Another nail in the coffin for California's aquatic ecosystems?

Invasion risks of introduced watersnakes

Brian D. Todd, PhD

UCDAVIS
UNIVERSITY OF CALIFORNIA

http://toddlab.ucdavis.edu

Collaborators

Jonathan Rose
Ecology PhD candidate
UC Davis

Dr. JD Willson
Assistant Professor
University of Arkansas

Dr. Bob Reed
Invasive Species Science
USGS

Overview

- The state of California's aquatic species
- Invasive species and aquatic systems in CA
- Effects of invasive species globally
- Natural history of watersnakes
- Status of watersnakes in CA
- Invasion process
- Predicted invasion risk and impact
- Future steps
- How you can be involved

Biological Conservation 144 (2011) 2414–2423

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journal homepage: www.elsevier.com/locate/biocon

Rapid decline of California's native inland fishes: A status assessment

Peter B. Moyle *, Jacob V.E. Katz, Rebecca M. Quiñones

Center for Watershed Sciences, University of California, 1 Shields Avenue, Davis, CA 95616, USA
Department of Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Avenue, Davis, CA 95616, USA

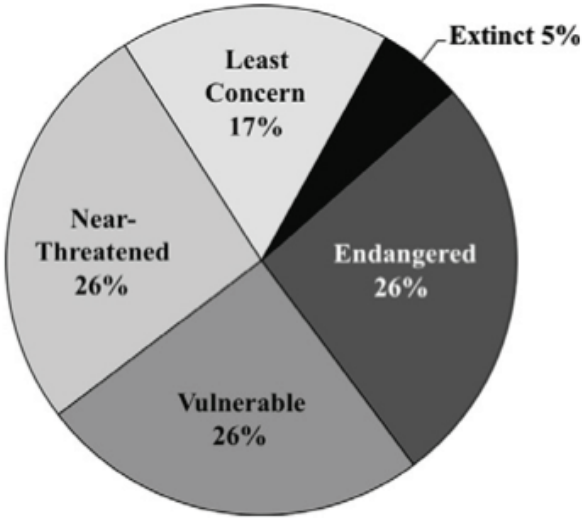
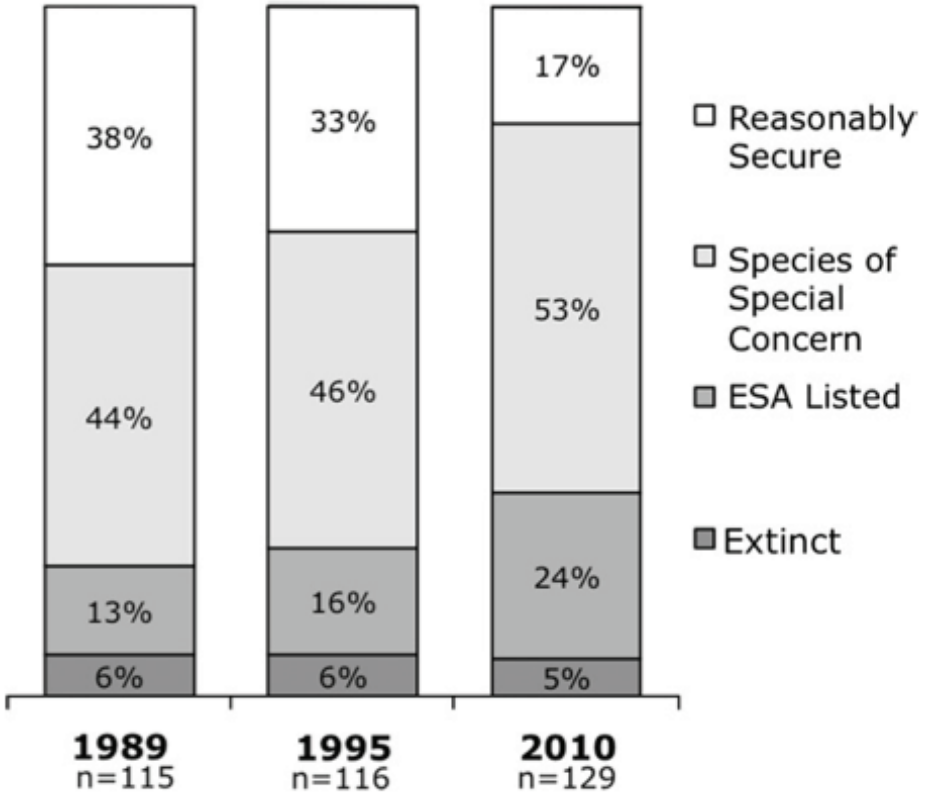


Fig. 1. Status of fishes ($N = 129$) native to inland waters of California in 2010. All threat categories are approximately equivalent to IUCN threat levels of the same name. Extinct = globally extinct or extirpated in the inland waters of California. Endangered = highly vulnerable to extinction in its native range, approximately equivalent to IUCN threat level of *endangered* or *critically endangered*. Vulnerable = could easily become threatened or endangered if current trends continue. Near threatened = populations in decline or highly fragmented. Least concern = no extinction threat for California populations.



Environ Biol Fish
DOI 10.1007/s10641-012-9974-8

2012

Impending extinction of salmon, steelhead, and trout (Salmonidae) in California

Jacob Katz · Peter B. Moyle · Rebecca M. Quiñones · Joshua Israel · Sabra Purdy

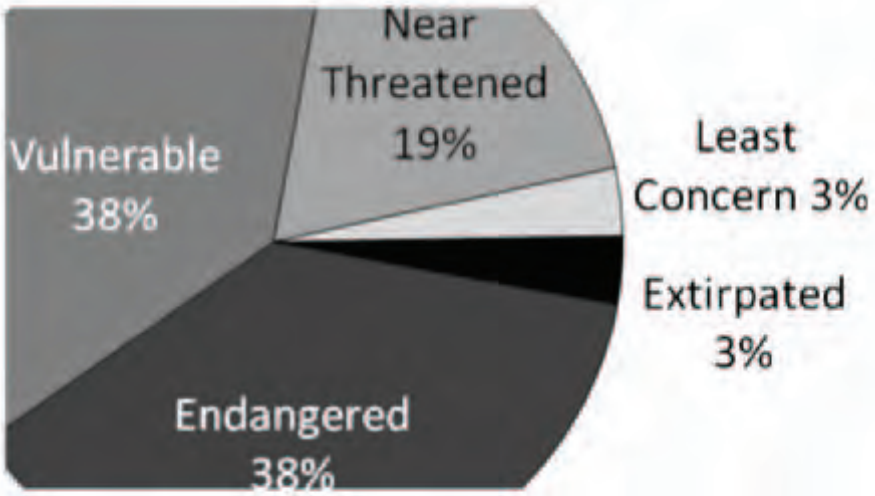


Fig. 1 2011 Conservation status of native salmonid fishes of California (N=32). See Table 5 for category definitions

1996

The Decline of Amphibians in California's Great Central Valley

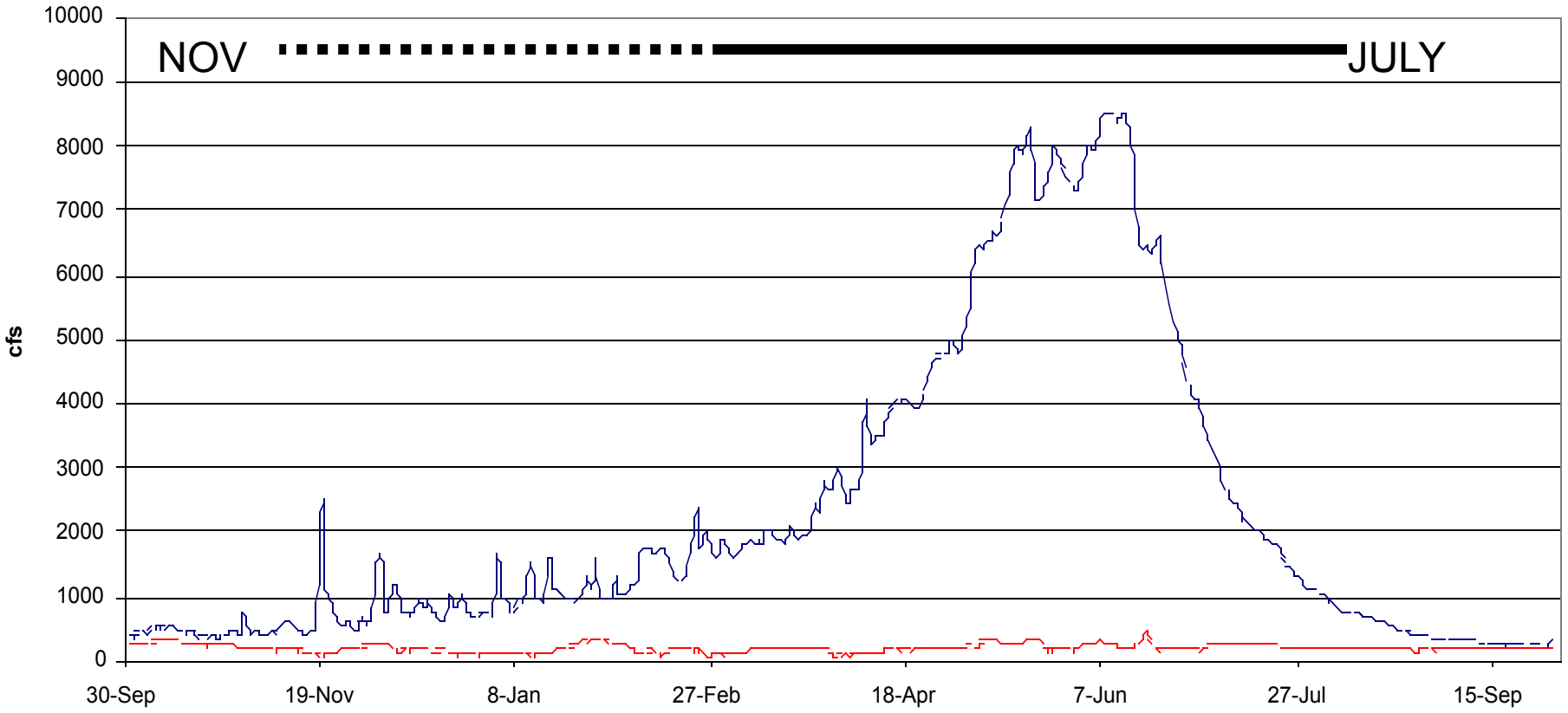
ROBERT N. FISHER* AND H. BRADLEY SHAFFER

Section of Evolution and Ecology and Center for Population Biology, University of California, Davis, Davis, CA 95616, U.S.A.

Current status of California species

	# "species"	Fed TE	State TE	SSC	SSC or greater
Amphibians	77	10%	17%	29%	46%
Reptiles	141	5%	6%	18%	23%
Total	218	7%	10%	22%	31%

River flow hydrograph



* Virtually all the flows released from Friant Dam in a normal year are diverted and no water reaches below Mendota Pool.

San Joaquin River

Flow regime before (blue) and after (red) dam

Ecological Applications, 22(5), 2012, pp. 1472–1482

Restoring native fish assemblages to a regulated California stream using the natural flow regime concept

JOSEPH D. KIERNAN,[1,2,4] PETER B. MOYLE,[2] AND PATRICK K. CRAIN[2,3]

[1]*Fisheries Ecology Division, Southwest Fisheries Science Center, NOAA National Marine Fisheries Service, 110 Shaffer Road, Santa Cruz, California 95060 USA*
[2]*Center for Watershed Sciences, University of California, One Shields Avenue, Davis, California 95616 USA*
[3]*ICF International, 630 K Street, Suite 400, Sacramento, California 95814 USA*

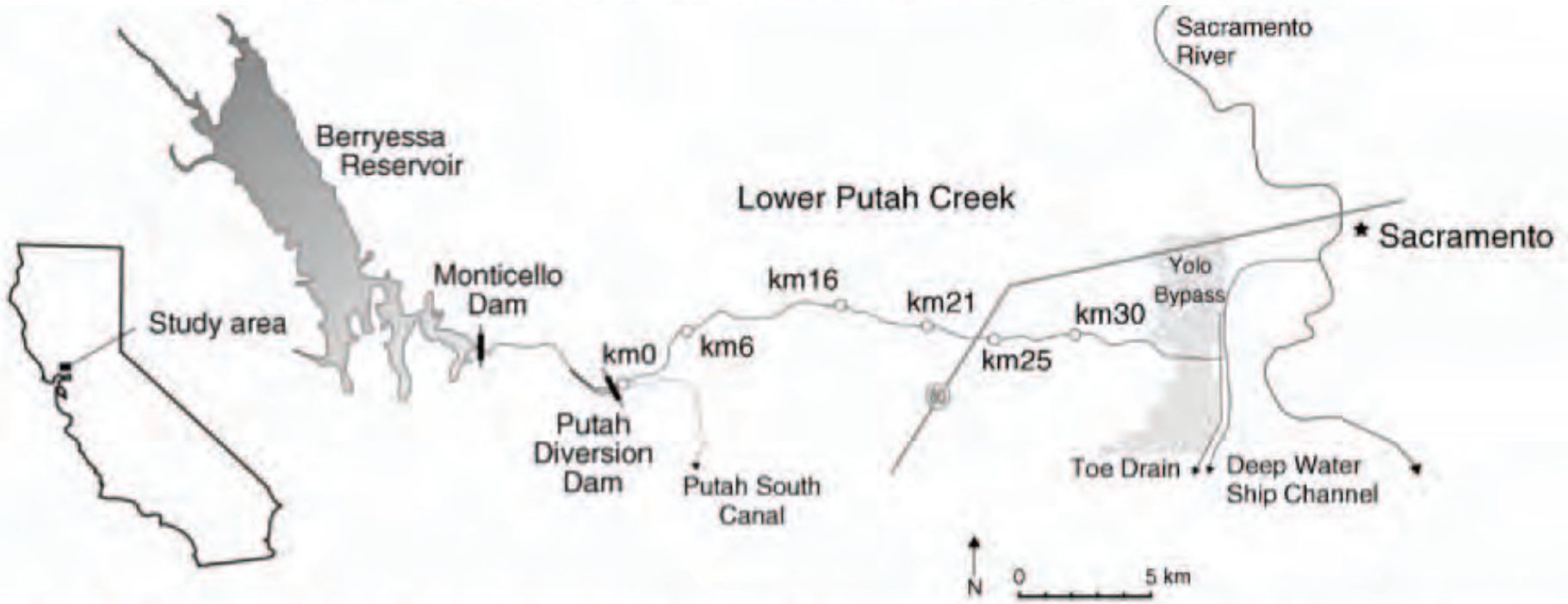


FIG. 1. Map of lower Putah Creek, Yolo and Solano counties, California, USA. Sample sites (open circles) are coded to reflect their approximate distance (in kilometers) downstream of the Putah Diversion Dam (e.g., km16 = 16.2 km below the diversion).

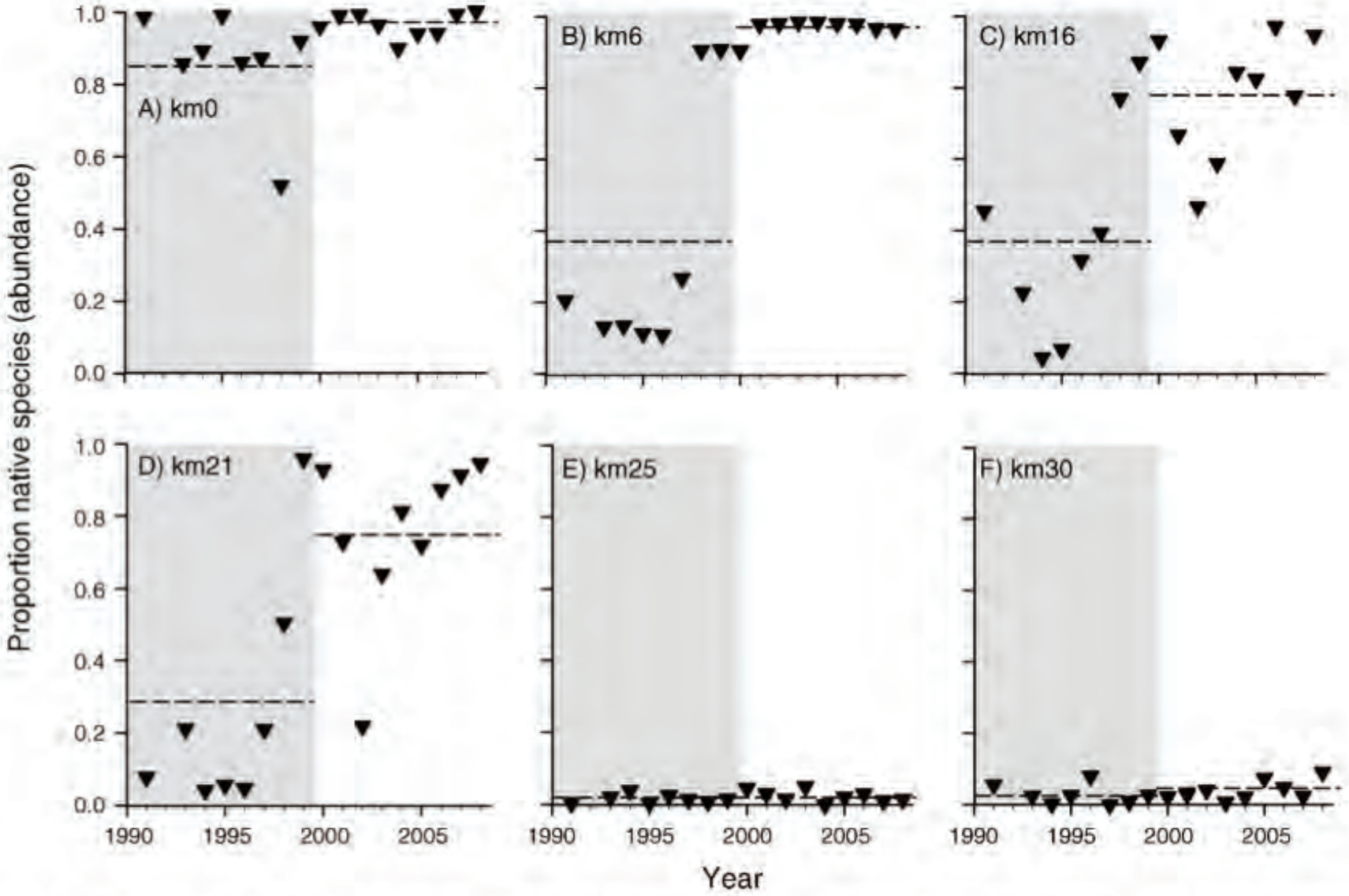


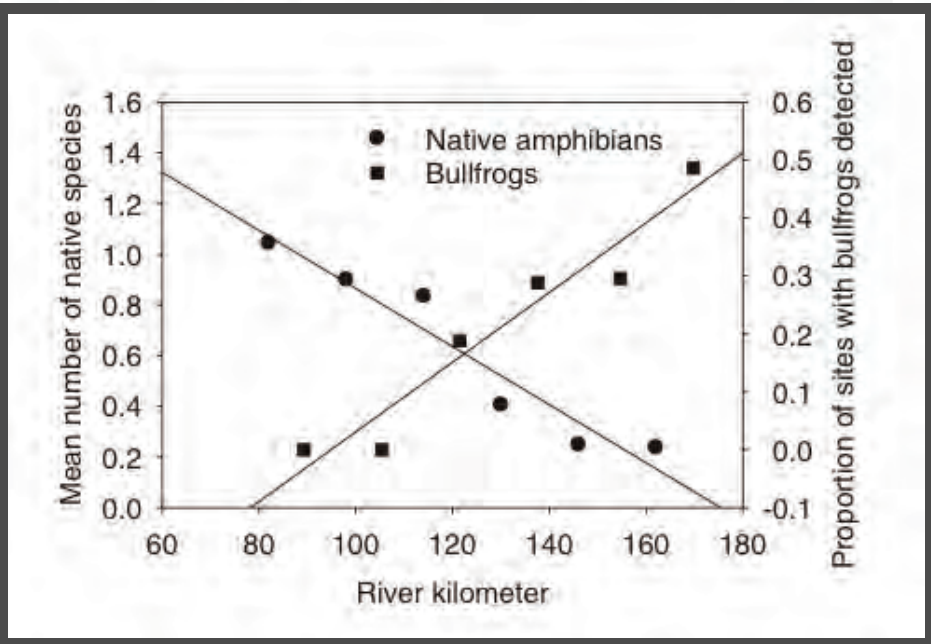
FIG. 5. Time series (1991–2008) of the proportion of the total fish assemblage composed of native species at six permanent sample sites. Sites are presented from upstream to downstream, and site codes (e.g., km0) reflect approximate distances downstream of the Putah Diversion Dam. The gray shaded region in each plot identifies the pre-Accord period (1991–1999). Horizontal dashed lines indicate the mean proportion of native species during each time period.

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL
2010

RESEARCH ARTICLE

Linking the Distribution of an Invasive Amphibian *(Rana catesbeiana)* to Habitat Conditions in a Managed River System in Northern California

Terra E. Fuller,[1,2,3] Karen L. Pope,[1] Donald T. Ashton,[1] and Hartwell H. Welsh Jr.[1]



Farther from dam

Closer to dam

Complications from invasive species

- Novel competitors
- Novel predators
- Novel prey
- Change in vegetation communities and habitat structure
- Change in ecosystem structure and function

Invasive predators

Opinion TRENDS in Ecology and Evolution Vol.19 No.9 September 2004
Full text provided by www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER

Are invasive species a major cause of extinctions?

Jessica Gurevitch and Dianna K. Padilla

Department of Ecology and Evolution, Stony Brook University, Stony Brook, NY 11794-5245, USA

"Based upon theory and observational data, **alien predators** and pathogens have been predicted to be far more likely … to cause the extinction of native species."

Invasive predators

Opinion TRENDS in Ecology and Evolution Vol.19 No.9 September 2004

Full text provided by www.sciencedirect.com

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Are invasive species a major cause of extinctions?

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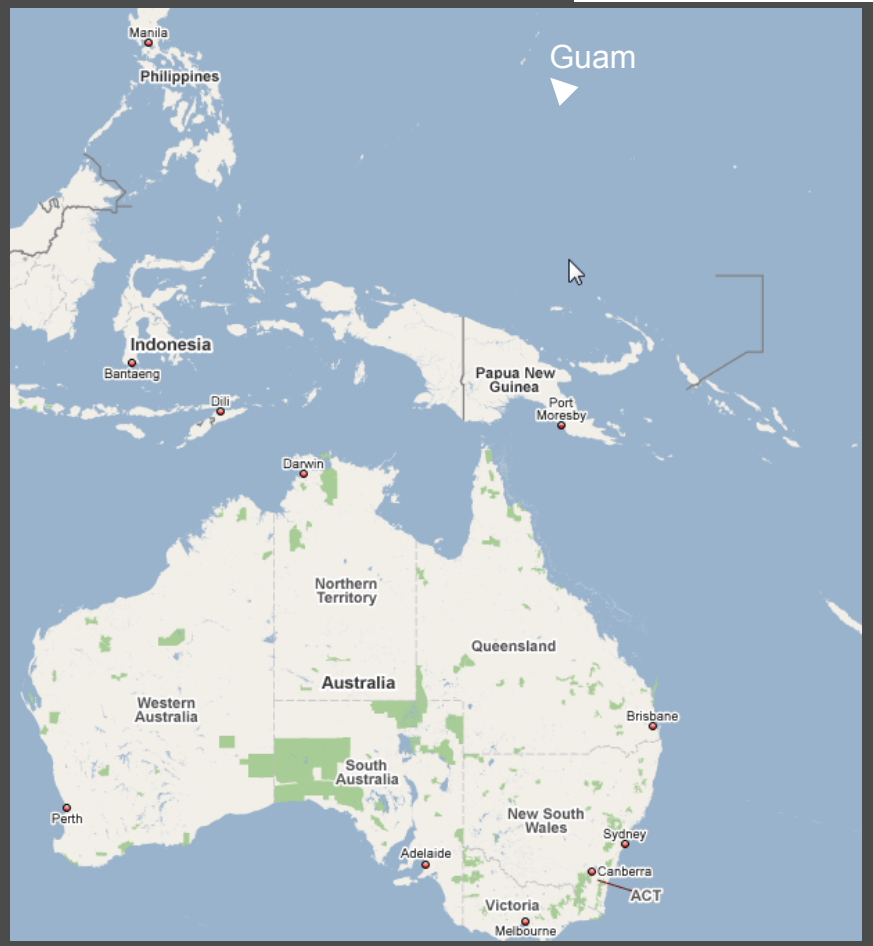
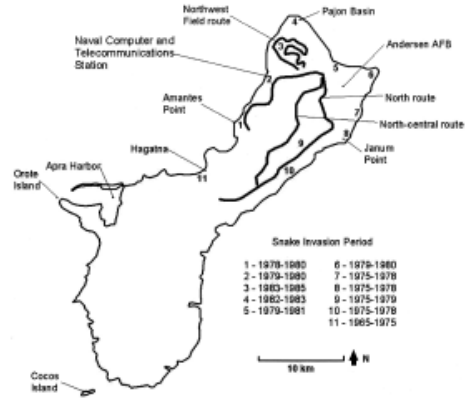
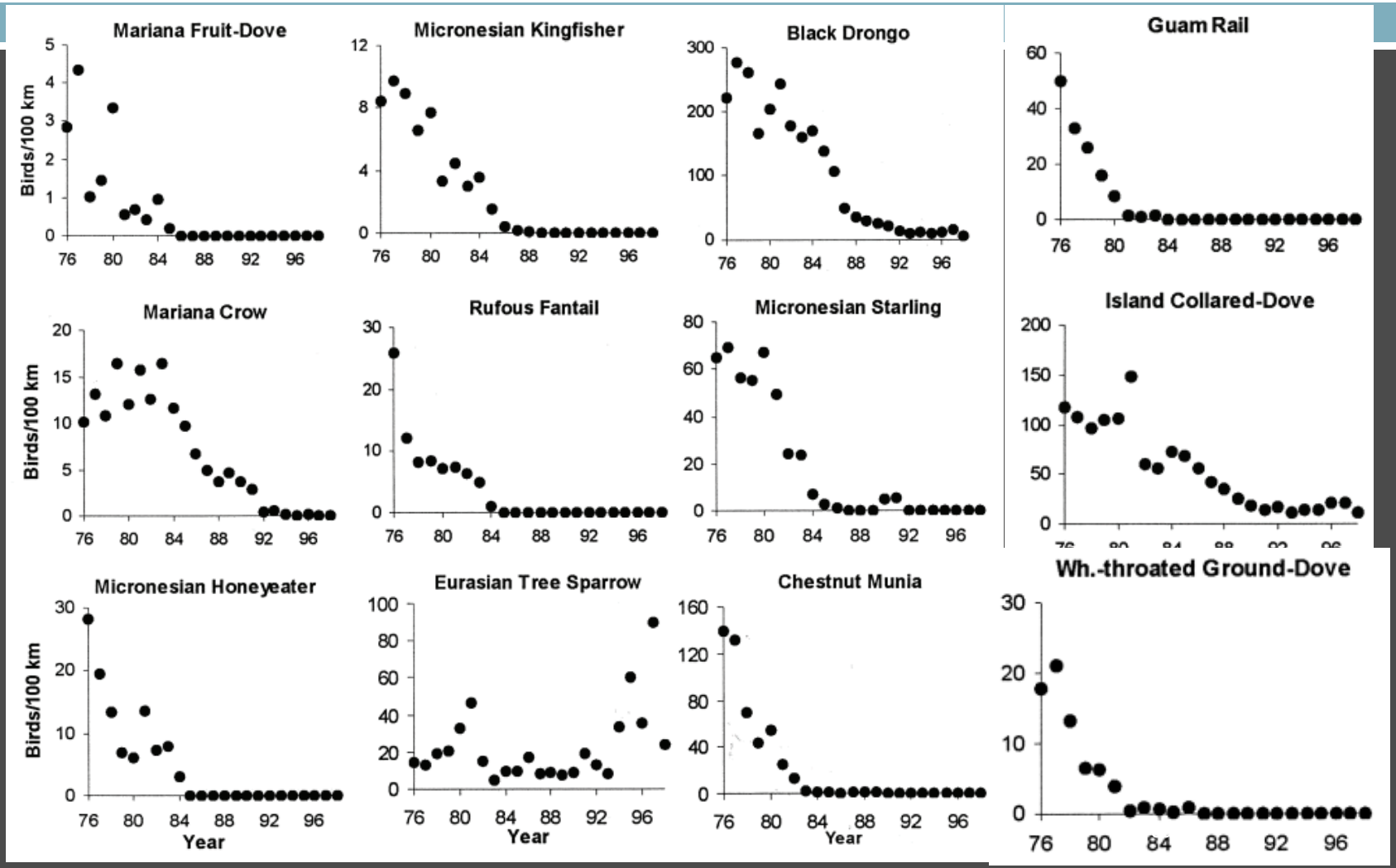
"Even within functional groups, a few species appear to have caused a disproportionate share of incipient and actual extinctions. A few widespread rat species, feral pigs, **several predatory snakes** …"

Brown tree snake in Guam



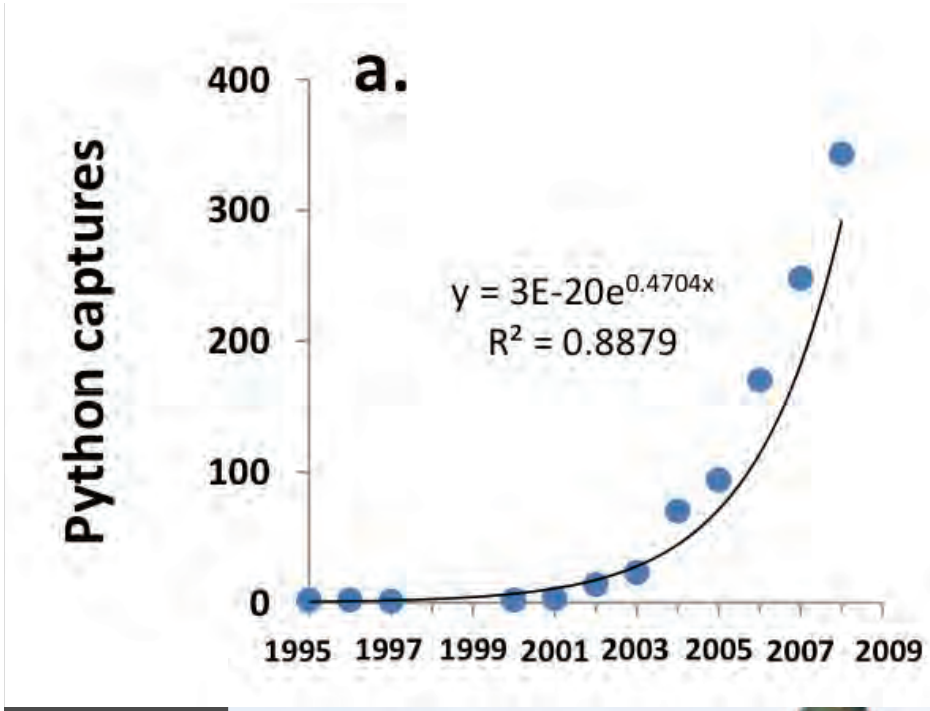


Bird extinctions on Guam



(Wiles et al. 2003. Conservation Biology)

Burmese pythons,
Python molurus,
in Florida Everglades


a.
Python captures
400
300
200
100
0
y = 3E-20e^0.4704x
R² = 0.8879
1995 1997 1999 2001 2003 2005 2007 2009

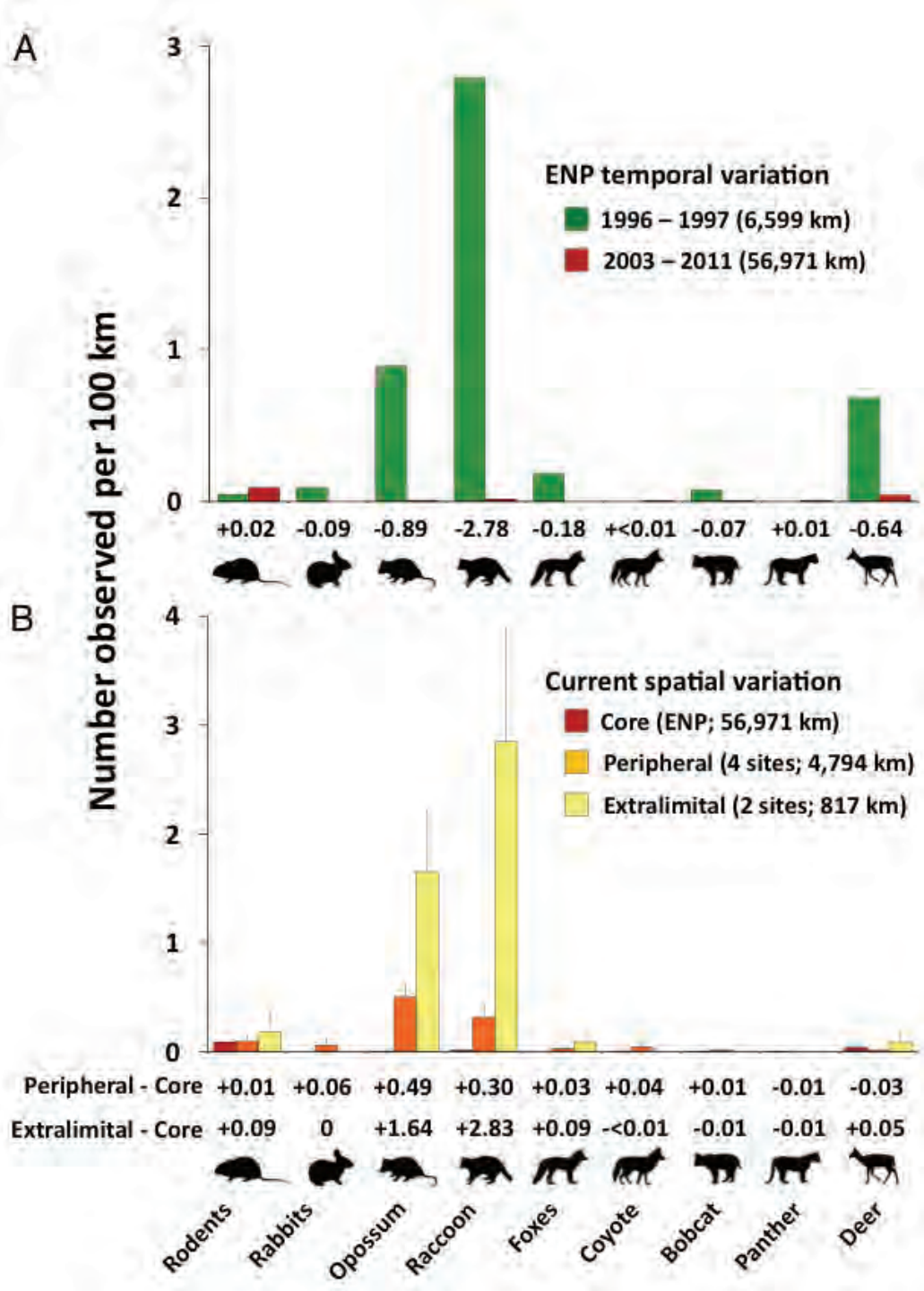
PNAS

Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park

Michael E. Dorcas[a,1], John D. Willson[b], Robert N. Reed[c], Ray W. Snow[d], Michael R. Rochford[e], Melissa A. Miller[f], Walter E. Meshaka, Jr.[g], Paul T. Andreadis[h], Frank J. Mazzotti[e], Christina M. Romagosa[i], and Kristen M. Hart[j]

[a]Department of Biology, Davidson College, Davidson, NC 28035; [b]Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; [c]Fort Collins Science Center, US Geological Survey, Fort Collins, CO 80526; [d]Everglades National Park, National Park Service, Homestead, FL 33034; [e]Fort Lauderdale Research and Education Center, University of Florida, Davie, FL 33314; [f]Department of Biological Sciences, Auburn University, Auburn, AL 36849; [g]State Museum of Pennsylvania, Harrisburg, PA 17120; [h]Department of Biology, Denison University, Granville, OH 43023; [i]Center for Forest Sustainability, Auburn University, Auburn, AL 36849; and [j]Southeast Ecological Science Center, US Geological Survey, Davie, FL 33314

Edited by Peter M. Vitousek, Stanford University, Stanford, CA, and approved December 21, 2011 (received for review September 26, 2011)



"…road surveys totaling 56,971 km from 2003–2011 documented a **99.3% decrease** in the frequency of raccoon observations, **decreases of 98.9% and 87.5%** for opossum and bobcat observations, respectively, and **failed to detect** rabbits."

Dorcas et al. 2012


D4

Non-native Watersnakes, *Nerodia* spp., in California

Natural history of Watersnakes

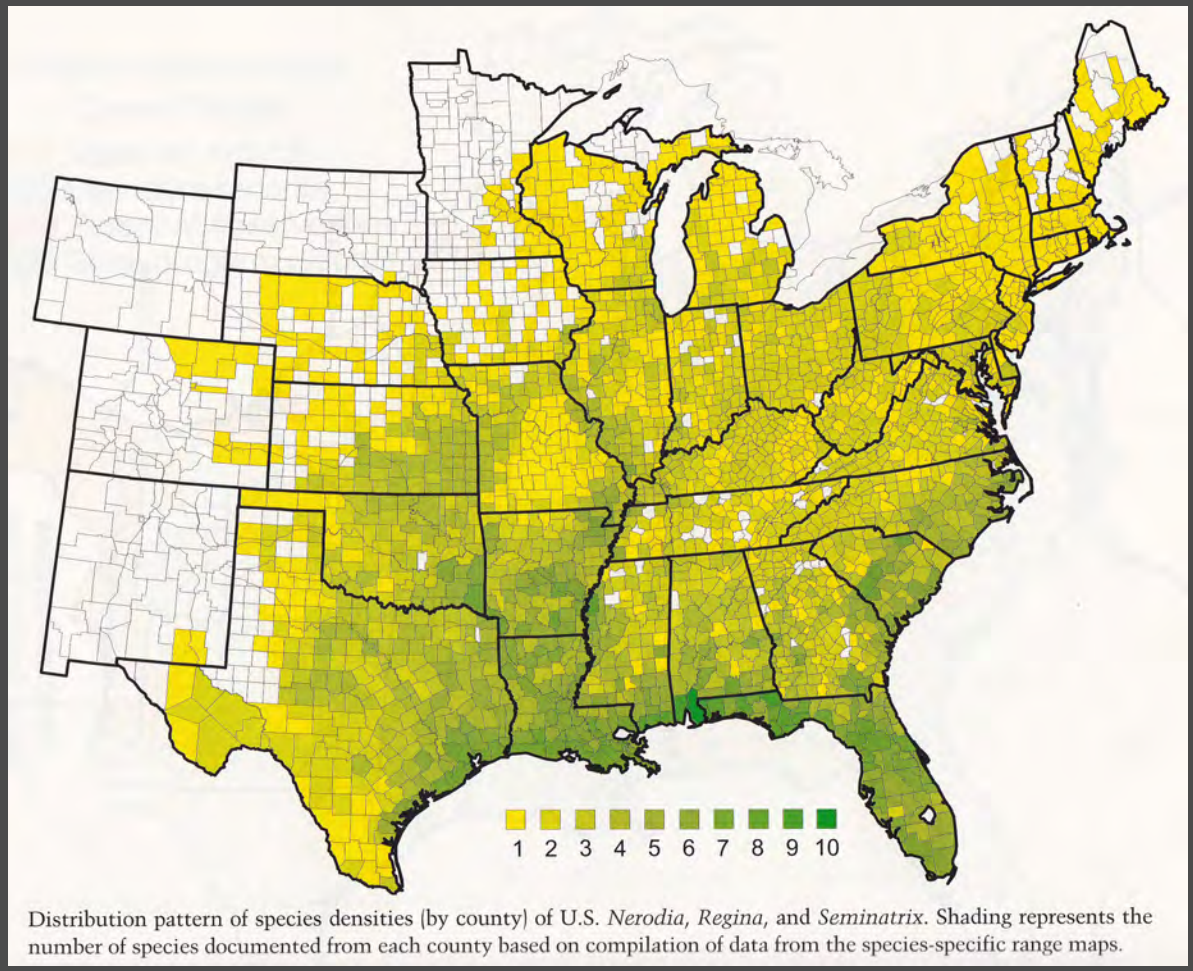
- Highly/entirely aquatic ("Watersnakes")






Natural history of Watersnakes

- Eastern North American clade
  - 10 species



Distribution pattern of species densities (by county) of U.S. *Nerodia*, *Regina*, and *Seminatrix*. Shading represents the number of species documented from each county based on compilation of data from the species-specific range maps.

Natural history of Watersnakes

- Voracious predators / dietary generalists

Natural history of Watersnakes

- Viviparous and highly fecund.

History of Watersnakes in CA

- 1976 – *Nerodia fasciata* seen in LA County
- 1980s – *N. rhombifer* in Contra Costa County (Lafayette Reservoir)
- 1992 – *N. fasciata* in Sacramento County (Folsom)
- 2006 – *N. fasciata* in LA County (Harbor City)
- 2007 – *N. sipedon* in Placer County (Roseville)

History of Watersnakes in CA

- ~~1976 – *Nerodia fasciata* seen in LA County~~
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- 2007 – *N. sipedon* in Placer County (Roseville)

Known populations in California

2007

Nerodia sipedon
Common Watersnake

1992

Nerodia fasciata
Southern Watersnake

2006

CDFW restricted possession in 2008

California Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

RESTRICTED SPECIES LAWS AND REGULATIONS

IMPORTATION, TRANSPORTATION AND POSSESSION OF WILD ANIMALS – MANUAL 671

(11)Class Reptilia -Reptiles

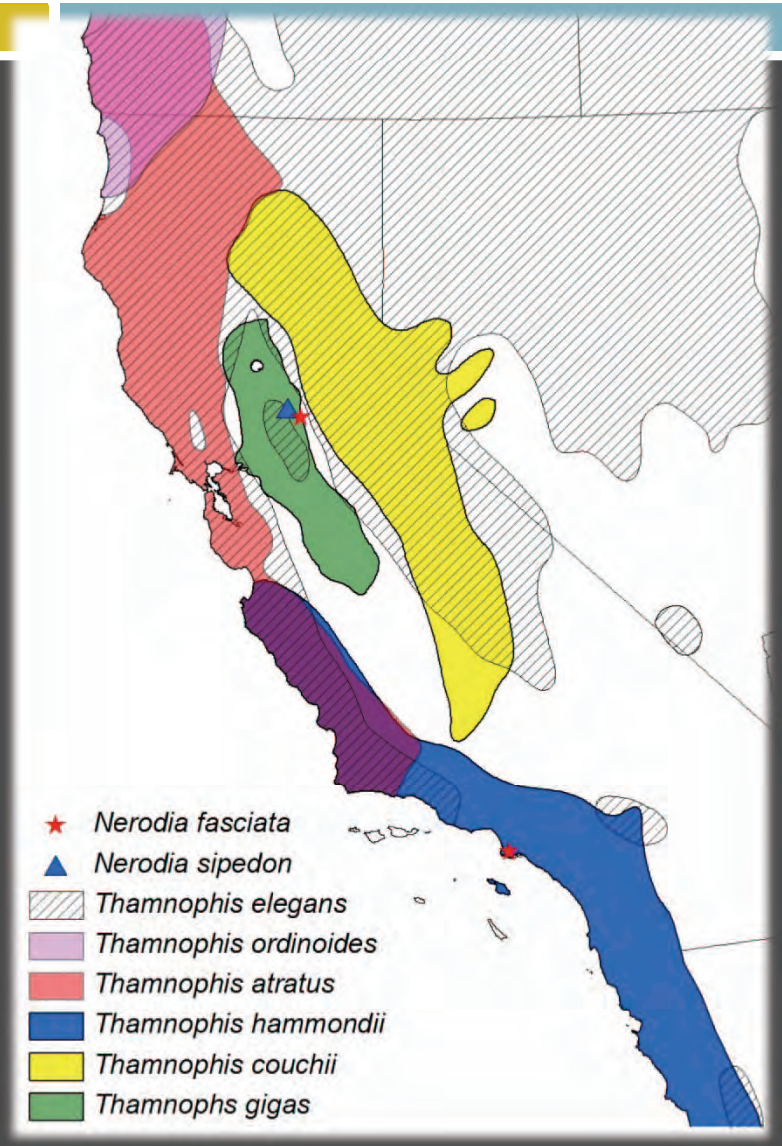
(A) Order Crocodilia -Crocodiles, Caimans, Alligators and Gavials: All species (D). (B)
Family Chelyridae -Snapping Turtles: All species (D).
(C) Family Elapidae -Cobras, Coral Snakes, Mambas, Kraits, etc.: All species (D). (D)
Family Viperidae -Adders and Vipers: All species (D).
(E) Family Crotalidae -Pit Vipers: All species (D), except Crotalus viridis (Western rattlesnake), Crotalus atrox (Western diamondback rattlesnake), Crotalus ruber (red diamondback rattlesnake), Crotalus scutulatus (Mojave rattlesnake), Crotalus mitchelli (speckled rattlesnake) and Crotalus cerastes (Sidewinder) not restricted.
(F) Family Colubridae -Colubrids:

1. Dispholidus typus (Boomslang) (D).
2. Theoltornis kitlandii (Bird or vine snake) (D).
3. All species of genus Nerodia (watersnakes) (D). (G)

Family Helodermatidae:

1. Heloderma suspectum suspectum (reticulate Gila monster) (D).

Gartersnakes in California



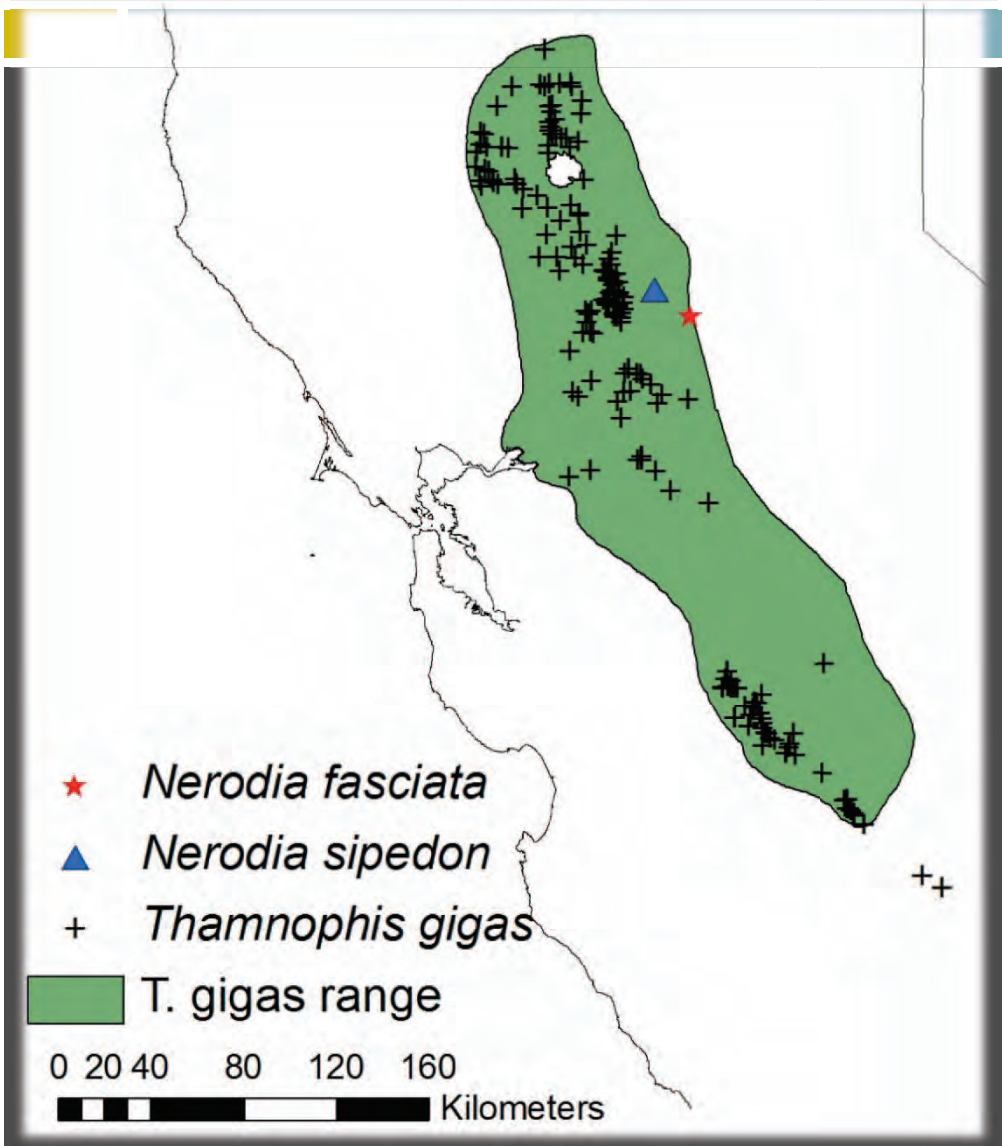
Closely related gartersnakes

- *Thamnophis* – 8 species ("Gartersnakes")
- Two state- and federally-listed species

San Francisco Gartersnake

Giant Gartersnake

Proximity to Giant GarterSnakes



- *N. fasciata*
  - Folsom in 1992
- *N. sipedon*
  - Roseville in 2007
  - ~ 13 km from GGS populations

Stages of Invasion

(Moyle and Light 1996; Richardson and Pysek 2006)

Native Species Pool

▼

Transport

▼

Incipient stages of invasion
Possibly preventable

▼

Introduction

▼

Establishment

▼

Eradication potentially still possible

▼

Spread

▼

Impact

▼

Requires adjustment to new reality and ongoing management

▼

??? Integration ???

Cost of invasives

Environmental and Economic Costs of Nonindigenous Species in the United States

DAVID PIMENTEL, LORI LACH, RODOLFO ZUNIGA, AND DOUG MORRISON

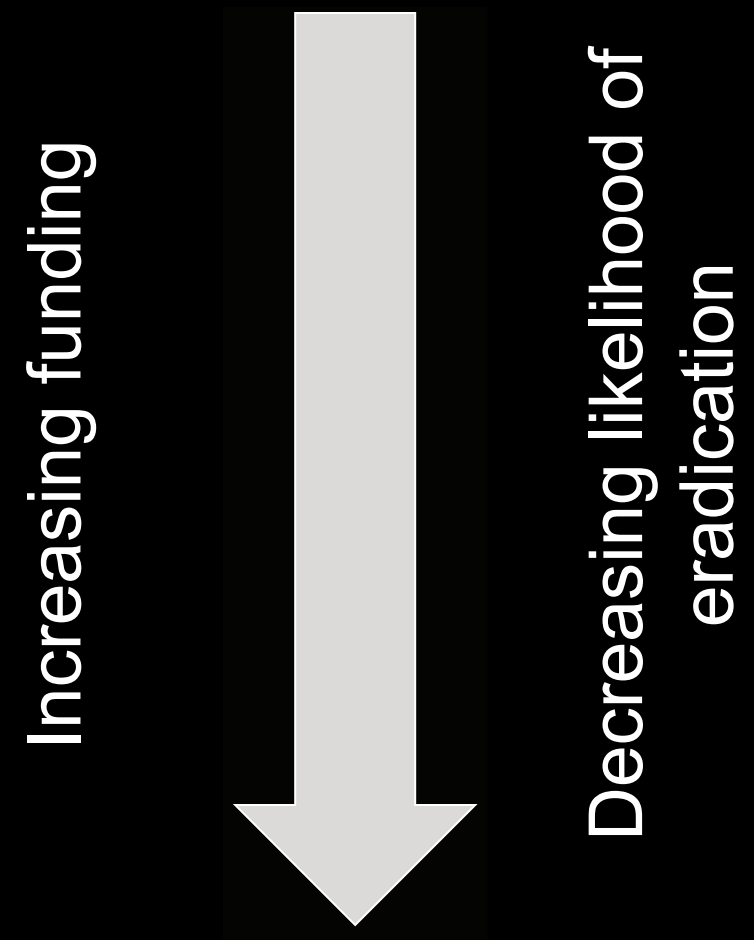
Approximately 50,000 nonindigenous (non-native) species are estimated to have been introduced to the United States. Some of these are beneficial; for example, species introduced as food crops (e.g., corn, wheat, and rice) and as livestock (e.g., cattle and poultry) now provide more than 98% of the US food system, at a value of approximately $800 billion per year (USBC 1998). Other exotic species have been introduced for landscape restoration, biological pest control, sport, pets, and food processing, also with significant benefits. Some non-

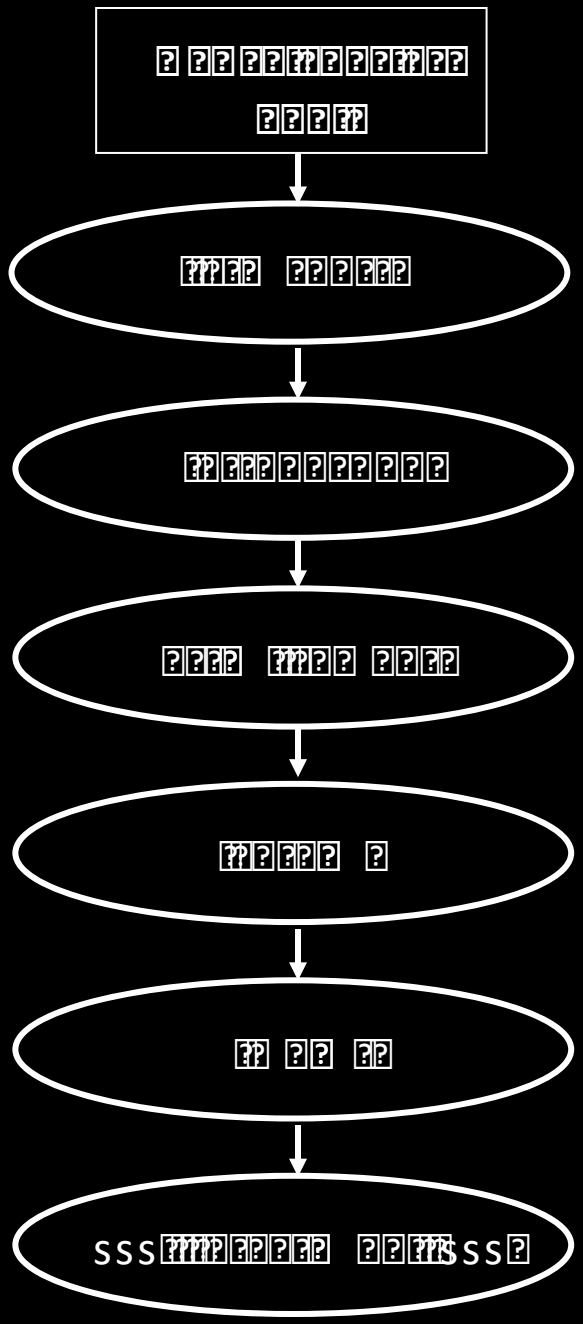
THE APPROXIMATELY 50,000 NONINDIGENOUS SPECIES IN THE UNITED STATES CAUSE MAJOR ENVIRONMENTAL DAMAGE AND LOSSES TOTALING APPROXIMATELY $137 BILLION PER YEAR

Pimentel et al. 2000 Bioscience

Stages of Invasion

(Moyle and Light 1996; Richardson and Pysek 2006)





Objectives

- What is the status of introduced populations?
- What is their likely ‘invasible’ range?
- What risk might they impose to imperiled native species?

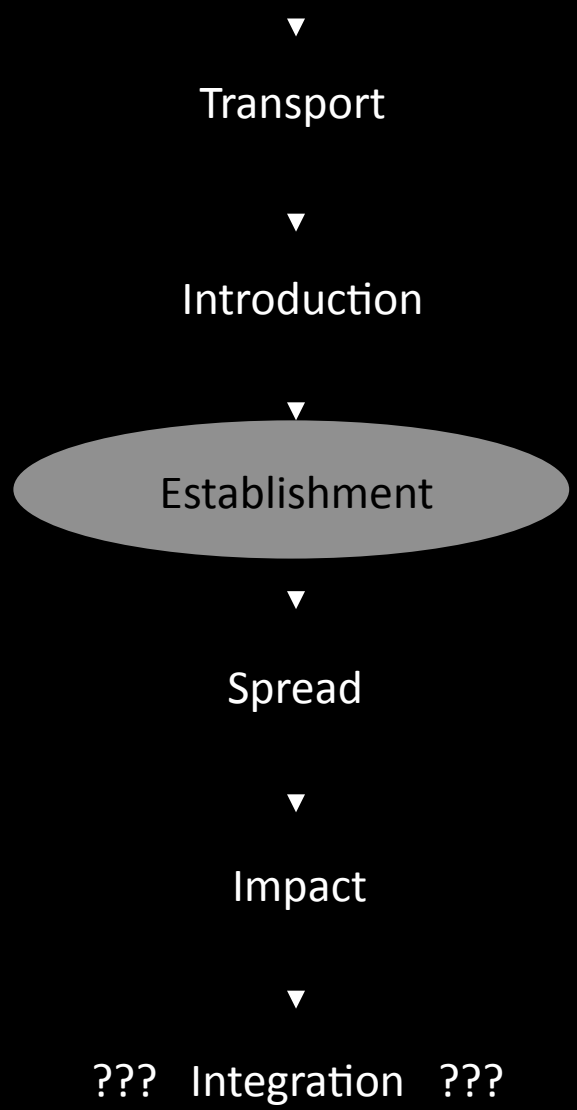
Stages of Invasion

(Moyle and Light 1996; Richardson and Pysek 2006)

Incipient stages of invasion
Possibly preventable

Eradication potentially still possible

Requires adjustment to new reality and ongoing management



Known populations in California

2007

Nerodia sipedon
Common Watersnake

1992

Nerodia fasciata
Southern Watersnake

2006

Status of Folsom population

- *N. fasciata* in Sacramento County
  - Known from 1992
  - Subject of 2003-2004 study
- Extant and reproductive

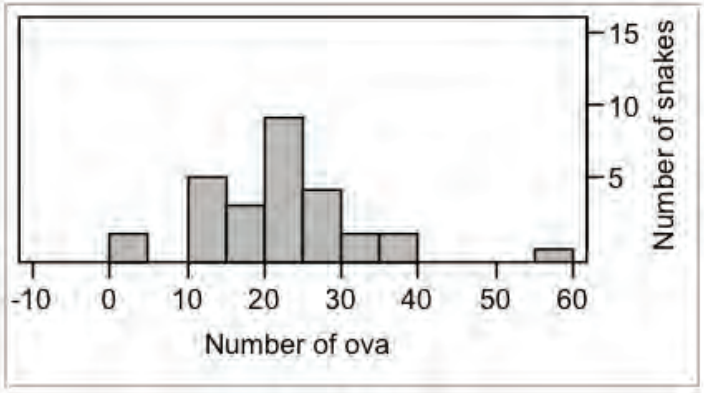
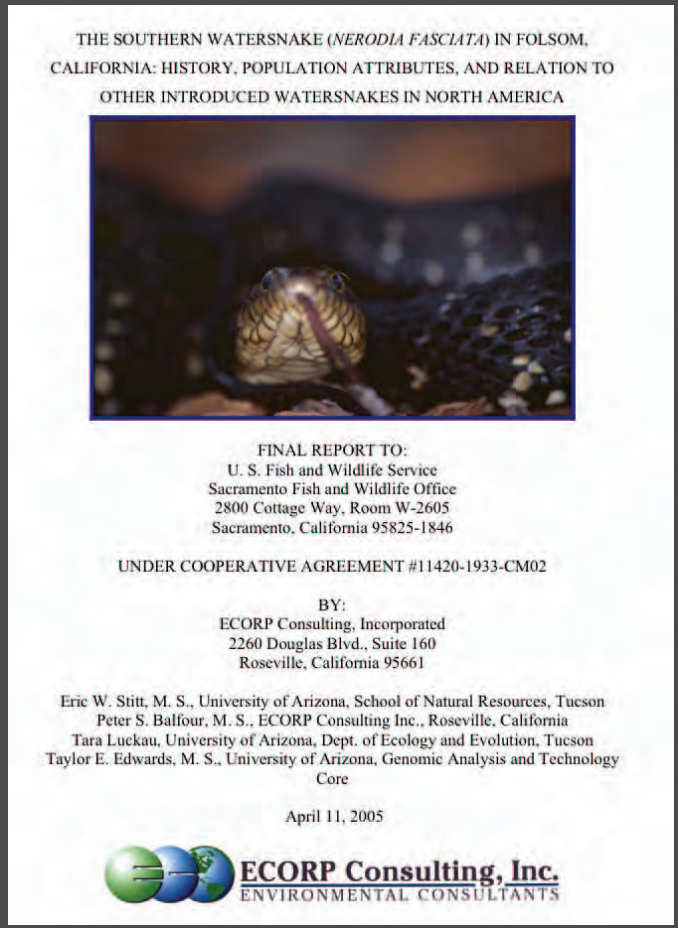


Figure 14. Number of ova for all dissected gravid watersnakes collected from Folsom, California (n = 32).



THE SOUTHERN WATERSNAKE (*NERODIA FASCIATA*) IN FOLSOM, CALIFORNIA: HISTORY, POPULATION ATTRIBUTES, AND RELATION TO OTHER INTRODUCED WATERSNAKES IN NORTH AMERICA

FINAL REPORT TO:
U. S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

UNDER COOPERATIVE AGREEMENT #11420-1933-CM02

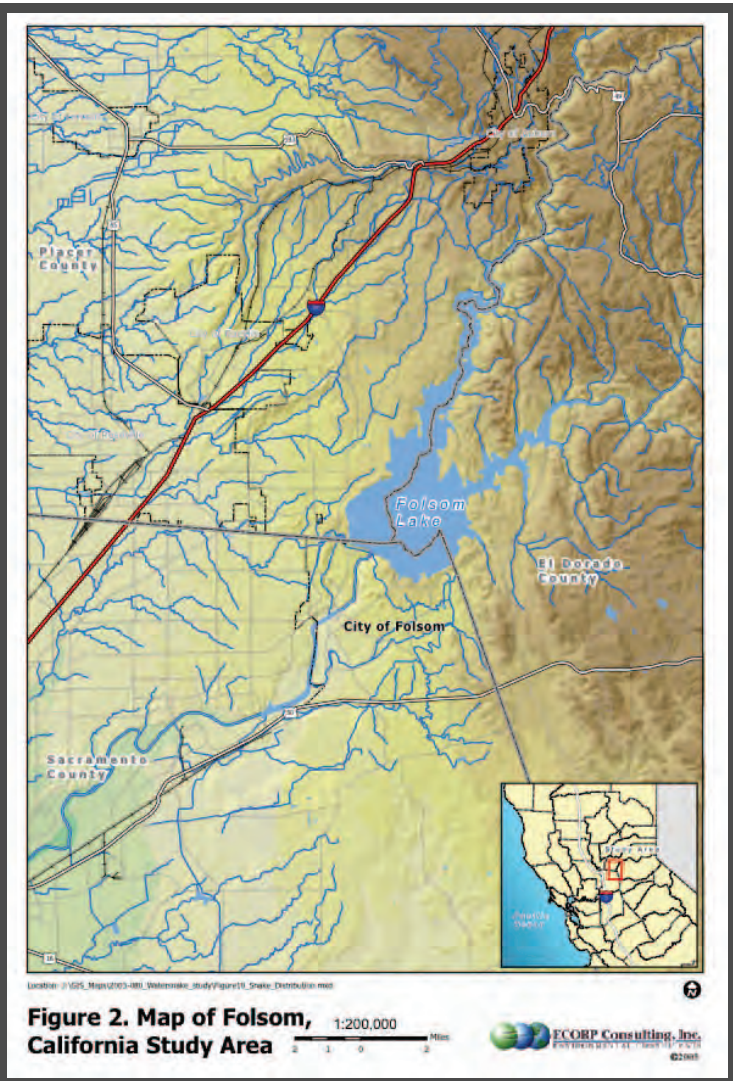
BY:
ECORP Consulting, Incorporated
2260 Douglas Blvd., Suite 160
Roseville, California 95661

Eric W. Stitt, M. S., University of Arizona, School of Natural Resources, Tucson
Peter S. Balfour, M. S., ECORP Consulting Inc., Roseville, California
Tara Luckau, University of Arizona, Dept. of Ecology and Evolution, Tucson
Taylor E. Edwards, M. S., University of Arizona, Genomic Analysis and Technology Core

April 11, 2005

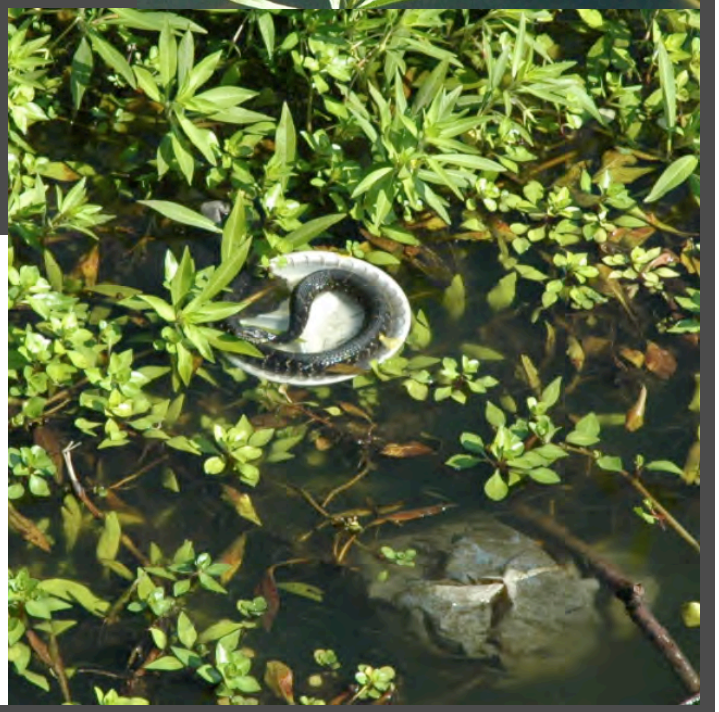
ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

Status of Folsom population



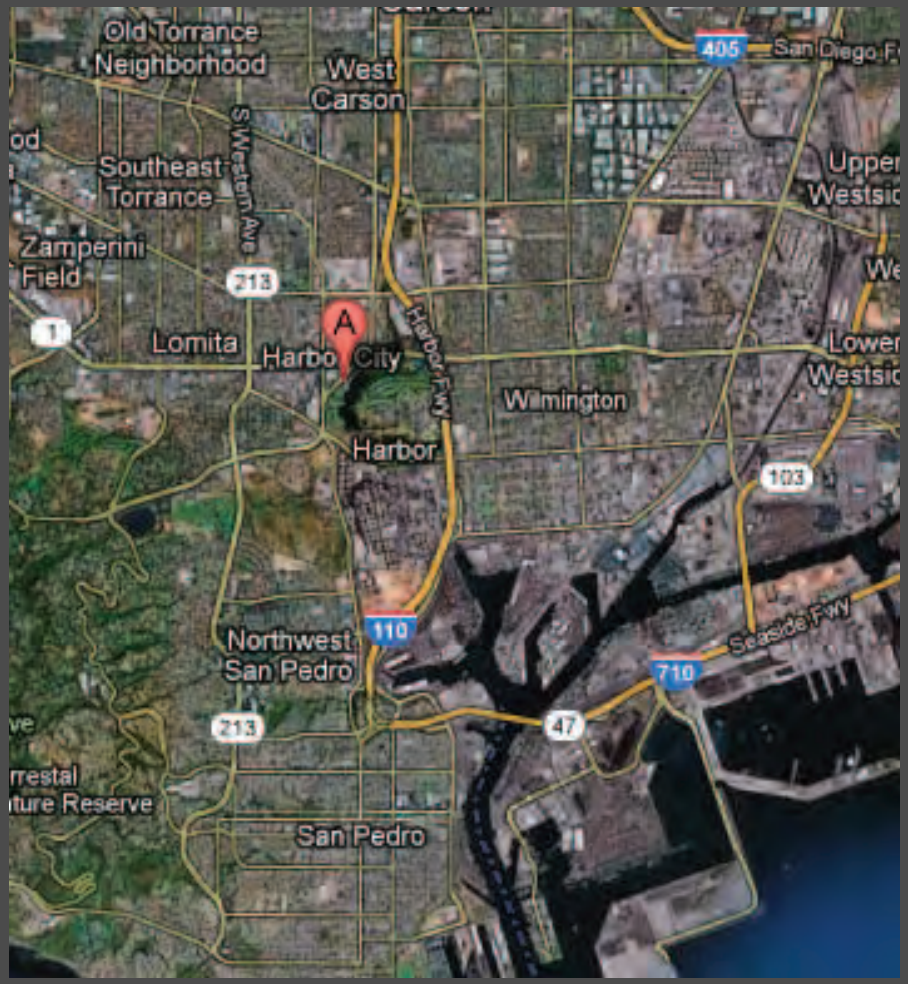
Status of Harbor City population

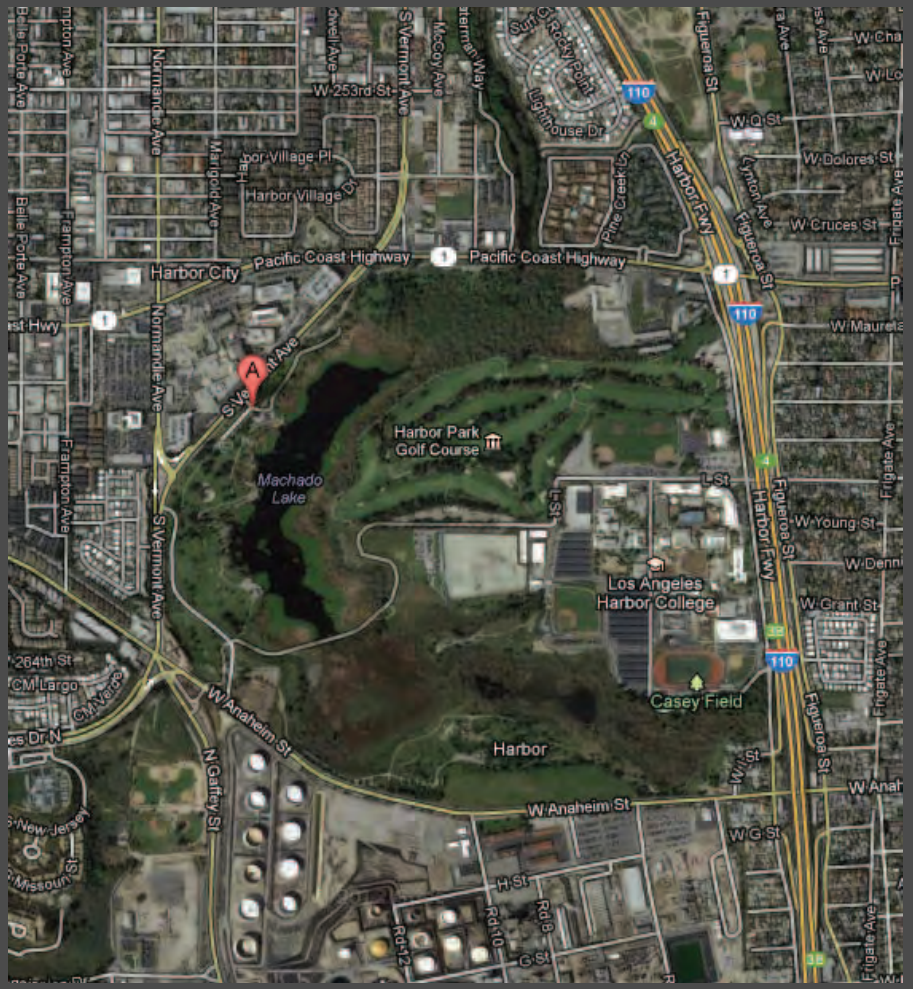
- *N. fasciata* in Los Angeles County
  - Known from 2006
  - No previous work here
  - Subject of our work in 2010
- Extant and reproductive



SVL	N	Mean (mm)	SD	Range
Overall	306	456.1	150.3	162 – 1023
Females	190	460.9	166.2	170 – 1023
Males	115	450.2	120.0	162 – 747

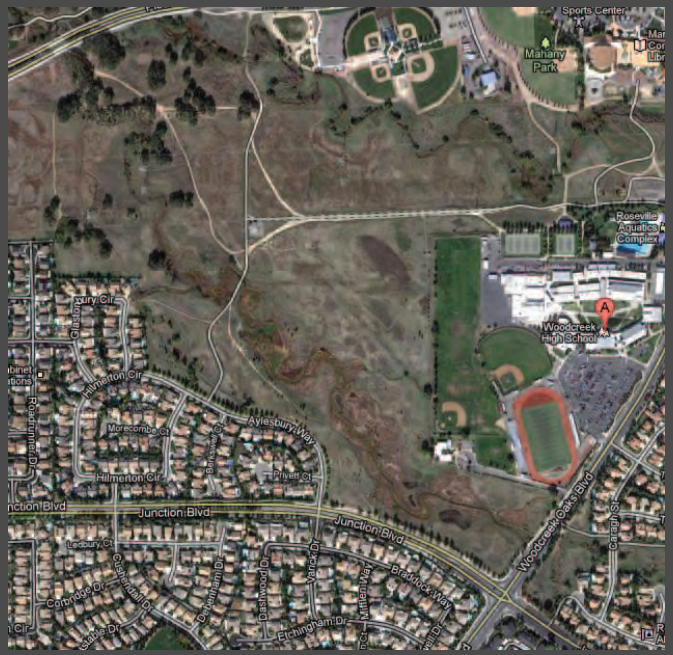
Status of Harbor City population





Status of Placer population

- Known from 2007
- *N. sipedon* in Placerville had not been studied
- Was subject of our work in 2011



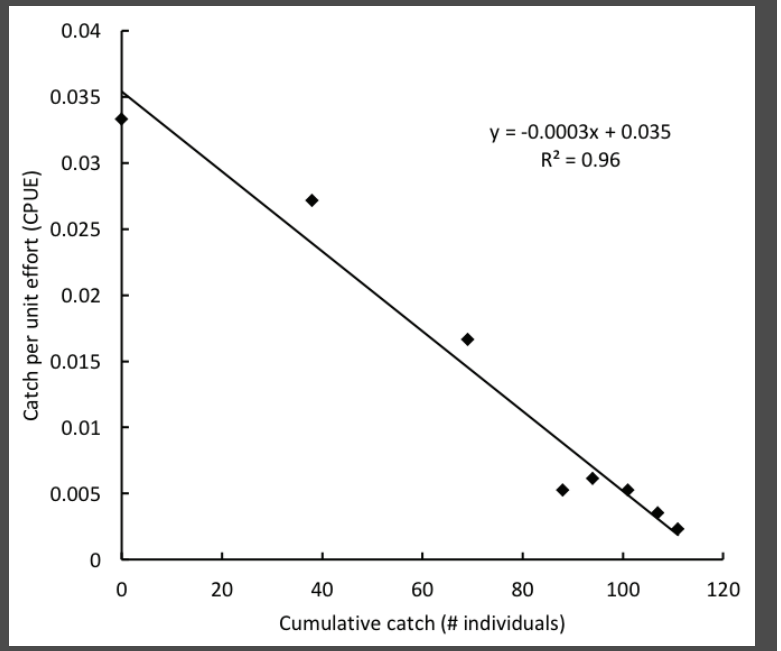
Box Funnel Traps

Aquatic minnow traps

Estimating population size

1) 10 day closed mark-recapture model

2) 57 day removal sampling
   - Leslie depletion curve



3) Count of removed individuals

Estimating population size: Results

1) MR Model: 112.4 (72-251)
2) Leslie depletion model: 114.6 (105-125)
3) Count individuals: 113

- Density: 56.2 snakes / ha
- Total population: 348 individuals

Rose, Miano, Todd 2013

Status of Placer population

- High fecundity
  - 70% of reproductively-sized females were gravid
  - Mean litter size of 19.5 (range: 2-48)

- High capture efficiencies
  - 1 capture per 19-35 trap-nights

Rose, Miano, Todd 2013

First evidence of feeding on natives

Miano, Rose, Todd 2012

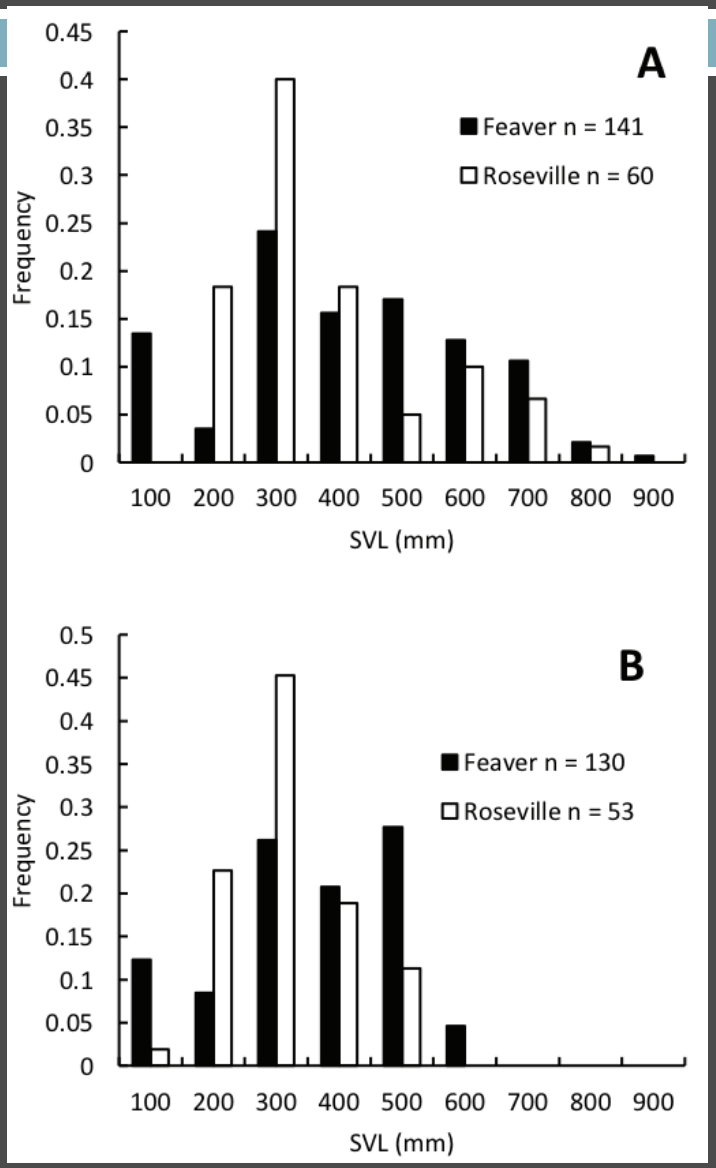
NERODIA SIPEDON **(Northern Watersnake). DIET.** Watersnakes of the genus *Nerodia* are widely distributed in eastern North America but historically have not occurred west of the Colorado River. At least two species of *Nerodia* are now firmly established outside of their native range after being introduced to at least three localities in California. *Nerodia fasciata* is known from Los Angeles Co. (Balfour and Stitt 2002. Herpetol. Rev. 33:150) and Sacramento Co. (Balfour et al. 2007. Herpetol. Rev. 38:489), and *N. sipedon* is known from Placer Co. (Balfour et al. 2007. Herpetol. Rev. 38:489). Although all three populations occur in highly modified suburban or urban habitats, there is growing concern that wider establishment of these introduced species may have deleterious consequences for native wildlife. Concerns include possible competition with native snakes or impacts on native fish and amphibians.

On 5 July 2011, a female *N. sipedon* (SVL = 273 mm; 16.11 g) was captured by hand in Roseville City, Placer Co., California, USA. The snake was palpated to cause it to regurgitate its gut contents, which included another species introduced to California (a small, metamorphic *Lithobates catesbeianus* [American Bullfrog]), and a native amphibian, (an adult *Pseudacris regilla* [Pacific Chorus Frog]). To our knowledge, this represents the first confirmed report of a non-native watersnake feeding on a western species and partly validates concerns over impacts to native species.

OLIVER J. MIANO, JONATHAN P. ROSE, and **BRIAN D. TODD** (e-mail: btodd@ucdavis.edu), Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, One Shields Avenue, Davis, California 95616, USA.

Many juveniles in population

- A) females
- B) males



Rose, Miano, Todd 2013

Objectives

- What is the status of current populations?
  - *N. sipedon* in Roseville: Established and reproductive
  - *N. fasciata* in Folsom: Established and reproductive
  - *N. fasciata* in Harbor City: Established and reproductive
- Can they be removed?
  - High trapping efficiency
  - Demonstrated reduction in CPUE
  - Diversity of size-classes
  - Largest/oldest animals likely poorly captured

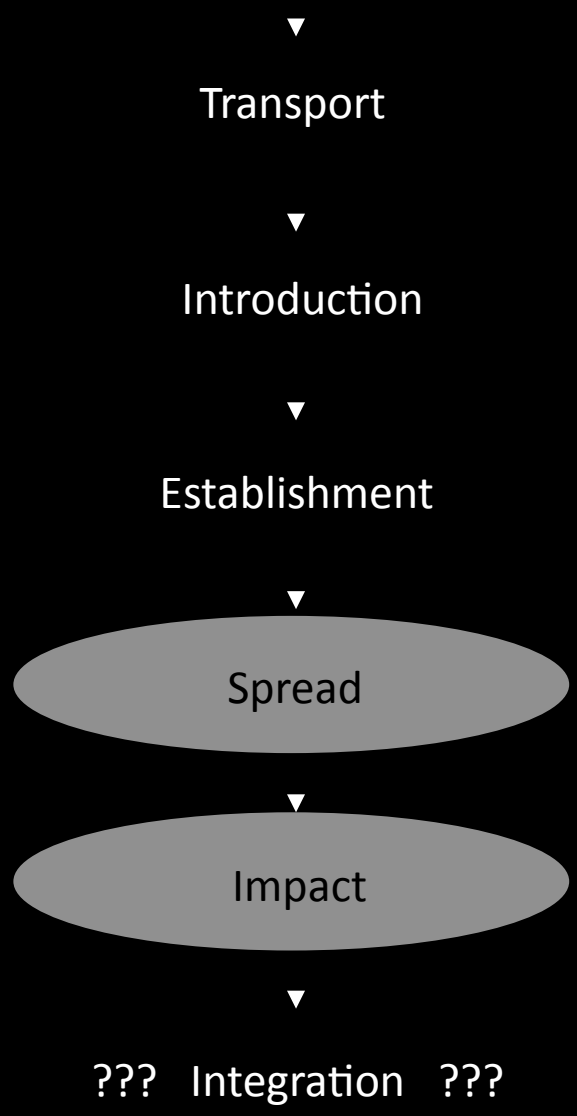
Stages of Invasion

(Moyle and Light 1996; Richardson and Pysek 2006)

Incipient stages of invasion
Possibly preventable

Eradication potentially still possible

Requires adjustment to new reality and ongoing management



Objectives

- What is the status of current populations?
- What is their likely ‘invasible’ range?
- What risk might they impose to sensitive status native species?

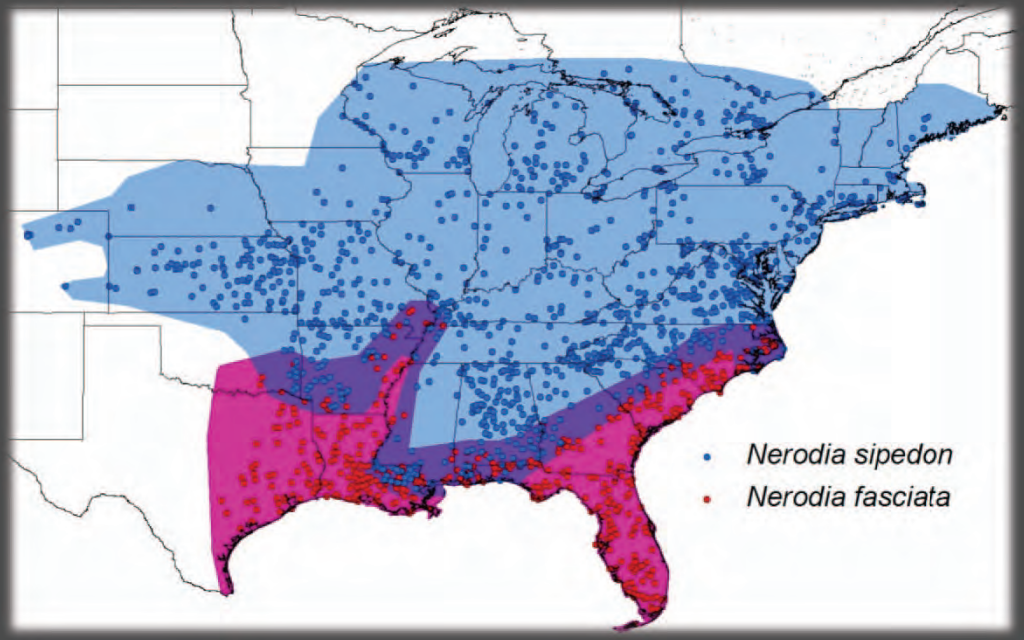
Species Distribution Modeling

- Use all occurrences of species
- Quantify climate where they occur
  - Range of temperature
  - Mean temperature of warmest quarter
  - Mean temperature of coldest quarter
- Identify similar areas across North America
- Include presence of aquatic habitat as limiting factor

Native Ranges

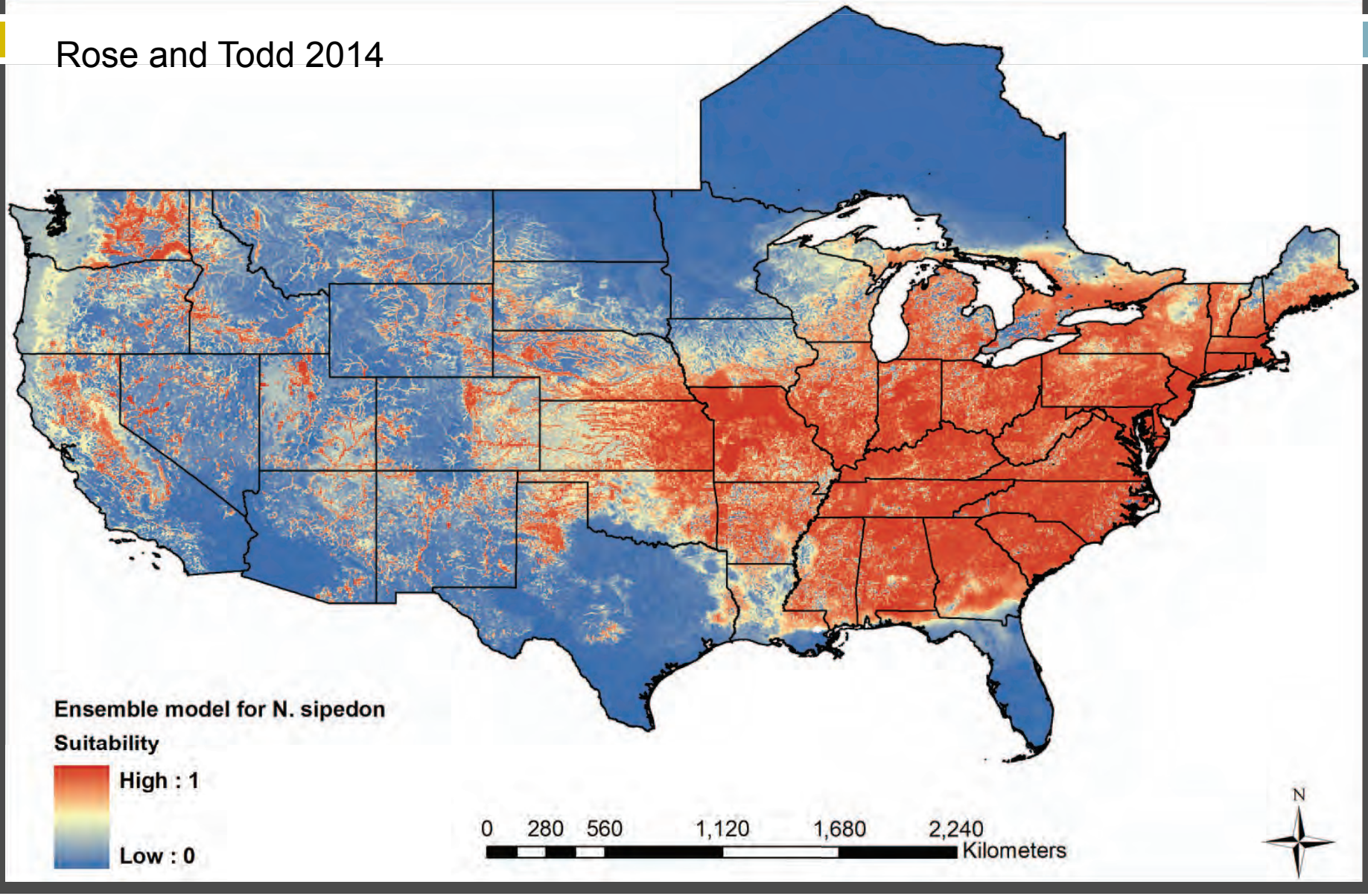
Common Watersnake (*Nerodia sipedon*)

Southern Watersnake (*Nerodia fasciata*)



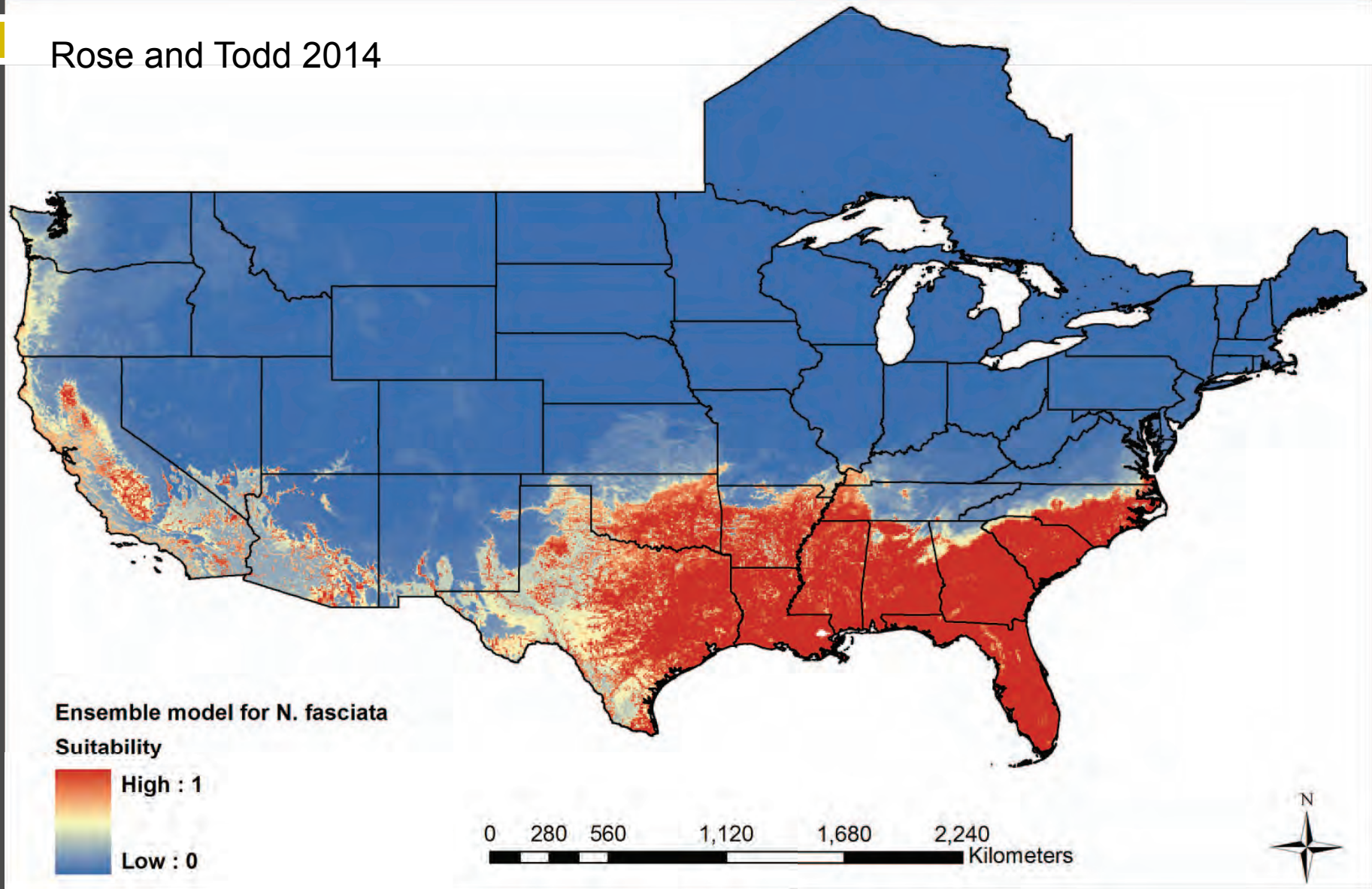
Common Watersnake projections

Rose and Todd 2014



Southern Watersnake projections

Rose and Todd 2014



Predicted suitable habitat

- Common Watersnake – *N. sipedon*
  - Northerly distribution in the West
  - Coastal regions, foothills, and higher elevations
- Southern Watersnake – *N. fasciata*
  - Southerly distribution in the West
  - Central Valley and inland areas

Rose and Todd 2014

Risk to native species?

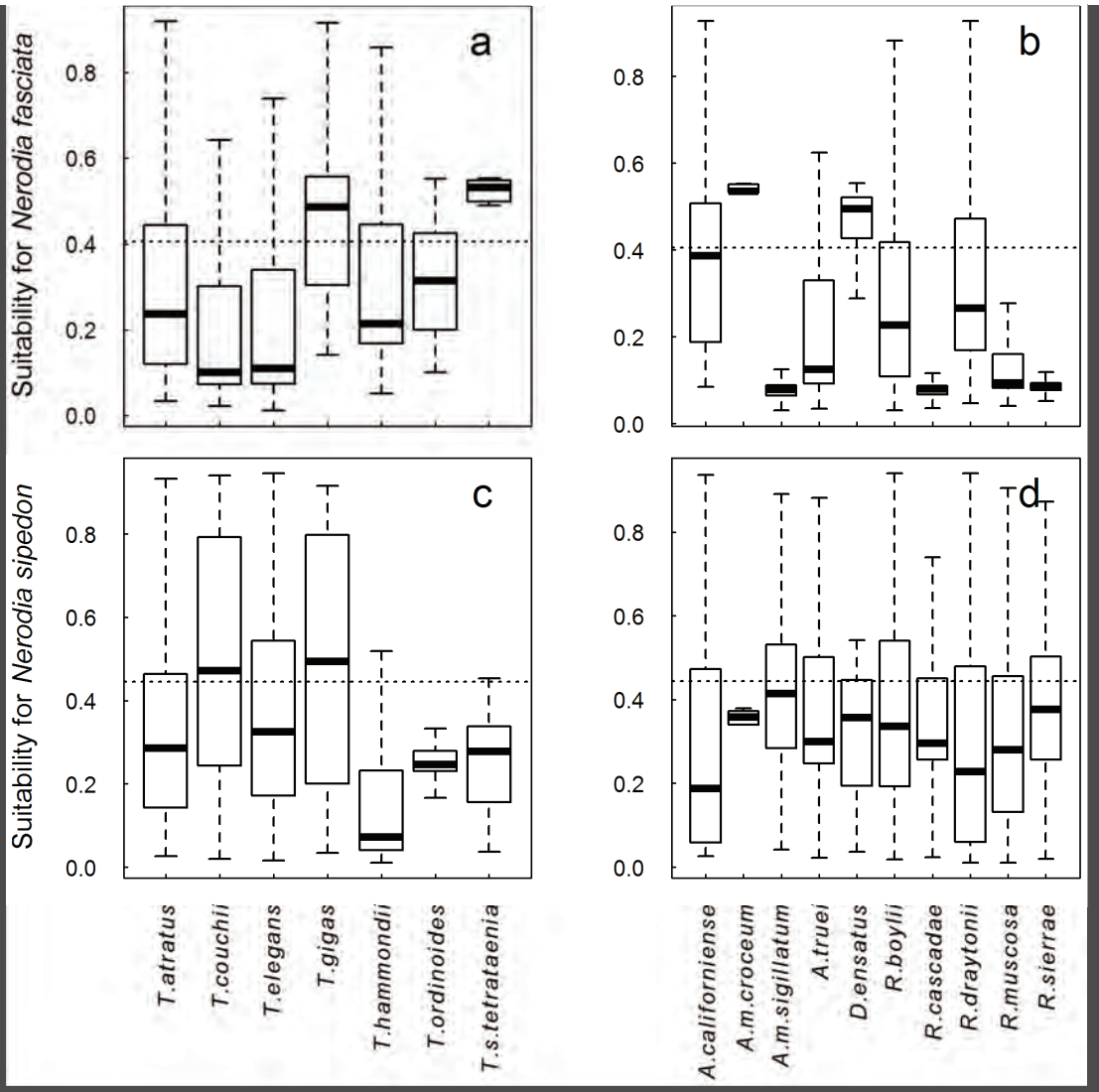
- Special status amphibians and fish that can be eaten by Watersnakes
- Native Gartersnakes that may compete with Watersnakes
- How do distributions of these natives overlap with projections for Watersnakes?

Rose and Todd 2014

Gartersnakes and amphibians

Southern Watersnake

Common Watersnake



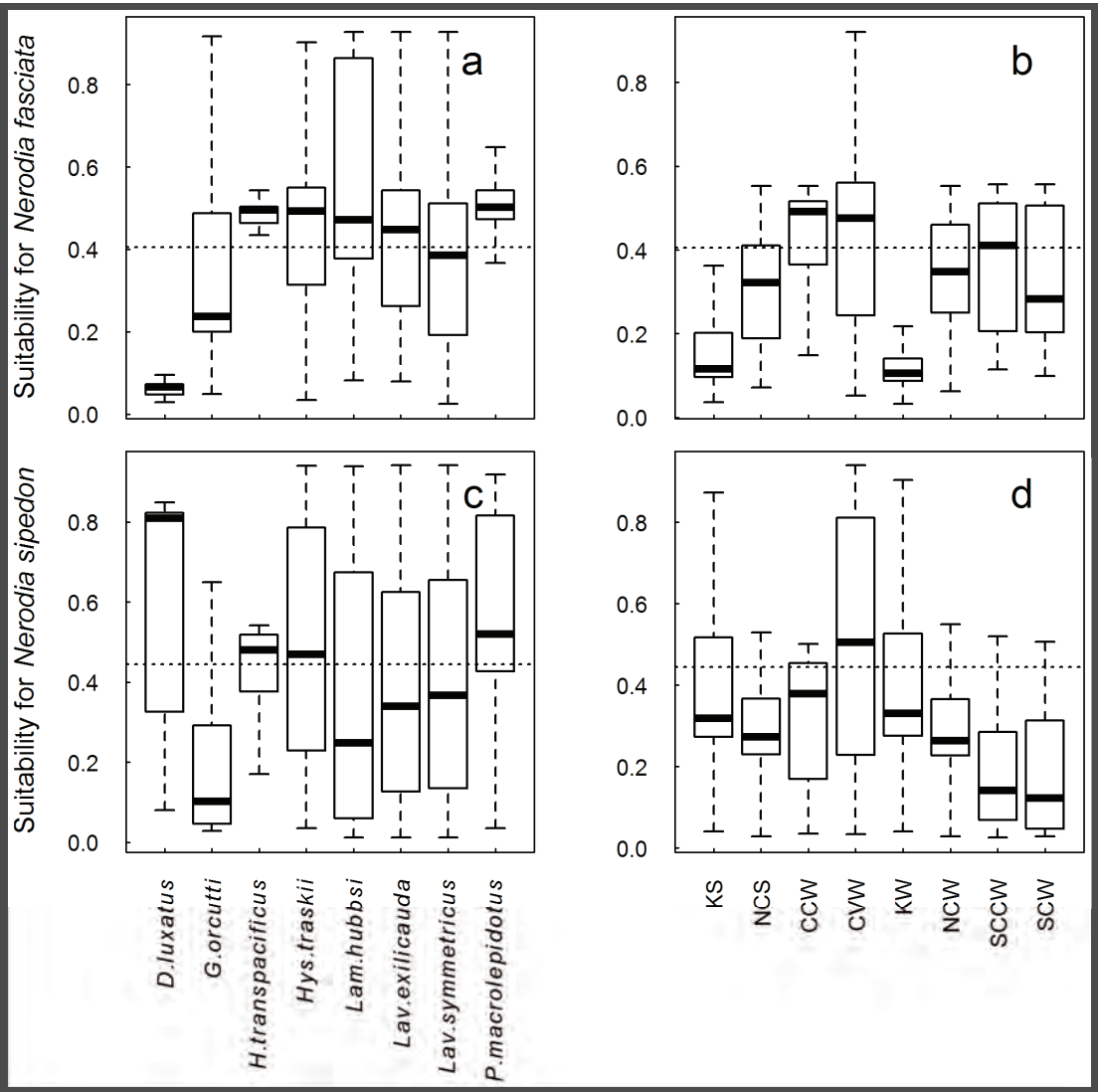
Rose and Todd 2014

Overlap with fishes

Southern Watersnake

Common Watersnake

Rose and Todd 2014



Potential species at risk

- Southern Watersnake – *N. fasciata*:
  - Giant Gartersnake
  - San Francisco Gartersnake
  - Santa Cruz Long-toed Salamander
  - California Giant Salamander
  - Delta Smelt
  - Tule Perch
  - Hitch
  - Sacramento Splittail
  - Steelhead CCW, CVW, SCCW

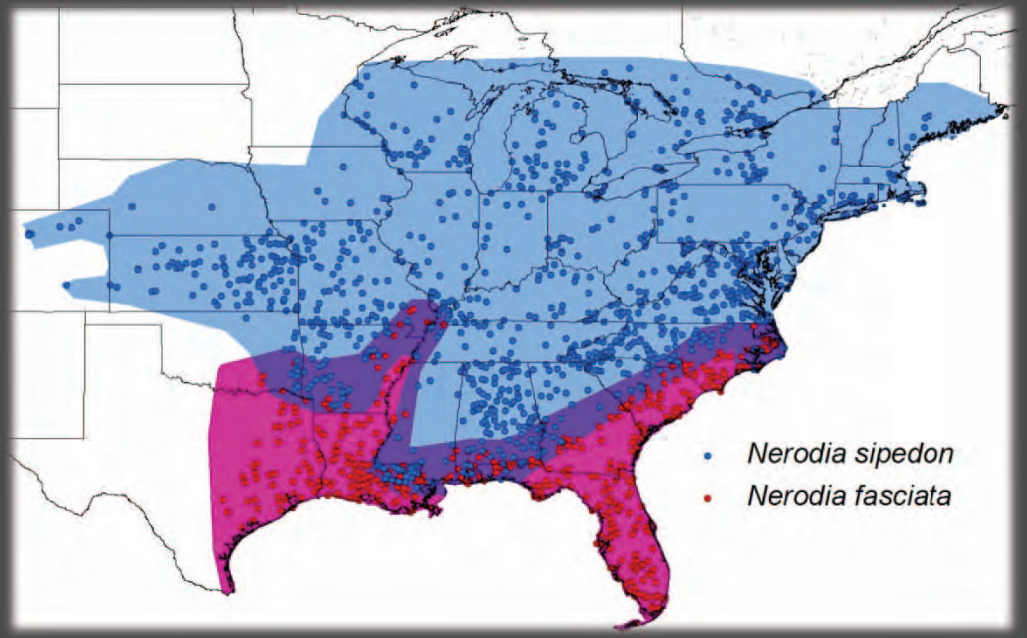
Potential species at risk

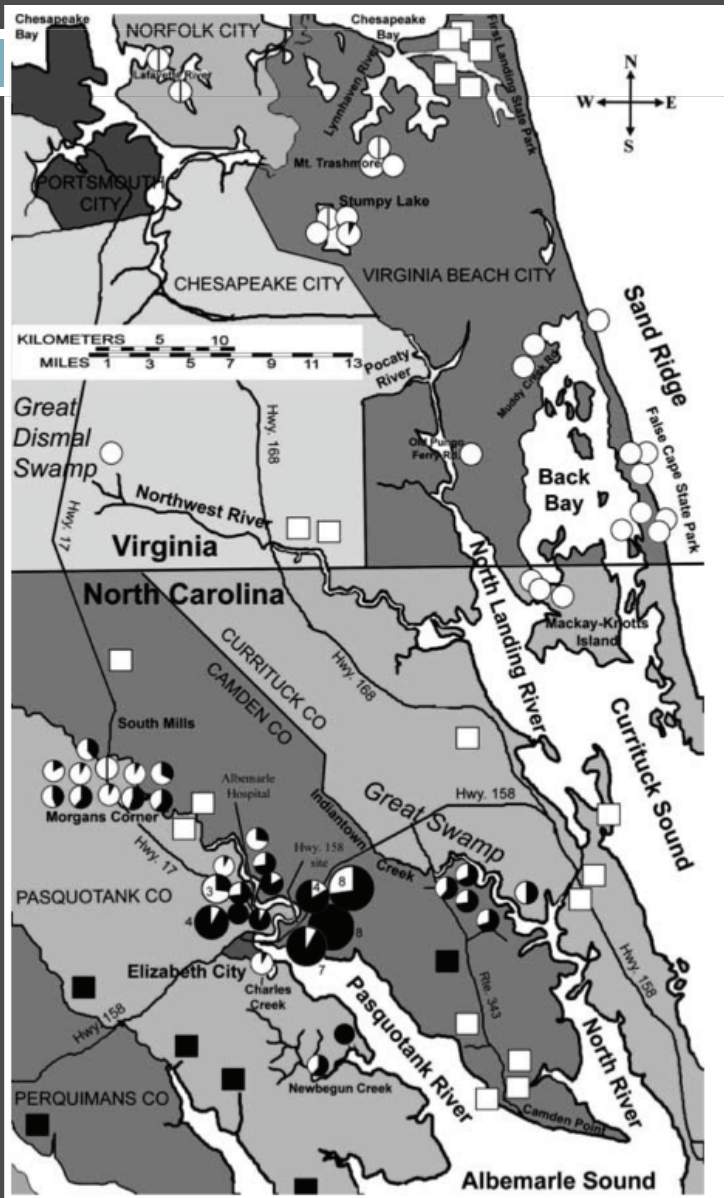
- Common Watersnake – *N. sipedon*:
  - Sierra Gartersnake
  - Giant Gartersnake
  - Southern Long-toed Salamander
  - Foothill Yellow-legged Frog
  - Lost River Sucker
  - Delta Smelt
  - Tule Perch
  - Sacramento Splittail
  - Steelhead CVW

Take home message from models

- Several sensitive status native amphibians and fishes that can be eaten may be affected
- Some native Gartersnakes at risk from competition

What about “hybrid vigor”?





Mebert 2008

Future directions

- How quickly can they spread?
- To what extent are they spreading?

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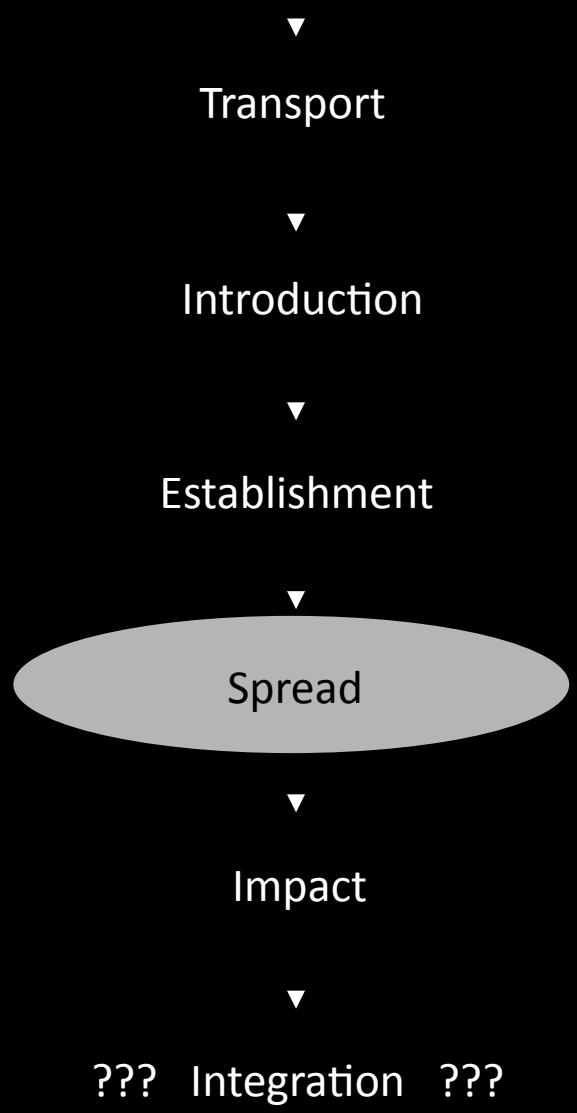
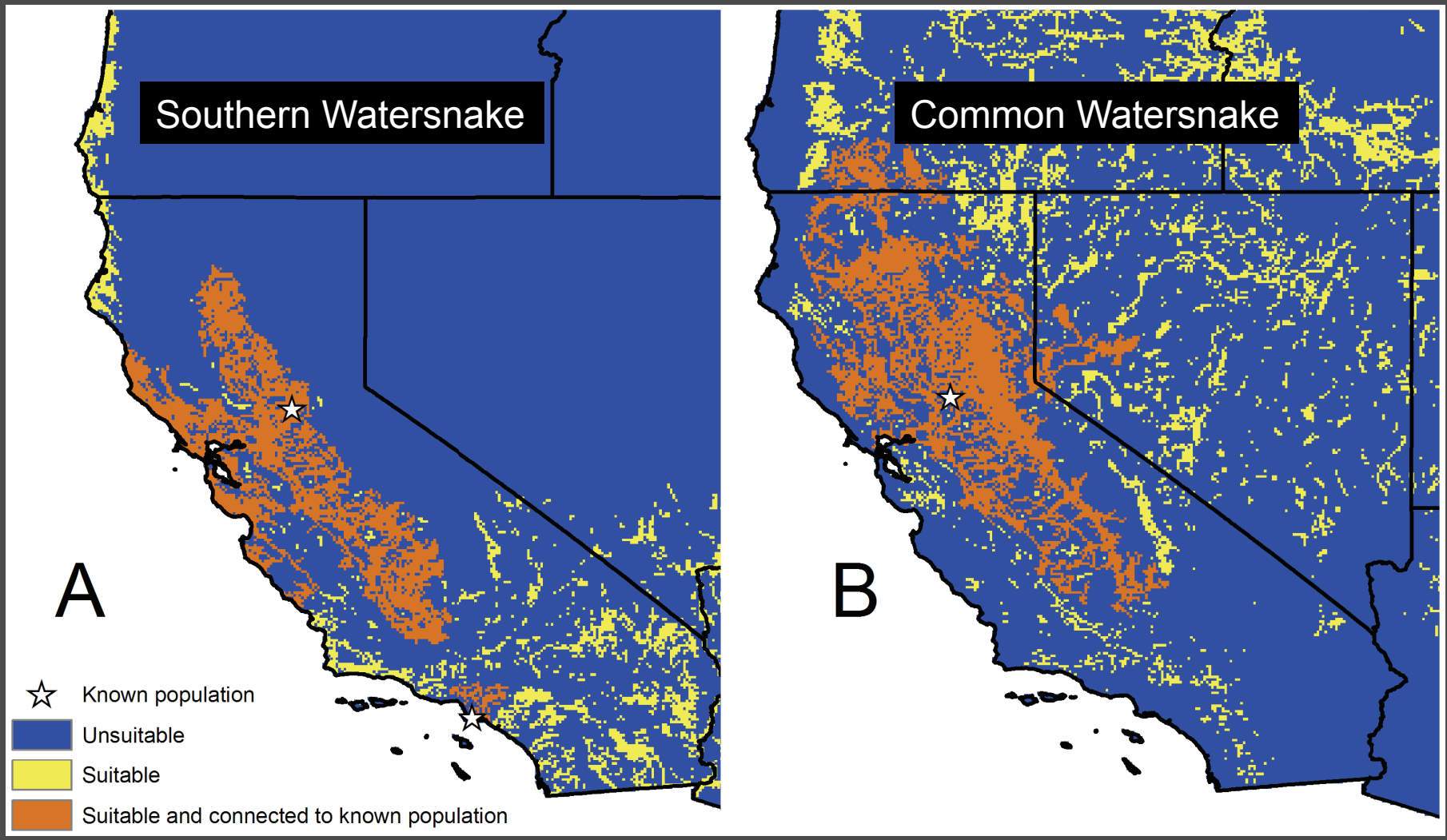


Spread via connected waterways



How quickly can they spread?

- Modeling population dynamics
- Connectivity of waterways
- Create spatial maps of potential rate of spread

Journal of Wildlife Management 75(1):36–45; 2011; DOI: 10.1002/jwmg.15

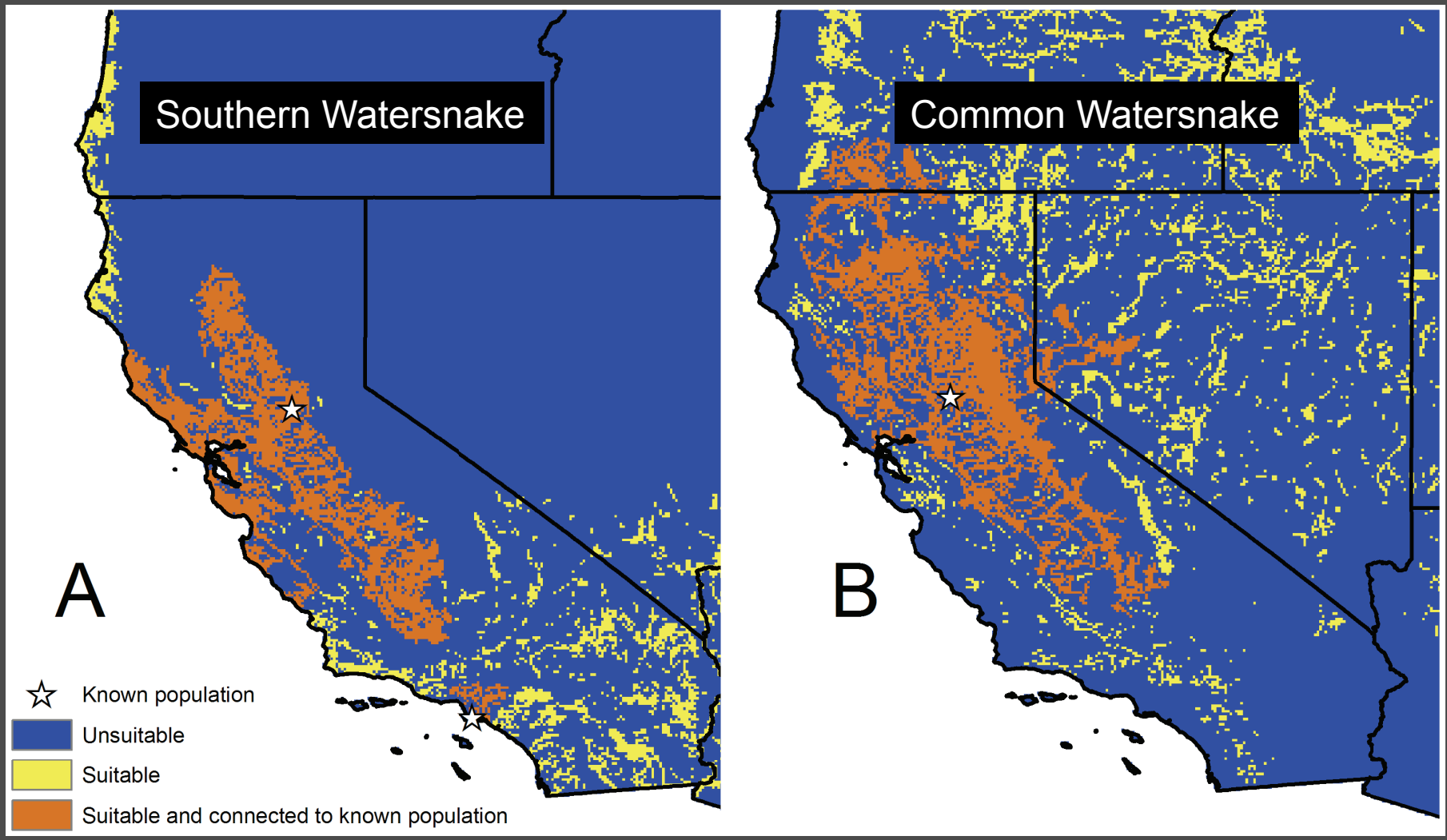
Research Article

Ecological and Methodological Factors Affecting Detectability and Population Estimation in Elusive Species

JOHN D. WILLSON,[1,2] *Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802, USA*
CHRISTOPHER T. WINNE, *Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802, USA*
BRIAN D. TODD,[3] *Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802, USA*

Willson, Winne, Todd 2011

Spread via connected waterways



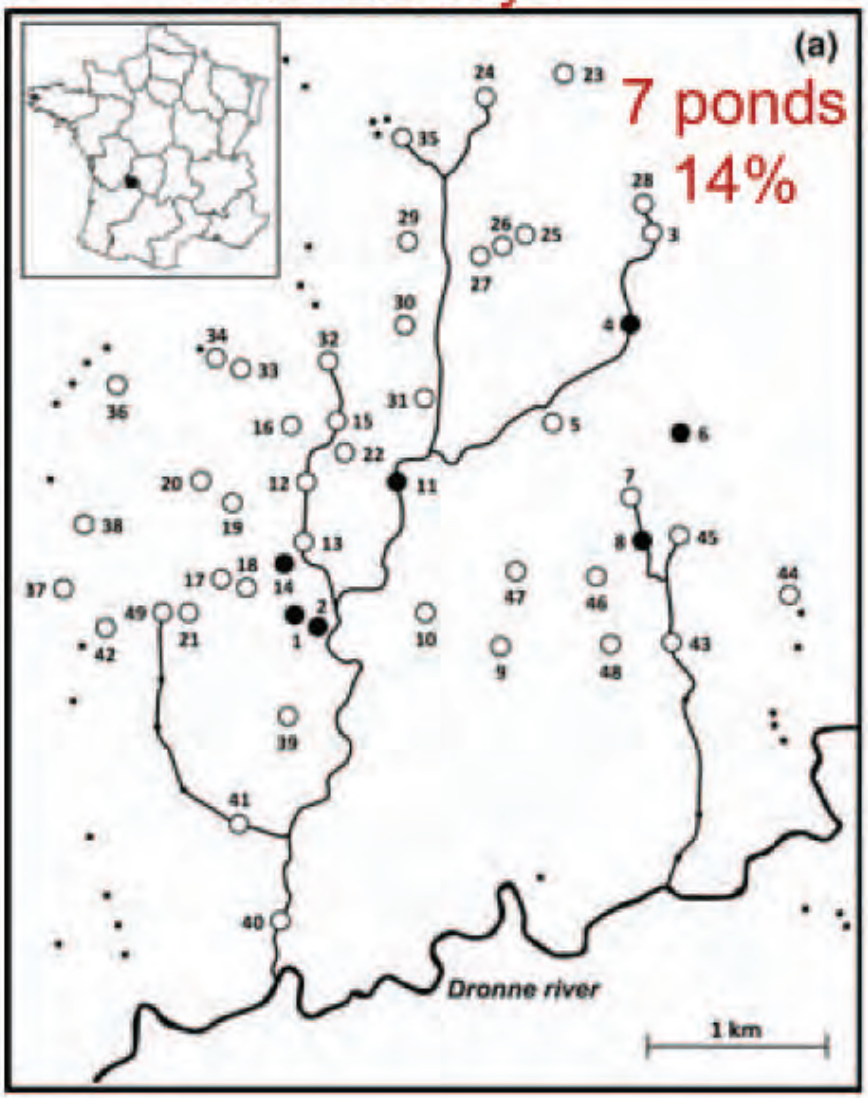
Where are they spreading?

- Citizen reports near Manteca, Stone Lakes Wildlife Refuge, Little Potato Slough

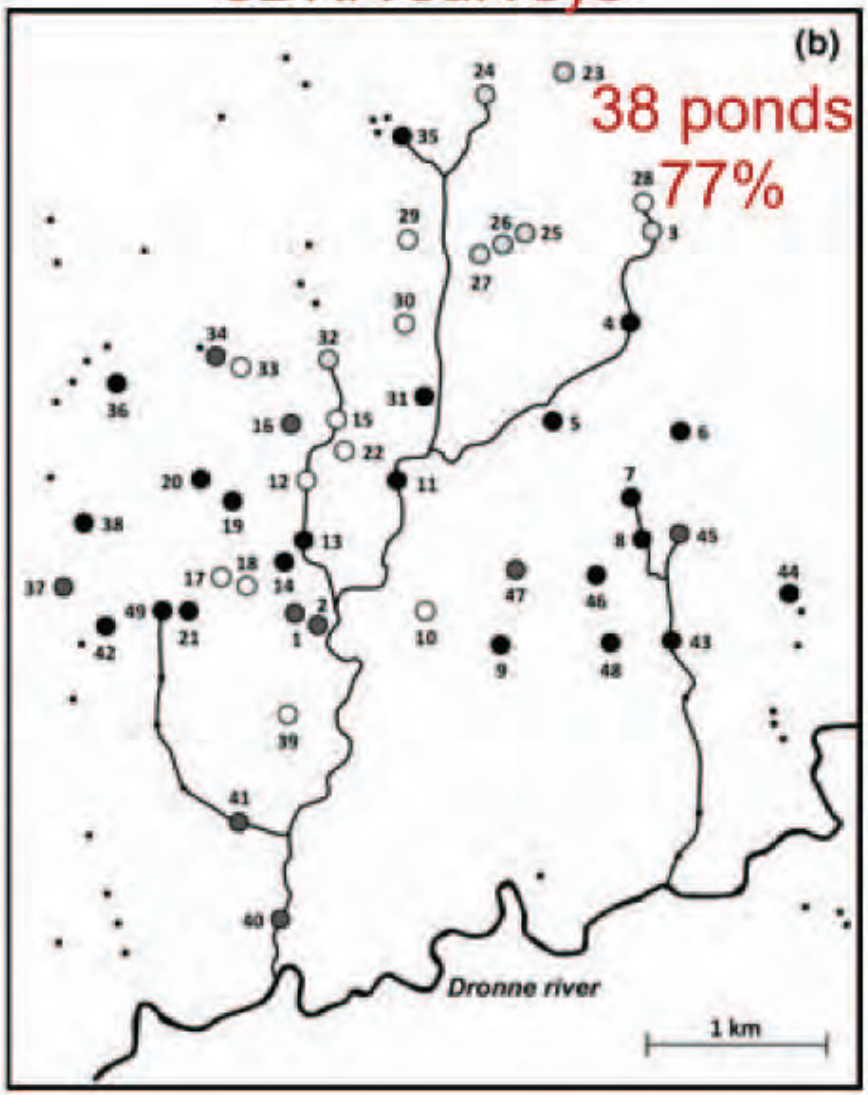
- eDNA sampling to detect dispersal

Bullfrog detection (Dejean et al. 2012)

Field surveys



eDNA surveys



Identifying Watersnakes

- Highly aquatic or riparian
- Brown to brownish-black with cross bands
- Large eyes set toward top of head

Identifying Watersnakes

Identifying Watersnakes

Similar native species

Northern Pacific Rattlesnake

Gopher Snake

Similar native species

Giant Gartersnake

Wandering Gartersnake

Sierra Gartersnake

Reporting Watersnakes

californiawatersnakes@gmail.com

Funding organizations