Cryptic Evolution in the Neural Circuits of *Pseudacris feriarum*

Colin Lewis and Dr. Alan Lemmon

FSU | FLORIDA STATE UNIVERSITY

FSU UNDERGRADUATE RESEARCH OPPORTUNITY PROGRAM
CENTER FOR UNDERGRADUATE RESEARCH & ACADEMIC ENGAGEMENT

Abstract:

Little is known about the relationship between the evolution of the brain and behavior. Looking specifically at mating behavior, an examination of *Pseudacris* feriarum, a species of chorus frog, can shine a light on this relationship. Previous research has shown that relatively recently in its evolutionary history, populations of *P. feriarum* have become allopatrically separated from one another, with some populations overlapping with populations of other members of the genus *Pseudacris*. The resulting interaction has led to the evolution of mating behaviors to avoid hybridization. Using a particle swarm optimization technique, we identify neural circuit models that fit previously collected female preference data from female *P. feriarum*. One compelling question is: can two or more neural circuits with different configurations produce the same mating behavior? Examining allopatric populations in North Carolina and Alabama with this method allows us to see if there is any evidence of cryptic evolution (The process by which neural evolution could occur with no observable change in behavior.)

Introduction:

- Overlapping populations of members of the genus *Pseudacris* exist in multiple areas in the United States.
- Previous research has shown that these overlapping (sympatric) populations have had at least one species' call, and both species' call preferences differentiate from that of a population of the same species that is allopatrically separated.
- This divergence occurred to reduce the sympatric populations' propensity to hybridize (Lemmon 2009).
- To get a deeper understanding of the evolutionary differences between allopatric populations of the same species we investigated cryptic evolution in *P. feriarum.*
- Cryptic evolution is the process by which evolution can happen in the neural circuitry of a species without an observed behavioral difference between populations
- Populations of *P. feriarum* in Alabama and North Carolina are allopatrically separated and have similar call responses
- We aimed to see if these populations utilized different neural components to achieve this similar behavior.
- Response to acoustic stimulus in long interval, relay, and interval counting neurons have been found
- Acoustic stimulus is found to have an excitatory effect on long interval neurons (LIN) and interval counting neurons (ICN)
- LIN is seen to have an inhibitory effect on the ICN
- The percent activation of LIN and ICN has been found to add up to 100%
- The balance of these percentages can estimate what a females binary choice response will be

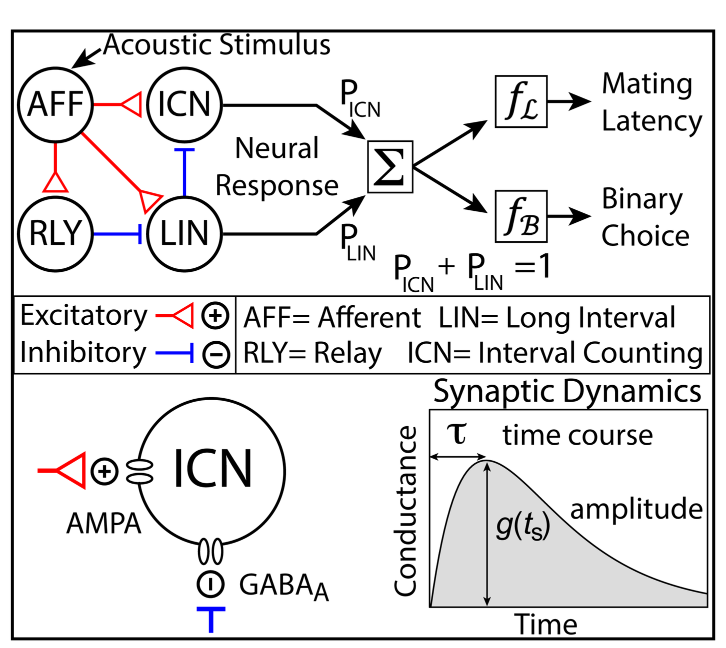


Figure 1. Depicts the effect that acoustic stimulus has on various neuron types that lead to physical response. Also shows synaptic dynamics along axes of conductance and time as well as the inhibitory effect of LIN on ICN and the excitatory effect of acoustic stimulus on ICN.

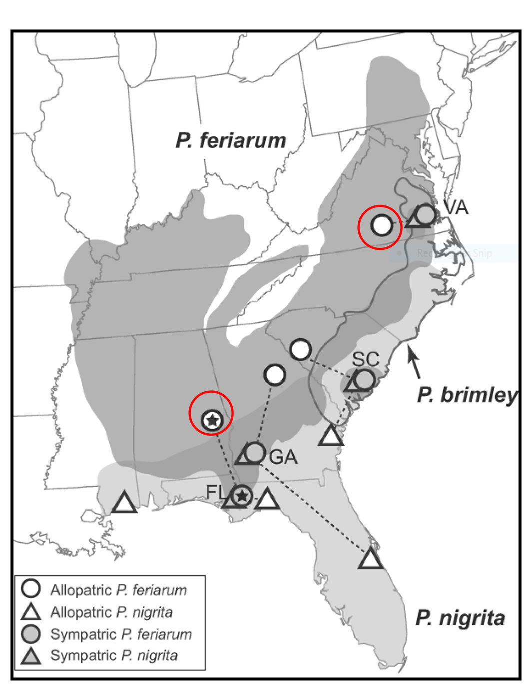


Figure 2. Depicts populations where calls and responses were collected from. Populations of interest circled. Derived from Figure 1. from Lemmon 2009.

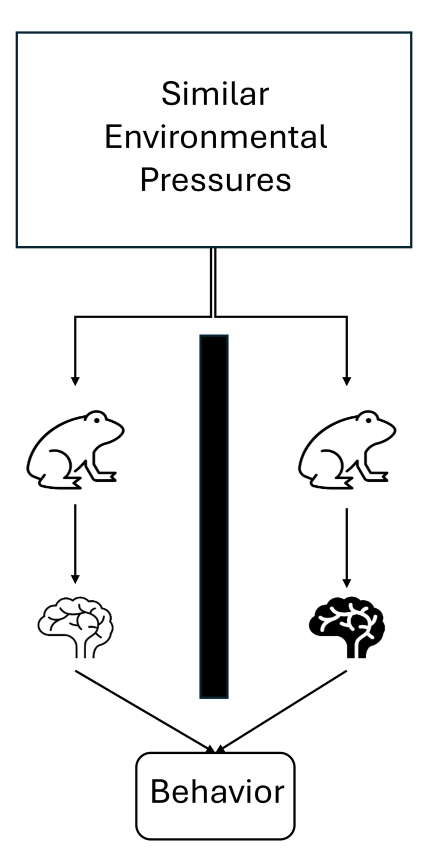


Figure 3. Basic model of cryptic evolution. Depicts similar environmental pressures acting on separated populations of the same species resulting in different neural circuitry still leading to the same behavior

Methods:

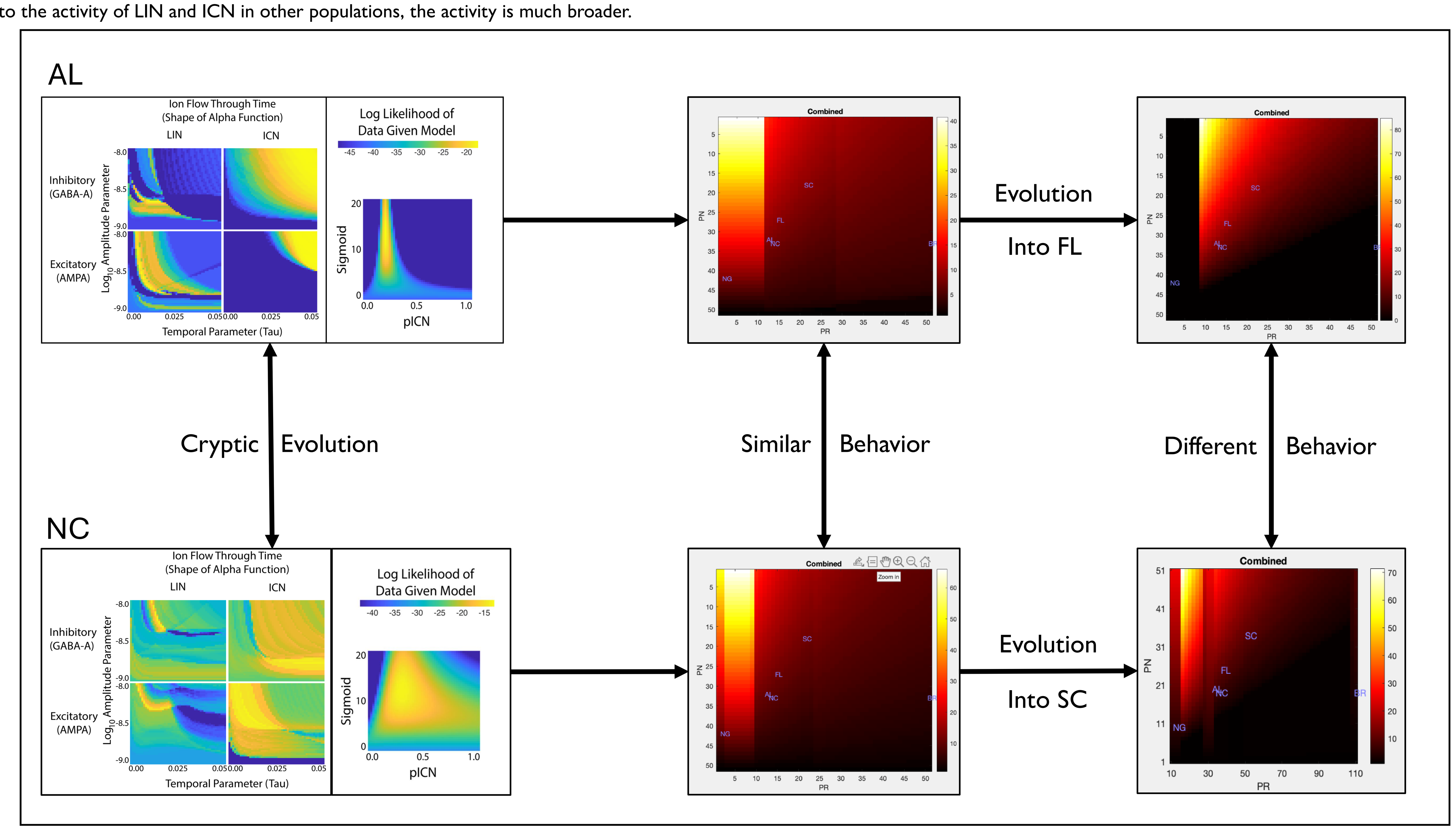
- Call response data for the female *P. feriarum* from the Alabama (AL) and North Carolina (NC) populations have been found through previous studies through binary choice testing
- Additionally, response to acoustic stimulus in long interval, relay, and interval counting neurons has been found.
- Using the neural circuit model previously developed (Naud et. al 2015) we modeled the ion flow through time of inhibitory GABA-A and excitatory AMPA for LIN and ICN of both populations
- We then compared those predicted neural activities to the observed binary choice preference date through the computation of a set of likelihood scores for each population.
- The particle swarm optimization method was used (Li 2010) to find neural circuits with LIN and ICN activation combinations that could feasibly produce the preferences observed.
- Movement was not directed toward a global solution as the goal was to find local peaks as cryptic evolution would lead towards those instead of the global maximum.
- We simulated these parameters in 3D space allowing us to get a greater understanding of the likelihood manifolds.
- From there we summarized global peaks and identify the manifolds where preference matches the neural circuitries.

Discussion:

These results suggest that cryptic evolution has occurred between the Alabama and North Carolina populations. This can be seen in how the results of their ion flow through time functions result in significantly different areas of levels of pICN while still resulting in similar behavior. Implications for what this means in evolutionary terms can be found in how the populations derived from AL and NC, FL and SC respectively, adapt to the presence of another chorus frog species with which hybridization is maladaptive. These populations exhibit different call response behavior from one another suggesting that the cryptic evolution of the neural circuits could have had an effect in how they diverged.

Results:

- Multiple local peaks were found through the particle swarm optimization.
- Different levels of activation of LIN and ICN between NC and AL resulting in similar combined outputs
- Combined outputs show that response to calls from all populations studied would be expected in varying amounts of likelihood.
- Compared to the activity of LIN and ICN in other populations, the activity is much broader.



Model 1. Depicts different results of ion flow through time of inhibitory GABA-A and excitatory AMPA for LIN and ICN between AL and NC populations, leading to no outward difference in call response behavior between the populations. Also shows how their evolutionarily derived populations that live in sympatry with *P. Nigrita* have evolved different behaviors to avoid *P. Nigrita* calls.

Resources:

Lemmon, Emily Moriarty. "Diversification of Conspecific Signals in Sympatry: Geographic Overlap Drives Multidimensional Reproductive Character Displacement in Frogs." Evolution 63, no. 5 (2009): 1155–70. http://www.jstor.org/stable/25483667.

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Naud R, Houtman D, Rose GJ, Longtin A. Counting on dis-inhibition: a circuit motif for interval counting and selectivity in the anuran auditory system. J Neurophysiol. 2015 Nov;114(5):2804-15. doi: 10.1152/jn.00138.2015. Epub 2015 Sep 2. PMID: 26334004; PMCID: PMC4737424.