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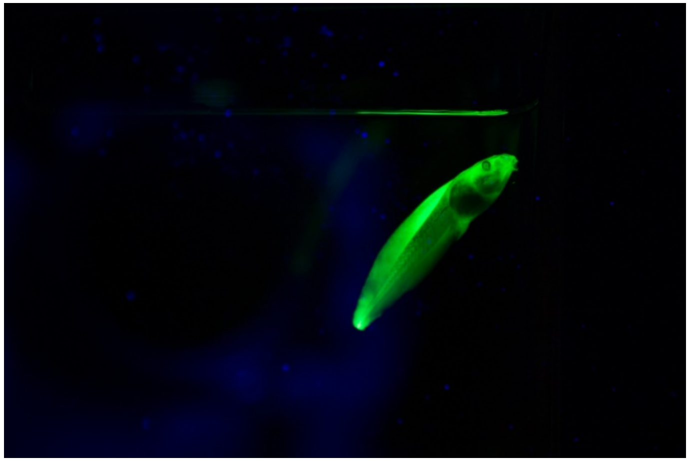
# *The evolution of intrinsic growth rates: can adaptation counteract environmental change?*

## Research Highlights

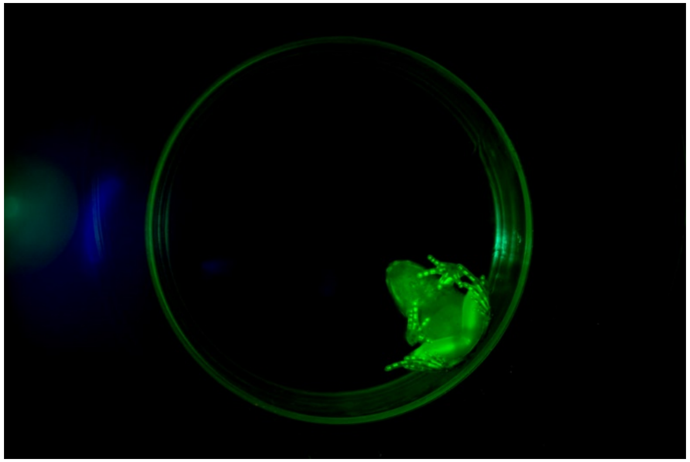
- Long-term data on forest canopy and wood frog development collected from YMF allowed us to uncover surprising and counter-intuitive phenological trends.
- A study of intrinsic developmental rates among wood frog populations demonstrated finely-tuned local adaptation at small spatial scales.
- A pilot study analyzing metabolic rates of wood frog larvae indicated a possible physiological trade-off between fast development and fitness--a potential explanation for the patterns seen in previous studies.
- We developed a new, non-invasive technique for marking larval amphibians that persists into adulthood and published the results (A.Z. Andis. 2018. A new, noninvasive method of batch-marking amphibians across developmental stages. *Herptetological Conservation and Biology*. 13(2): 21-24.).

## Management Implications

- Species may be able to adaptively evolve to environmental changes at incredibly small scales.
- The scale at which local populations harbor functionally relevant adaptive potential dictates how we manage populations and landscapes.
- As climate change alters temperature and precipitation patterns, microgeographic adaptation contribute greater resilience to impacted populations.



Wood frog larva marked with calcein. The mark is administered non-invasively and is only visible under UV light and viewed through a cancelation filter.



Wood frog juvenile that was marked as a larva with calcein. The calcein is absorbed through the skin and incorporated into the skeleton.

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**Research Summary**

We tend not to give organisms much credit when it comes to dealing with environmental change, instead treating them as helpless bystanders in the face of climate and landscape changes. However, this might not be the case. Our research on wood frog populations at Yale Myers Forest (YMF) has shown that organisms can adapt to changing environments at incredibly rapid rates and at finely-tuned spatial scales.

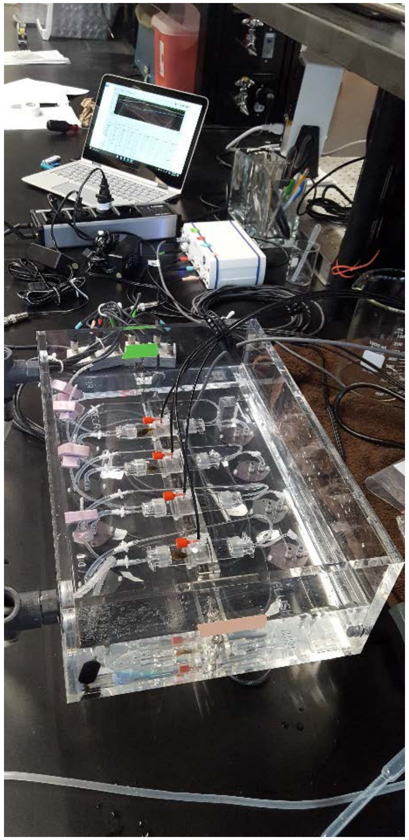
Wood frogs breed in the early spring, while snow and ice still cover the forest. They lay their eggs in ephemeral pools that dry up in early to mid-summer, which means that tadpoles must hatch and develop quickly in order to metamorphose before the pools evaporate.

Previous research in our lab from almost two decades ago showed that wood frog larval development is associated with the canopy cover over the ponds. Darker ponds with denser canopies tend to host frogs with faster developmental rates. From a tadpole's perspective, this makes sense: as cold-blooded animals, it is physically more difficult to develop in darker ponds; so, only those with the fastest intrinsic developmental rates can compete with their cousins in brighter ponds who had comparatively easier early life.

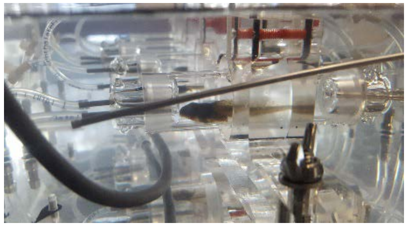
Both the forest canopy and spring temperatures are important drivers of wood frog adaptation. Interestingly, our research has shown that both the forest and water temperatures at the frog ponds are changing in considerable and counterintuitive ways. Over the past 17 years, the canopy at the ponds has grown in and now blocks about 10% more light. One might think that less solar radiation would lead to colder ponds, but in fact, we found the opposite relationship. Over the same time period, the average spring water temperature in the ponds has increased by 1.7C, due to climate change! What does this mean for the pond environment? Thanks to a collaboration with the Richardson Lab, we were able to use historic satellite imagery to show that the net result has been a shift to earlier spring phenology (trees bud and leaf-out up to two days earlier).

It seems that climate change has decoupled two of the most important evolutionary drivers for wood frogs. Nevertheless, a study we completed this year showed that the frog populations are evolving in pace with these changes. Ongoing research from long-term datasets of wood frog development at YMF indicates that while forest phenology has shifted to earlier green-up, wood frog phenology has shifted later hatching of eggs. Yet, adaptive developmental rates allow metamorphosis time to remain constant. In other words, frog lay eggs later now, but those tadpoles develop faster.

Our research gives us good reason to think that organisms can quickly react to environmental change in surprising ways. While this may give some hope for the future in the face of human-caused global change, it also reminds us that we need to take a much closer look at natural systems, as important adaptation might be occurring right under our noses.



Respirometery system, funded in part by the Kohlberg-Donohoe Research Fellowship.



Wood frog larvae in a respirometery chamber used to measure metabolic rates.