
Species-level variation in ranavirus susceptibility
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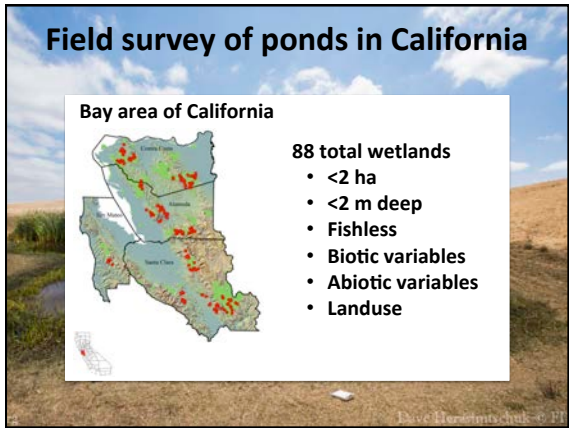
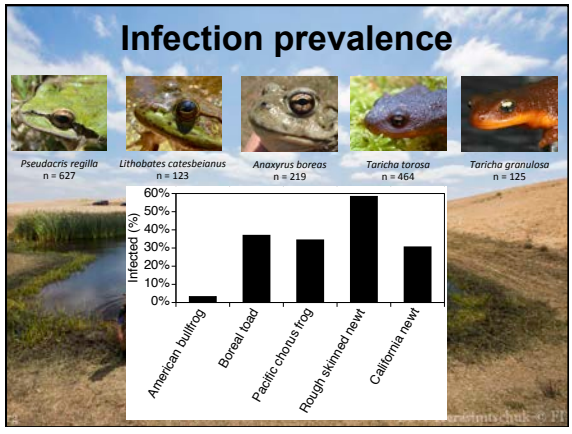

Field survey of ponds in California
Bay area of California
88 total wetlands
• <2 ha
• <2 m deep
• Fishless
• Biotic variables
• Abiotic variables
• Landuse


Infection prevalence
Pseudacris regilla
n = 627
Lithobates catesbeianus
n = 123
Anaxyrus boreas
n = 219
Taricha torosa
n = 464
Taricha granulosa
n = 125
Infected (%)
60%
50%
40%
30%
20%
10%
0%
American bullfrog
Boreal toad
Pacific chorus frog
Rough skinned newt
California newt

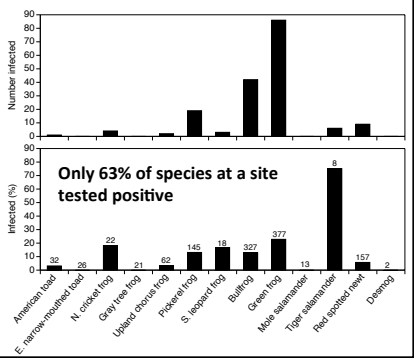
Field surveillance of ponds in Tennessee

33 of 40 sampled ponds (83%)
Prevalence ≥ 40% in 13 ponds (39%)
Detected across multiple seasons in 20 ponds (61%)
9 of 13 species tested positive (69%)

Infection prevalence

Ranids were the most frequently infected group

Variation in infection prevalence among species



Summary of field patterns

Ranavirus is common but there is variation

- Infection prevalence varies among species/groups
- All species at a site are not infected despite the presence of ranavirus

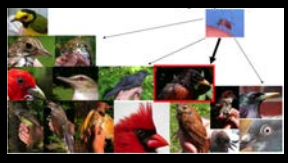
Inferring susceptibility from field data is difficult

- Bias in sampling
- Exposure history
- Confounding environmental variables

Variation in disease outcomes

Co-occurring host species often differ in:

- Infection
- Pathology

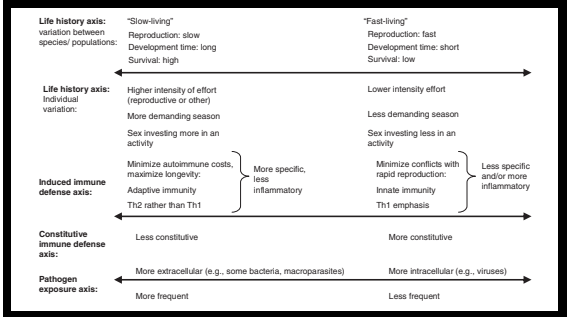


Variation is a product of:

- Phylogeny
- Ecology
- Life history

Exploring the influence of these factors on disease outcomes is a major step towards predicting disease risk within natural systems

Pace-of-life continuum



Lee 2006; *Integrative and Comparative Biology*

Examples

Tropical birds

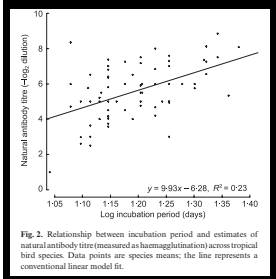
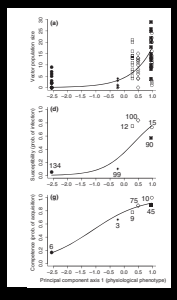


Fig. 2. Relationship between incubation period and estimates of natural antibody titre (measured as haemagglutination) across tropical bird species. Data points are species means; the line represents a conventional linear model fit.

Lee et al 2008; *J Animal Ecol*

Plants



Cronin et al 2010; *Ecol Letters*

Approach

Let's apply this framework to amphibians

- Collect as many species as possible
- Under controlled conditions exposure them to ranavirus and assess disease outcomes
  - Infection
  - Mortality
- Use phylogenetic methods to assess the relative importance
  - Phylogeny
  - Ecology
  - Life history

Species collection

19 species from 7 families tested

Ranidae (7)
Wood frog
Gopher frog
Southern leopard frog
Northern leopard frog
Pickerel frog
American bullfrog
Green frog

Hylidae (4)
Cope's gray tree frog
Western chorus frog
Upland chorus frog
Mountain chorus frog

Other anurans (3)
American toad
Eastern narrow-mouthed toad
Eastern spadefoot

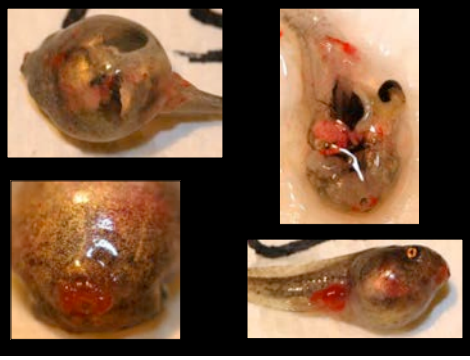
Ambystomatidae (4)
Mole salamander
Tiger salamander
Spotted salamander
Marbled salamander

Salamandridae (1)
Red-spotted newt

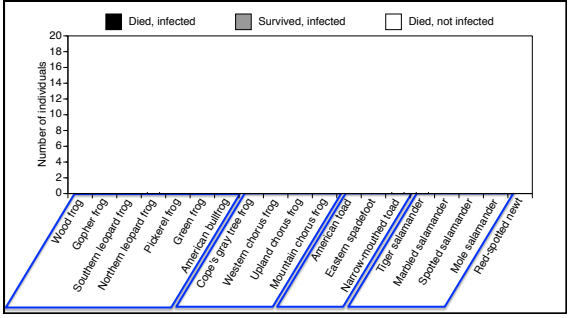
The experiments

Mortality and infection prevalence

Results

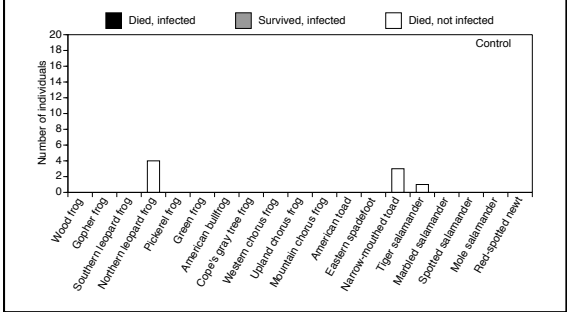


Species results



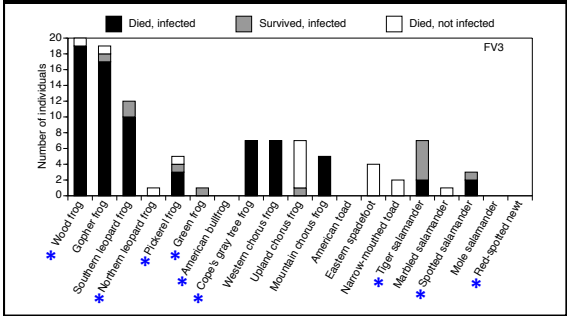
Species results

High survivorship and no infection in control animals



Species results

Broad host range with variation in disease outcomes



Species results

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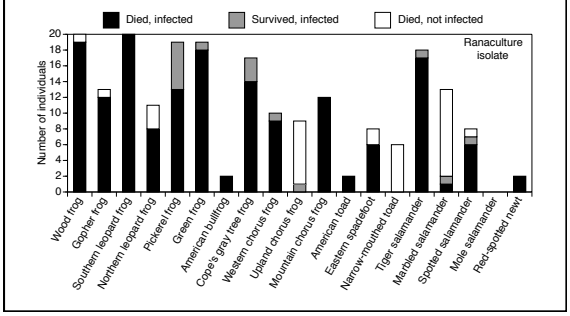
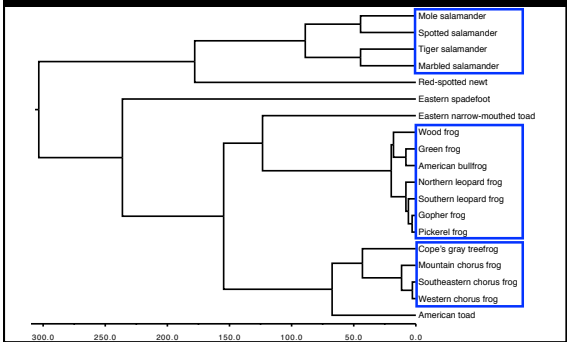
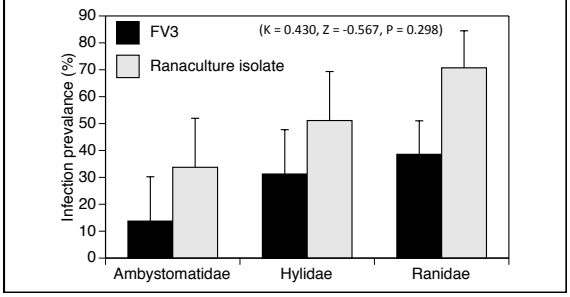


Phylogenetic comparative methods



Family-level patterns in susceptibility

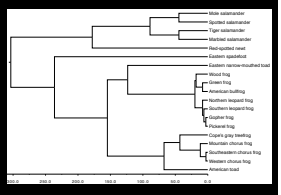
Ranids were generally the most susceptible to infection



Phylogenetic comparative methods

Are there associations between species traits and susceptibility?

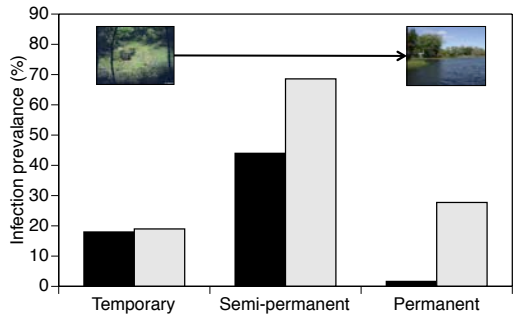
Species-level traits (9)
Breeding habitat
Breeding time
Duration of larval stage (d)
Size at metamorphosis (mm)
Clutch size
Duration of egg stage (d)
Adult body size (mm)
Time to maturity (yr)
Species range (km^2)



Phylogenetic independent contrasts
Phylogenetic generalized least squares

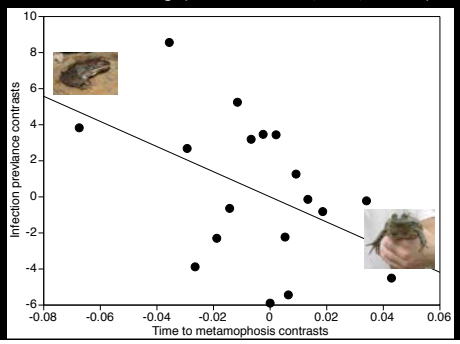
Ecology and susceptibility

Breeding habitat (r = 0.490, n = 17, P = 0.046)



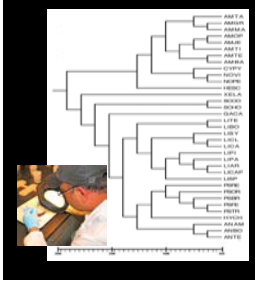
Life history and susceptibility

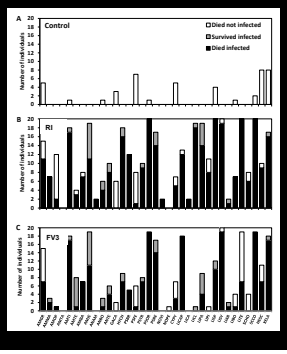
Duration of larval stage (Pearson's r = -0.460, n = 18, P = 0.046)



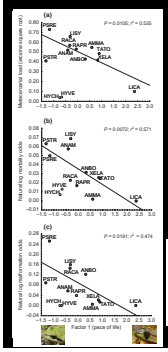
Including additional species

16 species added to the list
Same general patterns found

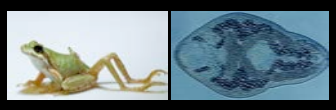




Pace-of-life with amphibian parasites



The trematode *Ribeiroia ondatrae*



Fast-paced species had:

- Greater parasite loads
- Greater probability of mortality
- More malformations

Figure 3 Relationships between Factor 1 from the factor analysis ('pace-of-life' axis) and responses variables: (a) parasite load at metamorphosis (arcsine-square root transformed); (b) mortality risk (ln-transformed odds ratio); (c) malformation risk (ln-transformed odds ratio). Trendlines and associated statistics plotted for each panel with *H. versicolor* and *H. chrysoscelis* excluded. For ease of presentation, graphs reflect data without correcting for phylogenetic relationships (see text for details).

Johnson et al. 2012. *Eco Letters*

Summary

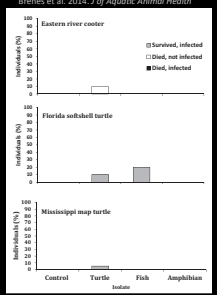
Species-level variation in susceptibility is not random

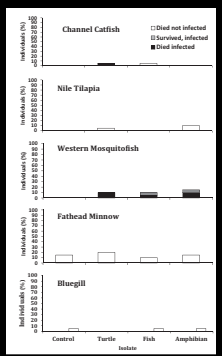
- Phylogeny – shared evolutionary history
- Ecology – habitat preferences that influence exposure
- Life history – Pace-of-life continuum
  - 'Fast-lived' species with rapid growth and short life spans invest little in pathogen defense
  - 'Slow-lived' species with slow growth and long life spans invest more in pathogen defense

Variation among other ectotherms

Fish and turtle species have been examined for susceptibility to different ranavirus isolates

Brenes et al. 2014. *J of Aquatic Animal Health*



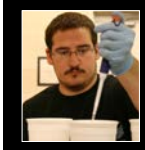


Influence of development on susceptibility

Individuals near metamorphosis are frequently reported in die-off events

Immune function decreases during metamorphosis

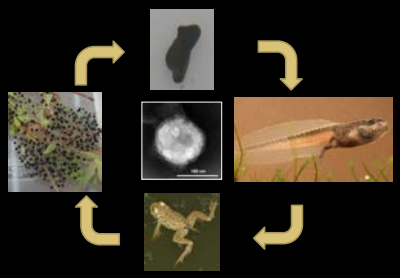
Susceptibility to pathogens should be highest at metamorphosis



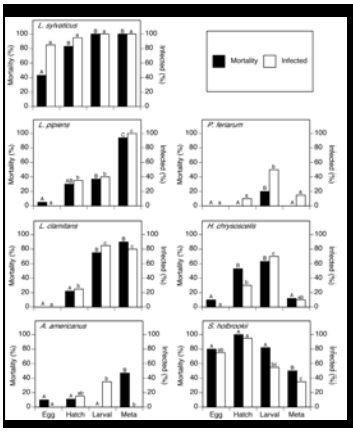
Nathan Haislip

Experimental approach

Does susceptibility vary across developmental stages?



Exposed to the virus for 3 days at each stage and moved to clean water



Results

- Variable patterns across species
- Metamorphic stages are not universally the most susceptible
- Eggs are generally protected from infection

Haislip et al. 2011 PLoS ONE