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

Invasion risks of introduced watersnakes

Brian D. Todd, PhD

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
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 = highlly 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.
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.
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

<table>
<thead>
<tr>
<th></th>
<th>Fed TE</th>
<th>State TE</th>
<th>SSC</th>
<th>SSC or greater</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amphibians</strong></td>
<td>77</td>
<td>10%</td>
<td>17%</td>
<td>29%</td>
</tr>
<tr>
<td><strong>Reptiles</strong></td>
<td>141</td>
<td>5%</td>
<td>6%</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>218</td>
<td>7%</td>
<td>10%</td>
<td>22%</td>
</tr>
</tbody>
</table>
* 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
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. Crain2,3

1Fisheries Ecology Division, Southwest Fisheries Science Center, NOAA National Marine Fisheries Service, 110 Shaffer Road, Santa Cruz, California 95060 USA
2Center for Watershed Sciences, University of California, One Shields Avenue, Davis, California 95616 USA
3ICF 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-A accordin period (1991–1999). Horizontal dashed lines indicate the mean proportion of native species during each time period.
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
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

“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

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

“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
Python captures

\[ y = 3 \times 10^{-20} e^{0.4704x} \]

\[ R^2 = 0.8879 \]
Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park


*Department of Biology, Davidson College, Davidson, NC 28035; bDepartment of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; cFort Collins Science Center, US Geological Survey, Fort Collins, CO 80526; dEverglades National Park, National Park Service, Homestead, FL 33034; eFort Lauderdale Research and Education Center, University of Florida, Davie, FL 33314; fDepartment of Biological Sciences, Auburn University, Auburn, AL 36849; gState Museum of Pennsylvania, Harrisburg, PA 17120; hDepartment of Biology, Denison University, Granville, OH 43023; iCenter for Forest Sustainability, Auburn University, Auburn, AL 36849; and jSoutheast 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
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
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
- 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
- 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)
Known populations in California

Nerodia fasciata
Southern Watersnake

Nerodia sipedon
Common Watersnake

1992
2006
2007
CDFW restricted possession in 2008

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. Theolomis kitianii (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 Garter Snakes

- **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)

Incipient stages of invasion
Possibly preventable

Eradication potentially
still possible

Requires adjustment to new
reality and ongoing management

Native Species
Pool

Transport

Introduction

Establishment

Spread

Impact

???
Integration
???
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-indigenous species cause major environmental damage and losses totaling approximately $137 billion per year.
Stages of Invasion
(Moyle and Light 1996; Richardson and Pysek 2006)

Increasing funding

Decreasing likelihood of eradication
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

Native Species Pool

Transport

Introduction

Establishment

Spread

Impact

??? Integration ???
Known populations in California

Nerodia sipedon
Common Watersnake

Nerodia fasciata
Southern Watersnake

2007

1992

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).
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

<table>
<thead>
<tr>
<th>SVL</th>
<th>N</th>
<th>Mean (mm)</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>306</td>
<td>456.1</td>
<td>150.3</td>
<td>162 – 1023</td>
</tr>
<tr>
<td>Females</td>
<td>190</td>
<td>460.9</td>
<td>166.2</td>
<td>170 – 1023</td>
</tr>
<tr>
<td>Males</td>
<td>115</td>
<td>450.2</td>
<td>120.0</td>
<td>162 – 747</td>
</tr>
</tbody>
</table>
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

**Pseudacris regilla**

**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: btdod@ucdavis.edu), Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, One Shields Avenue, Davis, California 95616, USA.

Miano, Rose, Todd 2012
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

Native Species Pool
  ▼
  Transport
  ▼
  Introduction
  ▼
  Establishment
  ▼
  Spread
  ▼
  Impact
  ▼
  ??? Integration ???
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
Common Watersnake (Nerodia sipedon)

Southern Watersnake (Nerodia fasciata)

Native Ranges
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?
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

Native Species Pool

Transport

Introduction

Establishment

Spread

Impact

??? Integration ???
Spread via connected waterways

A: Southern Watersnake

B: Common Watersnake

- Known population
- Unsuitable
- Suitable
- Suitable and connected to known population
How quickly can they spread?

- Modeling population dynamics
- Connectivity of waterways
- Create spatial maps of potential rate of spread
Ecological and Methodological Factors Affecting Detectability and Population Estimation in Elusive Species

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

Willson, Winne, Todd 2011
Spread via connected waterways

Southern Watersnake

Common Watersnake

A

B

- Known population
- Unsuitable
- Suitable
- Suitable and connected to known population
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

(a) 7 ponds 14%

eDNA surveys

(b) 38 ponds 77%
Identifying Watersnakes

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