



# Amphibian decline and the USGS Amphibian Research and Monitoring Initiative (ARMI)

Robert Fisher – Western Ecological Research Center

<https://armi.usgs.gov/>

# Amphibian declines

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Amphibians are the most endangered group of vertebrates

IUCN estimates that 1/3 of amphibians in US and worldwide are threatened or near-threatened

Current extinction rate is 105X higher than seen in past 10,000 years

Declines on protected areas

The International Union for Conservation of Nature (IUCN) is the world's oldest and largest environmental organization

- Official observer status at the United Nations General Assembly
- Maintains the “Red List” of threatened species

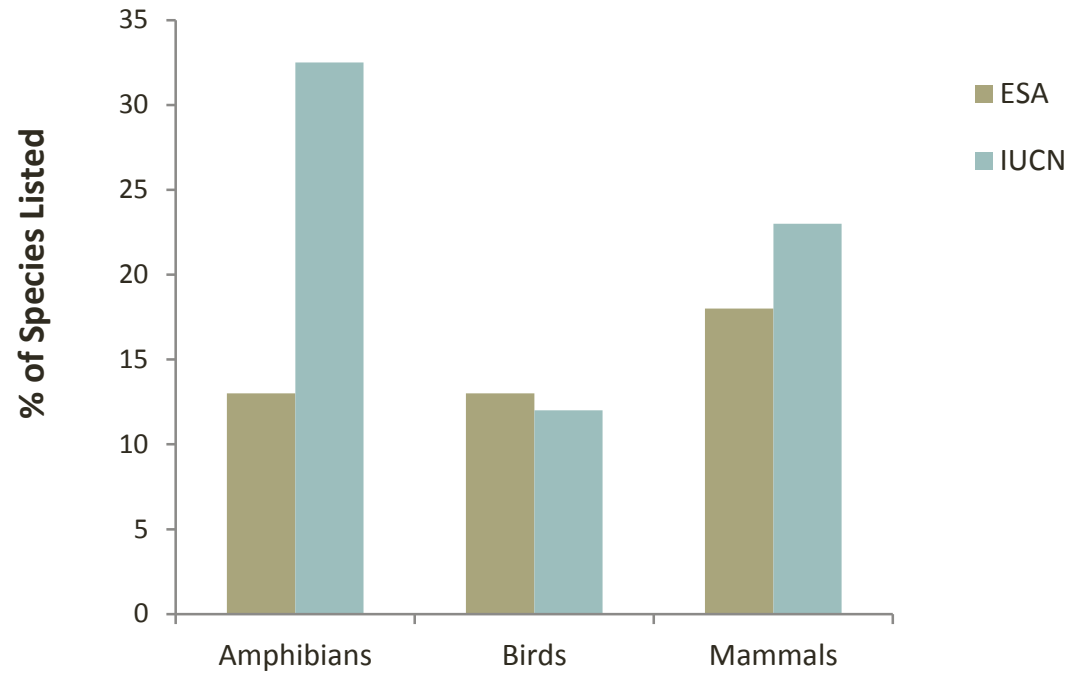


Night surveys at ARMI field site in Louisiana

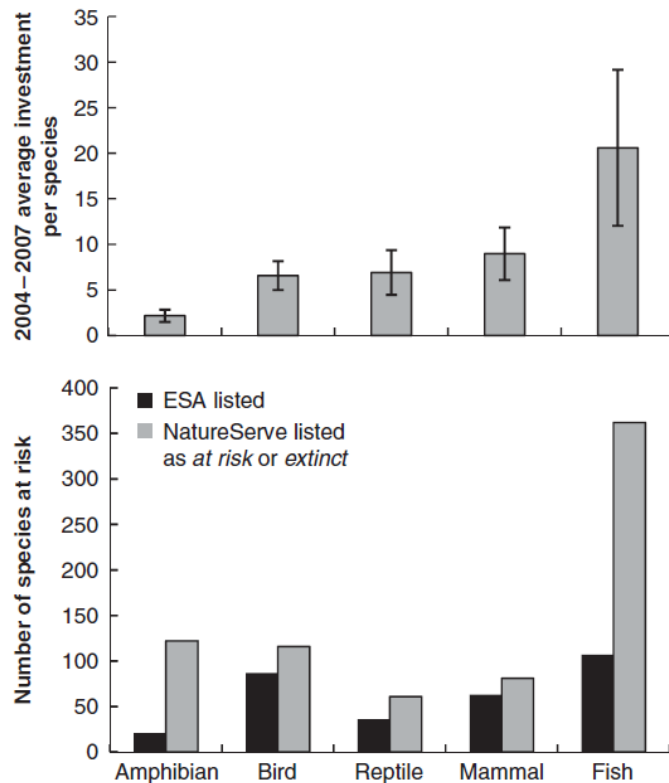
# Getting Worse

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## 1. ESA listing lag



# Getting Worse



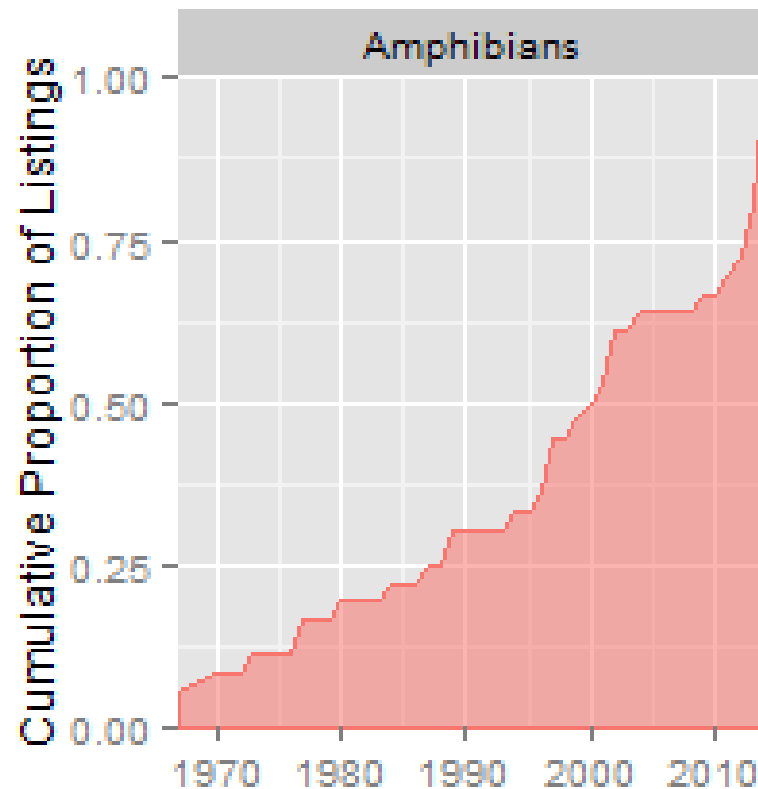
Gratwicke et al. 2012.  
BioScience 62:197.

*Figure 1. On average, Endangered Species Act (ESA)–listed amphibian species received less funding (upper panel, in millions of US dollars) than did other vertebrate classes. The error bars represent the standard error of the mean. This pattern is compounded by a disproportionately smaller number of ESA-listed species that are considered at risk (endangered and threatened) than those in NatureServe’s global assessment (bottom panel).*

# Getting Worse

## 2. The pace of listing is accelerating

Amphibians are the only group with an accelerating pace of listing under ESA.



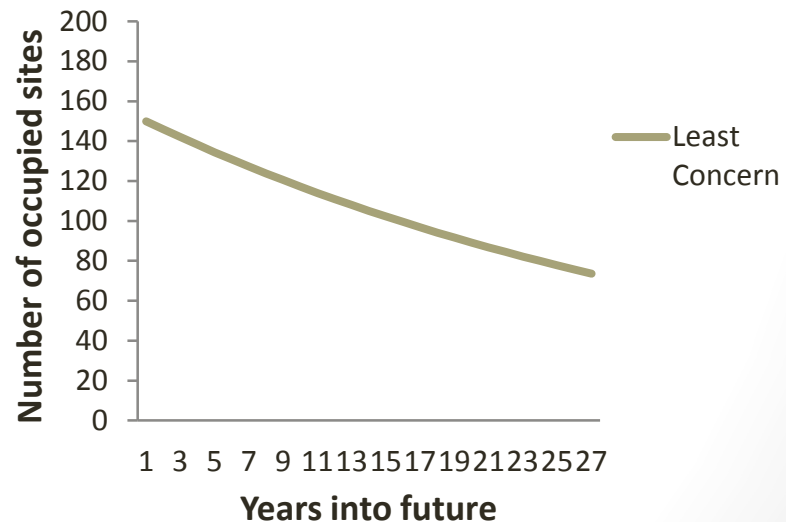
Data from ECOS. Accessed Nov 2014.

# Getting Worse

## 3. Even common species are declining

- The 66% of species in the US that are not Red-Listed are, on average, disappearing from 2.7% of the places they occur each year.
- This holds for protected and un-protected areas
- Based on 2 independent USGS studies.
  - Adams et al. 2013. PLoS One
  - Weir et al. 2014. Herp. Conserv. Biol.

### Common Species Declining



# Amphibians

B. Glorioso

- Ecosystem
- Source of medicines
- Environmental indicators
- Symbols of biodiversity
- People love amphibians!



Cope's gray treefrog



The tailed frog is the most ancient living frog...only found the Pacific Northwest.

# Causes of decline in the US

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- Habitat loss
- Disease
- Climate change
- Contaminants
- Invasive species

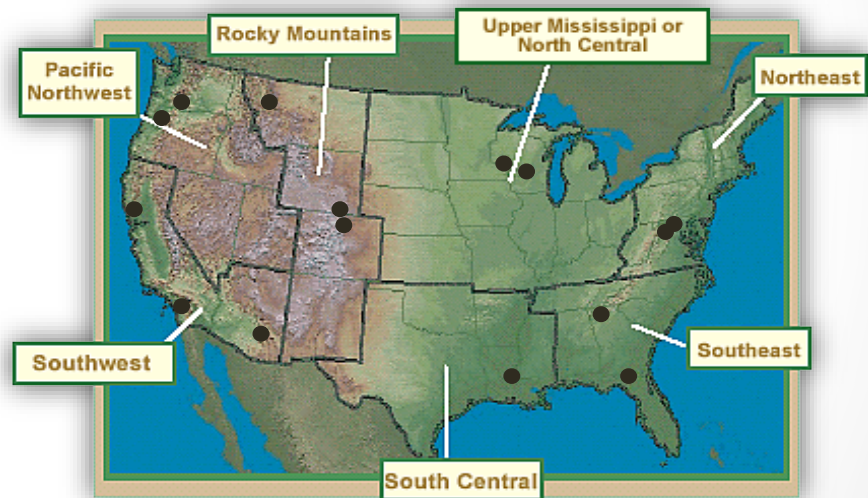


Tadpole mouthparts showing symptoms of chytridiomycosis. By G. Fellers.





# USGS Amphibian Research and Monitoring Initiative (ARMI)

- Began in 2000
- National coordinator
- 7 regions
- 14 USGS science centers from Ecosystems and Water
- 10 principal investigators
- Dozens of science support staff
- Hundreds of field technicians
- Biometricians, data managers
- [Armi.usgs.gov](http://Armi.usgs.gov)



ARMI regions and USGS science centers



https://armi.usgs.gov/



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## Amphibian Research and Monitoring Initiative


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[» State of the Amphibians](#)

All USGS  This site only


### News & Stories



[ARMI conducts national survey for salamander chytrid fungus](#)

By: Waddle H | October 12, 2016

In 2016 ARMI and National Wildlife Health Center scientists conducted a nationwide sampling effort to detect the salamander chytrid fungus *Batrachochytrium salamandrivorans* (Bsal). Bsal is native to Asia where indigenous salamanders carry the fungus without disease symptoms. However, Bsal has been spread through human facilitation to Europe where it has been implicated in major population(...[more](#))




### ARMI Mission Statement

In response to indications of worldwide declines in amphibian populations, the President and Congress directed Interior Department agencies to initiate a national program of amphibian monitoring, research, and conservation. There is an urgent need to determine the scope and severity of the problem and to investigate causes. The U.S. Geological Survey is uniquely qualified to coordinate and lead a cooperative national effort because its scientists have been in the forefront of studying amphibian populations and life history traits, measuring and monitoring environmental characteristics, and conducting research into potential causes of decline. As a result, the Agency formed the National Amphibian Research and Monitoring Initiative (ARMI).

### ARMI Goals and Objectives

- » Provide information to natural resource managers on the status and trends of amphibians
- » Relate status and trends to management options at the scale of management units.
- » Identify causes of declines.
- » Provide essential scientific information to support effective management actions to arrest or reverse declines.



Through the eyes of ARMI

### ARMI Topics

- Recent ARMI Products
- Annual Updates
- ARMI in Action
- Climate Change
- Disease
- Drought
- Fire
- Invasive Species
- Management
- Monitoring and Population Ecology
- Quantitative Developments
- Species and their Ecology
- Stressors
- Water

### ARMI Web Resources

- Bsal study sites map
- Search Products Database
- Taxonomy and Photo Gallery
- Research Projects
- Trend data
- News & Stories
- National Amphibian Atlas
- ARMI Publication Statistics

### ARMI Background

- Program Background
- Program Design
- ARMI Briefing Sheet
- Designing and Implementing a Monitoring Program
- Regions and People
- Contact Information

Annual meeting 2016, Madison, WI

Have had annual meetings since 2000. Helps build community, develop research goals for team, review progress, etc. Very important to program success



# USGS Amphibian Research and Monitoring Initiative (ARMI)

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- Focus on DOI needs
  - Local vs regional vs national
  - ESA listed vs. other species
  - Research vs. monitoring



Western spadefoot, California

# Research vs. Monitoring

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- Everyone wants trend information
- Cost/benefit of surveillance monitoring
- Many key research questions involve change over time
- ARMI focus on research

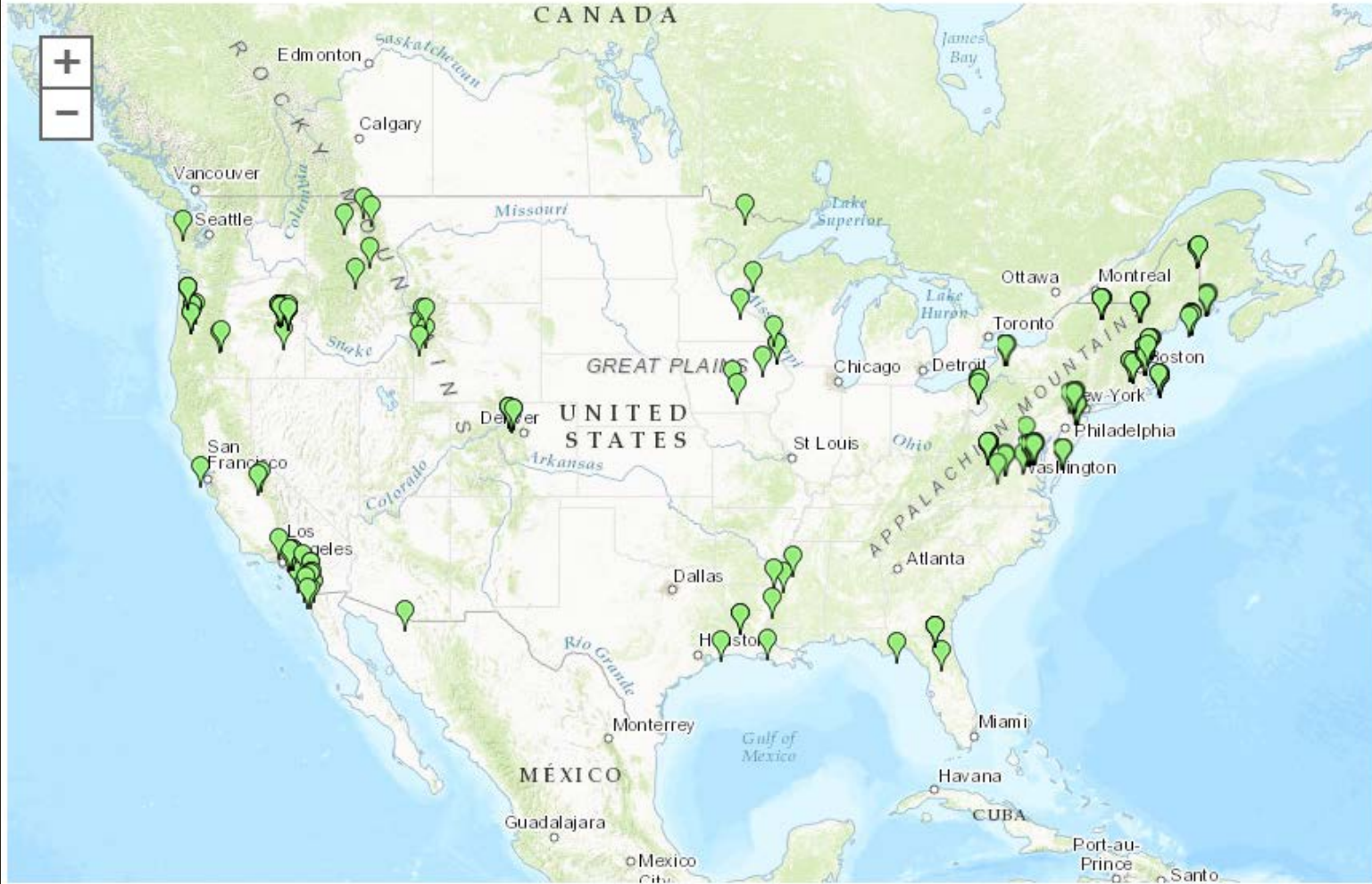


Measuring a green treefrog

# Research Projects

Like 0

[» View trend data](#)



# Occupancy

- Amphibian declines involve the disappearance of populations and subpopulations
- Much of ARMI research involves questions about occupancy dynamics
  - Local extinction and restoration options
  - Colonization and landscape characteristics
- Occupancy is the proportion of sites where a species occurs
  - A frog that occurs in half the ponds in a park has occupancy of 0.5 or 50%

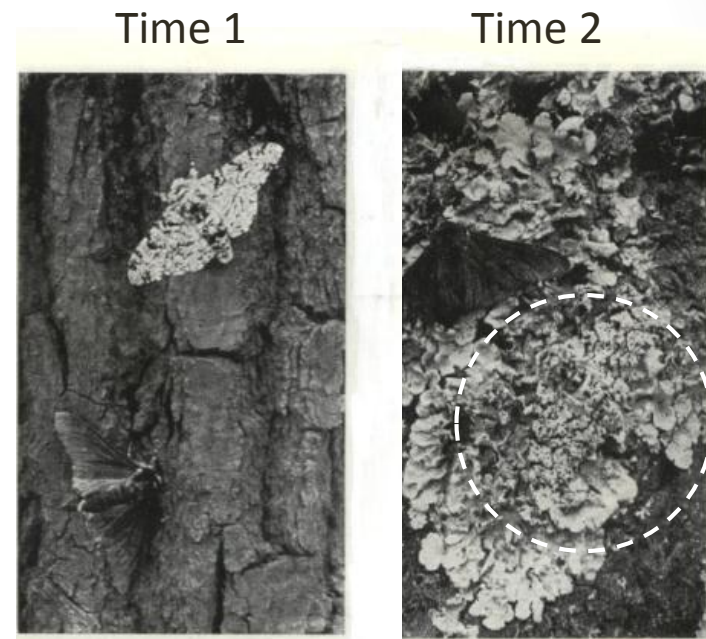


ARMI researcher Dr. Erin Muths in Colorado  
Above: Western toad

# Some species are hard to find

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- Problem: failure to detect species that are present
- Leads to erroneous conclusions
- Occupancy estimation corrects this problem
  - Estimates how often our surveys missed species that were present



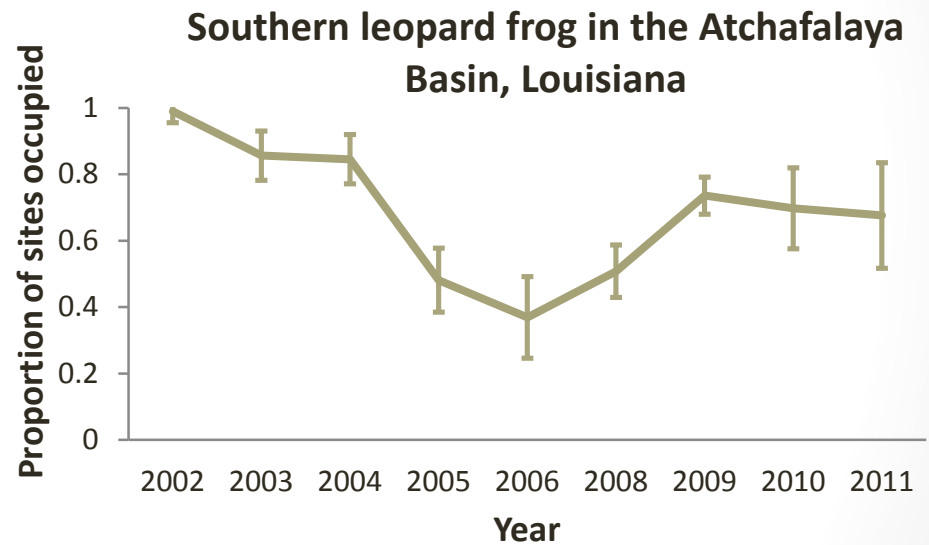
Are white moths declining or  
are they just becoming more  
difficult to see?



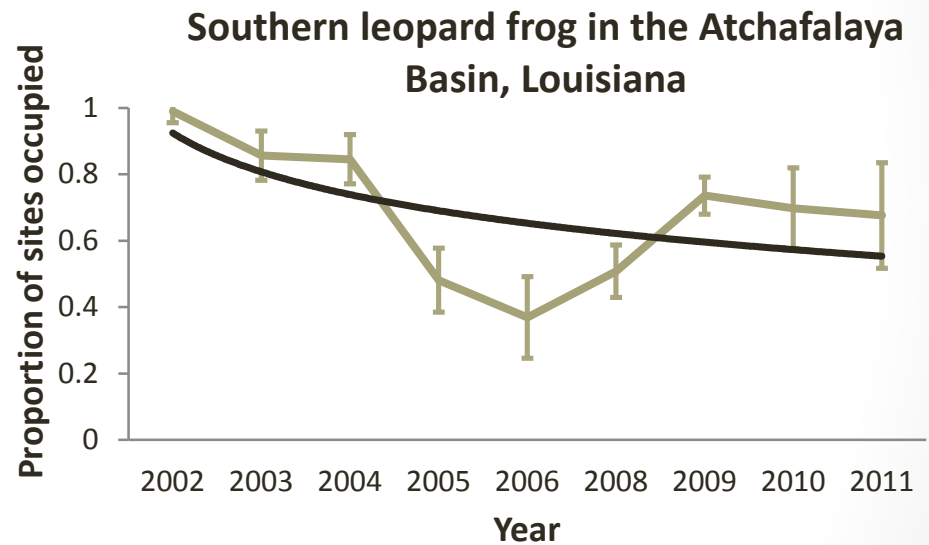
# Occupancy now used around the world



# ARMI data



# ARMI data



# Summary of ARMI occupancy data

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Adams MJ, Miller DAW, Muths E, Corn PS, Grant EHC, Bailey LL, Fellers GM, Fisher RN, Sadinski WJ, Waddle H & Walls SC (2013). Trends in amphibian occupancy in the United States. PLOS ONE

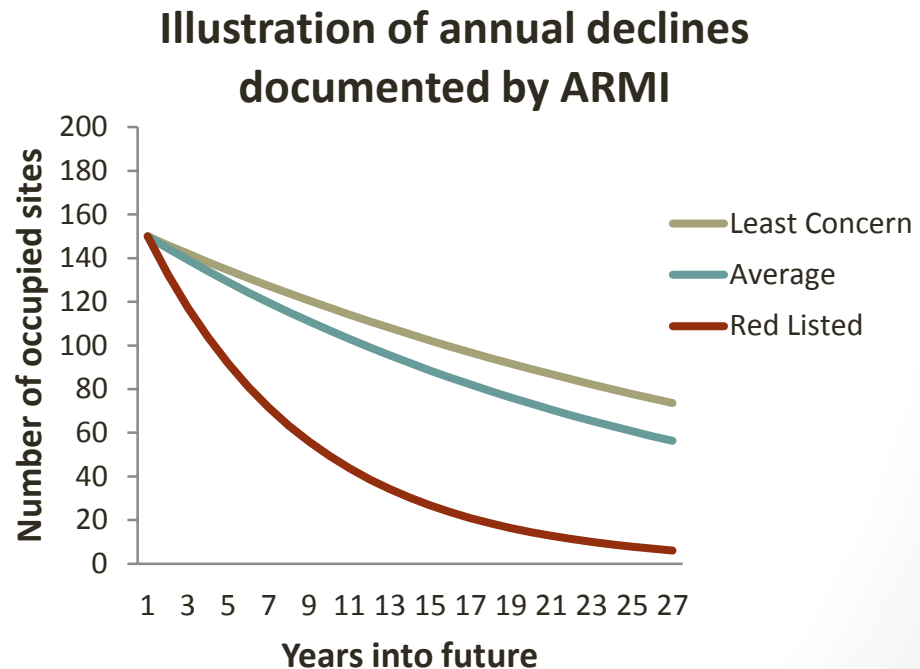
- First estimate of rate of decline for amphibians in US
- Declines are worse than we expected



Lowland burrowing treefrog at Buenos Aires National Wildlife Refuge, Arizona

# Trends

- Mean annual trend in amphibian occupancy
  - Overall mean: -3.7%
  - IUCN Least Concern amphibians: -2.7%
  - IUCN Red Listed amphibians: -11.6%
- A decline in Least Concern species demonstrates the importance of rigorous monitoring

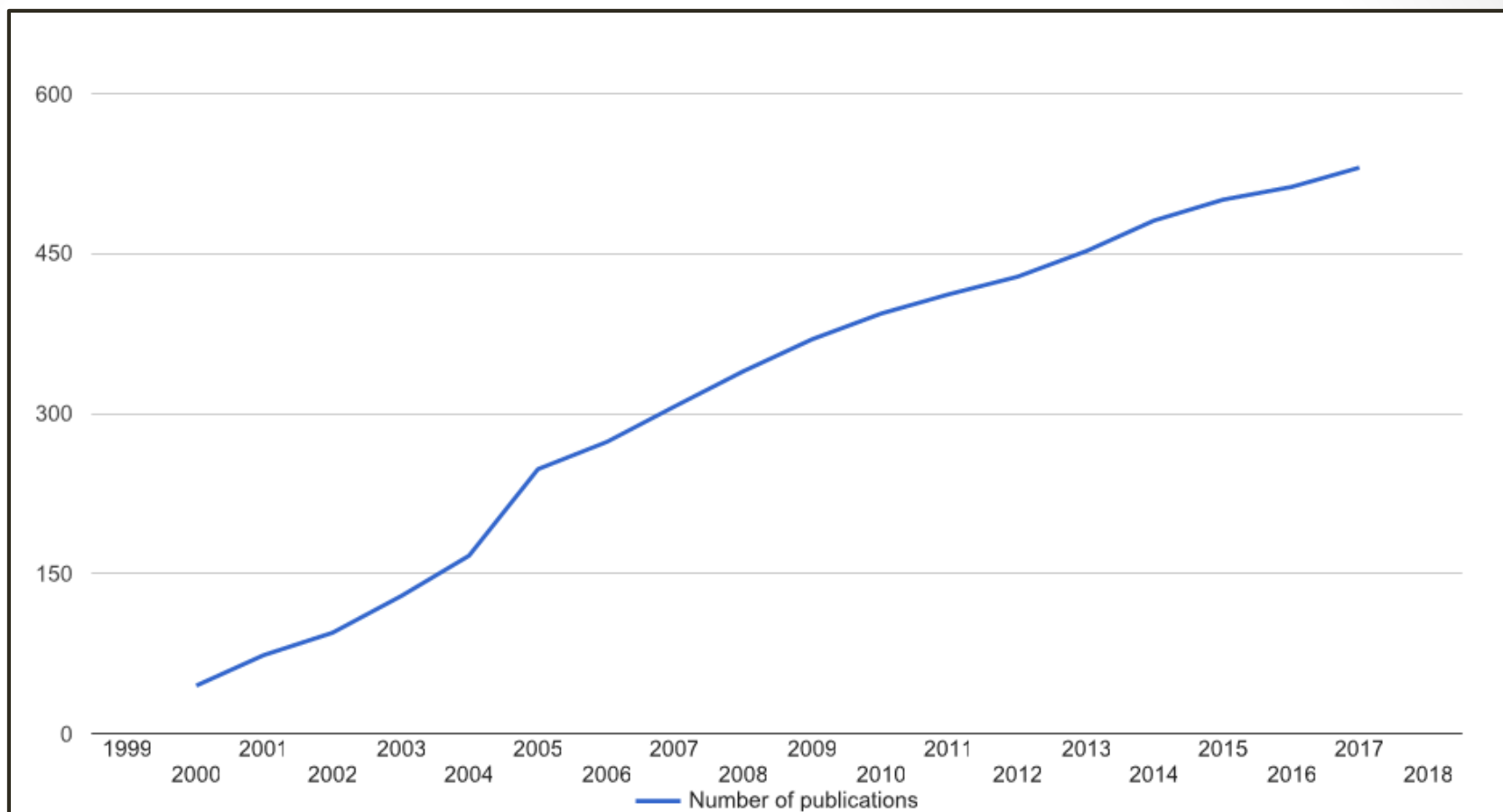


# Progress

- >500 diverse products
- Eliminated UVB hypothesis
- Pesticide accumulation in amphibian tissue
- Drought and restoration are major drivers for Columbia spotted frog
- Disentangled multiple drivers of trends in Arroyo Toad
- [armi.usgs.gov](http://armi.usgs.gov)



## ARMI Peer-reviewed Publications



Numbers of journal articles over time. All are searchable at:

<https://armi.usgs.gov/>

# Other Activities

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- Expert opinion
- Training
- Reviews
- Recovery teams
- Risk modelling



Three-lined salamander



# Examples of species of interest- themes

	Status		Contaminants	Climate	Invasive Sp	Habitat Mng	Reintroduction	Other Mng	Trends	Inventory	Methods
	FWS, IUCN	Disease									
Oregon Spotted Frog	T, VU	X			X	X	X		X	X	
Columbia Spotted Frog	C, LC	X							X	X	
Cascades Frog	UR, NT	X		X					X		
Chiricahua Leopard Frog	T, VU	X					X	X			
Western Toad	UR, NT	X				X			X	X	X
Sonoran Tiger Salamander	E, NE				X				X	X	
Shenandoah Salamander	E, VU			X		X			X		
Duskey Gopher Frog	E, CR						X				X
Mountain Yellow-Legged Frog	E, EN	X	X	X	X				X		
Sierra Nevada Yellow-Legged Frog	E, EN	X		X			X				
Arroyo Toad	E, EN	X		X	X	X	X		X		
Yosemite Toad	T, EN		X						X		
California Red-Legged Frog	T, VU	X					X		X		
Western Spadefoot Toad	UR, NT							X			
Wyoming Toad	E, EW							X			



Coastal giant salamander



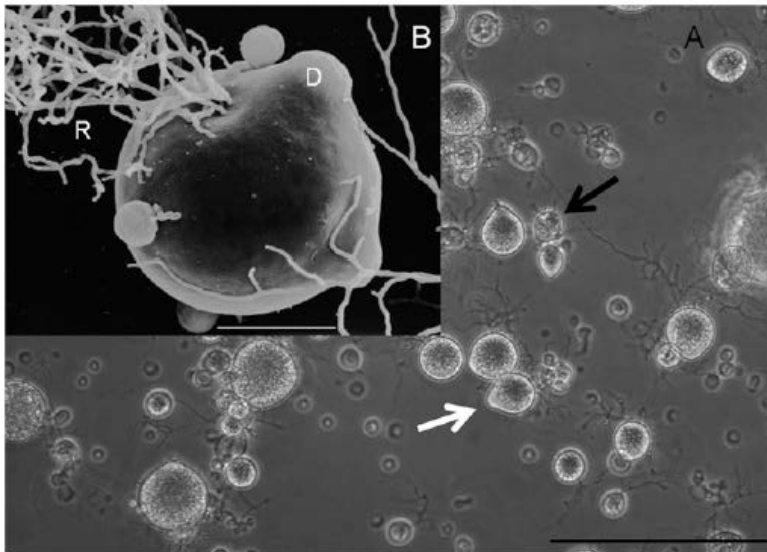
Sierra Nevada yellow-legged frog,  
Yosemite National Park

# *Batrachochytrium salamandrivorans* sp. nov. causes lethal chytridiomycosis in amphibians

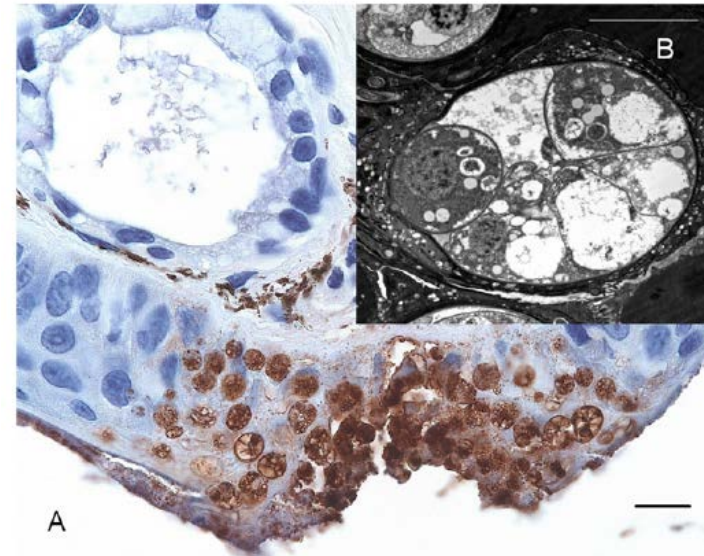
An Martel<sup>a,1</sup>, Annemarieke Spitzen-van der Sluijs<sup>b</sup>, Mark Blooi<sup>a</sup>, Wim Bert<sup>c</sup>, Richard Ducatelle<sup>a</sup>, Matthew C. Fisher<sup>d</sup>, Antonius Woeltjes<sup>b</sup>, Wilbert Bosman<sup>b</sup>, Koen Chiers<sup>a</sup>, Franky Bossuyt<sup>e</sup>, and Frank Pasmans<sup>a</sup>

<sup>a</sup>Department of Pathology, Bacteriology and Avian Diseases, Faculty of Veterinary Medicine, Ghent University, B-9820 Merelbeke, Belgium; <sup>b</sup>Reptile, Amphibian and Fish Conservation The Netherlands, 6501 BK, Nijmegen, Netherlands; <sup>c</sup>Department of Biology, Nematology Unit, Faculty of Science, Ghent University, 9000 Ghent, Belgium; <sup>d</sup>Department of Infectious Disease Epidemiology, Faculty of Medicine, Imperial College London, London W2 1PG, United Kingdom; and <sup>e</sup>Amphibian Evolution Lab, Biology Department, Vrije Universiteit Brussel, 1050 Brussels, Belgium

Edited by David B. Wake, University of California, Berkeley, CA, and approved August 1, 2013 (received for review April 18, 2013)



**Fig. 2.** In vitro culture of *B. salamandrivorans* in TGhL broth at 15 °C. (A) Monocentric thalli predominate, with the rare presence of colonial thalli (black arrow). Sporangia develop discharge tubes (white arrow) to release zoospores (Scale bar, 100  $\mu$ m.) (B) Scanning electron microscopic image of a mature sporangium with rhizoids (R), discharge tubes (D), and germ tube formation (arrow) (Scale bar, 10  $\mu$ m.)



**Fig. 3.** Microscopy of the skin of a fire salamander that died due to infection with *B. salamandrivorans*. (A) Immunohistochemical staining of a 5- $\mu$ m skin section. Intracellular colonial thalli abound throughout all epidermal cell layers and are associated with erosive lesions. (Scale bar, 20  $\mu$ m.) (B) Transmission electron microscopy picture of an intracellular colonial thallus of *B. salamandrivorans* inside a keratinocyte (Scale bar, 4  $\mu$ m.)



Endangered populations of fire salamanders in Europe have succumbed to a new fungus.

**IN DEPTH**

**CONSERVATION BIOLOGY**

# *The coming salamander plague*

Already harming a European species, an Asian fungus could wreak havoc in North America

By Erik Stokstad

■ new kind of amphibian apocalypse

salamander diversity in the United States.”

In 2010, volunteers at a nature reserve near Maastricht, the Netherlands, noticed

already been collected worldwide for studies of Bd. Ultimately, Martel’s team screened nearly 5400 samples, representing about

## USGS Modelled Risk of Invasion:

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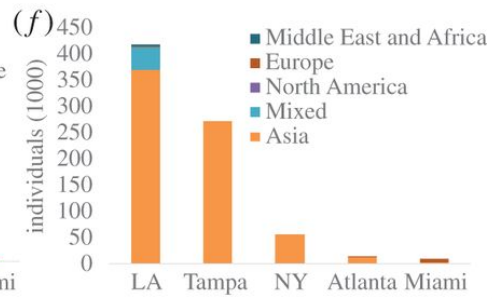
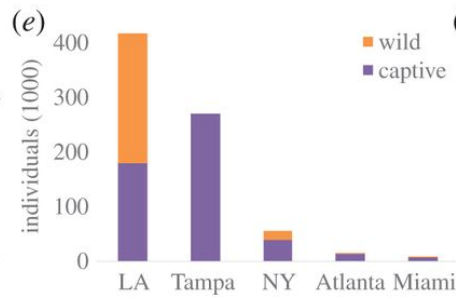
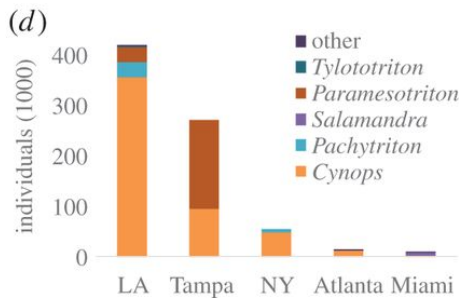
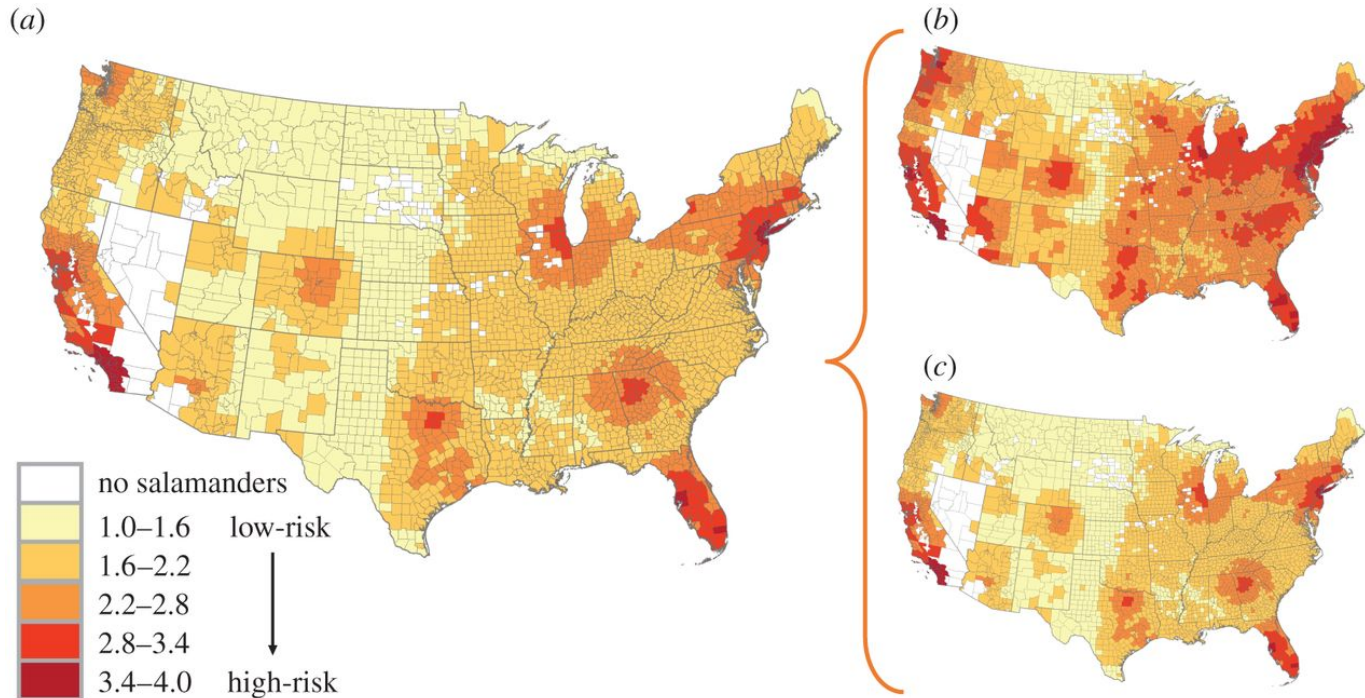
 Check for updates

**Spatial variation in risk and consequence of *Batrachochytrium salamandrivorans* introduction in the USA**

Katherine L. D. Richgels, Robin E. Russell, Michael J. Adams, C. LeAnn White, Evan H. Campbell Grant

Published 17 February 2016. DOI: 10.1098/rsos.150616

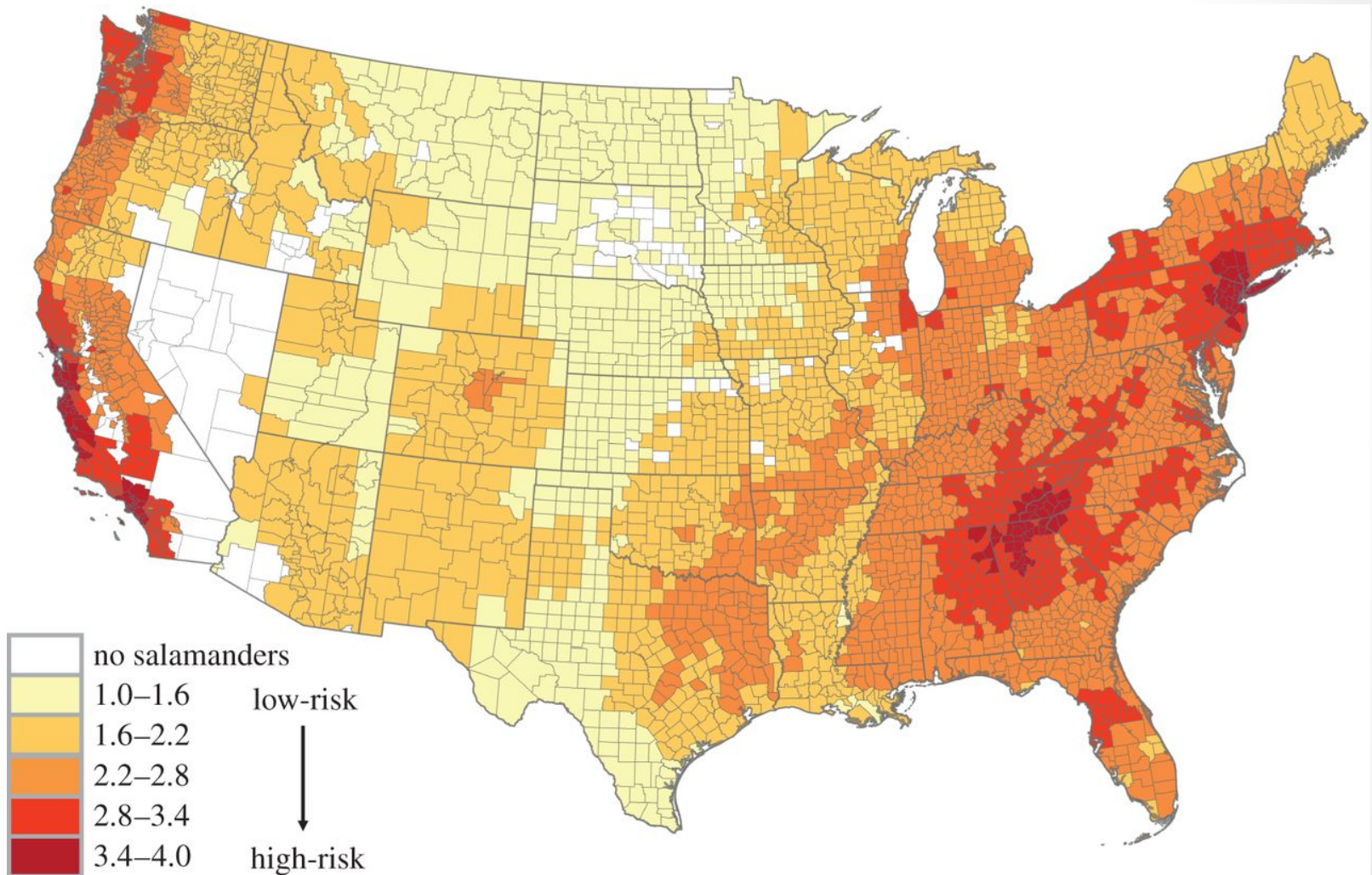
# Heat maps of the USA showing the Bsal introduction assessment.



Katherine L. D. Richgels et al. R. Soc. open sci. 2016;3:150616

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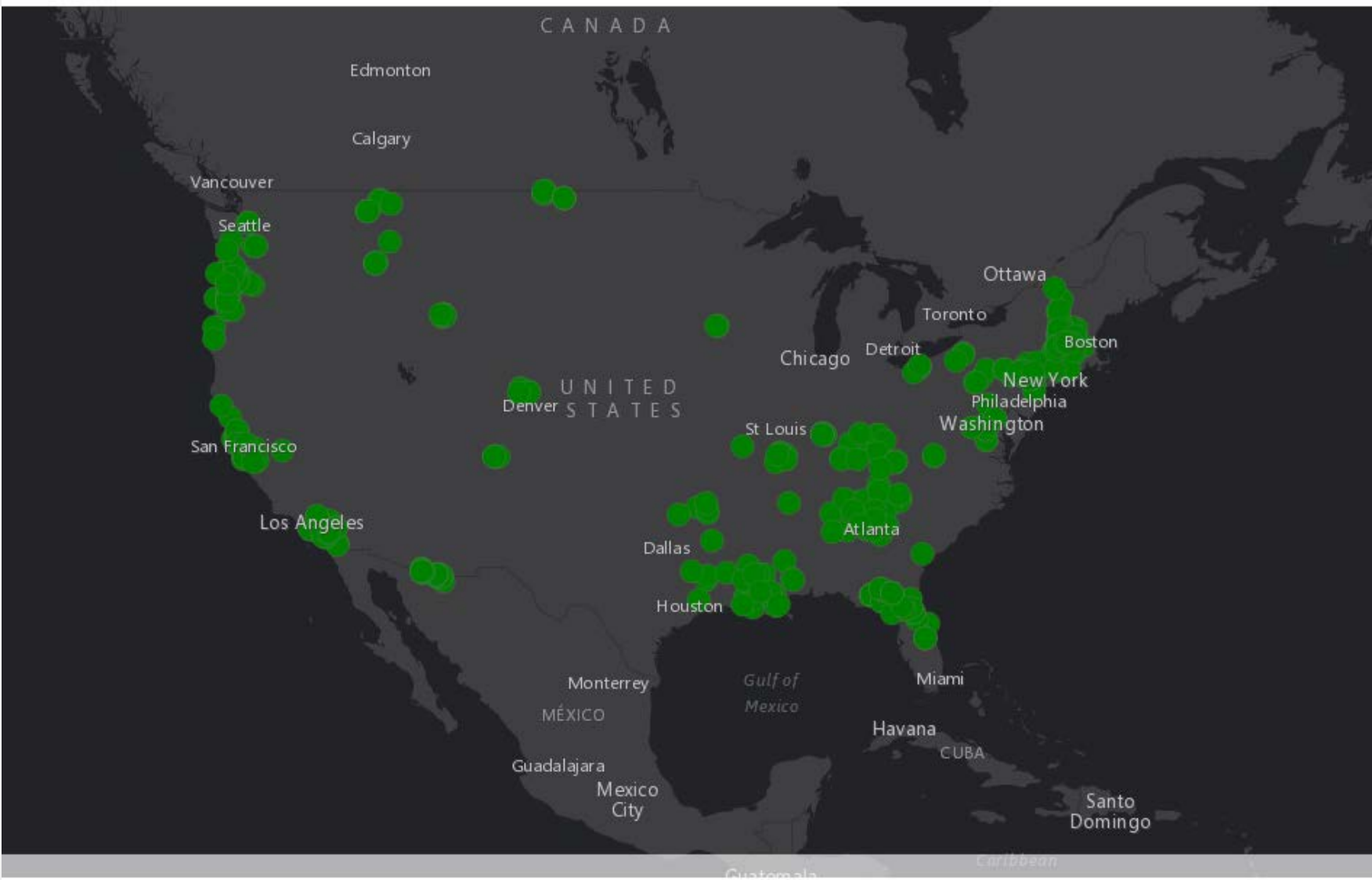
Heat map of the USA showing the total relative risk of Bsalto native US salamanders based on the introduction and consequences assessment.



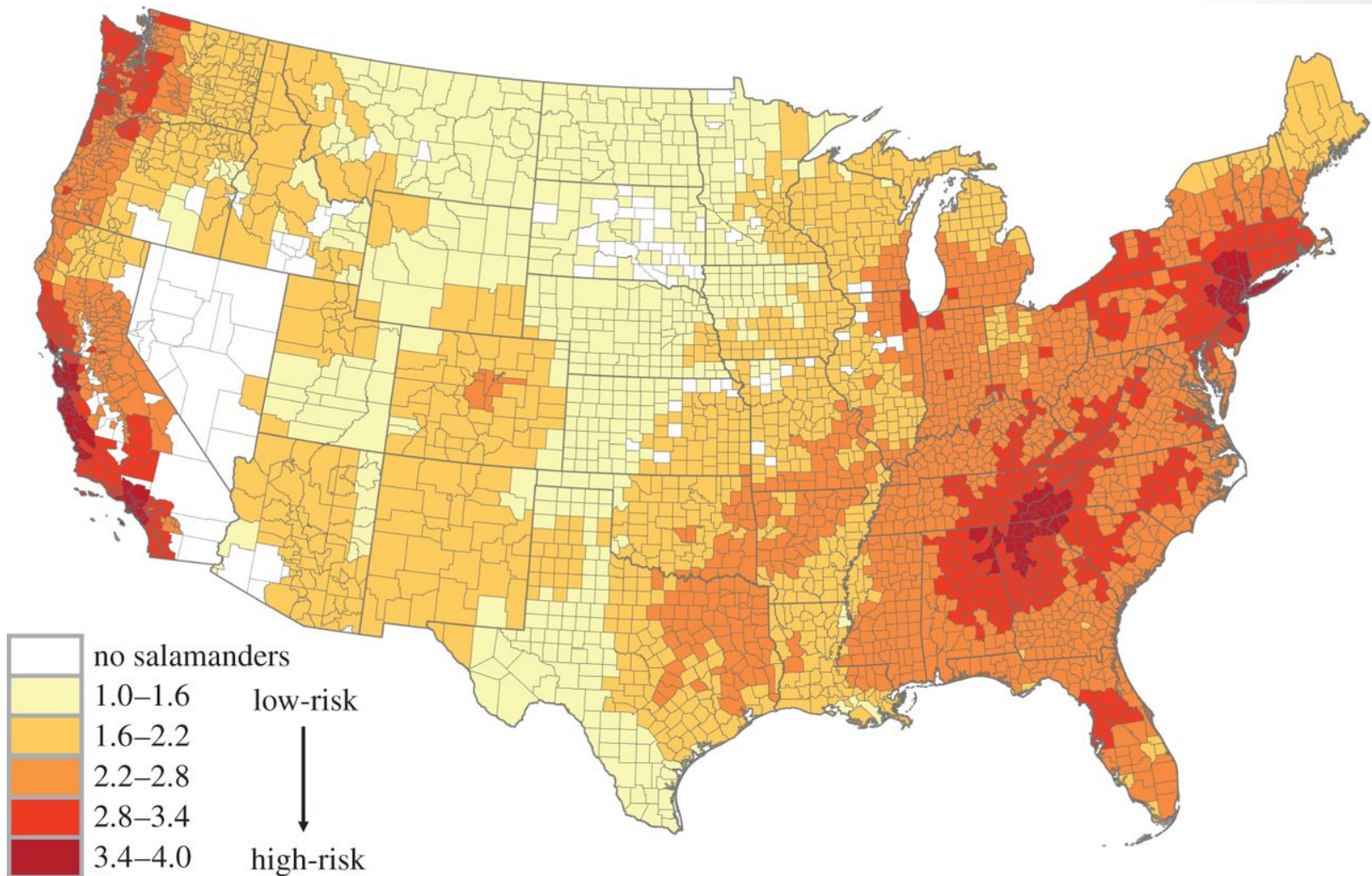
Katherine L. D. Richgels et al. R. Soc. open sci.  
2016;3:150616

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# Map of study sites



Heat map of the USA showing the total relative risk of Bsalto native US salamanders based on the introduction and consequences assessment.

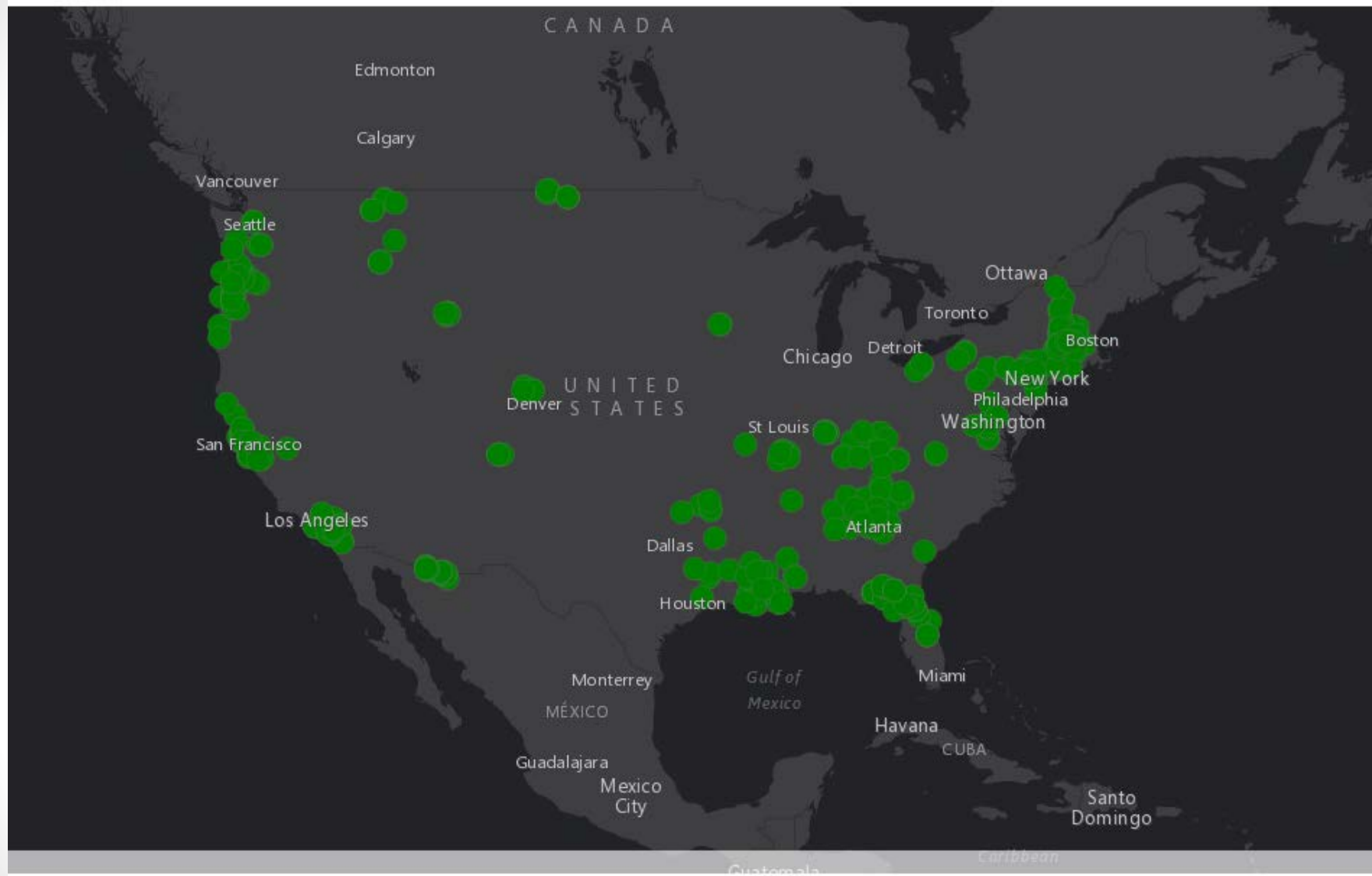


Katherine L. D. Richgels et al. R. Soc. open sci.  
2016;3:150616

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# Map of study sites



# Arroyo Toad (*Anaxyrus californicus*)

- **Federally Endangered**

- Monterey County to northern Baja
- Occupies 25% of former habitat

- **Habitat Specialist**

- Low gradient streams/rivers
- Sandy substrates
- Breeding- low flow shallow pools

- **Life History**

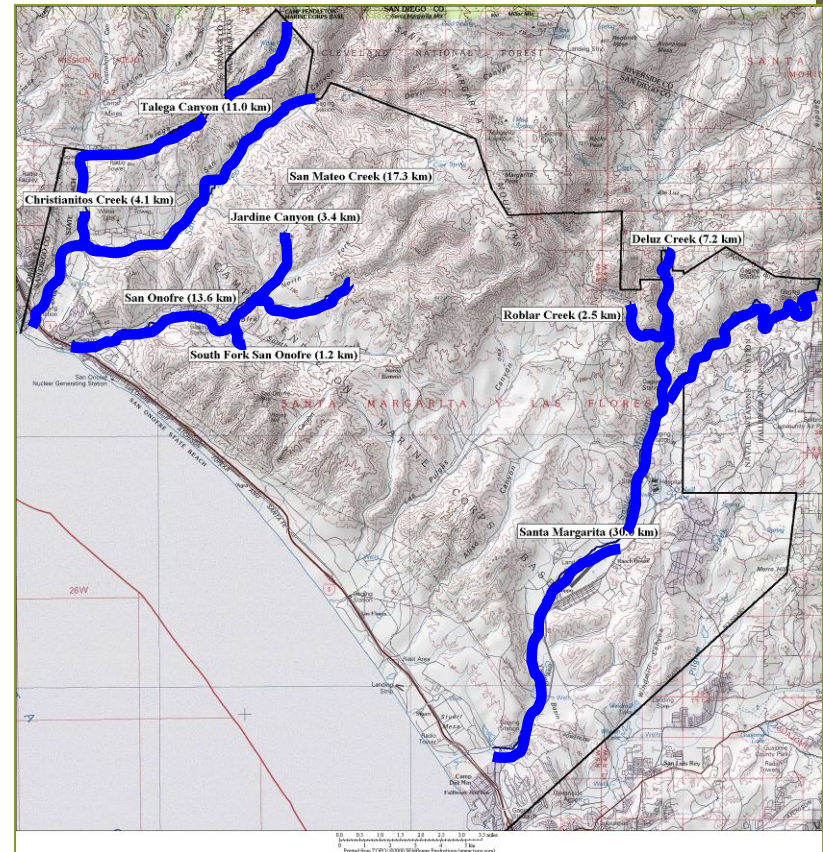
- Nocturnal
- Female deposits ~5000 eggs
- 4-6 days hatch
- 2-3 months metamorphosis



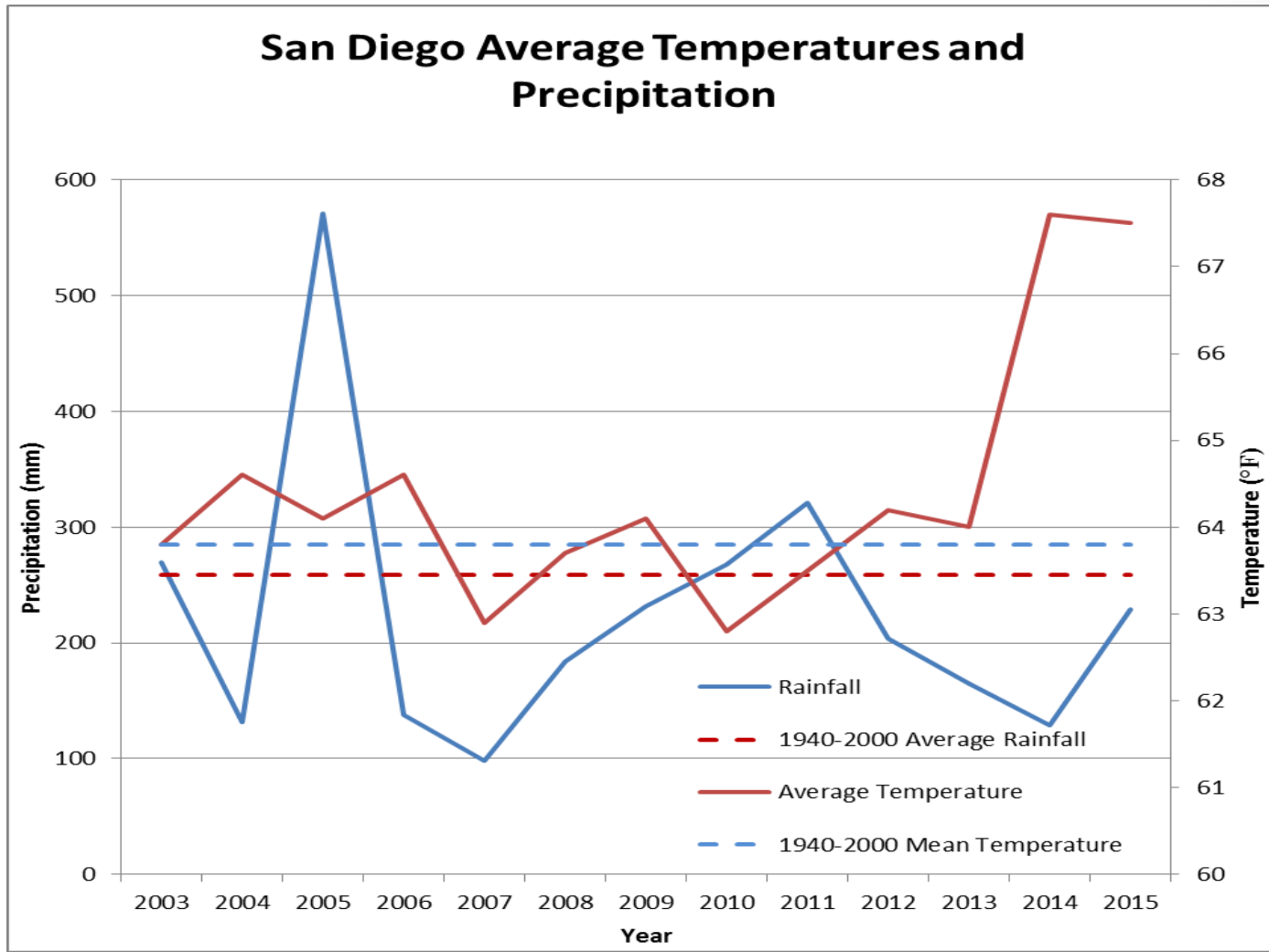
# Marine Corps Base Camp Pendleton (MCBCP)

## Arroyo Toad Monitoring: since 2003

- Coastal southern California-northern San Diego County
- 3 major watersheds
- 87 km arroyo toad habitat



# San Diego Climate Data

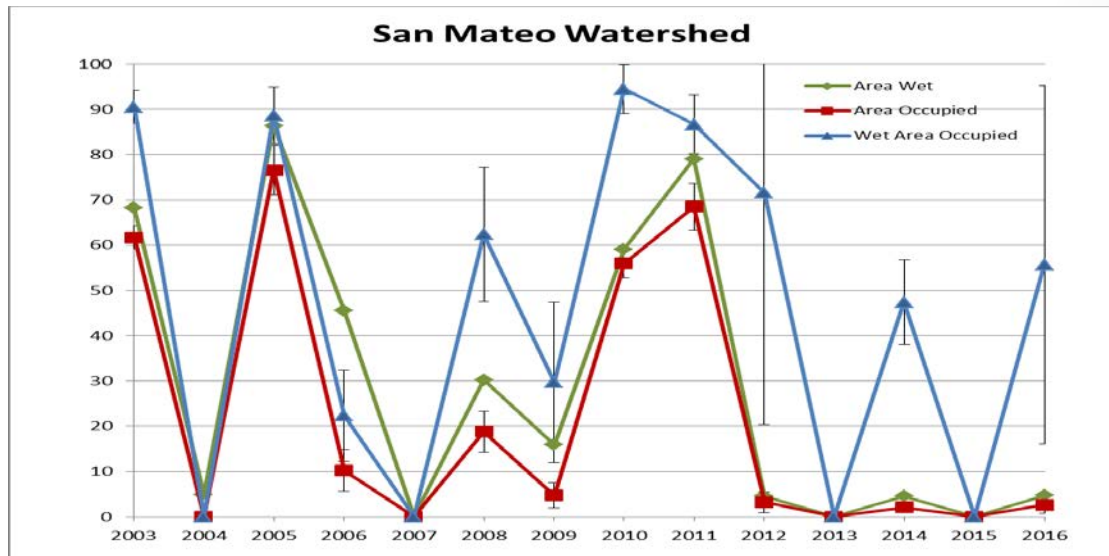
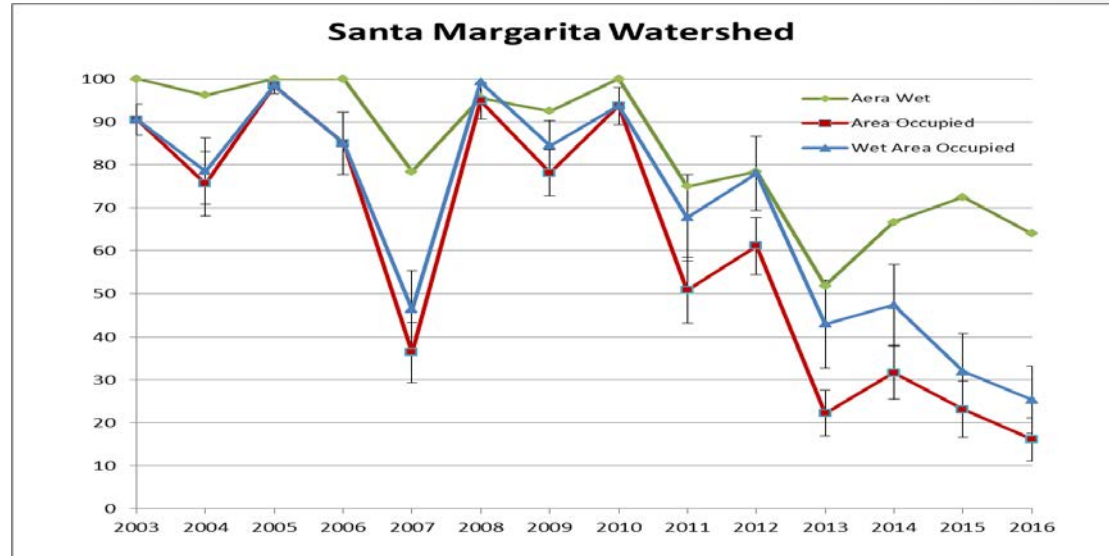
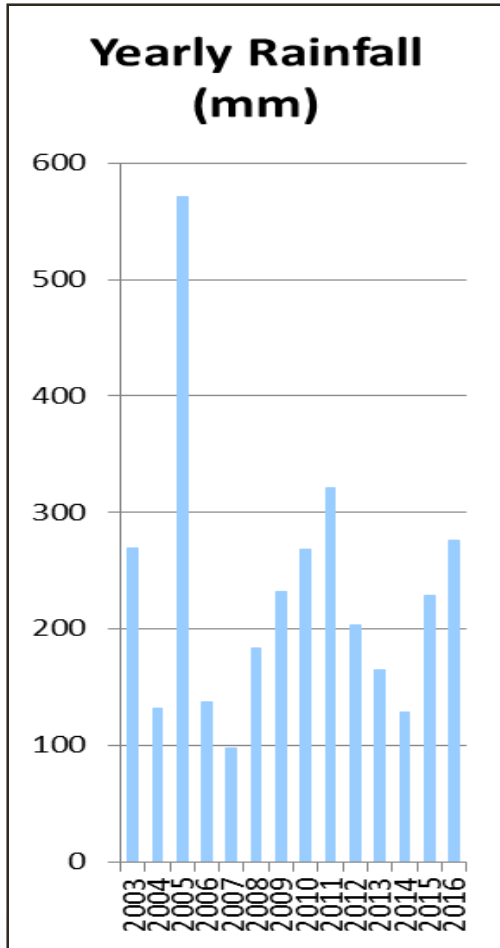


# Vegetation Growth

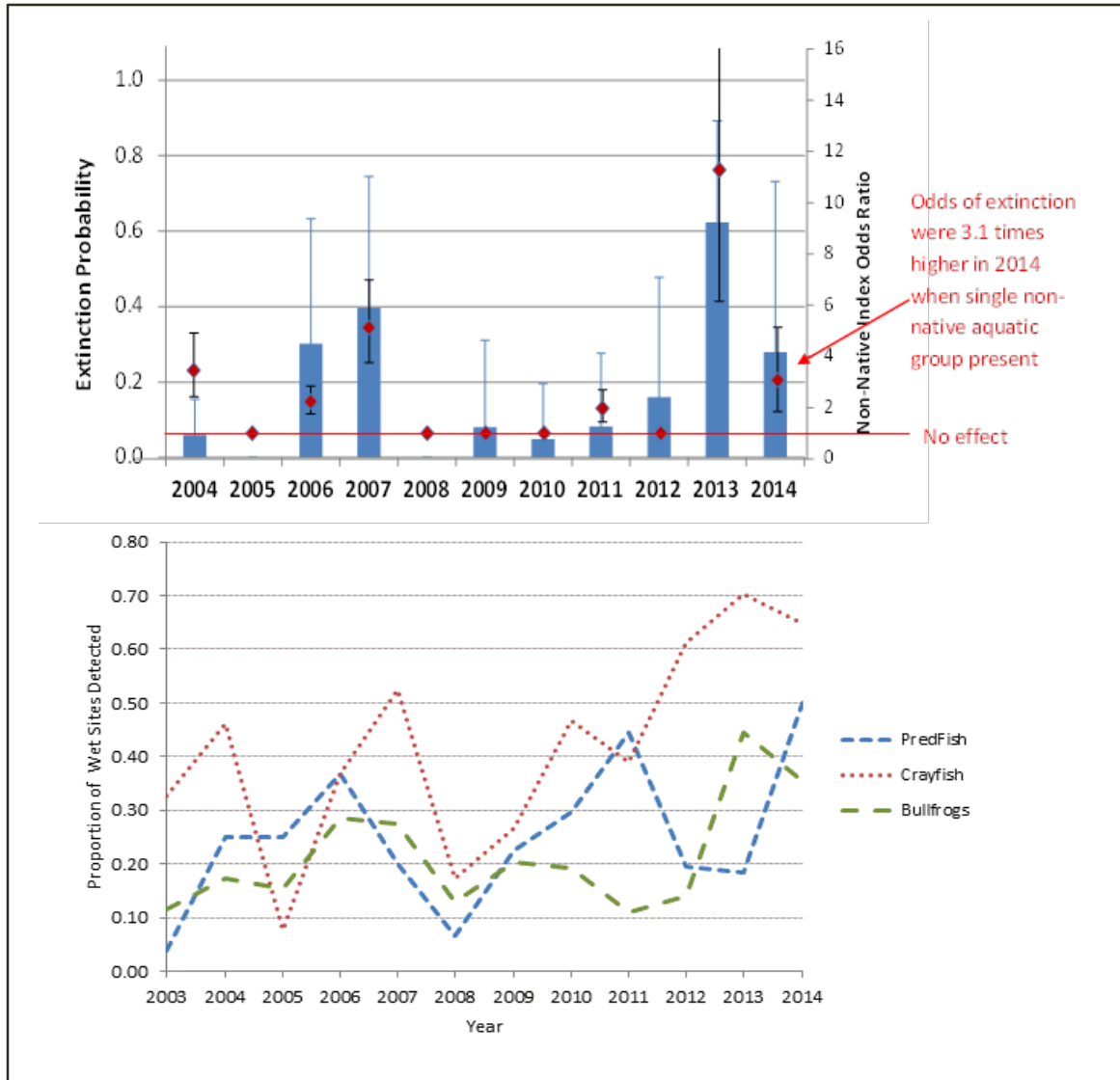
- Invasive plant growth
  - Yellow waterweed
  - Reduces suitable breeding habitat for arroyo toads
  - Reduces channel bank
  - Increases channel depth
- Lack of scouring events



# Dynamics differ between Ephemeral and Perennial watersheds



# Non-native aquatic species ( $\epsilon$ )



# Feedback Loop to Management- Perennial system MCBCP Invasive Aquatic Species Removal Efforts

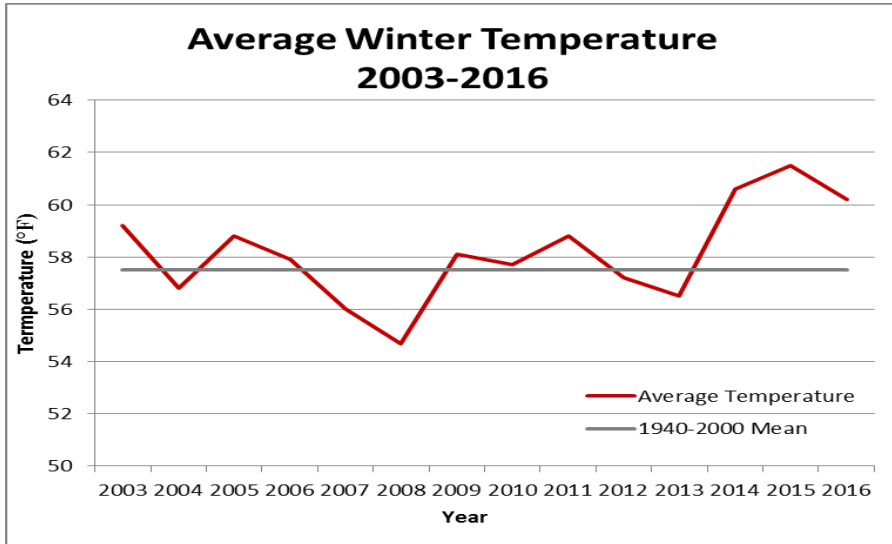


Santa Margarita 2008/9 Non-native Removal.  
Fish >5000  
Crayfish >1000  
Bullfrogs/tadpoles >75,000





# Breeding phenology in S. Margarita



- Drought and warmer winters resulting in earlier breeding

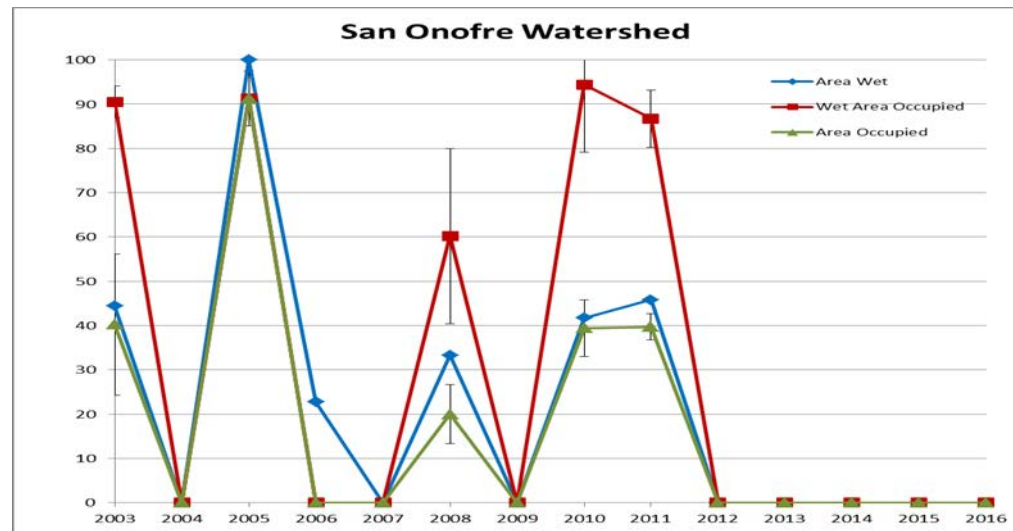
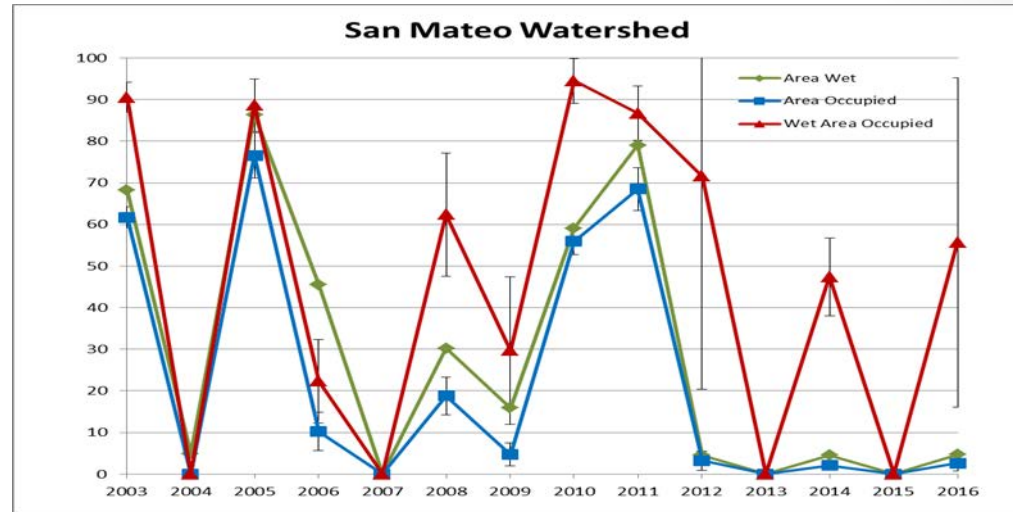
NOAA National Centers for Environmental Information, Climate at a Glance: U.S. Time Series, Average Temperature, published December 2016

Lower Santa Margarita River (Blocks 1-10)

	January	February	March	April	May	June	July
2003				■	■	■	
2004				■	■	■	
2005				■	■	■	
2006							
2007							
2008			■	■	■	■	
2009				■	■	■	
2010			■	■	■	■	
2011				■	■	■	
2012				■	■	■	
2013			■	■	■	■	
2014			■	■	■	■	
2015	■	■	■	■	■	■	
2016		■	■	■	■	■	

# Ephemeral System Dynamics

- Influenced primarily by stochastic processes (i.e., amount of rainfall).
- Expected to be more variable among years- higher chance of extirpation
- Keeps non-natives in check



# Review and What's next?

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- National Program within DOI
- Nimble for dealing with new national issues
- Visibility of products and successes to date
  
- Decision support
  - Moving forward despite uncertainty
- Synthesis
  - Regional and landscape questions and products
- Partnerships need to grow
- Thoughts?



Arroyo toad