# Lab 2 Assignment — Harvest Models
# Due before your next lab

Answer each of the following questions and upload your completed Excel file to ELC. Be sure to show your calculations.

**Exercise I**

The Excel sheet shows (fake) data on Burmese python abundance in south Florida.

1. What growth model best describes these data, geometric or logistic? Hint: calculate $\lambda_t = N_t/N_{t-1}$ to assess if growth rates change over time.
2. What is the growth rate ($r$)?
3. If you determine that the per-capita birth rate ($b$) is 2.0, what must be the per-capita mortality rate ($d$)?
4. What harvest rate ($h$) would result in a sustainable yield?
5. Use the harvest rate ($h$) from part (4) to project the population forward from 2012 to 2024. You will need to compute the number of individuals removed ($H_t$) each year using the equation $H_t = N_t h$[1]. Create a graph of python abundance from 2005–2024.

**Exercise II**

Imagine a population of northern bobwhite (*Colinus virginianus*) that is experiencing logistic growth with $r_{\text{max}} = 0.32$, $K = 2000$, and an initial population size of 100 individuals.

1. Project the population for 40 years, and plot abundance over time. Add axis labels as always.
2. Compute the number of individuals that could be sustainably harvested each year. Plot abundance on the x-axis and sustainable harvest on the y-axis.
3. At what value of abundance ($N$) would maximum sustainable yield (MSY) occur?
4. What is the value of MSY in this case? What is the harvest rate ($h$) at MSY?
5. Using the same values of $r_{\text{max}}$, $K$, and $N_0$, project the population forward again, but include harvest ($H_t$). Choose values of $H_t$ that allow for the greatest number of years at MSY. Hint: You can let harvest be zero in some years.

[1] $H_t$ can be greater than $N_t$ because harvest is assumed to occur at the end of the year, after the population has grown

**Exercise III**

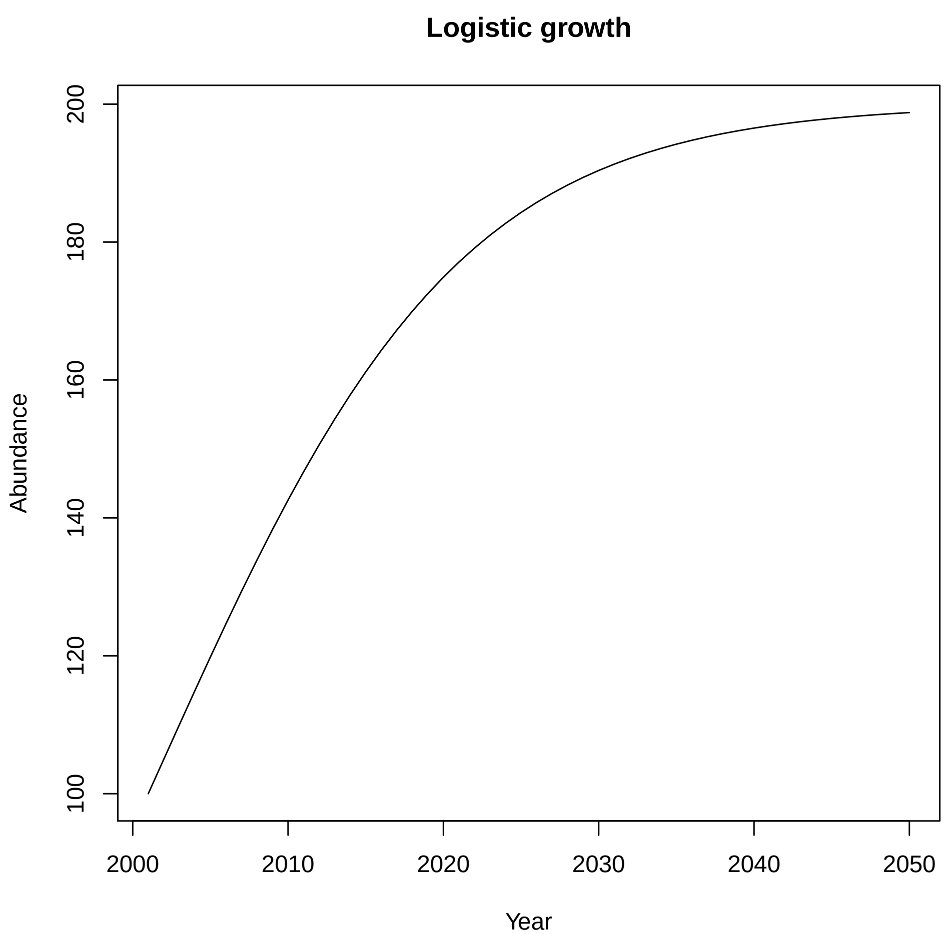
Suppose that annual survival of sitka deer (*Odocoileus hemionus sitkensis*) decreases as abundance increases according to the equation: $S = \beta_0 - \beta_1 \times N$.

1. Compute survival probability for each value of $N$ provided in the spreadsheet with $\beta_0 = 0.95$ and $\beta_1 = 0.003$. Create a graph with survival probability on the y-axis and abundance on the x-axis.
2. A manager is trying to decide how many deer to harvest, and is considering removing anywhere from 10 to 150 individuals from a population of 200. Use the equation above to determine how many deer will remain one year after harvest for each of the harvest options. To accomplish this:
   - Compute how many individuals will be alive immediately after harvest
   - Compute survival probability for these remaining individuals using the survival equation
   - Compute how many will be alive at the end of the year.
3. Create a graph with final abundance ($N$) on the y-axis and harvest ($H$) of the x-axis.
4. Determine how many deer will be alive if no harvest occurs. Are there any levels of harvest that can result in a larger population than the no harvest scenario? If so, how can this be?
5. If the manager's objective is to maximize harvest, while maintaining a herd size greater than it would be without harvest, how many deer should be taken?

### R tips

Here's an example of a logistic growth model.

```
rmax <- 0.1                ## max growth rate
K <- 200                   ## carrying capacity
years <- 2001:2050         ## years
nYears <- length(years)
N1 <- rep(NA, nYears)
N1[1] <- 100               ## abundance in first year
## for loop
for(t in 2:nYears) {
    N1[t] <- N1[t-1] + N1[t-1]*rmax*(1 - N1[t-1]/K)
}
plot(years, N1, type="l", xlab="Year", ylab="Abundance",
     main="Logistic growth")
```



Here's an example of a logistic growth model with harvest

```
rmax <- 0.1                ## max growth rate
K <- 200                   ## carrying capacity
h <- 0.02                  ## harvest rate
years <- 2001:2050         ## years
nYears <- length(years)
N2 <- rep(NA, nYears)
N2[1] <- 100               ## abundance in first year
H <- rep(NA, nYears-1)
for(t in 2:nYears) {
    H[t-1] <- N2[t-1]*h
    N2[t] <- N2[t-1] + N2[t-1]*rmax*(1 - N2[t-1]/K) - H[t-1]
}
plot(years, N1, type="l", xlab="Year", ylab="Abundance")
lines(years, N2, col="blue", lty=2)
legend(2000, 200, c("Logistic growth", "Logistic growth with harvest"),
       col=c("black", "blue"), lty=c(1,2))
```