Assessing the potential effects of changes in climate on the range and long-term persistence of the Mink Frog, *Lithobates septentrionalis*, in the Northern Forest

THEME FOUR: **Biodiversity and Protected Area Management**

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Completion date: December 2011

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service. http://www.nsrcforest.org

Project summary

- Based on the life-history characteristics of the Mink Frog, *Lithobates septentrionalis*, populations in the Northern Forest (hereafter "NF") are likely to be highly threatened by climate change.
- Our goal was to evaluate the effects of climate change on the range and persistence of the Mink Frog in the NF. Specific objectives included: (1) Understanding how changes in water temperature and dissolved oxygen (DO) influence egg and larval survival; (2) establishing the current occurrence of this species in the NF; (3) integrating data with an existing model predicting the distribution of Mink Frog in the NF
- We used a combination of laboratory experiments, field studies across an elevational and latitudinal gradient, and spatially explicit population models to understand the factors driving occurrence of this species
- Our research has shown that distribution of the focal species can be linked to water temperature and dissolved oxygen, but that the mechanisms for this linkage are likely to be indirect rather than direct
- This study has provided valuable information in helping to understand the implications of climate change for amphibians in the NF, including spatial data allowing us to understand and predict patterns of occurrences of the focal species, and research methods suitable for assessing additional species

Background and Justification

- Almost half of the known amphibian species worldwide are declining, with approximately 100 species already thought to be extinct
- Climate change is of particular concern for amphibians: Amphibians are highly prone to desiccation in the terrestrial environment, and any increases in temperature or reduction in moisture can prove rapidly fatal
- Climate change can also alter aquatic habitats, for example reducing the hydroperiod of temporary ponds such that they cannot sustain egg and larval development, and/or changing water temperatures and related levels of dissolved oxygen.
- In predicting the effects of climate change on populations, there are a number of *a priori* factors likely to increase the vulnerability of populations and species: (1) Species with a narrow range of habitat requirements; (2) less vagile species; and (3) populations on the edge of their range, or isolated populations at high altitudes.
- Populations of mink frog in the NF meet all of these criteria, and yet despite evidence of range-reductions are not the focus of conservation efforts

- The mink frog is a medium-sized anuran, with a limited range in the United States. Also known as the frog of the North, the mink frog occurs only at latitudes greater than 43°
- This southern range limit is thought to be determined by physiological limitations linked to abiotic conditions: specifically, this species needs cold, highly-oxygenated water for successful egg and larval development
- In the NF, these conditions only occur in high altitude areas such as the Tug Hill Plateau and Adirondack Park or at higher latitudes, including northern Maine, New Hampshire, and Vermont.

- Trends in climatic conditions in the NF have specific implications for mink frog: Recent studies have indicated that areas of the Northern Forest are gradually warming, particularly during the winter, and we are seeing reductions in the amount and duration of snow-cover
- Moreover, Popescu and Gibbs (2009) clearly demonstrated that higher temperatures during the breeding season (July-August in the NF) result in a dramatic decrease of pond occupancy by mink frogs, with the potential for declines given the future climate change scenarios for the NF. Importantly, we are also seeing a warming of larger water bodies, such as those used by mink frog for breeding, associated with increased drought during the breeding season
- This warming will also result in a reduction in dissolved oxygen, and a likely increase in the suitability of aquatic sites for egg and larval development of species such as bullfrog with which the mink frog competes.
- A warming climate not only has implications for aquatic habitats: if mink frog are to persist in the landscape over the long-term, they need the ability to disperse to new sites to remain within the limits of their ecological tolerance. Given their existing proneness to desiccation, increases in temperature and reductions in available moisture are likely to result in inhospitable terrestrial habitat.

Methods

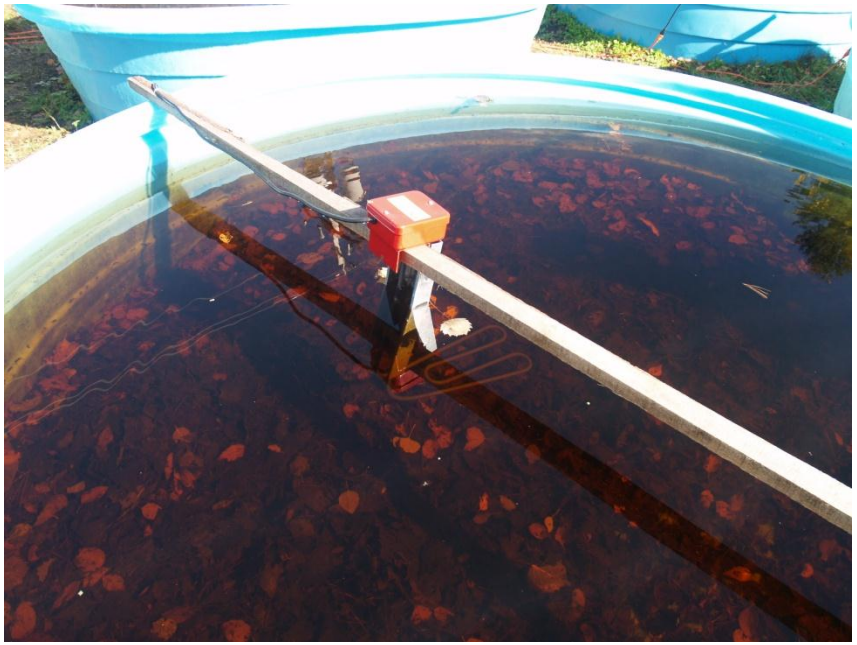
1. Laboratory studies
2. Mesocosms
3. Field studies
4. Spatially-explicit occurrence modeling

Laboratory studies

- Established 27 containers in the lab
- 3 dissolved oxygen levels (high, med, low)
- Aquarium heaters used to provide range of temperatures
- 7 tadpoles (Gosner stage 25) randomly assigned to each treatment
- Study ran from 21st August to 15th September 2011
- GLM's used for analyses

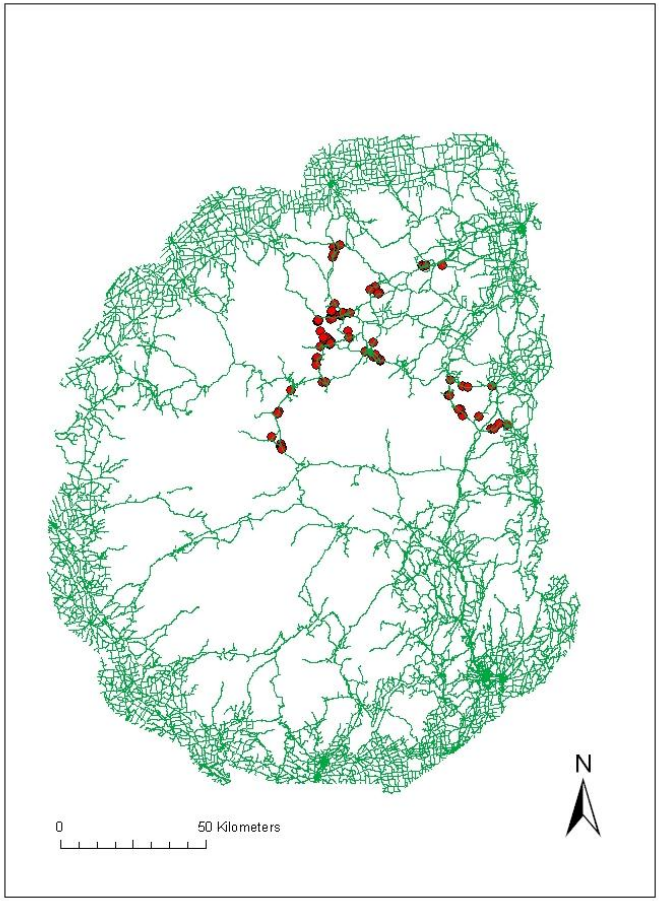
Mesocosms

- Cattle tank heaters used to create a range of temperatures



Field studies

- Study conducted from 28 June to 17 August 2011
- 73 palustrine and lacustrine wetlands chosen
- Elevation from 202 to 711 m
- Size of wetlands ranged from 0.03 to 22.7 ha



Results from laboratory studies

- Mean temperatures ranged from 19.5 to 25.9 °C
- DO ranged from 3.10 to 7.87 ppm
- Mean tadpole final length (mm) ranged from 31.9 to 47.2
- Mean tadpole final mass (g) 0.42g to 0.90g
- Survival ranged from 43% (3 out of 7) to 100%
- Almost all mortality occurred within the first week of tadpoles being placed in mesocosms
- Analyses indicate survival not driven by temperature ($P = 0.655$) or oxygen ($P = 0.392$)

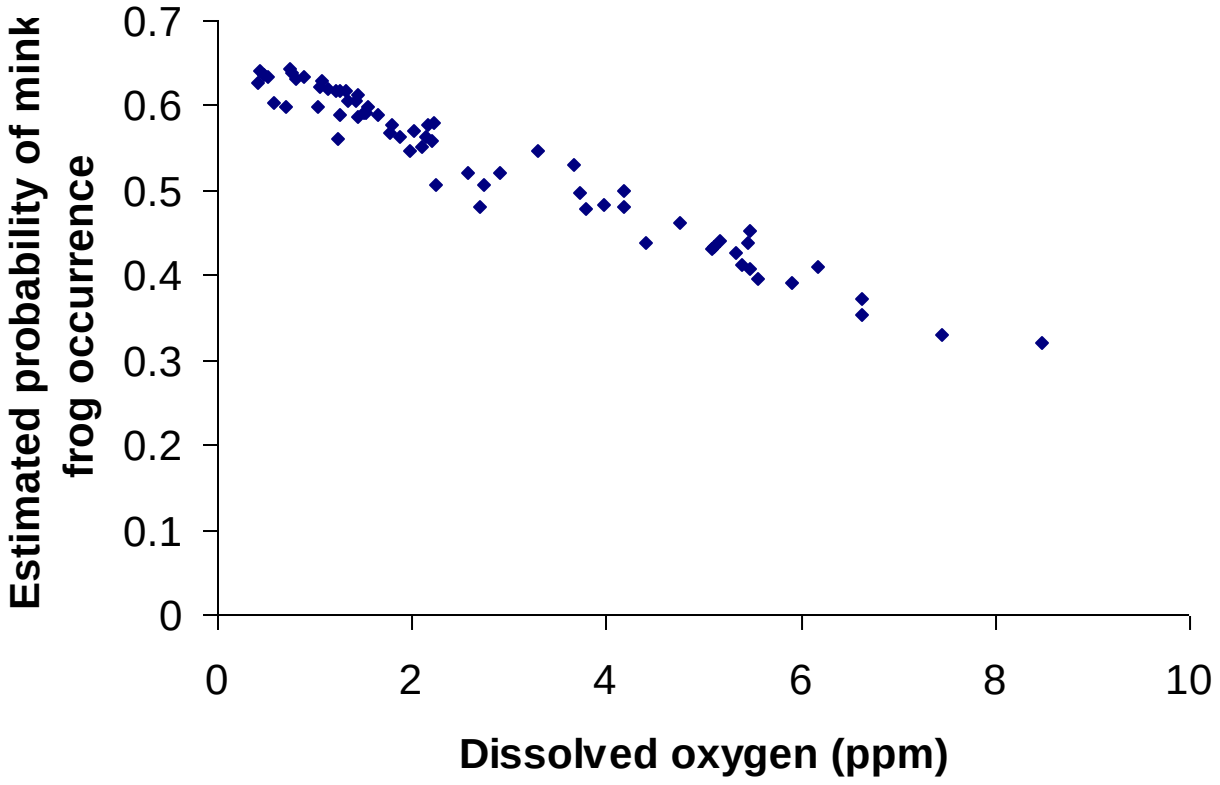
Drivers of larval growth

- Temperature, survival, and the interaction of the two drove both length and mass (P <0.05 for all factors and interactions)
- Higher temperatures lead to longer, heavier tadpoles
- Lower densities resulted in more rapid growth
- The largest tadpoles were at high temperatures and low densities
- Dissolved oxygen levels did not influence larval length and mass (P = 0.954 and 0.985 respectively)

Drivers of mink frog occurrence: Occurrence

- Best fitting models indistinguishable from null (null ΔAIC 0.67)
- Model with dissolved oxygen and temperature as covariates performed best
- As dissolved oxygen decreased and temperature increased, so did the probability of occurrence
- 95% CI for temperature includes 0, however

Drivers of mink frog occurrence: Occurrence



Outreach efforts

- Two peer-reviewed publications sent to relevant management agencies (including Maine Inland Fisheries and Wildlife and NYSDEC) and researchers
- Discussion with NYSDEC regarding conservation of the mink frog
- Public presentations across the Adirondacks and at academic institutions including University of Connecticut, Storrs.

Implications and applications in the Northern Forest region

- Our research has greatly increased the overall understanding of how climate change affects both the focal species and amphibians in general
- This understanding informs both the current distribution of amphibians in the region, and helps in predicting future distributions of amphibians under continued climate change
- We have also developed a suite of novel experimental techniques and field research suitable for asking questions regarding climate change
- We have established a network of ~80 wetlands in the region suitable for long-term monitoring efforts

Future directions

- Since completing this research we have continued our evaluation of indirect linkages between climate and amphibian populations including studies of competition and predation
- We have also expanded our research to look at interactions across trophic levels including food availability
- The next steps in our research are to assess climate effects on early spring breeding amphibians, allowing us to build a comprehensive picture of climate change effects on the full community of amphibians found in the NF

List of products

1. 80 wetlands suitable for long-term monitoring
2. Mentoring ~20 undergraduate students in research design and implementation
3. Two peer-reviewed publications published including 14 undergraduate co-authors
4. Three peer-reviewed publications in preparation, with two due for submission by Dec. 2012
5. Data integrated into a GIS allowing prediction of the effects of continued climate change for the focal species across the NF
6. Presentations and public workshops across northern NY and at academic venues across the US
7. Use of equipment purchased under the grant for an investigation of the effects of climate change on competition between native and non-native/invasive aquatic plants including a peer-reviewed publication and dissemination of results
8. Development of novel experimental techniques suitable for a wide variety of studies focusing on climate change