**Local Mate Competition**

Curtis M. Lively, Rebecca Penny, and Lauren Smith (Indiana University)

To understand this lab, you need to think like an intertidal barnacle. Barnacles are sessile simultaneous hermaphrodites with internal fertilization. So, they gain fitness though both sperm and eggs. But being sessile, the number of individuals with which they can mate with is limited to the size of the local group (i.e., those that can be fertilized by the relatively long extendable penis). Hence, the mating group can be just a handful of individuals. The question is, how should barnacles allocate limited resources to male function (sperm) and female function (eggs)?

Consider this thought experiment. You are a barnacle, and you have only one possible mate. Should you allocate half your resources to male function? If not, what fraction resources should you allocate to male function? In making your decision, you should try to maximize the number of zygotes that you contribute to, through either sperm or eggs. Remember that your partner should be thinking the same way. But in any case, your total fitness depends on what your partner decides. (But you don't get to discuss this. Barnacles can't talk.)

Now repeat the thought experiment, assuming now that there are 4 barnacles in the mating group. Would you allocate more or less to male function given this increase in group size? Why?

One more thing. The solution for the Fisherian sex ratio assumed an infinite, randomly mating population. In such situations, the optimal allocation to male and female function is 1:1. Hamilton relaxed the assumption of infinite population size in his 1967 paper on local mate competition. In this paper, Hamilton was able to generalize Fisher's idea, as well as to explain female-biased sex ratios in nature (Hamilton, 1967). In 1980, Charnov extended Hamilton's model to simultaneous hermaphrodites (Charnov, 1980).

--------------------------------------------

Note for instructors. In lecture, we use the exercise below. It works on zoom as well by constructing break out rooms. It takes about 20-30 mins.

**Local Mate Competition: relaxing the assumption infinite population size.**

**The barnacle game**. to get an intuitive feeling for Local Mate Competition, we will play the barnacle game.

Rules: You are all hermaphrodites.

You have 100 units of resources for reproduction.

1. One egg costs 10 units

2. One sperm costs 1 unit.

So, you could make 10 eggs and no sperm,

Or you could make 9 eggs and 10 sperm,

Or 5.5 eggs and 45 sperm

Or 0 eggs and 100 sperm.

Get into groups of two and "cross-fertilize." Then count the number of zygotes that you contributed to through male and female function. The goal is to maximize the total number of offspring that you genetically contributed to.

Now get into groups of 4… Did you change your strategy? If so, how? Why?

-----------------------------------------------

Using Excel to study local mate competition. Download the file (local mate competition lab v3.xls). Open the file. Note that there are two tabs, “Calcs” and “Graphs.” You will be working within the Graphs tab. You will see entries in Blue and in Red. We will be changing the blue ones only.

The blue values are variables. The first one is ***K,*** the number of mates. The second variable is ***ares***, the population mean allocation to male function. We will be changing these two variables in order to answer questions regarding the shape of fitness functions and the approach to the ESS.

The red entries are calculated from the blue entries. For example, the ESS is calculated as *a*\* = (*K* - 1)/(2*K* - 1). (The solution is a very clever extension of Hamilton's model for barnacles by Charnov (1980)). This is the barnacle model. Remember that barnacles are simultaneous hermaphrodites. They allocate their reproductive resources (*R*) to either male function (sperm) or female function (eggs). Total fitness for an individual barnacle is the sum of the gains through male and female function.

1. We will start with small mating populations, as envisioned by Hamilton. Set *K* = 2 and *ares* to 0.1. Draw the observed fitness curve below.



2. For these conditions, do you think natural selection would favor individuals that increased or a decreased their allocation to male function? Why?

3. Look at the panel on the right. It shows the gains curves through eggs and sperm separately. Why does the blue line for male function flatten out? This is called **diminishing returns.** Why is the red line for female function so straight?

4. Now increase that value for *ares* to 0.2. Draw the output below.



5. Compare this new graph to the graph in question 1. What happened to the shape of the total fitness function? Did total fitness increase or decrease? Why?

6. Now increase that value for *ares* to 0.3. Make sure *K* is still set at 2. Draw the output below.



7. What happened to the fitness function and population mean when *ares* was increased to 0.3? When will the population stop evolving?

8. The solution for the ESS is 0.333. Set *ares* to 0.333. Graph the results below



9. Compare this new graph to the fitness curve observed when the population was at *ares* = 0.1? Would genetic drift be more likely or less likely for the population at the EES or for a population at *ares* = 0.1? Why?

10. Now consider what would happen if average male allocation in the population is greater than the ESS. Set *ares* to 0.5. Graph the results?



11. Under these new conditions (*ares* to 0.5), would natural selection favor individuals that increase or decreased male allocation? Explain your reasoning.

12. Set *ares* to 0.2. Increase the number of mates (*K*) from 2 to 4. Graph the results.



13. What happened to the male gains curve (blue line, right-hand graph) when you increased the number of mates from 2 to 4? Why did that happen?

14. Why do the male and female gains curves always cross at *ares*? What does that mean?

15. Enter different values for *K* and *ares.* Do you see any general patterns emerging? If so, what are they? (You can be brief: 2-3 sentences is fine.)

16. In Fisher’s model, he assumed that the population was infinite and that individuals mated at random. We will now consider the shapes of curves and the ESS for large populations. Set *K* = 10,00 and *ares*= 0.2. Graph the results below.



17. What are the shapes for the gains through female function (Weggs, red curve) and male function (Wsperm, blue curve) in relation to *a*i? How are they different from the cases above for K = 2 and K = 4? What explains the difference?

18. Now, set *ares*= 0.4. Graph the results below.



19. What happened compared the previous case for *ares*= 0.2?

20. Finally, set *ares*= 0.5. This is the ESS. Graph the results.



21. How do you interpret these new results? If the population is at the ESS, do you think the population would drift? Why or why not?

22. If the population does drift, so that male allocation is greater than the ESS, what would you predict? Set *ares*= 0.6? Graph the results below.



23. Would selection favor increase or decrease allocation to male function? When would the population stop evolving under the action of natural selection?

**References**

Charnov, E. L. 1980. Sex allocation and local mate competition in barnacles. *Marine Biology Letters* **1**: 269-272.

Hamilton, W. D. 1967. Extraordinary sex ratios. *Science* **156**: 477-488.