Population ecology assignment: Population regulation

1. A population of bacteria have a constant instantaneous death rate of 0.4/day. When they are not crowded, they have an instantaneous birth rate of 0.7/day. Assume that they experience density dependence, but not Allee effects.

a. (1 point) What is the instantaneous growth rate of this population when at very low density (r_0)?

$r_0 = b_0 - d_0 = 0.3/\text{day}$. The answer is not correct without the units.

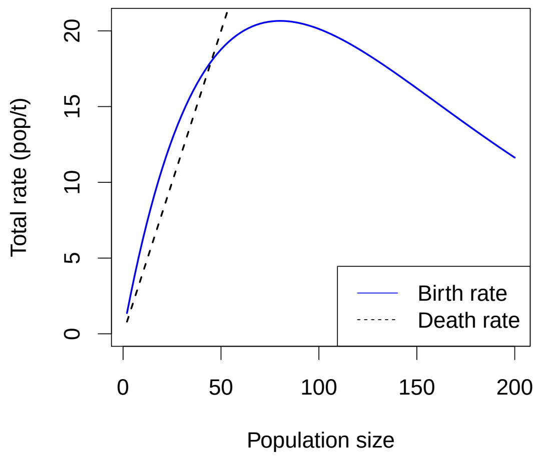
b. (1 point) What is the reproductive number of this population when at very low density ($\mathcal{R}_0$)?

The average life span is $1/d$, so $\mathcal{R}_0 = b_0/d_0 = 1.75$. The units cancel out.

c. (2 points) Use the function `bd` to plot the relationship between population size and *total* growth rate for a population like this. What is the carrying capacity (stable equilibrium) for your population? You will have to choose your own scale for density dependence, and to make sure that the equilibrium value is shown on your plot. Read the documentation at `http://bio3ss.github.io/materials/bd.export.html`

We chose to use a characteristic scale of 80 individuals for density dependence, and to increase `popMax` so that the intersection showed up more clearly:

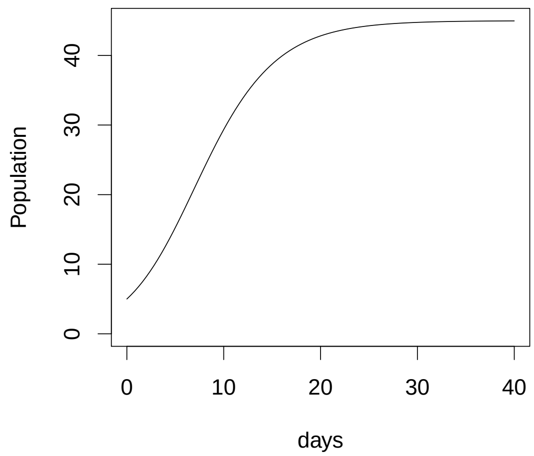
```
bd(b0=0.7, d0=0.4, bDD=80, popMax=200)
```



The carrying capacity is where these curves intersect, around 45 individuals.

d. (2 points) Show *one* time plot for your population, starting from a low population density (relative to equilibrium), but not zero. What size does the population approach? Make your time window long enough that you can show this clearly.

We added `N0 = 5` and `MaxTime=40` to make this plot. We also added a `tlab` argument.

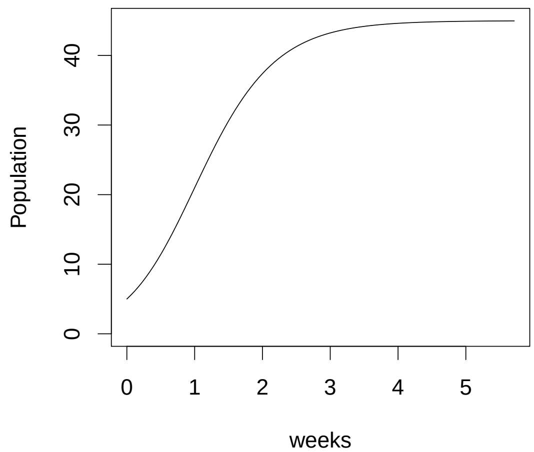


The equilibrium it converges to is the same as the carrying capacity (around 45 individuals).

e. (2 point) Rescale your last plot above by changing all necessary unit-ed values to show time in units of weeks instead of days.

We multiply the rates by 7, and divide the size of the time window by 7:

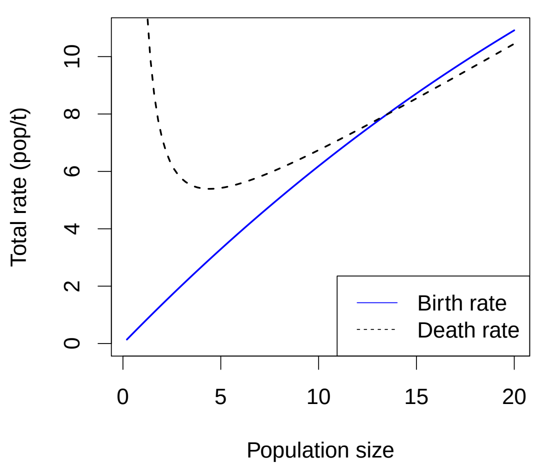
```
bd(N0=5, b0=7*0.7, d0=7*0.4, bDD=80, popMax=200, MaxTime=40/7,
tlab="weeks")
```

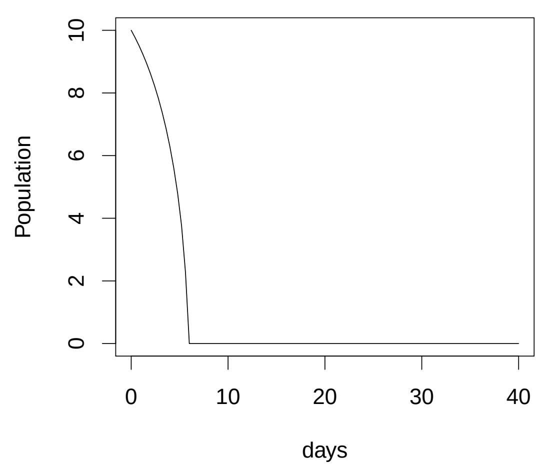


2. What might happen if the population above experienced Allee effects?

a. (2 points) Show a plot of *per-capita* growth vs. population size, and also *one* time-series plot, reflecting what might happen to this population if Allee effects were operating.

We chose to add an Allee effect in the death rate with `dAllee=5`. We also changed N0 to 10.





b. (2 points) Explain what you assumed about the Allee effect, and what dynamics resulted.

We assumed an Allee effect in the death rate with a characteristic scale of 5 individuals. The dynamics we observed (starting from 10 individuals) was extinction. From the rate plot, we can see that there is an unstable equilibrium at about 11 individuals. If the population starts above that, we would expect it to approach the regulated equilibrium.

c. Is this a strong or weak Allee effect (how does R_0 compare to 1)? Try different values of N0 (i.e. before, between, after the equilibriums).

This is a strong Allee effect: $\mathcal{R}_{\mathsf{max}} > 1$, but $R_0 < 1$. At our starting point, the population went extinct, but for a higher starting point (higher N_0) it could persist.