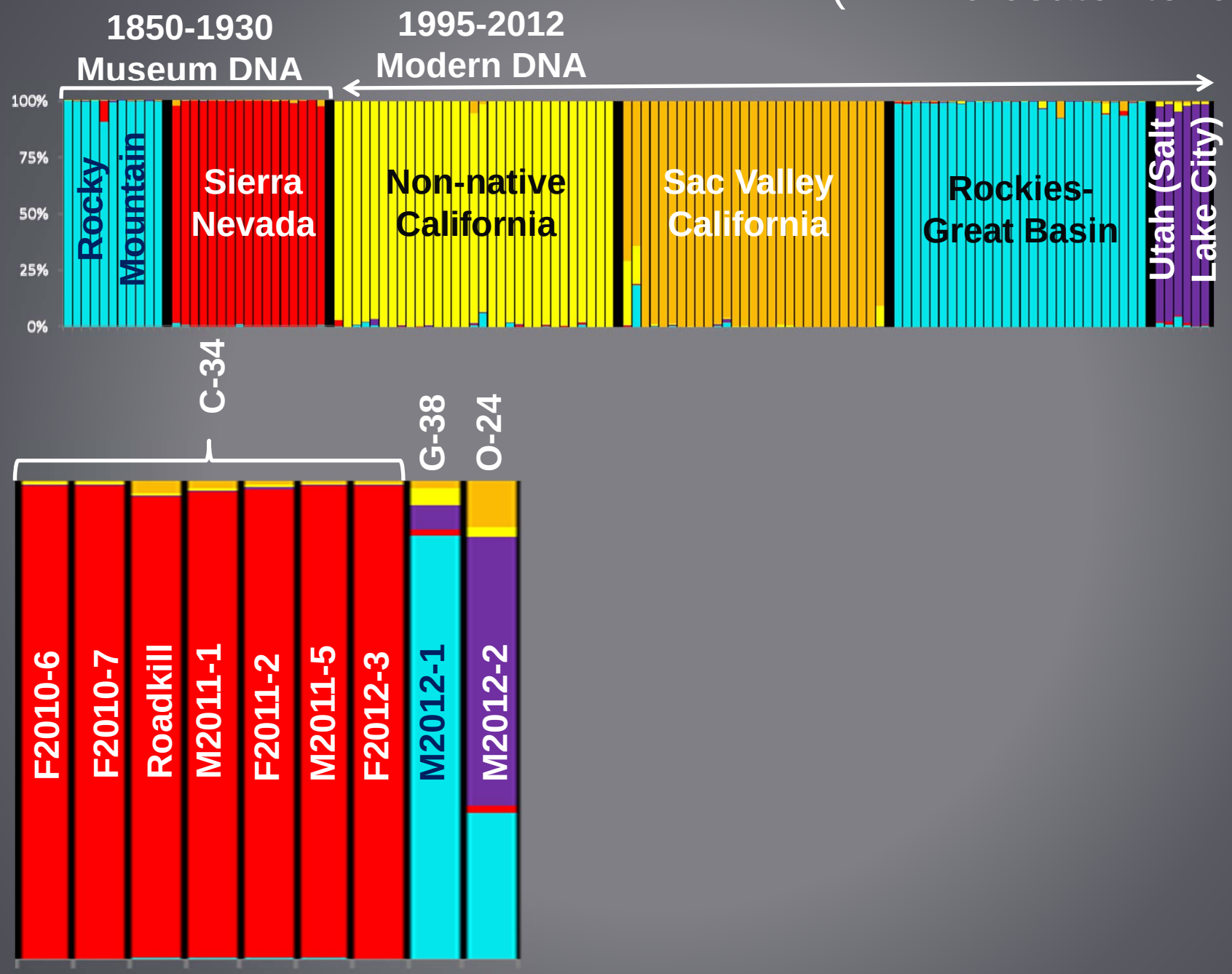

M2011-5
South
F-Roadkill
Sonora
Pass
2011-3
F2011-2
F2010-6
M2011-1
F2010-7
Aug-10
Oct-10
Dec-10
Feb-11
Apr-11
Jun-11
Aug-11
Oct-11


South
F-Roadkill
M2011-5
M2012-2
M2012-1
F2012-3
Sonora Pass
2011-3
F2011-2
F2010-6
M2011-1
F2010-7
Aug-10
Oct-10
Dec-10
Feb-11
Apr-11
Jun-11
Aug-11
Oct-11
Dec-11
Feb-12
Apr-12
Jun-12
Aug-12

Demography

- Adults live a long time
- Few offspring are detected
- Reproduction or neonatal/juvenile survival limits population
- Also appears true in the Lassen population (Figura/Sacks, unpub.)
- Explanations: inbreeding depression? Nutrition? Predation?

(14 microsatellite loci)



(population assignment based on 33 microsatellite loci)

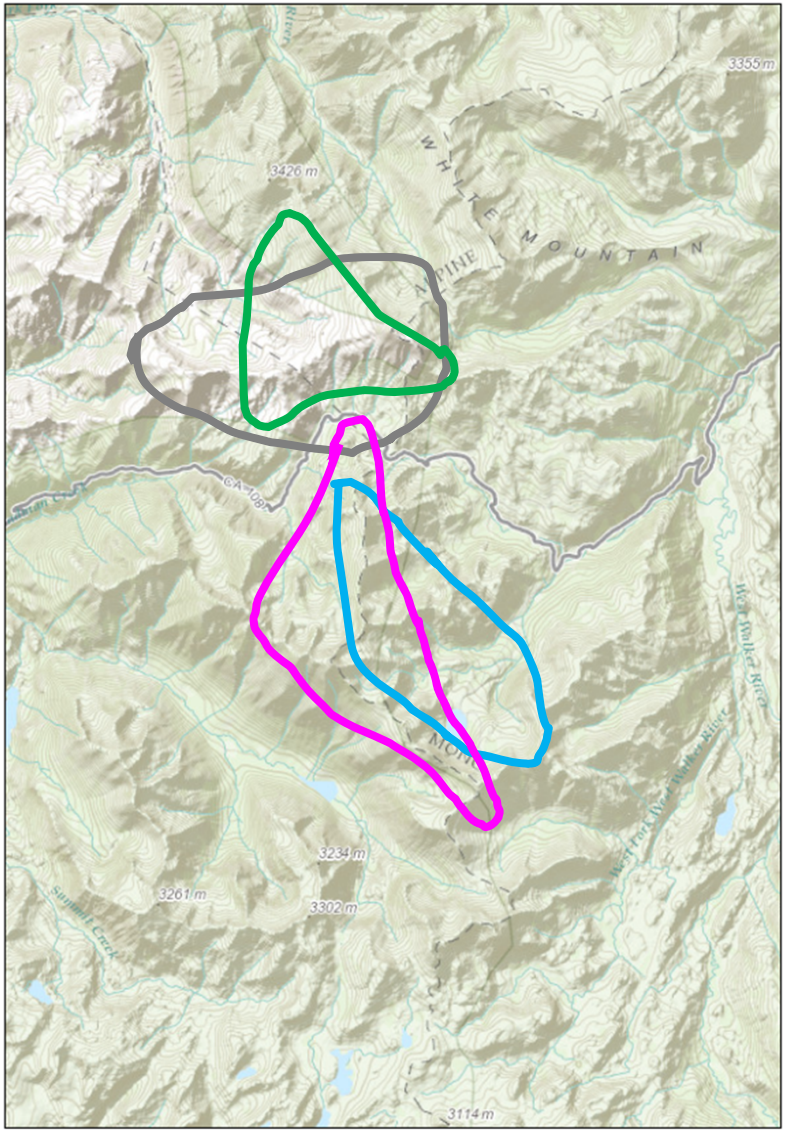
H_o: Individual genotype originated from population

Probability (*P*) of these (or more unusual) genotypes if H_o is true:

Fox ID	East Coast	Nonnative California	Rocky Mountains	Nevada	Lassen	Sac Valley	Washington Cascades	Sonora Pass
F2010-6	***	***	**	**	***	***	***	0.59
F2010-7	***	***	**	**	***	***	***	0.90
M2011-1	***	***	**	***	***	***	***	0.72
F2011-2	***	***	***	**	***	***	***	0.62
M2011-5	***	***	**	**	***	***	***	0.67
2012-3	***	***	**	**	***	***	***	0.56
F2010-8	***	***	***	**	***	***	***	0.57
M2012-1	***	***	**	0.03	***	***	***	**
M2012-2	***	***	**	0.02	***	***	***	***

**$P \leq 0.01$

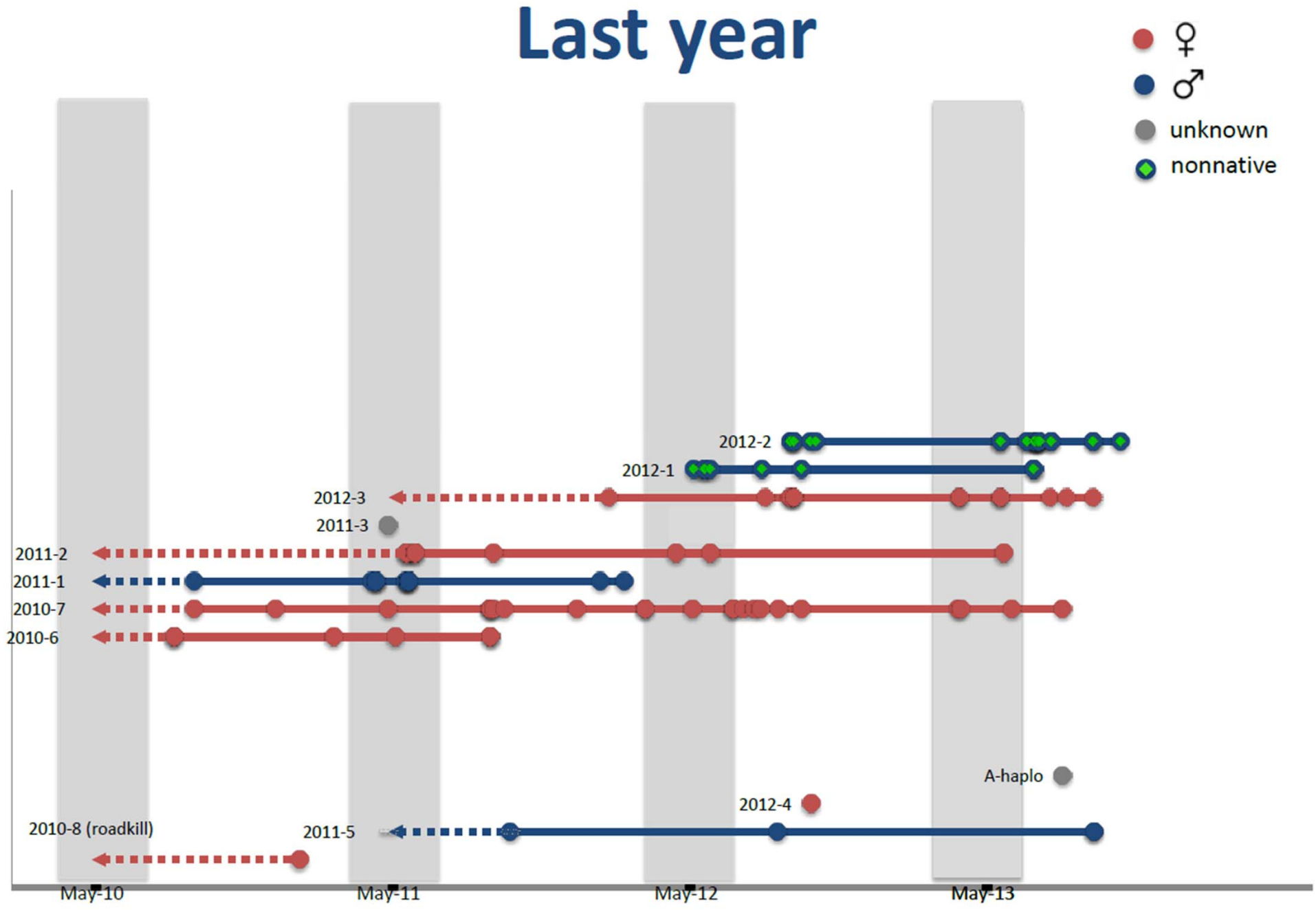
***$P \leq 0.001$


3355 m
3426 m
WHITE MOUNTAIN
CA-108
West Walker River
3234 m
3261 m
3302 m
Summit Creek
3114 m
Kilometers
0 0.5 1 2 3 4

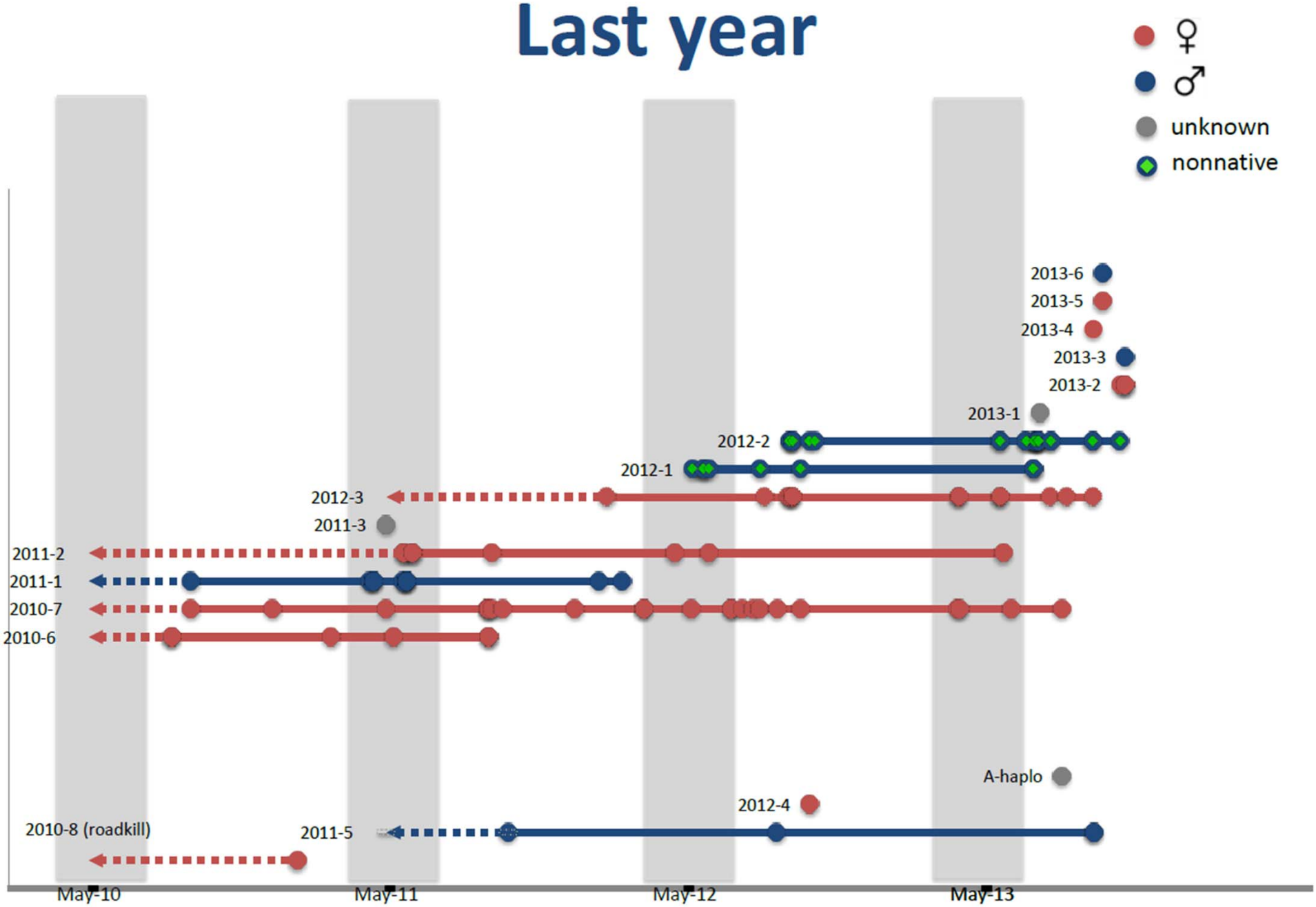
Outcomes/concerns

- Failure to survive and reproduce
- Competition with native foxes (esp males)
- Nonnative hybridization and introgression
  - Temporary genetic “rescue”
  - Outbreeding depression/swamping
  - Extirpation

Last year


♀
♂
unknown
nonnative
2012-2
2012-1
2012-3
2011-3
2011-2
2011-1
2010-7
2010-6
A-haplo
2012-4
2010-8 (roadkill)
2011-5
May-10
May-11
May-12
May-13

Last year


♀
♂
unknown
nonnative
2013-6
2013-5
2013-4
2013-3
2013-2
2013-1
2012-2
2012-1
2012-3
2011-3
2011-2
2011-1
2010-7
2010-6
A-haplo
2012-4
2010-8 (roadkill)
2011-5
May-10
May-11
May-12
May-13

Parentage tests confirm hybrid pairings in both cases

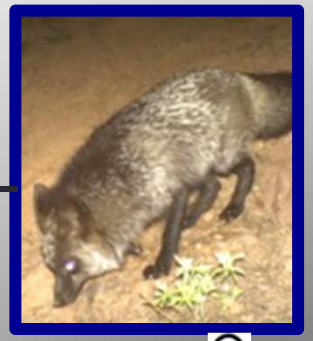
LITTER 1

North territory

2012-1

Nonnative ♂

2011-2



Native ♀

2013-1
?

2013-2 ♀

2013-3 ♂

LITTER 2

South territory

2012-2

Nonnative ♂

2012-3

(Red)

Native ♀

2013-4 ♀

2013-5 ♀

2013-6 ♂

Sierra Nevada red fox

- Small number of individuals
- Inbreeding depression a concern
- Genetic swamping could be a bigger one
- What can we do?
  - Remove nonnative males?
  - Translocations of other native foxes?
  - Nothing (monitor)
    - Hope for the best
    - Learn from the worst

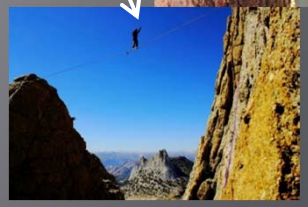
California red fox recap

- Sacto Valley and SN red foxes are native and have declined
- Nonnative RFs have increased (encroachment minimal)
- Status of Sacto Valley red foxes uncertain (stay tuned)
- Sierra Nevada red foxes
  - Extremely rare
  - Reproduction/recruitment limited
  - Recently exposed to outbreeding
    - "Rescue" from inbreeding depression (at least in the short term)?
    - Swamp existing populations with non-locally adapted genes?
- Recommendations for SNRF
  - Continue noninvasive genetic monitoring
  - Capture and collar critical to study and management
  - Consider and plan translocations

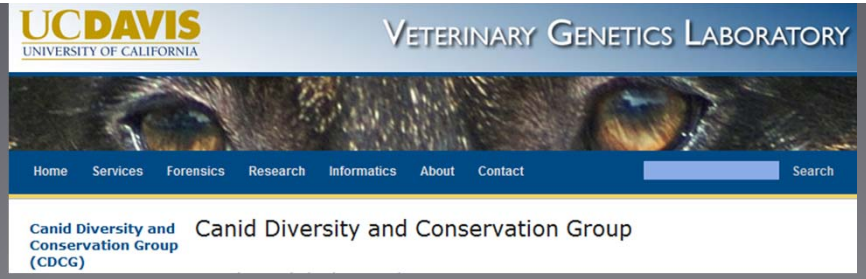
Primary co-investigators and facilitators

- Worldwide red fox
  - Mark Statham
  - Keith Aubry
  - Sam Wisely
- Sac Valley red fox
  - Marcelle Moore*
  - Karen Converse*
  - Kathleen Miles*
  - Heiko Wittmer
  - Armand Gonzalez
  - David Wright
  - Canh Nguyen
  - Stacy Hemingway

- Sierra Nevada red fox
  - Cate Quinn*
  - Jocelyn Akins*
  - Preston Alden*
  - David Wolfson
  - Chris Stermer
  - John Perrine
  - Esther Burkett
  - Adam Rich
  - Sherri Lisius
  - Pete Figura



- *Graduate students (underlined = current research coordinators)



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-Rachel Mazur (USDA/FS, R4)
-JoAnne Lowden (USDA/FS, R4)
-Andrew Irvin (USMC)
-Greg Gerstenberg (CDFW, R4)
-Tim Taylor (CDFW, R6)
-Lily Douglas (USDI/BLM)
-Lindsay Cline (NPS)
-Rich Callas (CDFW, R1)\
-Kristy Fien (CDFW, GIS)
-Maureen Easton (USDA/FS-R4)
-Diana Craig (USDA/FS-R5)
-Diane McFarlane (USDA/FS-R5)
-Peggy O'Connell (USDA/FS-R5)
-Keaton Norquist (USDA/FS-R5)
-CSERC volunteers
-**MANY, MANY fantastic** undergraduate interns and volunteers from UC Davis, Sac State Univ, and American River College

Questions?

Further reading

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