Following Strategies Reduces Accidents, but Makes Outcomes Worse

Evidence from Simulated Treefrog Mating Scenarios

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Introduction

- Mate selection is an important problem in biology because species that sexually mate need to find a good partner
- Females typically choose males based on the attractiveness of their displays (e.g., calls)
- Mate selection strategies used by females, however, are not always clear
- Two general strategies have been hypothesized to explain the female choices in many social animals:
  - *Best-of-closest-n: f*emales choose the male with highest attractiveness within the *n* closest males
  - *Minimum-threshold:* Females select the closest male with an attractiveness higher than a *minimum quality threshold*

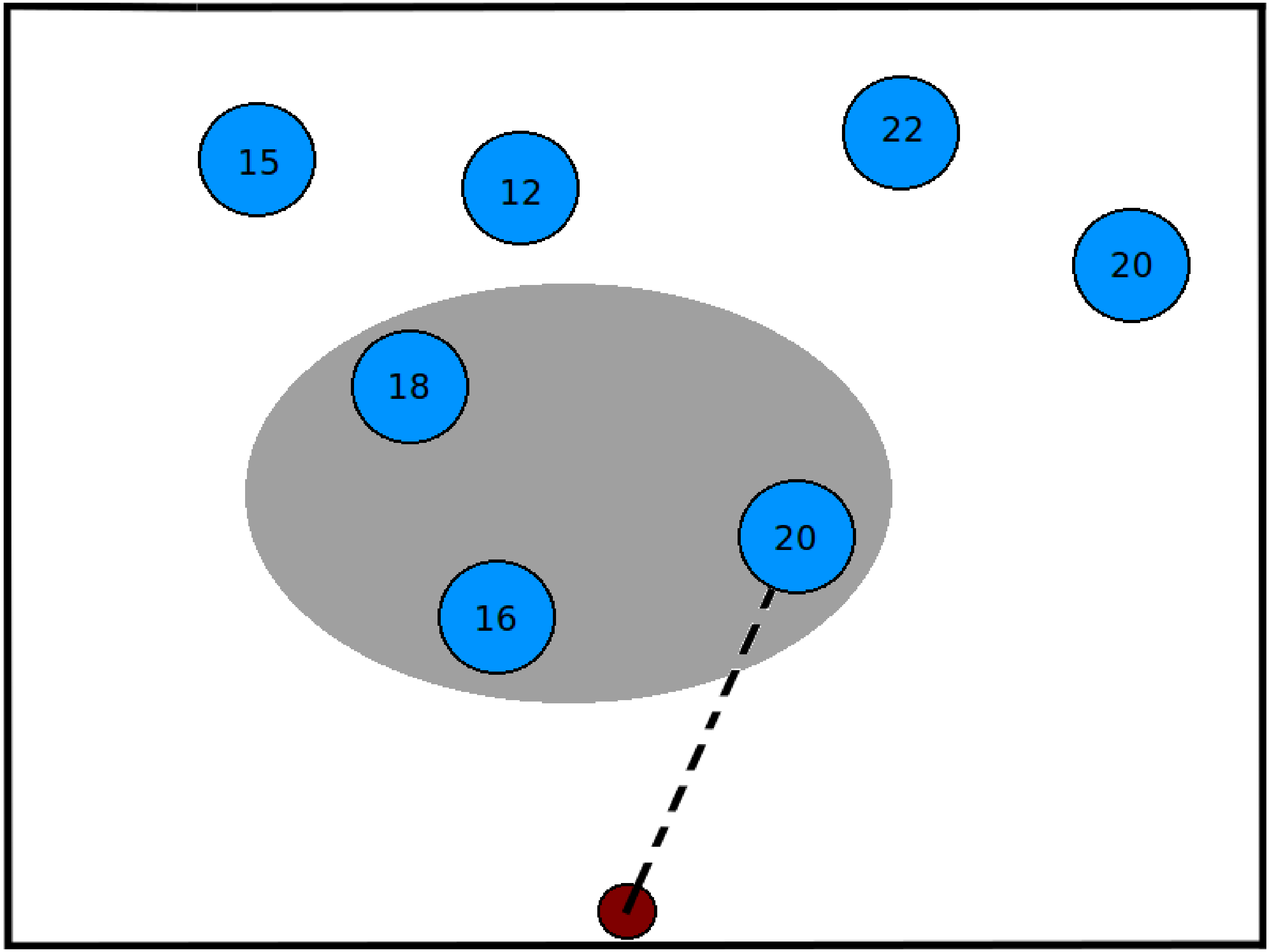
The mate choice problem in treefrogs

Male treefrogs move at night into swamps establishing “calling sites” where they call to attract females

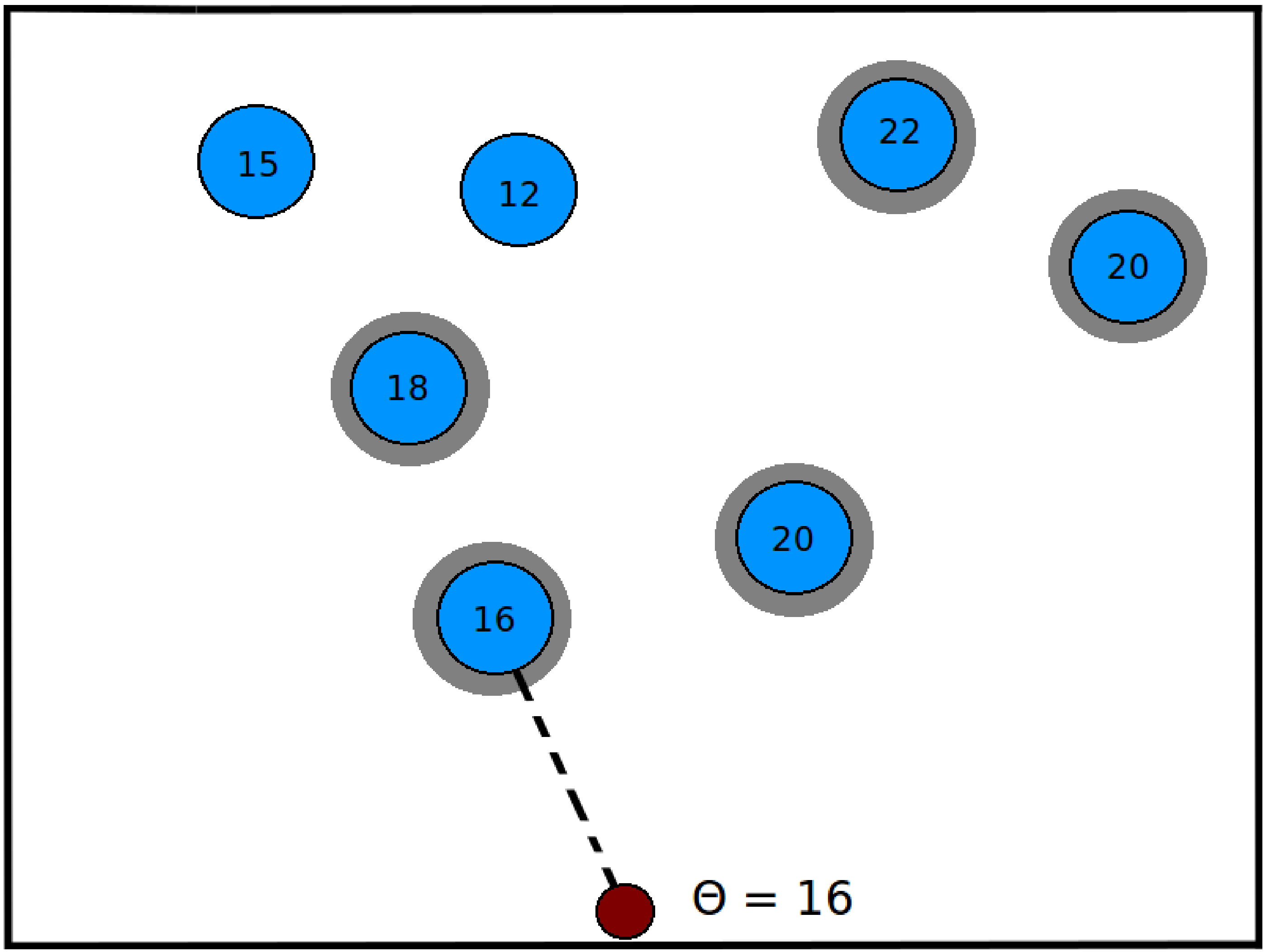
The attractiveness of a male call is determined in part by its “pulse number”.

Females pick males based on the male call characteristics and move towards their chosen male...

Example: the best-of-3 strategy



Example:
the minimum-threshold strategy



Some important differences between the two strategies

- If there are more males than females in the swamp, females playing the best-of-n strategy will always mate.
- If there are fewer males with pulse number above threshold than females, some females will not get to mate, and as a result, they leave the swamp.
- Best-of-1 never mate by accident because it always goes to the closest male.
- Minimum-threshold never mate by accident with a male with pulses per call higher than theta.

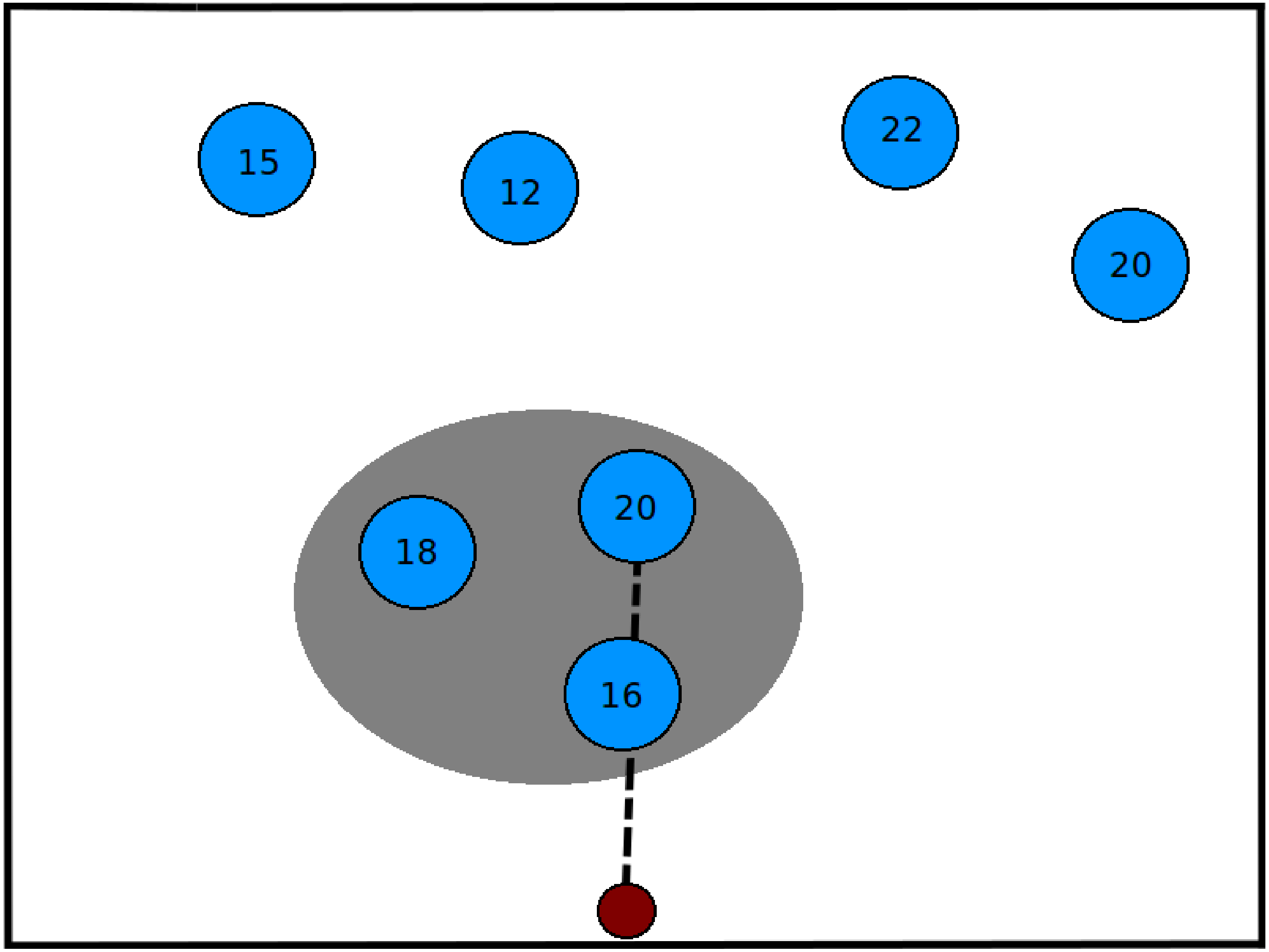
Mate choice as an optimization problem

- The mating problem can be viewed as an **optimization problem** in a partially observable competitive multi-agent environment.
- Given *n* males and *m* females distributed in the environment where the males' locations and call qualities are observable (due to their advertisement calls), but locations of any female are unobservable, find a mate choice policy for females (based on the perceivable call qualities only) to select a male mate such that the average male call qualities of the mated males is maximized.
- Other optimization measures could be used (e.g., find the policy that will lead to the shortest path to male mates or mating time).

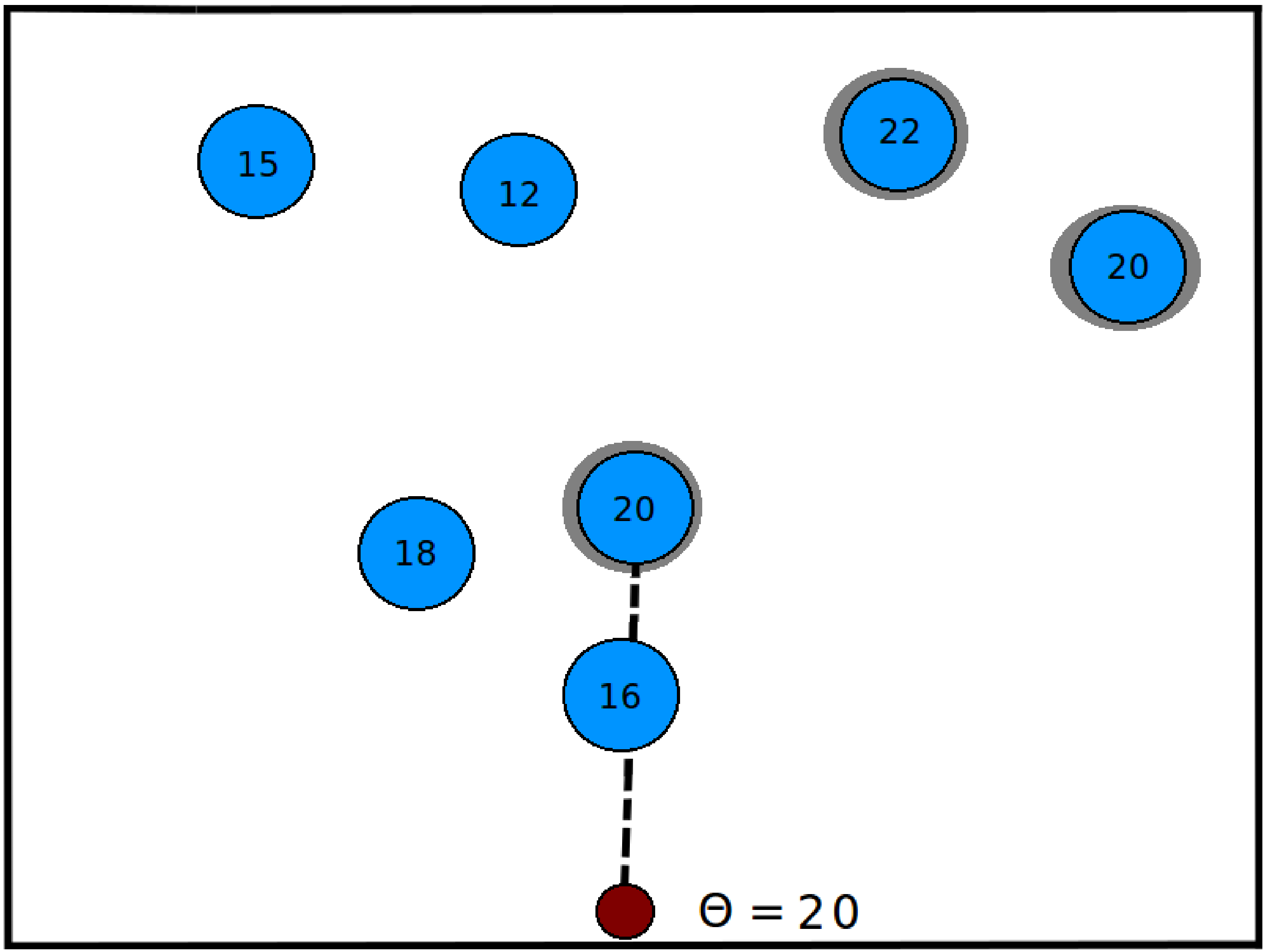
Accidental Mating

- Of particular interest is the extent to which **females mate by accident**, i.e., the *frequency mating* with an unintended male (that was not chosen by the female strategy) and the *average fitness of the accidentally mated males* compared to the frequency of non-accidental matings and the average fitness for the chosen and mated males
- These trade-offs are important for two reasons:
  - Accidental matings could have a negative if not detrimental consequences for females' offspring.
  - Lower quality mates, even though they might have negative consequences in the short term, might be able to preserve the variety in the gene pool in the long term, and thus be positive for the species.

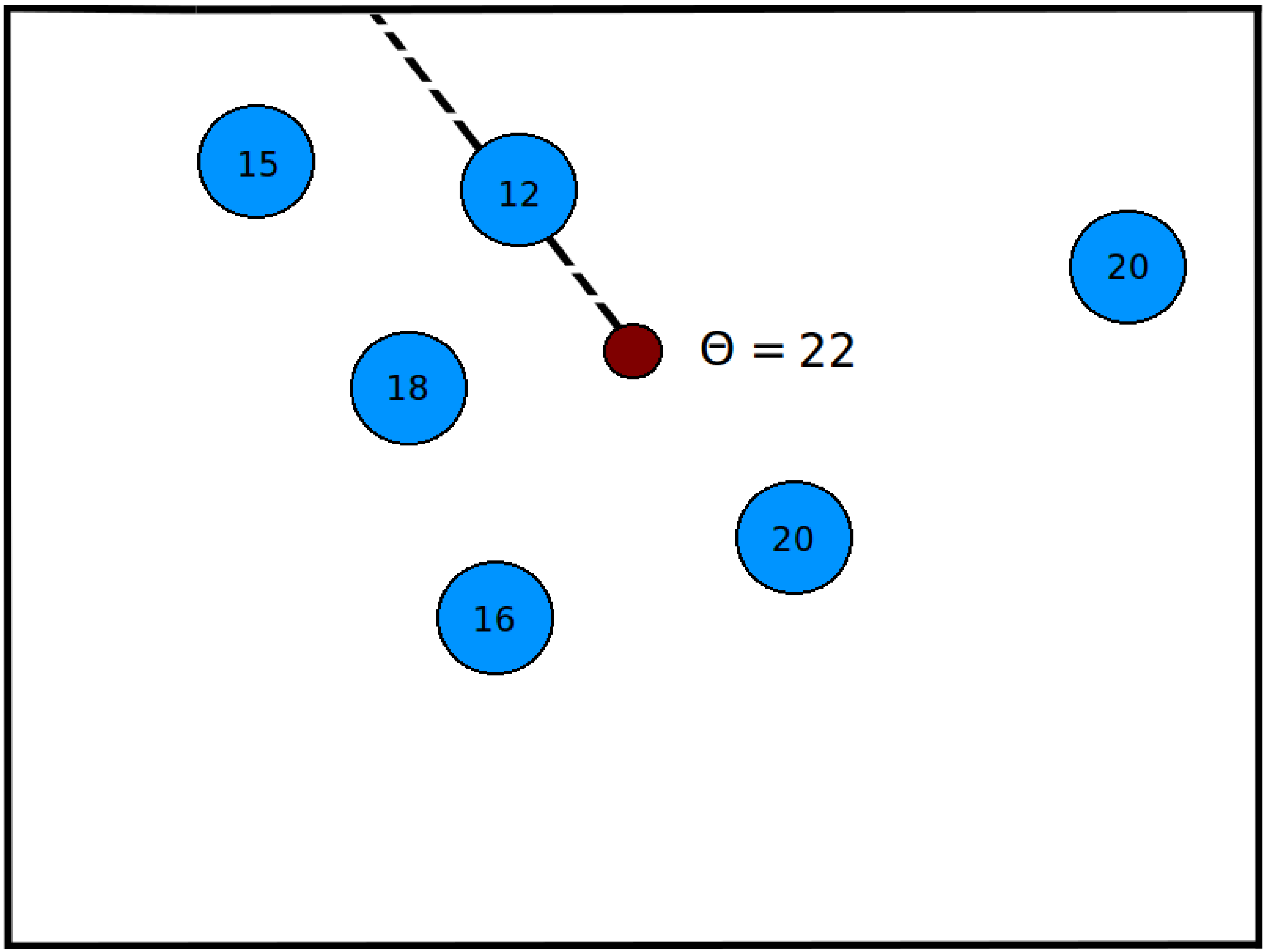
Accidental mating on the best-of-3 strategy



Accidental mating on the minimum-threshold strategy



Accidental mating on the minimum-threshold strategy



How can we investigate accidental matings?

- The accidental mating problem has both individual as well as environmental (including social) parameters
- Individual parameters include male call features, female mating range, mate choice strategy, etc.
- Environmental parameters include the number and distribution of agents (and thus the distances among them)
- Given the number of parameters and the complex interplay among them, analytic solutions to the accidental mating problem are not feasible (if not impossible)
- Hence, we use simulations of a **spatially extended agent-based model** to explore the trade-offs among the various individual and environmental parameter for pre-defined ranges

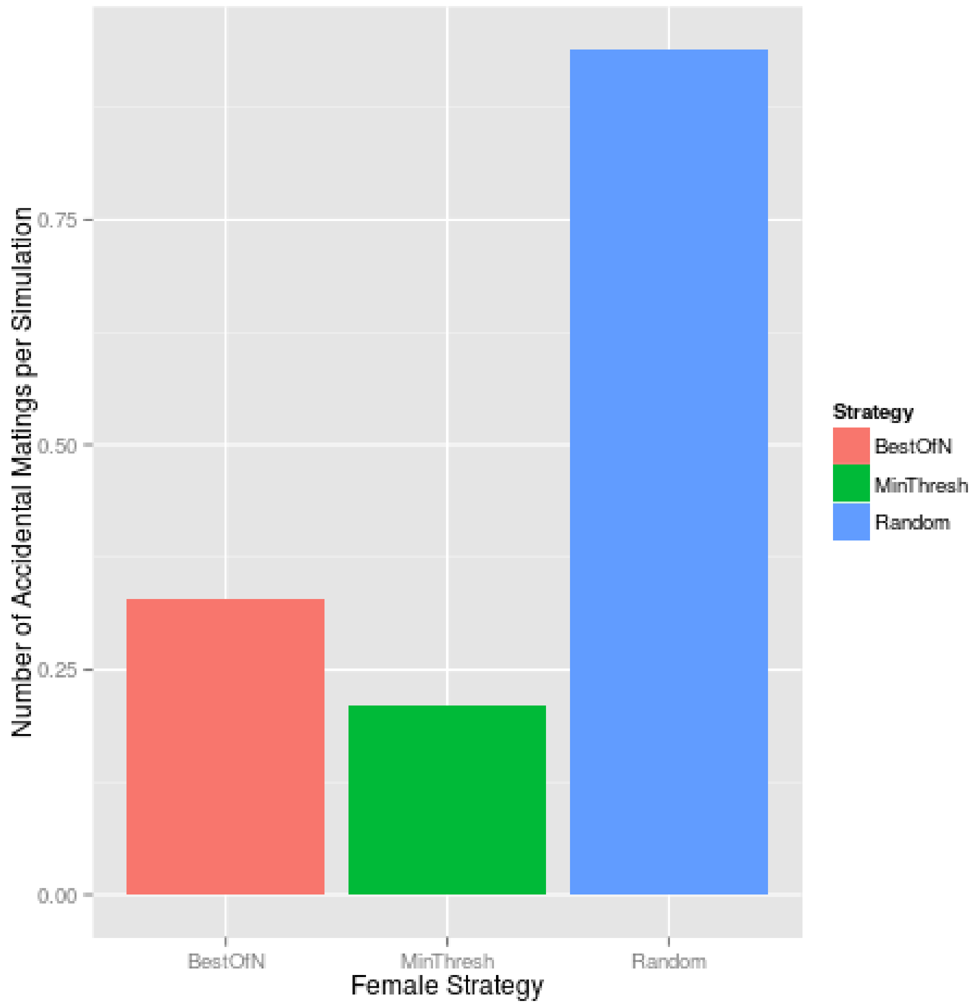
Example of simulation run

Parameters of the agent-based model

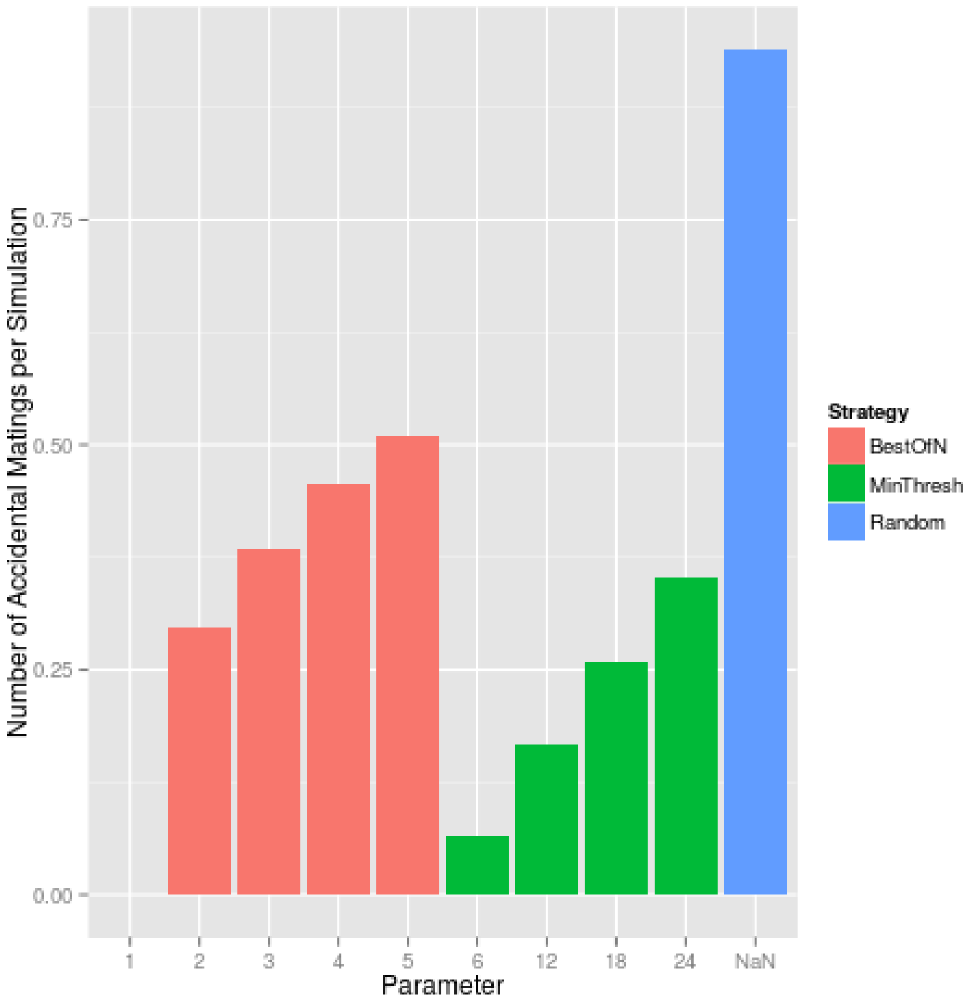
Free Parameters	
Number of Females	5, 10, 15, 20
Female Distribution	Random at Edges
Male Distribution	Gaussian
Mean Male Pulses	6, 12, 18, 24
Mating Strategy Plus Parameter	Random, Best-of-N (1, 2, 3, 4, 5) and min-thresh (6, 12, 18, 24)

- We ran 100 simulations with different initial conditions.

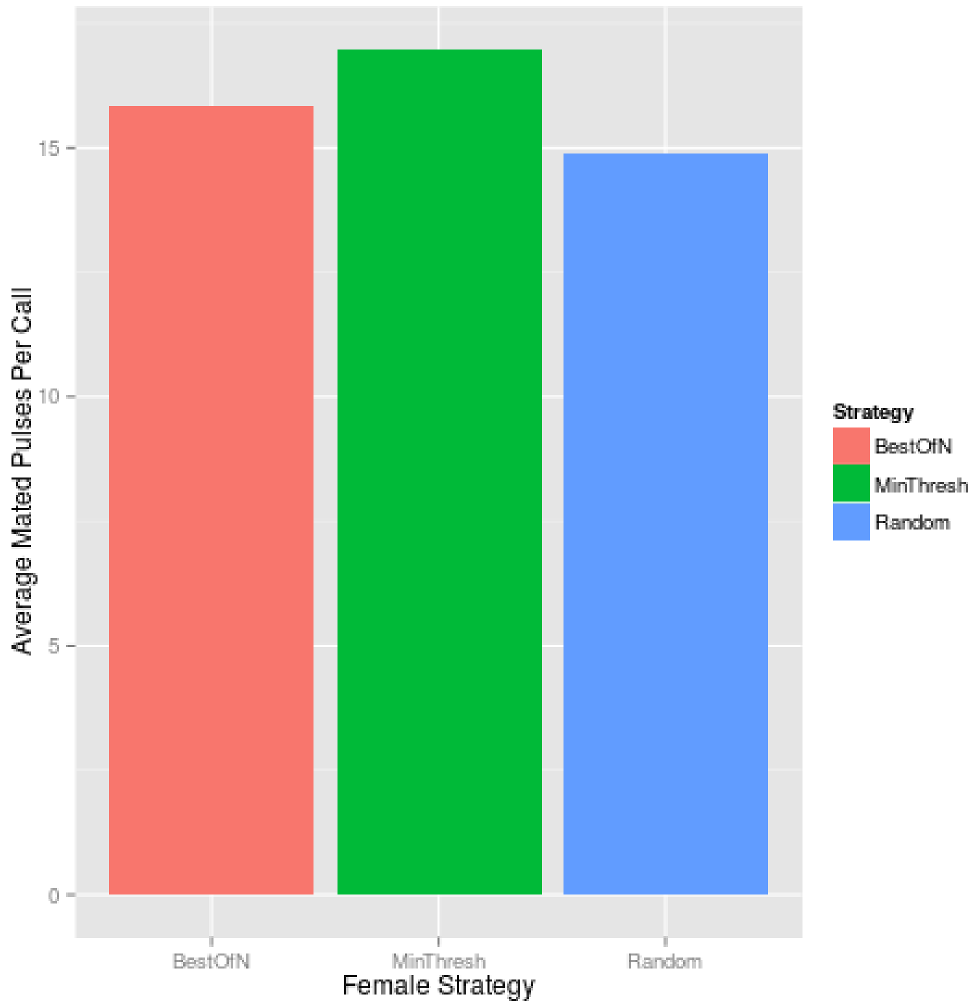
Results:
rate of accidents



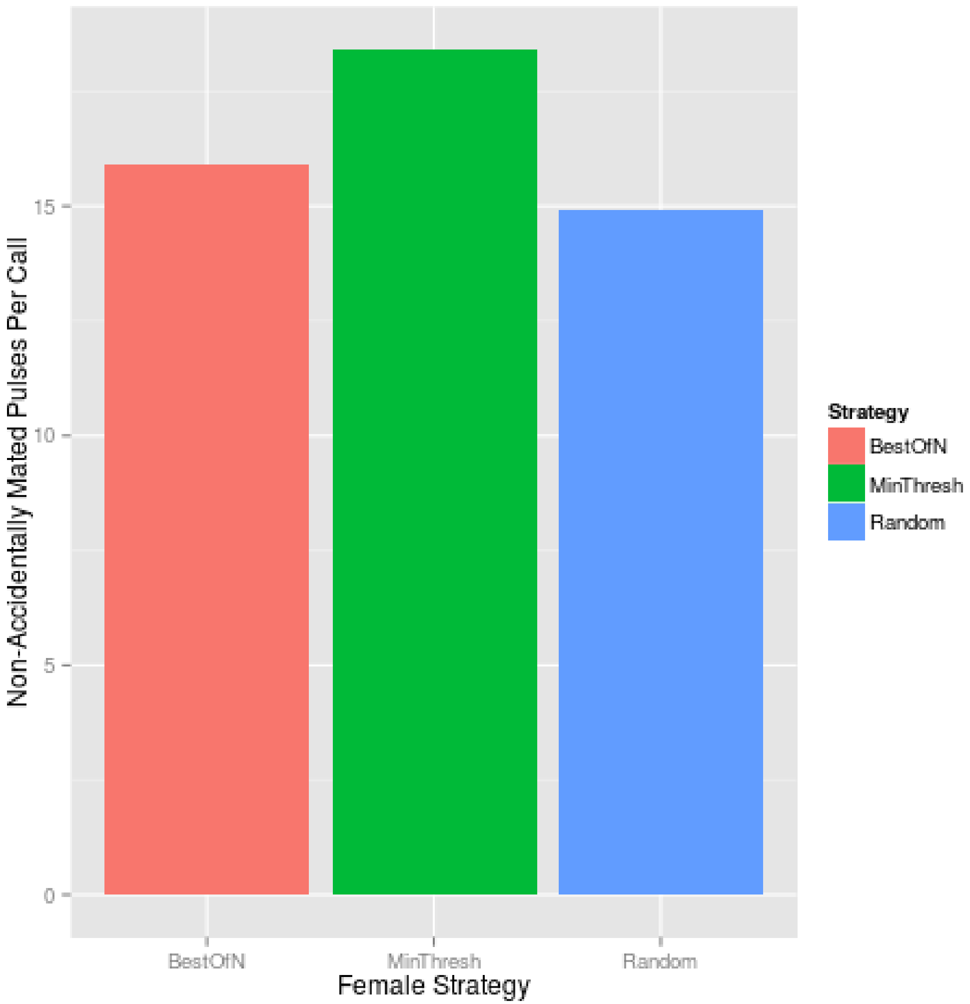
Results: rate of accidents



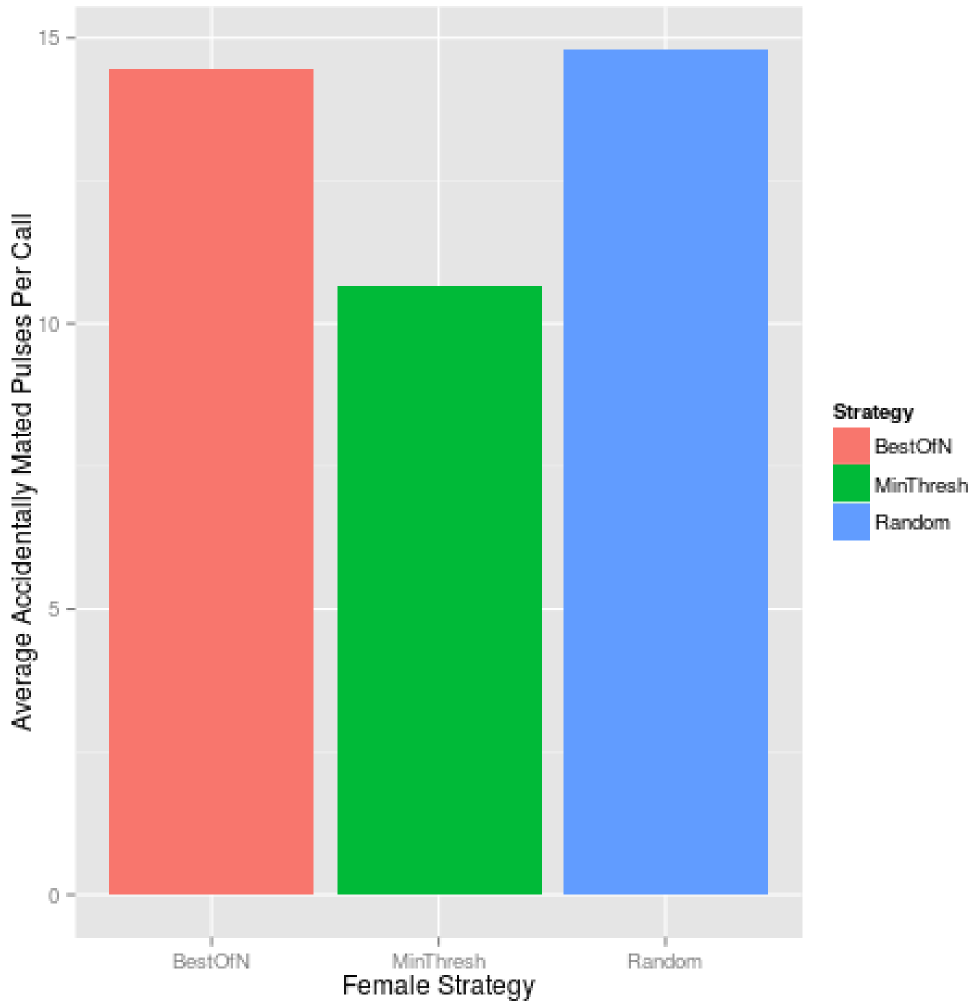
Results:
fitness of mated males



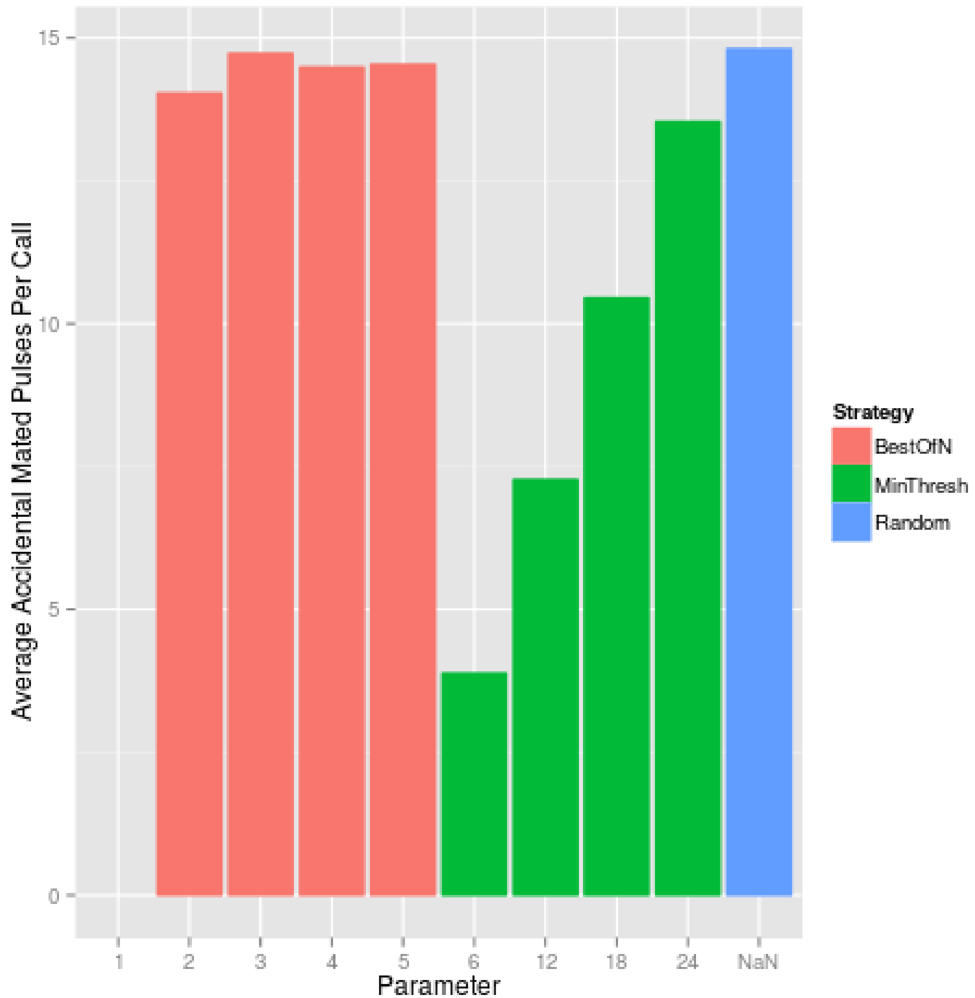
Results:
fitness of non-accidentally mated males



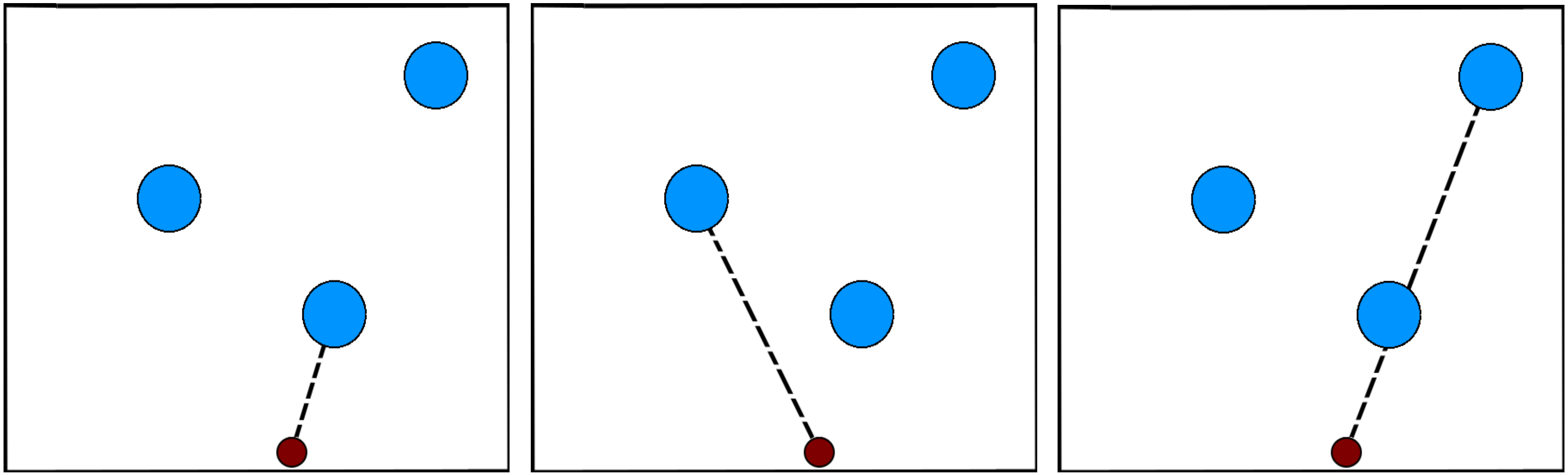
Results:
fitness of accidentally mated males



Results: influence on threshold

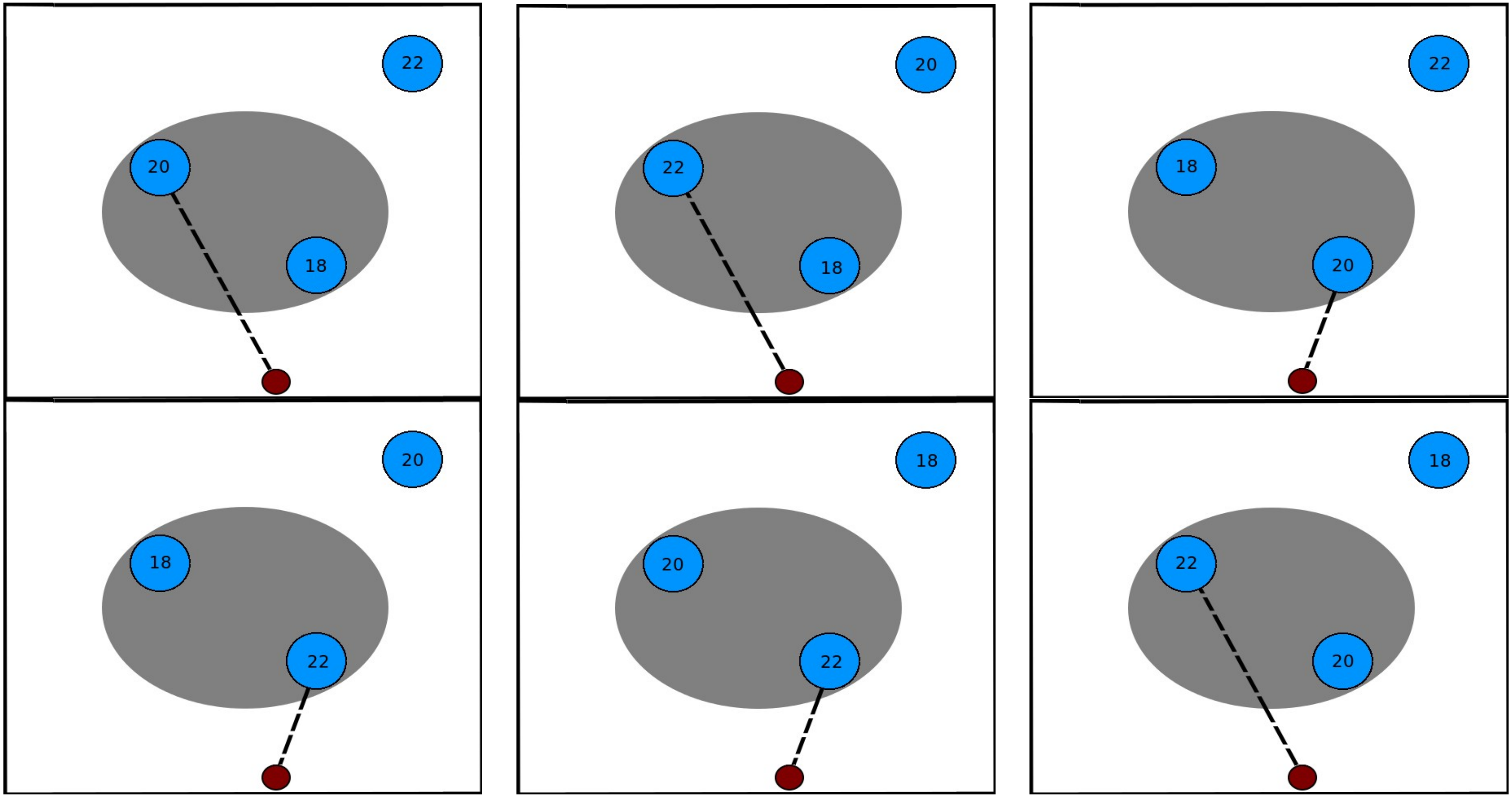


Analysis: accidents with a random mate choice strategy



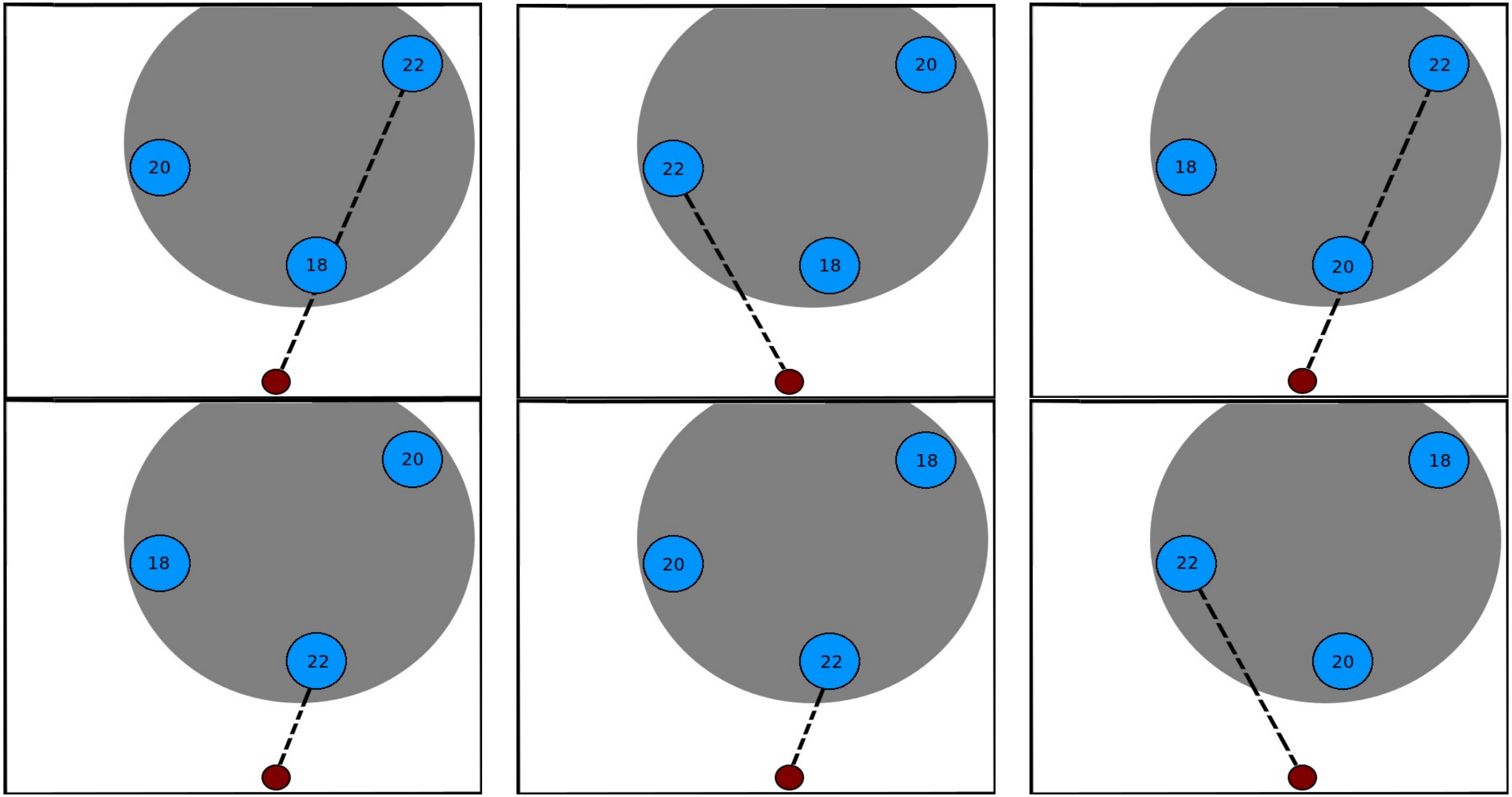
- For this swamp configuration, the probability of occurring an accident using the random strategy is equal to 1/3.

Analysis: accidents with a best-of-2 mate choice strategy



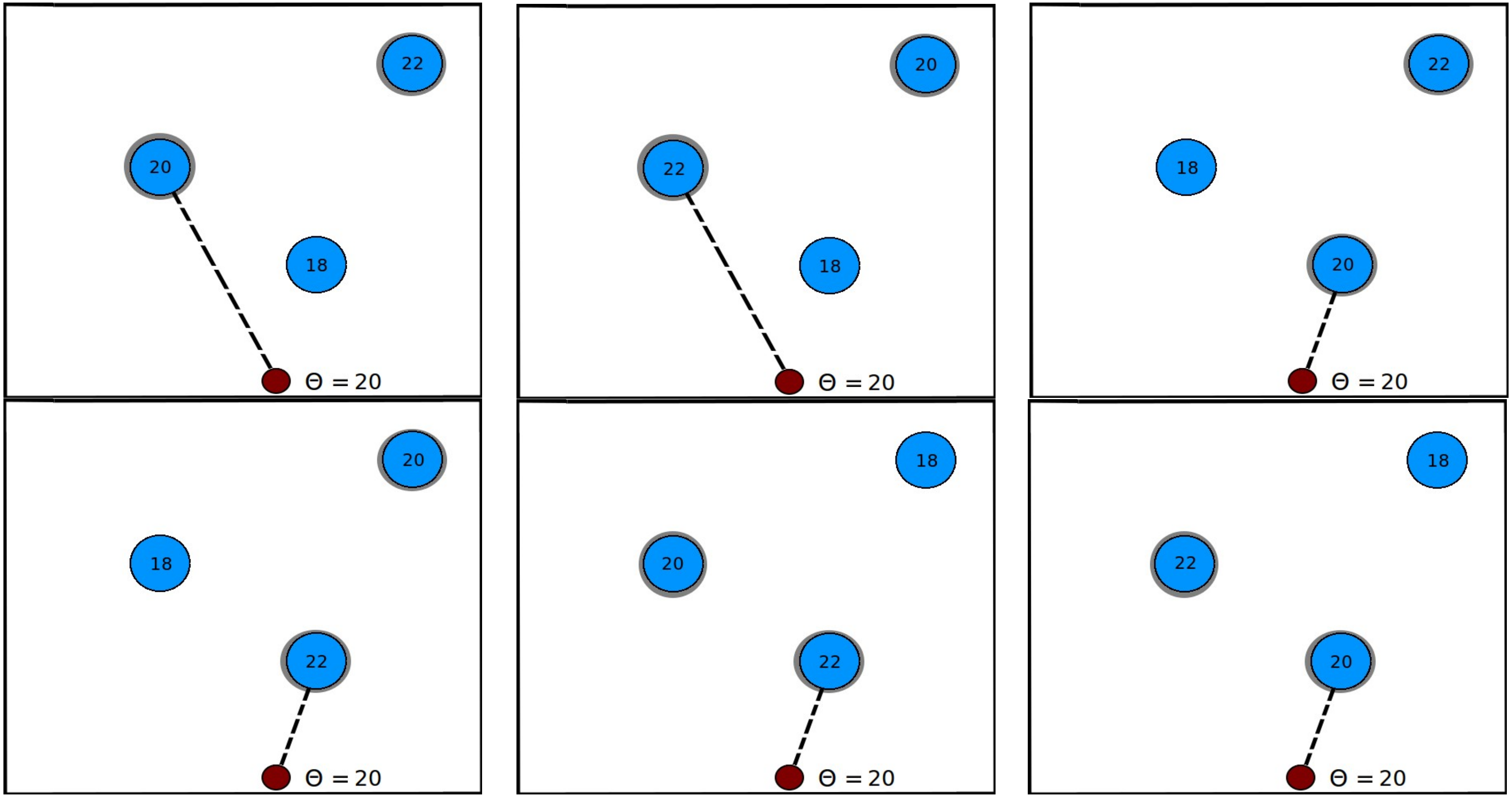
- For this swamp configuration, the probability of occurring an accident using the best-of-2 is equal to 0.

Analysis: accidents with a best-of-3 mate choice strategy



- For this swamp configuration, the probability of occurring an accident using the best-of-3 is equal to 1/3.

Analysis: accidents with a minthresh mate choice strategy



- For this swamp configuration, the probability of occurring an accident using the minimum-threshold is equal to 0.

Summary

- We investigated the frequency and quality of accidental matings in the mate choice scenario in treefrogs using a Gaussian distribution of male callers in the swamp
- Using the best-of-n or minthresh strategies leads to better average mated male fitness and lower accident rates than picking a mate at random (as expected)
- The best-of-n strategy leads to a higher accident rate than the minimum-threshold
- On the other hand, the accidents in the minimum-threshold have a higher influence on the overall fitness of mated males than the accidents in the best-of-n

Future work

- We are currently investigating whether different male distributions in the swamp would have a different impact on the results we found for the Gaussian distribution, i.e., in particular, on the probability of females accidentally bumping into a non-chosen male
- We are also interested in evaluating the accident rates when males are allowed to reposition themselves both when establishing calling sites and in response to other male callers
- We expect that accident rates can be increased based on the positioning strategy chosen by males
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