Amphibian declines as a result of climate change

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Introduction

- Amphibians are a sensitive class
  - Ectothermic - rely on external surroundings for metabolic processes
  - Thin, cutaneous skin
    - Inhabit humid, moist environments
    - More susceptible to: drought; UV-B radiation
- Global climate change disrupts abiotic conditions on which amphibians depend for survival
  - Habitat quality
    - Annual warming (lethal thresholds)
    - Reductions in: precipitation; pond depth; humidity (Pounds 2001)
  - Increased UV-B exposure

Amphibian Biogeography

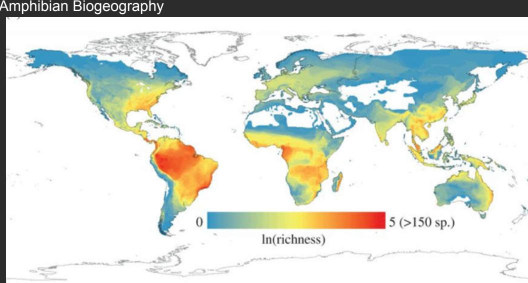

Fig 1. Biodiversity and global distribution of amphibian taxa (Pyron & Wiens 2013)

Main Concerns

- Population continuity (abundance, diversity)
  - Lethal temperature thresholds
  - Earlier breeding; abnormal larval development (McMenamin, Hadly, & Wright 2008)
  - Enhanced disease transmission (McMenamin, Hadly, & Wright 2008)
- Migration/dispersal habits
  - Habitat loss
    - Reduced quality/availability of refugia
    - Dried streambeds
- At-risk spp.
  - Endangered spp.
    - Arroyo Toad (*Bufo californicus*)
  - Habitat specialists
  - Endemic spp.

Photo credit: https://www.nwf.org/News-and-Magazines/National-Wildlife/Animals/Archives/2010/Most-Threatened-Frogs-US.aspx

Effect of Climate Change on Richness

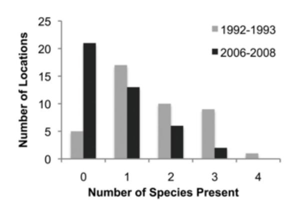

Fig. 5. Changes in species richness between 1992–1993 and 2006–2007. The graph shows number of locations containing 0, or at least 1, 2, 3, or 4 species of amphibians in 1992–1993 and 2006–2008. Of the 21 ponds lacking amphibians in 2006–2008, 11 were dry all 3 years. Changes in pond richness are highly significant (Paired t test: $t = 5.6848$, $P = 1.214E\text{-}06$).

(McMenamin, Hadly, & Wright 2008)

Infection

- Reduced precipitation leaves many viable ponds shallow
- El Niño/Southern Oscillation events
  - Greater UV-B exposure; increased susceptibility to infection
  - Increased embryonic/larval mortality
    - *Saprolegnia ferax*: fungal contagion afflicting Western Toad (*Bufo boreas*) egg masses in the Pacific Northwest (Carey 2003; Kiesecker, Blaustein, & Belden 2001)
- Chytrid fungus
  - Chytridiomycosis is an infectious disease afflicting amphibians
  - Caused by the chytrid *Batrachochytrium dendrobatidis*
  - Non-hyphal zoosporic fungus
  - Researchers say may be exacerbated by climate change (Aldred 2008)

Photo credit: http://www.nature.com/nature/journal/v410/n6829/fig_tab/410639a0_F1.html

Effects of Rising Winter Temperatures on Amphibians

- Winter temperatures increase with general warming of annual climate
- This increase of hibernating temperatures
  - Slows the growth rates
  - Increases mortality
  - Loss of essential hibernation time (Jorgenson 2009)
- The higher temperature in hibernation periods has also been linked to diminished body sizes in amphibians due to the higher metabolic rates that they have in warmer temperatures (Reading 2006)

Methods

- Mature male and female common toads (Bufo bufo) were captured from the study pond each year from 1983-2005.
- They were marked with a toe clip to show the year of capture
- Snout vent length (SVL) and body condition index (BCI) were recorded each year prior to spawning
- Measurements were compared year to year and showed a downward trend in the BCI of both male and female toads corresponding to the steady rise in temperature that was recorded throughout the study (Reading 2006)

Results

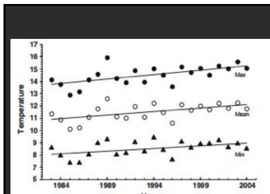

Fig. 1 Change in the mean maximum, mean and mean minimum temperatures (°C) between the 1st April each year and the start of the common toad breeding season the following year (1982–2004). Regression analysis: mean max. temperature = 8.18+0.068 year (R^2=36.6%; P=0.002; n=23). mean temperature =6.67+0.052 year (R^2=29.0%; P=0.008; n=23). mean minimum temperature = 5.18+0.036 year (R^2=17.2%; P=0.049; n=23). The start of the toad breeding season was the date when toads first arrived at their breeding pond in large numbers

Fig 1. Increase in annual global temperatures

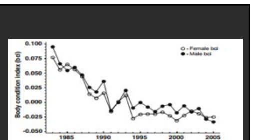

Fig. 2 Change in female and male body condition index (BCI) between 1983 and 2005

transients and trap dependence TEST3.SR, χ^2_{22}=58.82, P<0.0001; TEST3.SM, χ^2_{16}=2.15, P=0.99; TEST2.CT, χ^2_{14}=62.69, P<0.0001; TEST2.CL, χ^2_{5}=1.40, P=0.92. However, the results of TEST3.SR and TEST2.CT do not preclude the subsequent data analysis (Schmidt et al. 2002) and should both be treated with caution, as they were based on sparse data, i.e., from a total of 3,178 capture histories, just 453 females were captured more than once and of these only 44 (9.7%) were not captured in consecutive years.

The $QAIC_c$ weight values derived for each of the models showed that the model with female BCI as a covariate fitted the data best (Table 1), with the next best two models, including a combination of BCI and

Fig 2. Decrease in average annual BCI of male and female toads

Severity and Importance of Climate Change

- Lost habitat directly influenced by climate change
  - Lamar Valley, Yellowstone (McMenamin, Hadly, & Wright 2008)
    - 1990s: 93% hydrated ponds supported amphibians (nearly full occupancy);
    - 2000s: 73% ponds hydrated, of which 61% supported amphibians
    - fewer viable ponds; fewer amphibian communities in viable ponds
- Warming conditions increase evaporation in aquatic habitats
  - Increased cloud coverage
  - Thermal insulation (heat blanket)
    - Optimal conditions for the spread of chytrid fungus
- J. Alan Pounds (Resident Scientist at Tropical Science Center's Monteverde Cloud Forest Preserve in Costa Rica):
  - "Disease is the bullet killing frogs, but climate change is pulling the trigger." (Handwerk 2006)

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