

# Co-occurrence patterns in northern and plains leopard frog species in Iowa

Emily Bierbaum and Dr. Stephen Dinsmore

## INTRODUCTION

Interspecific competition is an important mechanism shaping community dynamics. Two possible outcomes are competitive exclusion or co-existence. Such competition excludes individuals from vital resources, which may initiate risky movement to other habitats.

For amphibians, interspecific competition enhances risks of energy depletion, predation, and unfavorable environments in search of resources needed for survival and reproduction. When habitat fragmentation is present, even more tribulations occur for amphibians (Pough et al. 2016). Such habitat modification could result in an alteration of available resources, and isolated patches of habitable land. According to Koumaris and Fahrig (2016), altered adult habitats have a greater impact on anuran species abundance when compared to changed larval habitats. Since most anurans have biphasic life cycles, movements to and from water sources are essential for species survival (Semlitsch 2008). Amphibian movements, either migration or dispersal, and competition thus provide important knowledge for developing solutions in anuran management and conservation.

The interspecific interactions of the leopard frog species native to Iowa have not been thoroughly studied. Two leopard frog species ripe to be analyzed using a co-occurrence model are *Lithobates pipiens* (northern leopard frog) and *Lithobates blairi* (plains leopard frog). The two frogs are similar in appearance, with *L. blairi* having broken dorsolateral folds near the hind leg and a white spot on its tympanum, and *L. pipiens* having complete dorsolateral folds and lacking the white spot (LeClere 2013: 107). Moreover, *L. pipiens* appears to out-compete *L.*

*blairi* because the range of *L. pipiens* has increased while the range of *L. blairi* has decreased statewide over the past ten years (Unpublished DNR). Incorporating data into a two-species co-occurrence model is novel compared to other models, and the lack of research on the two anuran species makes it a valuable relationship to analyze. Furthermore, it would prove beneficial to generate a co-occurrence model of *L. pipiens* and *L. blairi* because co-occurrence models evaluate the interspecific interactions of two species. The organisms' presence in a given locality could result from one species' success in obtaining shared resources, which could lead to one species displacing the other (Gotelli et al. 2015).

The purpose of this research is to use data collected from the Multiple Species Inventory and Monitoring (MSIM) program of the Iowa DNR to determine if there is evidence of ongoing competitive exclusion in Iowa between these two frog species. I hypothesize the presence of *L. pipiens* competitively excludes *L. blairi* across a large sample of MSIM properties surveyed during a 10-year period because *L. pipiens* has a larger geographic range in Iowa. If supported, this outcome would suggest *L. pipiens* has displaced *L. blairi*. For instance, according to Adams et al. (2011) bullfrogs (*L. catesbeianus*) already out-compete and consume most native frog species, so it would prove to be advantageous to determine if *L. pipiens* possesses some of those harmful attributes that could cause a severe population decline in other frog species, including *L. blairi*.

## **METHODS**

### *Study area*

The sampling sites collected by MSIM technicians are wetlands on public properties throughout Iowa. The wetlands on each public property are selected at random by broad habitat

classification, and there can be >1 wetland per property. Sampling the sites at random permits inferences of the habitats surveyed to other habitats throughout the state (Kinkead 2006).

### *Frog surveys*

The data were collected as part of MSIM efforts in Iowa. The data include a 10-year period (2006 to 2015) during which anuran species, including *L. pipiens* and *L. blairi*, were sampled at wetlands. The number of *L. pipiens* and *L. blairi* was determined by visual encounter surveys (VES), where field technicians conducted standardized time limited surveys on a property and recorded the amphibian species encountered. Each VES lasted four hours per site. However, the survey time was adjusted if multiple technicians conducted the VES at the same time and at the same site. For example, one technician surveying for four hours was considered equivalent to two technicians surveying for two hours each (Kinkead 2006). The presence or absence was recorded for both *Lithobates* species for each property. Properties were surveyed  $\geq 3$  times per year during the spring (15 April to 15 June), summer (16 June to 15 August), and fall (16 August to 15 October) seasons; visits were occasionally skipped. The data were truncated to dates where *L. pipiens* and *L. blairi* species were most active: 15 May through 31 July of each year (LeClere 2013).

### *Analyses*

I used the two-species co-occurrence model in program MARK to assess if competitive exclusion occurred in these two species (Richmond et al. 2010). First, I summarized the frog survey data into an encounter history for each wetland, where a species was either detected (1) or not detected (0); missed surveys were coded as a (.). The model estimated five general parameters. The model estimated the probability that a wetland was occupied (Psi [ $\psi$ ]) by a species for each year of the study. The model further estimated two conditional parameters

associated with changes in occupancy of wetlands between years. These are the probability that an unoccupied wetland became occupied in the next year (Gamma [ $\gamma$ ], also known as the recolonization probability) and the probability that an occupied wetland became unoccupied in the next year (Epsilon [ $\epsilon$ ], also known as the extinction probability) (Figure 1). Next, the model estimated the probability of detecting a species, given that it is present, and did this in several combinations where one or both species were present (detection probability,  $p$  or  $r$ ). Lastly, the model calculated a Species Interaction Factor (SIF), which is the ratio of the probability of occupancy of both species *L. pipiens* and *L. blairi* divided by the product of their independent occupancy probabilities. The SIF is interpreted according to Richmond et al. (2010): a SIF <1 means the two species co-occur less frequently than expected if occupancy probabilities were independent, whereas a SIF >1 indicates that the two species co-occur more frequently than expected if occupancy probabilities were independent.

When modeling the co-occurrence of the two species of *Lithobates*, I evaluated various combinations of effects on the parameters described above. The effects of year and within-year patterns (linear and quadratic) were considered on each parameter. In addition, I included three environmental covariates (a daily measure of temperature, wind speed, and cloud cover) on the detection probability parameters ( $p$  and  $r$ ), where  $p$  is the probability of detection given the other species is absent and  $r$  is the probability of detection given the other species is present.

## RESULTS

The naïve site occupancy varied, because *L. pipiens* were more common than *L. blairi* other than in 2006 (Table 1). However, few sites were sampled in 2006, so the data were regarded as non-estimable. The probability of occupancy fluctuated by year and species (*L.*

*pipiens*: 0.52 – 0.88; *L. blairi*: 0.03 – 0.38). The importance of the probability of occupancy vs. the naïve site occupancy is that detection rate is factored into the occupancy probability. Consequently, the occupancy findings imply that the detection probability [ $p$ ] varied a lot for each species. Furthermore, they also indicated the detection probability for *L. blairi* was low, with a mean of 0.07. Overall, competitive exclusion was detected, but only in three of the ten years of study (Figure 2); in other words, *L. pipiens* excluded *L. blairi* in 2007, 2009, and 2011, when the SIF ratio was above 1.

## DISCUSSION

In the absence of direct experimentation, co-occurrence modeling of survey data can provide important insights into community dynamics. Overall, there was mixed evidence for competitive exclusion in this study, because *L. pipiens* appeared to competitively exclude *L. blairi* in only three of the ten years. In order to attain more definitive data, we could include additional covariates, such as wetland size or time of day. Another option is to examine *L. pipiens* and *L. blairi* data from neighboring states to observe how their distribution compares to Iowa's. The decreased range of *L. blairi* may be a result of *L. pipens* displacing it by controlling their shared resource, or it could be a factor of habitat loss and not solely due to the interspecific competition between the species (Blomquist and Hunter 2009). More research could be implemented to determine if habitat alteration and pollution has a stronger effect on the decline of *L. blairi* rather than the presence of *L. pipiens* alone.

Not only do interspecific interactions play an important role in the survival of the two *Lithobates* species, but so does the environment they inhabit. As an example, *L. blairi* prefers prairie potholes that change water depth from year to year because those hydrology changes

make the wetland unlikely for large predatory fish to occupy (Grant et al. 2015). Additionally the same study used habitat and landscape covariates to observe which factors affected the distribution of the two *Lithobates* species the most. Grant et al. (2015) concluded there were a greater probability of *L. blairi* presence in smaller wetlands, and a higher probability of *L. pipiens* presence in areas with abundant emergent vegetation. The emergent vegetation traps moisture in the detritus and soil, and because *L. pipiens* is not as desiccation tolerant as *L. blairi*, that vegetation provides the wet microhabitat *L. pipiens* requires. However, when macrophytes are uprooted or destroyed from flooding, *L. pipiens* may become more vulnerable to displacement. Increased precipitation or increased surface water flow may destroy vegetation and significantly change the spatial distribution of *L. pipiens*.

In addition, studies have presented evidence that *L. pipiens* employs remarkable antipredator mechanisms. According to Bennett and Murray (2015), *L. pipiens* tadpoles receive cues from nearby dragonfly larvae to grow larger tails. The greater the length of the tadpole tail, the better the tadpole is at evading predation. Those antipredator mechanisms give *L. pipiens* an advantage over *L. blairi*. Moreover, other studies found that *L. pipiens* is efficient at avoiding predation or parasitism by invasive species such as introduced fish, amphibian species, or parasite pin worms (Rhoden and Bolek 2011). Unfortunately, there is a lack of research and knowledge on *L. blairi*, especially compared to *L. pipiens*. It is not well-known if *L. blairi* has any of the same antipredator strategies that *L. pipiens* possesses. Whenever the two species are mentioned in the same scientific paper, there is usually a comment mentioning the lack of knowledge on *L. blairi*. Papoulias et al. (2013) discussed the lack of information on the anatomical functions of *L. blairi*. More specifically, the developmental biology and sexual differentiation of *L. blairi* is not well known, yet the same information is identified in *L. pipiens*.

Because of the shortage of definitive research on *L. blairi*, further study of this species could help provide knowledge in ways to develop conservation plans for the species or manage its populations.

## Literature Cited

- Adams, M.J., C.A. Pearl, S. Galvan, and B. McCreary. 2011. Non-native species impacts on pond occupancy by an anuran. *Journal of Wildlife Management* 75:30-35.
- Bennett, A. M., and D. L. Murray. 2015. Carryover effects of phenotypic plasticity: embryonic environment and larval response to predation risk in Wood Frogs (*Lithobates sylvaticus*) and Northern Leopard Frogs (*Lithobates pipiens*). *Canadian Journal of Zoology* 93:867-877.
- Blomquist, S.M., and M.L. Hunter. 2009. A multi-scale assessment of habitat selection and movement patterns by northern leopard frogs (*Lithobates [Rana] pipiens*) in a managed forest. *Herpetological Conservation and Biology* 4:142-160.
- Gotelli, N.J., E.M. Hart, and A.M. Ellison. 2015. Co-occurrence analysis. EcosimR.
- Grant, T.J., D.L. Otis, and R.R. Koford. 2015. Short-term anuran community dynamics in the Missouri River floodplain following an historic flood. *Ecosphere* 6:1-16.
- Kinkead, K. 2006. Amphibian and Reptile Monitoring Protocol. Pages 47-55 in Iowa multiple species inventory and monitoring program technical manual. Des Moines, IA: Iowa Department of Natural Resources.
- Koumaris, A., and L. Fahrig. 2016. Different anuran species show different relationships to agricultural intensity. *Wetlands* 36:731-744.
- LeClere, J.B. 2013. A field guide to the amphibians and reptiles of Iowa. ECO Herpetological and Distribution, Rodeo, NM.
- Papoulias, D.M., M.S. Schwarz, and L. Mena. 2013. Gonadal abnormalities in frogs (*Lithobates spp.*) collected from managed wetlands in an agricultural region of Nebraska, USA. *Environmental Pollution* 172:1-8.

- Pough, H.F., R.M. Andrews, M.L. Crump, A.H. Savitzky, K.D. Wells, and M.C. Brandley. 2016. Herpetology. Sinauer Associates, Inc., Sunderland, MA.
- Rhoden, H.R., and M.G. Bolek. 2011. Distribution and reproductive strategies of *Gyrinicola batrachiensis* (Oxyuroidea: Pharyngodonidae) in larvae of eight species of amphibians from Nebraska. *Journal of Parasitology* 97:629-635.
- Richmond, O.M.W., J.E. Hines, and S.R. Beissinger. 2010. Two-species occupancy models: a new parameterization applied to co-occurrence of secretive rails. *Ecological Applications* 20:2036-2046.
- Semlitsch, R.D. 2008. Differentiating migration and dispersal process for pond-breeding amphibians. *Journal of Wildlife Management* 72:260-267.

Figure 1. Schematic of a co-occurrence model showing the parameters Psi (probability of occupancy), Gamma (probability of recolonization), and Epsilon (probability of extinction).

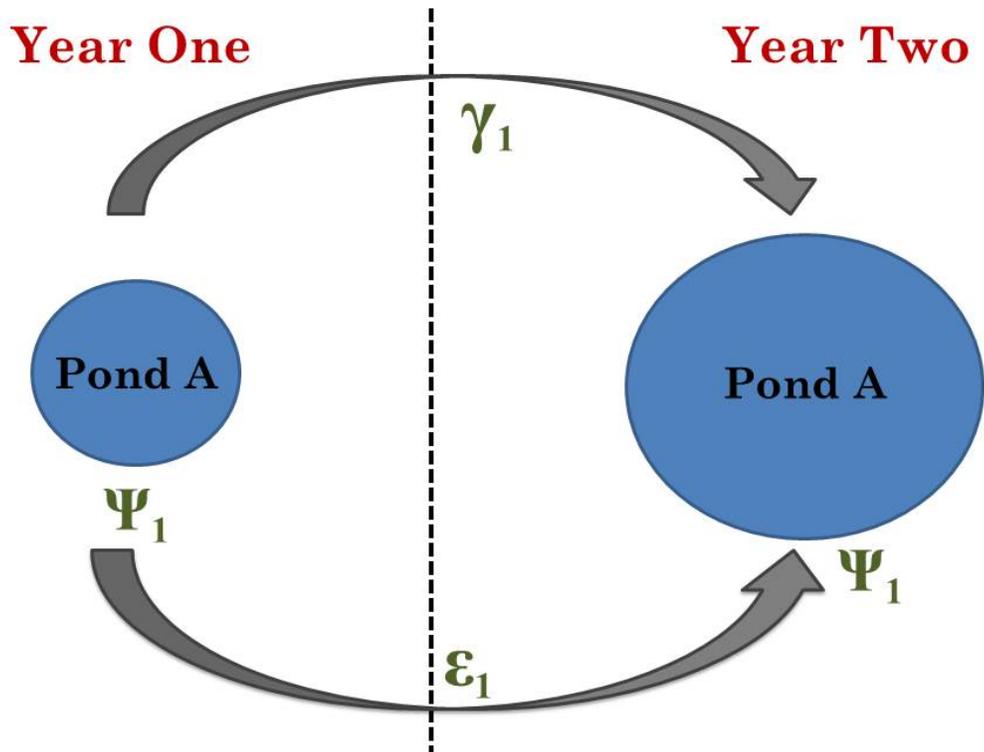


Table 1. Proportion of total leopard frogs (*Lithobates*) by species and the species interaction factor across all MSIM sites in Iowa, 2006-2015.

<b>Years</b>	<b><i>L. pipiens</i></b>	<b><i>L. blairi</i></b>	<b>SIF</b>
2006	50%	50%	NE
2007	61%	39%	1.16
2008	92%	8%	0.21
2009	86%	14%	1.09
2010	100%	0%	0.57
2011	96%	4%	1.02
2012	100%	0%	0.81
2013	88%	12%	0.93
2014	100%	0%	0.88
2015	97%	3%	0.90

Figure 2. SIF ratio predicts the likelihood the two species of leopard frogs (*Lithobates pipiens* and *L. blairi*) would co-occur in Iowa wetlands compared to if their occupancy probabilities were independent. If the SIF>1, then competitive exclusion presumably occurred.

