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Evolving an optimal group size in groups of prey under predation

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Considerable progress has been made in understanding the evolutionary forces underlying animal group-living behavior. Even so, Krause and Ruxton (2002) identified optimal group size as an under-researched area characterized by unwieldy large-predator study systems and simulations based on group rather than individual decision-making. Therefore, we present a simple, flexible simulation of foraging and predation that demonstrates that the evolution of an optimal, evolutionarily stable group size is in fact possible.

Prey genomes are evolved in subpopulations, each with a coevolved group size factor. These groups can be either heterogeneous or homogeneous. Genome fitness is determined by placing the subpopulation in the predator simulation used in Olson et al. (2014). Fitness-proportionate selection first acts on entire subpopulations (where a subpopulation's fitness is the mean fitness of its genomes) and then on genomes within each subpopulation (if the subpopulation is heterogeneous). Group size can also mutate between generations, with selection again choosing candidates for removal when a group shrinks and reproduction when it grows.

To study the potential disadvantages of living in large groups (e.g., competition for mates and resources), we apply a grouping penalty to foraging prey proportionate to the size of the group. This penalty is described by the equation:

$$\text{Food} = \frac{1}{G^P} \quad (1)$$

where G is the group size and P is the grouping penalty.

We find that at small grouping penalties, large group sizes evolve to share the expensive task of anti-predator vigilance. As the grouping penalty increases, group size declines gradually, causing individual vigilance to increase in turn. Once a large enough grouping penalty is reached, group-living ceases to be viable strategy, and prey instead evolve to live as solitary individuals.

When and how quickly this decline in group-living occurs is a function of reproductive strategy. Group-living falls off quickly in iteroparous prey, while group-living is preserved among semelparous prey until much larger grouping penalties are reached. In contrast, group composition has little impact on when group-living is no longer sustainable.

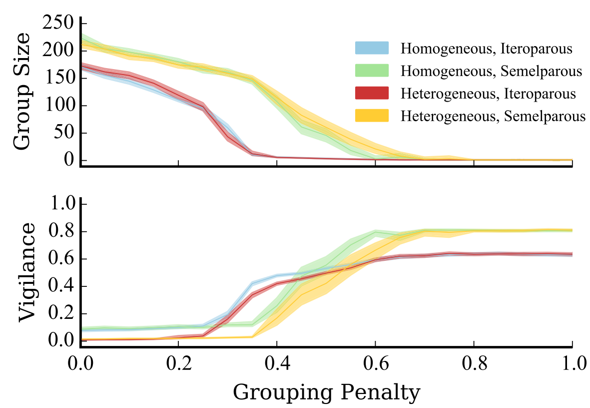

Figure 1: Group size and vigilance across various grouping penalties. Shaded regions show 95% confidence intervals.

These experiments represent an intial foray into using simulations to understand whether an optimal group size exists. An advantage of our system is that in the future we can model the individual decision-making endorsed by Krause and Ruxton (2002). Future simulations also can consider complex factors like food scarcity. Still, these results suggest that prey can evolve to live at an optimal, stable group size, which is mediated by the costs of living in groups.

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