Lizard Mating Games

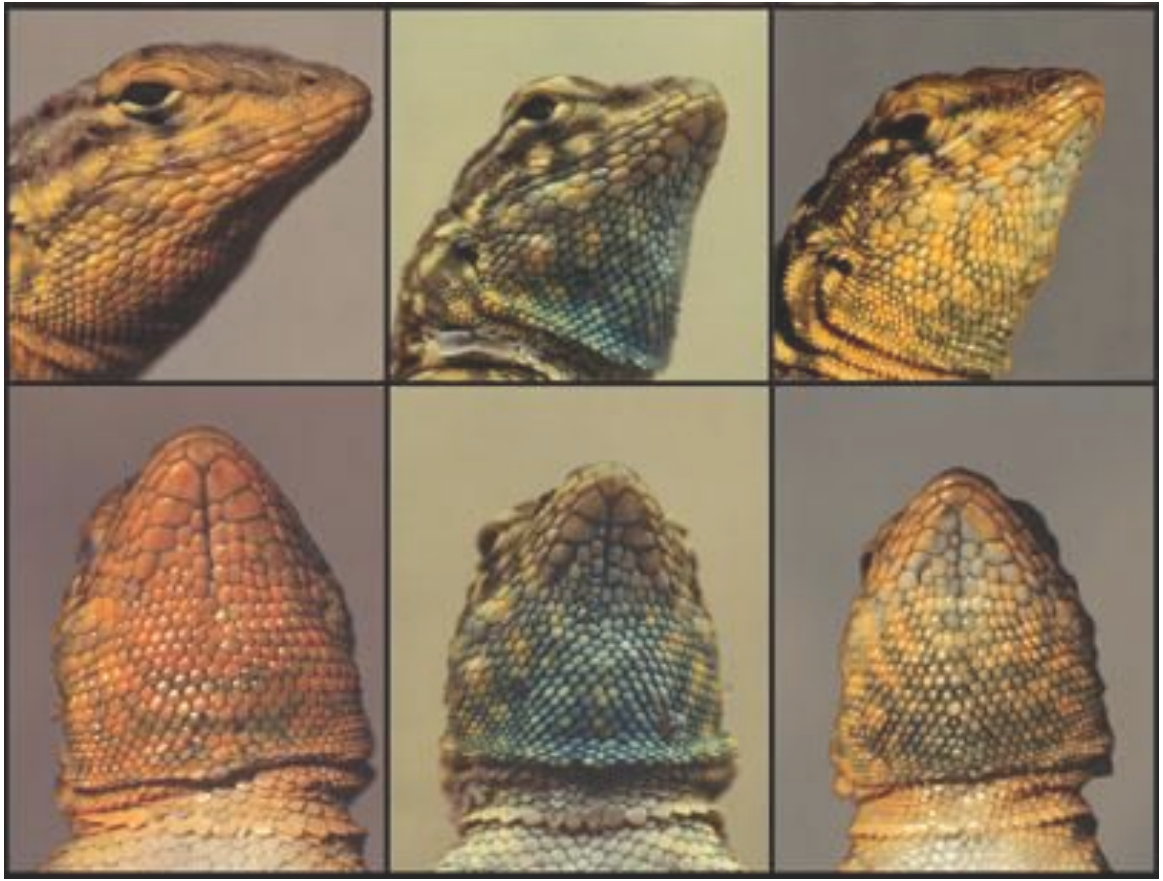
with Prof. Barry Sinervo

CMPM 290A Fall '18, Jasmine Otto

Game theory

Male strategy in the side-blotched lizard

- heritably determined by three possible alleles
- that also correlate with throat color
  - **o**range
  - **b**lue
  - **y**ellow



territorial
oo, bo, yo

mate guarding
bb

sneaker
by, yy

Game theory

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Each strategy loses to the next strategy

o > b > y > o ...

yielding population **cycles**

(as in Rock Paper Scissors)

around the ‘coexistence equilibrium’

as determined by a ‘payoff matrix’, e.g.

	...o	...b	...y
o vs …	0	.25	.02
b vs…	.14	.06	.19
y vs...	.17	.17	0

Game theory

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Each strategy loses to the next strategy
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yielding population **cycles**
(as in Rock Paper Scissors)
around the ‘coexistence equilibrium’

as determined by a ‘payoff matrix’.

We have *payoffs* for each strategy [oo, bb, yy].
We assert that allele frequency depends only on these homozygotes

(i.e. heterozygote advantage isn’t maintaining diversity)

So we follow the population of *each allele*:

territorial	*mate guarding*	*sneaker*
o	*b*	*y*

Data

Dominant strategy

Given the **fitted model**, our males receive e.g.

(at 1.1 hours of restricted activity per day)

$$\begin{bmatrix} 0 & .05 & .003 \\ .1 & .01 & .03 \\ .05 & .03 & 0 \end{bmatrix} * \begin{bmatrix} \vdots \end{bmatrix}$$

‘expected offspring’ through competition,
given the allele frequency vector of this year.

This is the *growth rate* of each morph,
which yields the allele frequency vector of next year.

Calculation

Isoclines

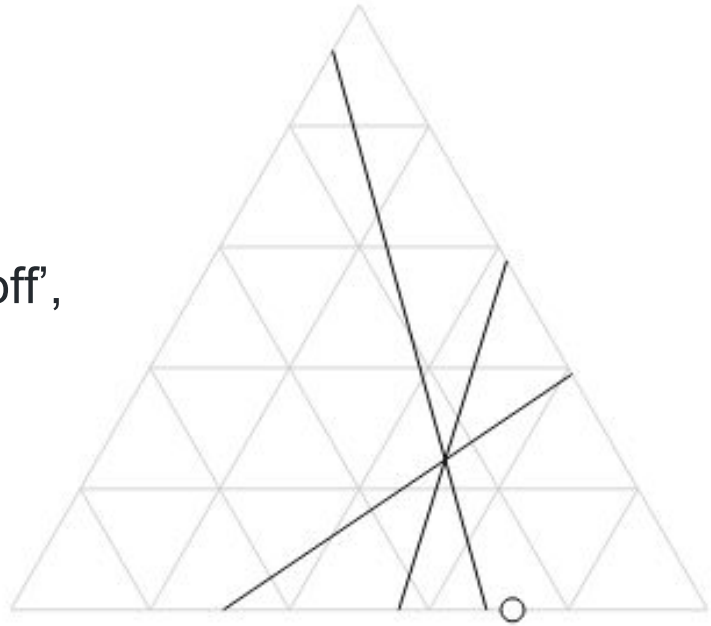
We solve for the three lines of ‘equal payoff’, such that e.g.

frequency [o,b,y] □ payoff [*, *, .]

(i.e. *orange, blue* are tied.)

If the three lines intersect at a valid strategy vector [*,*,*],

that *mixed strategy* will replicate itself perfectly: it is an **equilibrium**.



▸ Array(3) ["0.087", "0.052", "0.081"]

Calculation

Isoclines

We solve for the three lines of ‘equal payoff’,
at whose intersection,
frequency [o,b,y] □ payoff [*, *, *]

Depending on the parameterization of our payoff matrix
(by hours of restriction & population density)
we may have a coexistence equilibrium [*o**, *b**, *y**].

If this equilibrium is **stable**,
any point in frequency space will *spiral in* toward it.

Otherwise we will *spiral out* toward the extinction of some morphs.

Task

What do payoff matrices look like?

- Barycentric coordinates are standard in game theory.

- Isoclines in barycentric coordinates are nontrivial to read.
- How do we color each grid cell with this information?

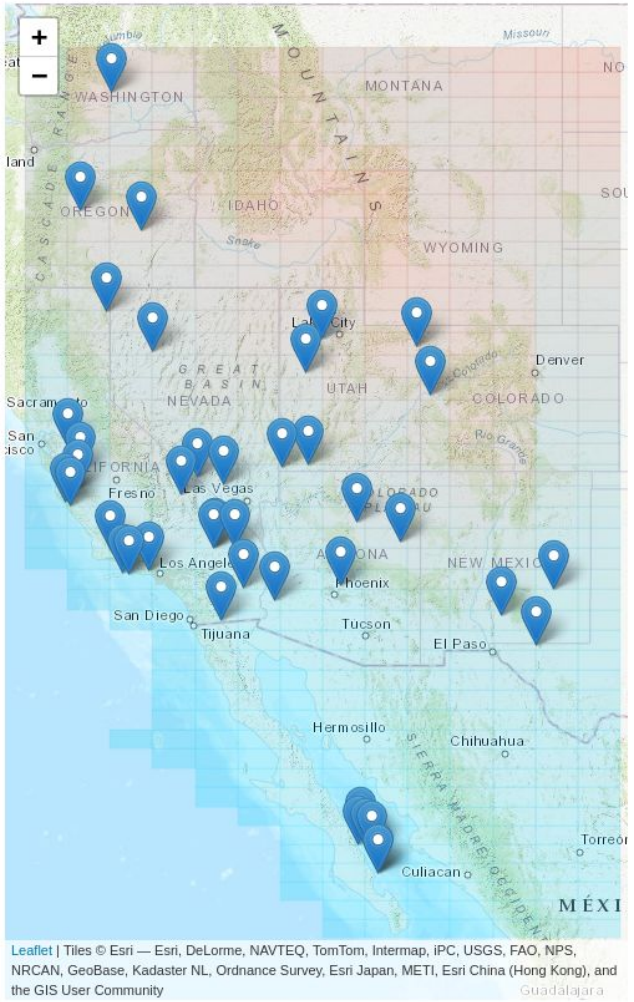
Data

Spatial variation

- Determines hours of restriction for lizards here, given their basal temperature.
- Determines whether a coexistence equilibrium is stable.

The male competition payoff matrix is adjusted by their hours of restriction.

This is a **nonlinear function** of the difference between the lizards' basal temperature and the site temperature (neglecting microclimates).



▸ Object {time: 0, pop: 10}

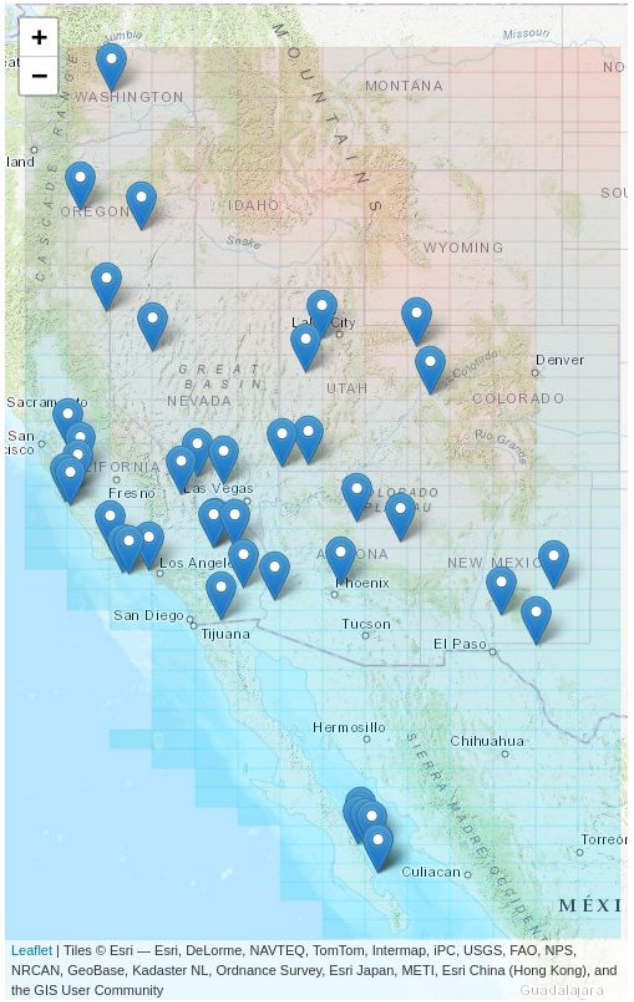
Data

Spatial variation

- Determines hours of restriction for lizards here, given their basal temperature.
- Determines whether a coexistence equilibrium is stable.

Site temperatures are increasing due to climate change, potentially destabilizing coexistence equilibria.

Which ones? We need to plot the payoff matrix (nine dimensions) for every location (thousands of grid cells) to see.



▸ Object {time: 0, pop: 10}

Task

Heatmap the 'elevator to extinction'.

- Climate patterns force the observed phenotypes to cycle (around the coexistence equilibrium).
- Higher temperatures can cause the coexistence equilibrium to become unstable.
- Simulated climate data for the western US lets us observe climate change before it acts.

Analysis Tasks

- What's my equilibrium, for this basal temperature and density, at this site in a given year?
  - What trajectories are possible, given these isoclines?
  - Which morph is dominant? (Which morph is prevalent?)
- What do our predictions of rising, more variable temperatures do to this complex system?
  - How does climate cycling drive the RPS cycle?
  - When will climate forcing outrun the selection differential on basal temperature, and drive the population extinct?

Potential Audience

Side-blotched lizards are a model species, and the specialty of Prof. Sinervo's lab. But - in theory, the ecology is already worked out!

- Spatialization of game theory is used in population modelling more generally, e.g. in urban planning.
- Intuition for dynamic equilibria is a topic of systems thinking, e.g. in basic biology, and management theory.
- d3 and leaflet are established viz tools, but there isn't a ton of open-source code that uses both, especially that is up-to-date.