

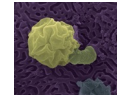
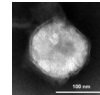
UNSEEN THREATS OF TRADE TO FLORIDA'S BIODIVERSITY

FWC's RANA 2022, 26 October 2022

Matthew J. Gray

University of Tennessee

<https://www.healthyamphibiantrade.org/>



Collaborators:

- Neelam Poudyal and Nina Fefferman, University of Tennessee
- Jesse Brunner and Jonah Piovio-Scott, Washington State University
- Alexa Warwick, Michigan State University
- Molly Bletz, University of Massachusetts-Amherst
- Julie Lockwood, Rutgers University
- Josh Jones, Pet Advocacy Network
- Josh Willard, Zach Brinks, Josh's Frogs
- Mark George, Neil Moherman, Reptiles by Mack

Partners:



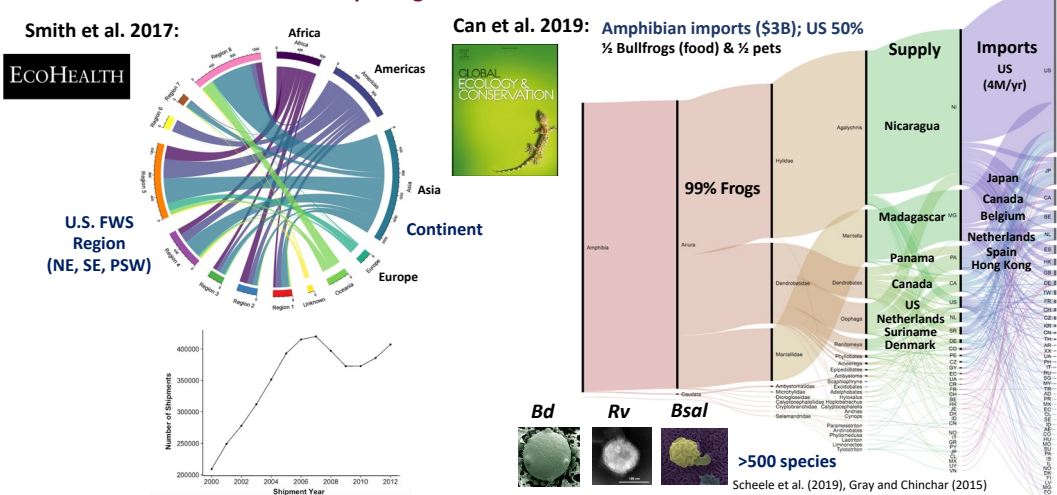
ONE HEALTH INITIATIVE



1

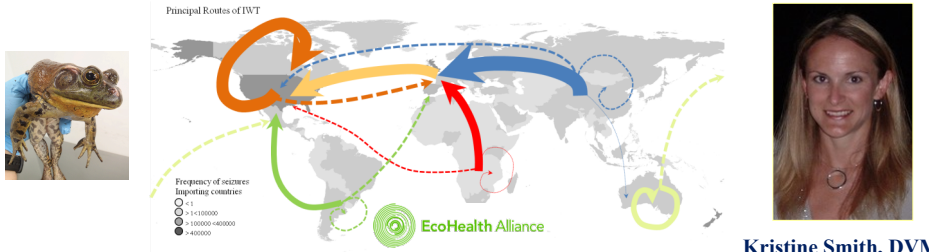
Wildlife Trade and Pathogens

- Wildlife Trade = \$300B annual, 2B specimens/yr (1/3 live), ~1000 species, 180 nations
- High-income Countries (USA, EU) drive market demand
- No U.S. programs or regulations to support clean (healthy) trade of wildlife (Ag: OIE/USDA)
- Introduction of novel pathogens: Industry economics; biodiversity (spillover); human health



2

Amphibian Pathogens in Legal Trade



From 2000-2006, 25 million **live** amphibians (4M/yr) imported to USA (Smith et al. 2009, Schloegel et al. 2009) – American bullfrogs (50%)

8 – 62% Rv, Bd
US Imports

First Evidence of Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*) and Ranavirus in Hong Kong Amphibian Trade **2014**

Jonathan E. Kolby^{1,2*}, Kristine M. Smith², Lee Berger¹, William B. Karesh², Asa Preston³, Allan P. Pessier³, Lee F. Skerratt¹

• Hong Kong = 12-57% Bd, Rv infected

3

Amphibian Pathogens in Illegal Trade

Batrachochytrium dendrobatidis in amphibians confiscated from illegal wildlife trade and used in an *ex situ* breeding program in Brazil

C. D. De Paula^{1*}, E. C. Pacífico-Assis², J. L. Catão-Dias¹



Dendrobates tinctorius

DAO
Diseases of Aquatic Organisms
2012

67% infected with Bd



2016

Telmatobius

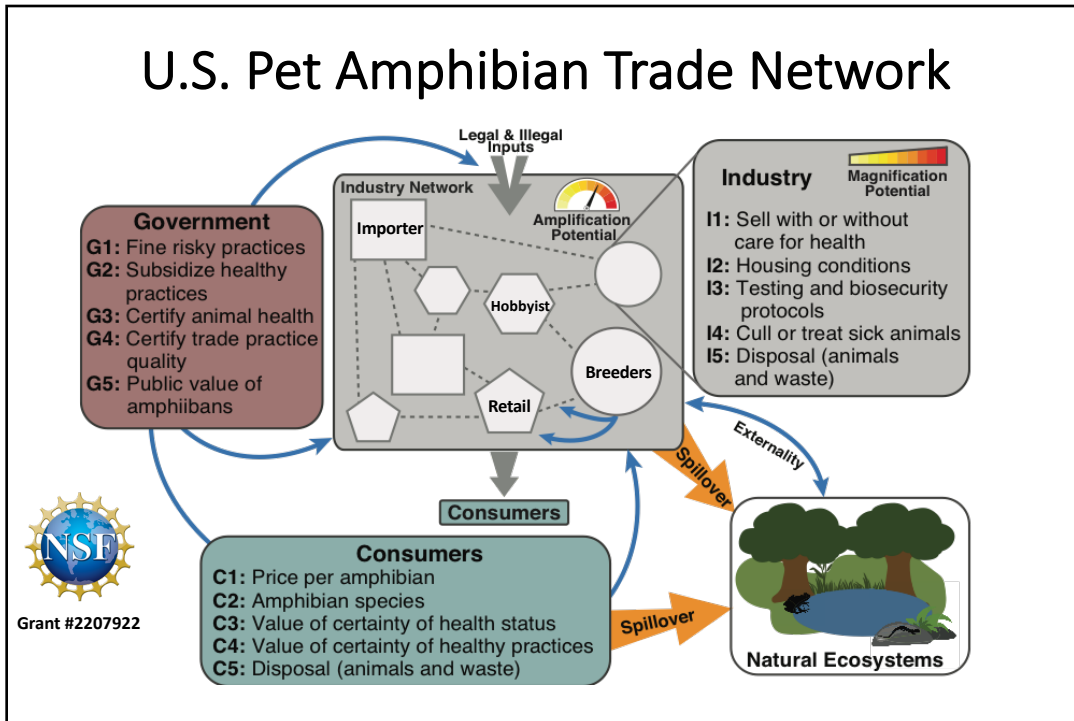


Batrachochytrium dendrobatidis in Confiscated *Telmatobius* in Lima, Peru

Samanta Zevallos^{1,5}, Roberto K. Elías^{2,3}, Raúl A. Berenguel³, Thomas J. Weaver², and Richard P. Reading⁴
¹Universidad Científica del Sur, Km 19 Panamericana Sur, Villa El Salvador, Lima, Perú; ²Denver Zoological Foundation, 2300 Steele St., Denver, Colorado 80205, USA; ³Universidad Peruana Cayetano Heredia, 430 Honorio Delgado St., San Martín de Porres, Lima, Perú; ⁴University of Denver, 2199 S University Blvd., Denver, Colorado 80208, USA; ⁵Corresponding author (email: samanta.zevallos@gmail.com)

60% infected with Bd

4






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Amphibian Release Happens!

www.caudate.org

Identification needed - Cynops in wild in USA

This salamander was found in the wild in the San Francisco Bay Area -

Chinese fire belly newt

Re: Identification needed

Yes. It was found in a meadow that has three small ponds, a meadow along a trail between the Nature Center of a regional park and a very popular small man-made lake in the regional park. I did collect her. I usually don't collect wildlife but she didn't belong there.

The ponds (which are permanent most years) have the mentioned California Newts, though the newts tend to prefer the vernal ponds higher on the surrounding hills. The ponds also have Sierran Treefrogs (*Pseudacris sierra* - formerly *Pseudacris regilla*) and I assume those tadpoles is what the newt was largely feeding upon at the time (probably in addition to inverte), that is what she (she?) readily took for me. I will make sure she takes traditional food, which I haven't even tried, before I re-home her (I don't wish to keep her, but I don't want to kill her either, she didn't ask to be there). The ponds traditionally had the federally threatened California Red-legged Frogs (*Rana draytoni*) but I did not see any on this visit, hopefully they are still there though.

I'm not an Asian newt guru, but I see no reason why the species couldn't thrive there, except for possibly being out-competed by the larger native newts.

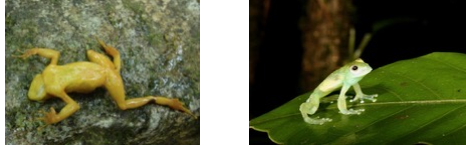
Re: Identification needed

I am in no way condoning people releasing Cynops into the wild. What I'm saying is that it's unlikely this species could become a threat to other species.

6

Emerging Infectious Diseases: Amphibians

Batrachochytrium dendrobatidis (Bd)



- Discovered 1997; Global
- >90 Species Extinctions (frogs)
- Epidermal hyperplasia: skin thickens
- Osmoregulation: Electrolytes

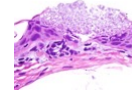
Transmission: 1 contact sufficient;
Environmental Persistence: 3 – 14 days
R₀ = 3 – 10; Rapid Invasion

Ranavirus (FV3: Type Species)

- Discovered 1965; 6 Species; Global
- Severe Declines in Wild and Captivity
 - Amphibians (>100 spp), Reptiles (>30), Fish (>50)
- Hemorrhagic Disease
- Liver, spleen, kidney, brain

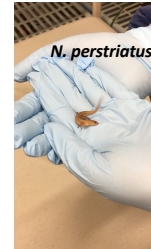


Batrachochytrium salamandrivorans (Bsal):



- Discovered 2013; Europe/Asia
- Severe Population Declines (salamanders)
- Epidermal Necrotic Ulcerations: holes in skin
- Osmoregulation, Respiration, Bacterial

GRSM National Park, Cades Cove, Gourley Pond



7



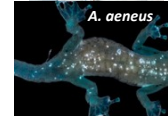
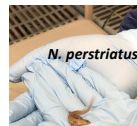
Species Susceptibility to Bsal

36 Species (10 Families)

- 72% Species became Infected
 - Newt and Lungless Salamanders (Salamandridae, Plethodontidae)
 - 5 of 9 Frog Species (52%; Cuban tree frog)
 - Mexican axolotl (endangered; medical and pet trade)
- 36% Species (41% Sal) developed Bsal chytridiomycosis
 - 4 of 5 Newt species (*Notophthalmus*, *Taricha*)
 - 2 of 2 Arboreal Salamanders (*Aneides aeneus*, *A. hardii*)
 - 2 of 3 Brook Salamanders (*Eurycea*, endemic genus to eastern NA)
 - 2 subspecies of *Ensatina* (West Coast: yellow-blotched and large-blotched)
 - 2 species from Mexico (*Aquiloerycea*, *Chiropterotriton*)
 - 2 Frog species (Cuban tree frog and eastern spadefoot)



(Invasive: 14 countries, 4 states)



Journal of Wildlife Diseases, 57(4), 2021, | DOI: 10.7589/JWD-D-20-00214

Significant Phylogenetic Signal

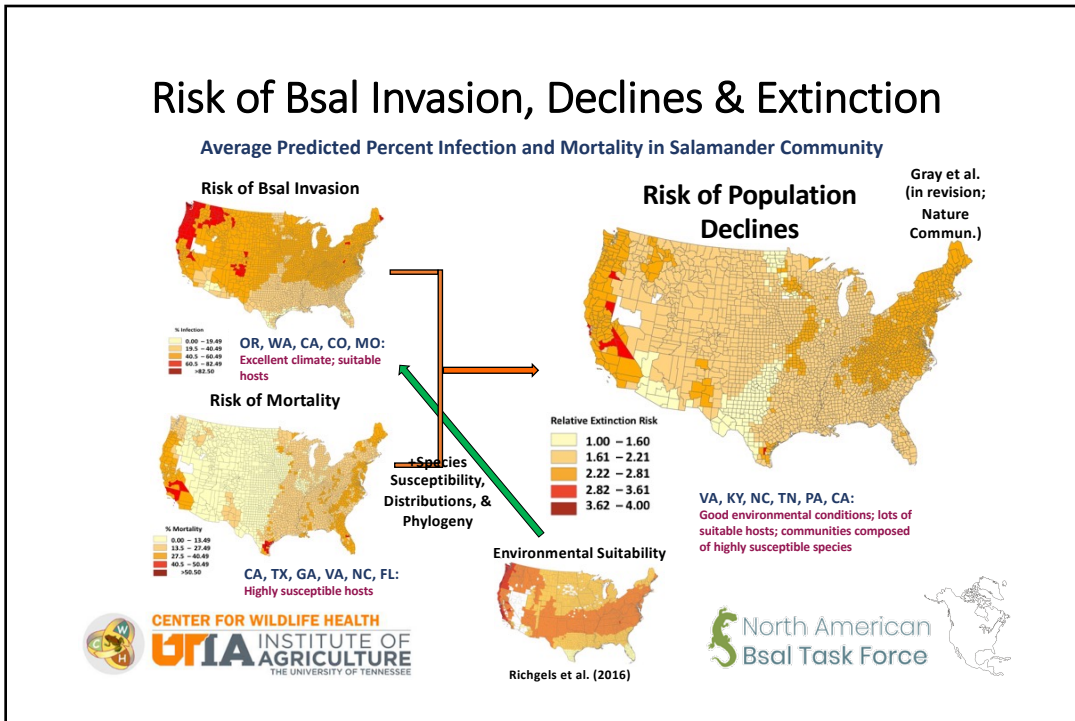
>60 Species in U.S. and >140 Species in North America
Could Experience Declines or Extinctions



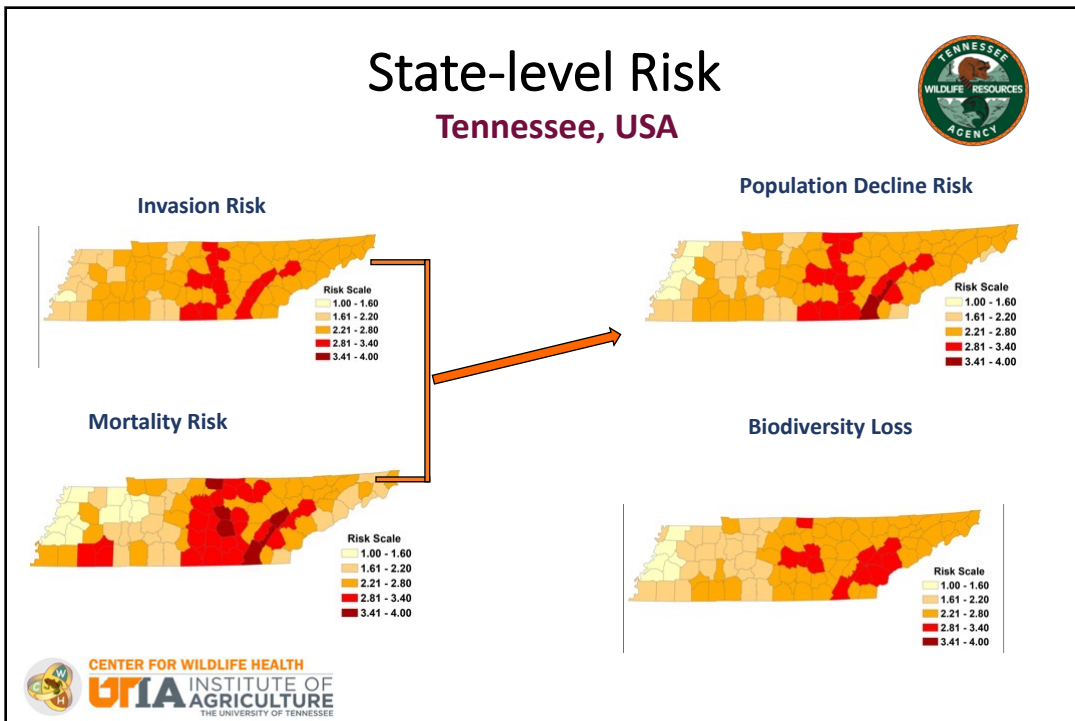
Gray et al. (in revision; Nature Communications)



8




9




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Bsal in Legal Trade

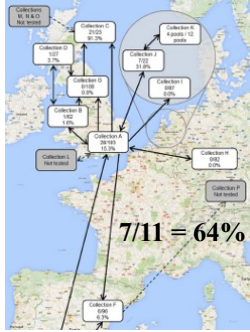


3.5 mil
in 8 yrs



35K Bsal+
per yr

Fitzpatrick et al. 2018



Epidemiological tracing of *Batrachochytrium salamandrivorans* identifies widespread infection and associated mortalities in private amphibian collections

POLICY PERSPECTIVE **2018** **WILEY** Conservation Letters
Journal of the Society for Conservation Biology

Widespread occurrence of an emerging fungal pathogen in heavily traded Chinese urodelan species

Zhiyong Yuan^{1,2} | An Martel³ | Jun Wu⁴ | Sarah Van Praet³ | Stefano Canessa³ | Frank Pasmans³

Trade in wild anurans vectors the urodelan pathogen *Batrachochytrium salamandrivorans* into Europe


2017 (detected in German pet store; 3/36 = 8%)
Tao Thien Nguyen^{1,2}, Thinh Van Nguyen², Thomas Ziegler^{3,4}, Frank Pasmans³, An Martel^{3,5}

2.2M


3% Prevalence ➔ 66,000 Bsal+ newts ('08)

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University of Tennessee One Health Initiative Seed Grant Objectives



ONE HEALTH INITIATIVE



<https://tiny.utk.edu/pijac>

1. Evaluate **business husbandry and biosecurity practices** and knowledge of disease threats in amphibian trade.
2. Evaluate **consumer preferences** and knowledge of disease threats in amphibian trade.
3. Obtain preliminary estimates of **pathogen prevalence** in illegal and legal trade pathways for the U.S. amphibian pet industry (confiscations, borders, trade nodes).
4. Build a **simplified model** to determine optimal locations in the trade network to sample, and identify which factors should be measured to detect changes in disease dynamics.

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Methods

INNOVATIVE SOLUTIONS TO REDUCE DISEASE RISK IN AMPHIBIAN TRADE

<https://tiny.utk.edu/pijac>




- Partnership with PAN and two prominent retail businesses
- Anonymous and voluntary survey (using Qualtrics) in summer 2021 (UTK IRB-21-06494-XM Protocol)
- Recruitment through email, online presence, and industry trade shows
- n = 103 businesses and n = 393 consumers




Questions Focused on:

- **Characteristics** (e.g., businesses: size [annual sales], trade partners; consumers: education, acquisition, price per amphibian).
- **Knowledge** of Amphibian Pathogens and Threat of Spillover
- **Biosecurity** and Husbandry Practices
- **Willingness to Pay** for Clean Trade (certified, pathogen-free amphibians)

Business and Consumers

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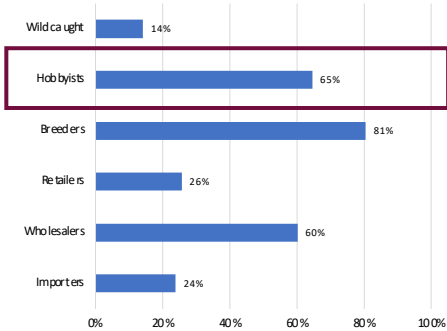
U.S. Business Characteristics

International Trade
Plays a Role in Introduction of Novel Pathogens (2M live to pet industry)

- 10% Imported Amphibian from Outside of US
- 82% Only Domestic Transactions
- 8% Unsure

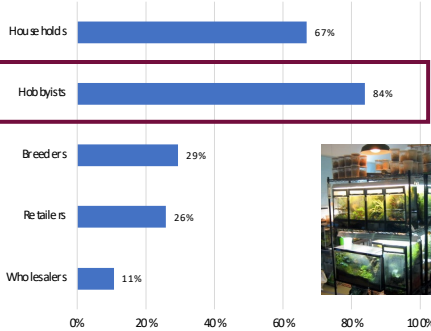
Domestic Trade Plays a Major Role in Pathogen Dynamics (maintaining, amplifying; >18M amphibians)

Acquire Amphibians From:




Source	Percentage
Wild caught	14%
Hobbyists	65%
Breeders	81%
Retailers	26%
Wholesalers	60%
Importers	24%

Sold Amphibians To:



Destination	Percentage
Households	67%
Hobbyists	84%
Breeders	29%
Retailers	26%
Wholesalers	11%



- **Hobbyists (<20 tanks, <\$5K/yr):** Could Play a Major Role in Pathogen Dynamics

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U.S. Businesses: Biosecurity Practices

- Majority of businesses **use disinfectants (92%)** , **disposable gloves** when handling animals (**60%**) , and **quarantine** new shipments (**66%**) .
- Few businesses (<25%) test** arriving or resident animals for pathogen infection. Outreach = Importance of testing new arrivals
- 75%** of businesses **don't decontaminate** wastewater or aquarium contents, which can be a pathway for pathogen spillover to wild populations.



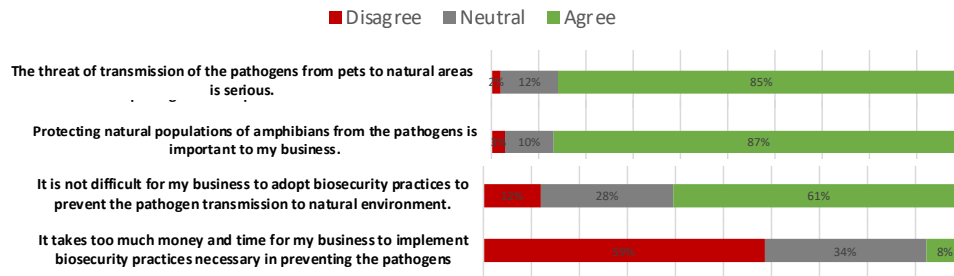
CMTV-like ranavirus infection associated with high mortality in captive catfish-like loach, *Triplophysa siluorides*, in China
 Lishuang Deng, Yi Geng, Ruoxuan Zhao, Matthew J. Gray, Kaiyu Wang, Ping Ouyang, Defang Chen, Xiaoli Huang, Zhengli Chen, Chao Huang, Zhijun Zhong, Hongrui Guo, Jing Fang



Transboundary and Emerging Diseases

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U.S. Business Knowledge & Attitudes Toward Biosecurity



U.S. Businesses **understand the threat** but some are **hesitant** to incorporate biosecurity practices because it is **difficult** (lack of knowledge) or **costs time/money**

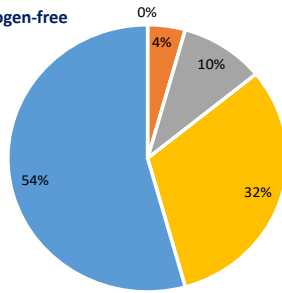
Education Outreach
Cost-share (Gov't Subsidized) Programs

16

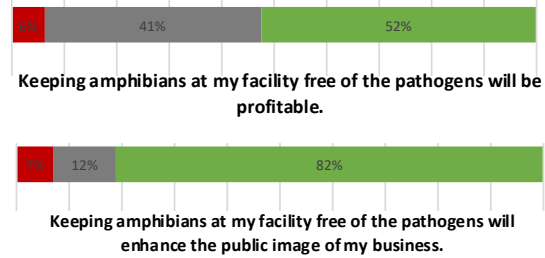
Businesses' Willingness to Accept Clean Trade

97% of U.S. Businesses were Interested in Acquiring Amphibians Certified as Pathogen Free (Bd, Bsal, Ranavirus)

Acquire Pathogen-free Amphibians:



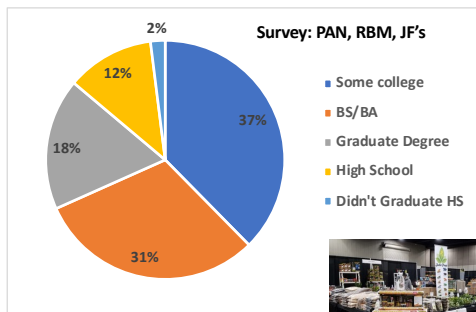
■ Not at all important ■ Slightly important ■ Moderately important
 ■ Very important ■ Extremely important



Majority of businesses are willing to pay up to 20% more for pathogen-free amphibians.

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U.S. Pet Amphibian Consumers Education and Purchasing



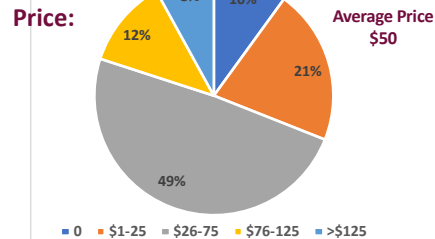
* Where amphibians were acquired (n=388)

In-store retailer/pet store	59
Online retailer	49
Pet show	37
Hobbyist	29
Collected from wild	19

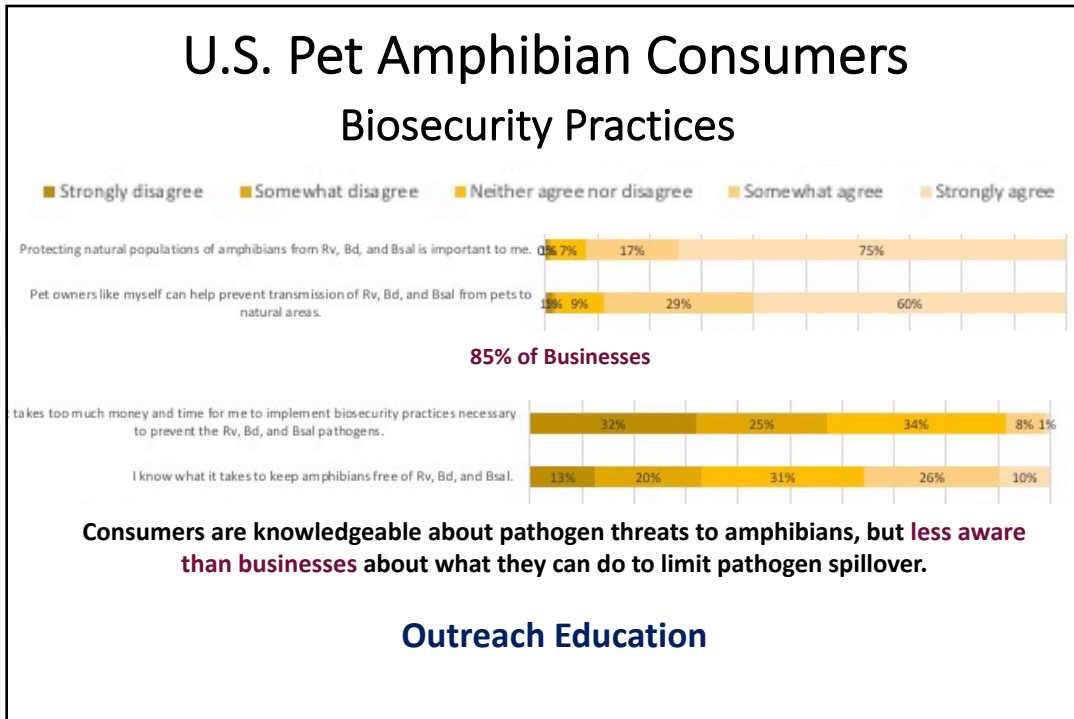
* Sources of amphibian care information (n=387)

Websites	92
Self-learning/Personal experience	87
Scientific journals	61
Social media	44
Magazines	37
Formal training	16

93% indicated being at least moderately familiar with the general knowledge of amphibians and their role in the environment






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Consumers: Amphibian Death & Disposal

- Dead:** Nearly **80%** of respondents reported having had a pet amphibian die. Disposal techniques included **burying (61%)**, placing in the **garbage (21%)**, flushing down the **toilet (3%)**, leaving the animal **outdoors (3%)**.
 
- Unwanted:** Most (**59%**) of those who had been unable to keep an amphibian indicated they had **given away or sold their animal, 8%** each indicated they had taken their animal to a rescue facility/**pet amnesty** event or returned to where **it was acquired**, while **5%** reported **euthanizing** the animal.

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Consumer Support for Clean Trade

- Over half (**52%**) of respondents indicated if they were to acquire another pet amphibian in the future, it would be extremely important the **animal is free of the pathogens** and another **27%** indicated very important;
- **Three-quarters (76%)** of the respondents indicated, when acquiring an amphibian, they would be **willing to pay more** for an animal that is certified free of the pathogens.

Turnbull lower-bound mean WTP for certified pathogen-free amphibians, compared to non-certified amphibians:

=\$38.65 per animal (in 2021 USD)

Avg Cost = \$50
(77% higher cost)

\$25 to test Bd, Bsal, Rv

Profit = \$13 / amphib
Increase Profits 26%!

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Summary

- Businesses and consumers are **aware** of pathogen threats, but **they (esp. consumers) need to be informed** about biosecurity practices.
- Businesses and consumers are **willing to participate** and place value on acquiring pathogen-free amphibians.
 - Businesses were willing to pay **up to 20% more**.
 - Consumers were willing to pay **up to 77% more**.
- Profit margin = **26% increase** to sell pathogen-free amphibians.

Our results support:

- **Industry-led, Market-supported Healthy Trade Certification Program for Amphibians**
- **Outreach Education on Biosecurity Practices** (quarantine, testing, disposal of aquarium contents and animals).

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U.S. Healthy Trade Certification Program for Pet Amphibians

<https://www.healthyamphibiantrade.org/>



Met in June, July, and August 2022



Name	Organization
Anibal Armendaris	Pet Smart
Molly Bletz	University of Massachusetts
Zach Brinks	Josh's Frogs
Jesse Brunner	Washington State University
John Clare	Caudata.org
Devin Edmonds	University of Illinois
Mark George	Reptiles by Mack
Matt Gray	University of Tennessee
Scott Hardin	Pet Advocacy Network
Tim Herman	Indoor Ecosystems
Josh Jones	Pet Advocacy Network
Jonathan Kolby	Former FWS Import Inspector
Pat Kline	Frog Depot
John Mack	Reptiles by Mack
Neil Moherman	Reptiles by Mack
Marshall Myers	Advisory Council
Allan Pessier	Washington State University
Neelam Poudyal	University of Tennessee
Jose Salmeron	Two Amigos Import & Export, Inc.
Tom Waltzek	USDA - APHIS
Alexa Warwick	Michigan State University
Josh Willard	Josh's Frogs



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NSF EEID Grant 2207922: Socioeconomic and Epidemiological Drivers of Pathogen Dynamics in Wildlife Trade Networks

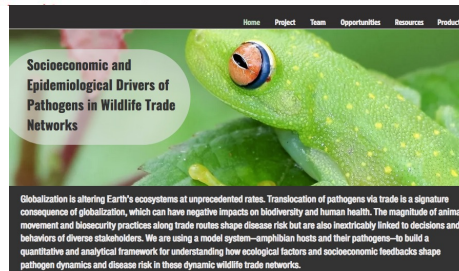
Partnerships:



NEWS RELEASE 12-AUG-2022

UT researchers receive \$2.75 million grant to investigate movement of amphibian pathogens in wildlife trade networks

Grant awarded by NSF, NIH and USDA NIFA



PIs:

- Matt Gray
- Nina Fefferman
- Neelam Poudyal
- Jesse Brunner
- Alexa Warwick
- Jonah Piovita-Scott
- Molly Bletz
- Julie Lockwood



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<https://www.healthyamphibiantrade.org/>



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University of Tennessee Center for Wildlife Health

Amphibian Disease Laboratory

<https://amphibiandisease.tennessee.edu/>

<https://www.facebook.com/UTIAAmphibianDiseaseLab>

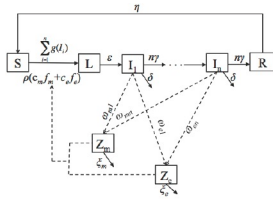
Research



Diagnostic Services



Outreach/Guidance



Lead Scientists

- Matt Gray, Ph.D., mgray11@utk.edu
- Deb Miller, DVM, Ph.D., dmille42@utk.edu
- Mark Wilber, Ph.D., mwilber@utk.edu
- Wesley Sheley, DVM, Ph.D., wsiniard@utk.edu
- Davis Carter, Ph.D., ecarte27@utk.edu

