Final Synthesis

Instructions:

- The synthesis is open book/slides/notes, though the use of AI services is strictly prohibited. Any resources from outside of the course should be cited both within your text and in a complete bibliography at the end. However, there should not be a need to use any external sources, and I do not recommend doing so as they may approach topics/concepts within a different context, and in some cases can be simply incorrect.

- This assignment is effectively in lieu of a self-scheduled examination. Thus, I am happy to answer clarifying/technical questions, but I am not planning to provide specific help as I might with other assignments.

    - For questions about coding in R: I may be somewhat flexible in my help with respect to coding. For example, if you are receiving an error message, I can help interpret what it means and potentially what the general problem is, but I will be less forthcoming with how exactly to solve it…

- For the assignment you should submit:

    1. A **PDF** document with written answers and figures. Be sure to clearly indicate the question or sub-question that you are answering.

    2. Your knitted R Markdown code as a **PDF**.

- Due Thursday May 9 at 4:00pm –

(Upload form available on the course website)

1. Below is the life cycle diagram and timing of the modeled annual transition period (census to census) for the critically endangered spider tortoise (*Pyxis arachnoides*) found in Madagascar. In a paper by Ryan Walker and colleagues, they provide *matrix elements* (P_x, G_x, and F_x in the lifecycle diagram), but not the underlying *vital rates*.

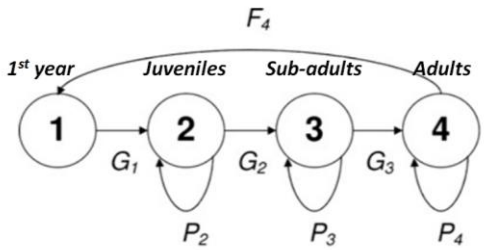
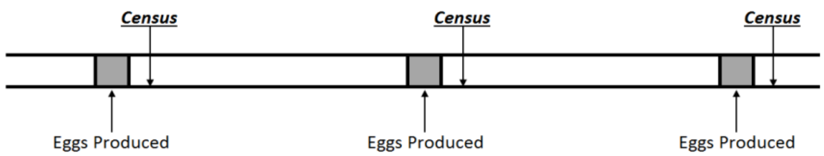


Fig. 2. Life-history diagram of *Pyxis arachnoides*. Where G_i = annual probability of surviving and recruiting into the next size class, P_i = annual probability of surviving and staying within the same size-class and F_i represents the annual production rate of female offspring per adult female.



(1a) 4 pts Create a projection matrix (either using a table in Word/Docs or drawn by hand) using the vital rates provided. Add zeros where appropriate and consider the timing of the life cycle relative to the model annual transition period (i.e. census to census). Be sure to indicate which rows/columns correspond to which stage.

Vital Rates:

S_1	1st year survival (from egg to juvenile)
S_2	Juvenile survival
S_3	Sub-adult survival
S_4	Adult survival
M_2	Fraction of juvenile survivors that become sub-adults
M_3	Fraction of sub-adult survivors that become adults
E	Per capita adult fecundity (number of eggs)

(1b) 3 pts Create the matrix in R and calculate the population growth rate (λ).

1) Go to RStudio Cloud and open up the "Final Synthesis" project. The *Final Synthesis Template.Rmd* file includes code chunks for you to add to.
2) The first code chunk includes the actual values for the vital rates listed above. The existing code creates a 4 × 4 matrix of zeros and then "fills in" one of the matrix elements as an example.
3) Finish creating the rest of the projection matrix based on your answer to **(1a)**, then calculate the population growth rate. (Refer to lab handouts / code for the `get.lam` function.)

(1c) 2 pts Poaching/harvesting of adult turtles (for meat, shells, and the pet trade) is a major threat to the persistence of the spider turtle. How could you incorporate a new vital rate ***P***, which represents the fraction of adult turtles taken by poachers? Which matrix transition(s) would need to be modified and what would the new formulation be?

(1d) 2 pts Modify the code to incorporate poaching based on your answer to (1b).

- Copy your code from **(1b)** into the next code chunk and modify it to incorporate the effect of poaching.
- What is the population growth rate if the level of poaching is 0.05 (5%)?

(1e) 1 pt Based on the population growth rate values from (1b) and (1d), what is the sensitivity value associated with poaching?

- Be sure to show your work.
- *Hint*: No coding is required for this, but you can do this in *R* if you like. Be sure to consider how sensitivity values are calculated and how the equation applies in this case.

Information for (1f) and (1g):
Another major threat to the spider tortoise is increased resource extraction in southwest Madagascar. Although mining operations in the region are only just beginning, the potential area of mining is considerable (map below from Walker et al. 2013). For the next two questions, extend the fundamental tools of geometric population growth to scenarios of habitat loss for the spider turtle. In other words, instead of thinking about changes in the population size over time, think about changes in the quantity of available habitat.

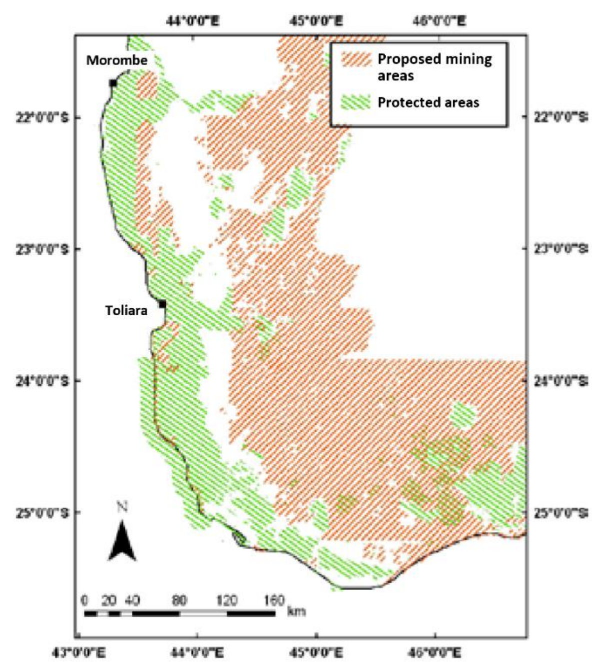


Figure 3. Spatial distribution of existing or proposed protected areas under the Madagascar Protected Areas expansion program and sites proposed under the Madagascar Mining Code for mineral extraction within the southwest coastal zone of Madagascar.

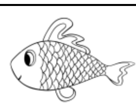
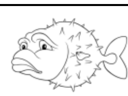
(1f) 2 pts Turtle habitat is currently declining at 1.2% a year due to deforestation. Assuming this rate of change remains constant, what would be the fraction of habitat projected to remain after 20 years? Be sure to show your work/equation(s).

(1g) 2 pts Now assume a scenario where mining activity increases in southwest Madagascar after five years. In this case, the rate of habitat loss is 1.2% for the first five years but increases to 3.5% per year after that. What would be the fraction of habitat projected to remain after 20 years in this scenario? Be sure to show your work/equation(s).

2. The next several questions focus on the concept and application of maximum sustainable yield (MSY) in fisheries management.

   (2a) 2 pts According to the theoretical framework for maximum sustainable yield (based on the deterministic logistic model), what will ultimately happen to the population size if you start fishing at the predicted maximum amount (i.e. fishing exactly at MSY) from a population that begins at its carrying capacity of 8 million fish? Briefly explain how you arrived at this answer, e.g. *why*?

   Questions 2b-c are based on the table below that shows important values for two different hypothetical fish species: the abundant Red Bellied Snarlfish and the delicious, but potentially poisonous, Barbed Flobberfish. Note that all abundance values are in millions of fish, and the MSY value refers to the number of fish caught each year.

Species	**Maximum λ**	**Carrying Capacity (*K*)** (millions)	**MSY** (millions / year)
Red Bellied Snarlfish 	3.4	500	300
Barbed Flobberfish 	1.1	40	1

   (2b) 3 pts Calculate the exploitation rate (*F*) for each species when the population is being fished exactly at MSY. In other words, what is F_{MSY} for these two species?

   - Be sure to show your work.

(2c) 3 pts Briefly interpret the two F_{MSY} values from (2b).

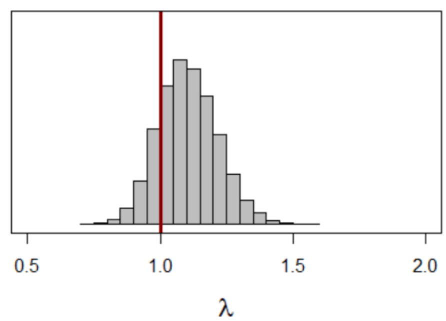
- What do those values actually mean?
- What can you infer about the lifecycles of the two species that explains the differences in F_{MSY} values?

Questions 2d-e use the MSY app available here: https://wellesley.shinyapps.io/fish-msy.

Run a stochastic model using data for the Barbed Flobberfish as indicated in the table below. Population values are from the previous table (in millions) and the annual fish take is set to MSY (1 million fish / year). The model assumes that the average maximum λ is 1.1 and incorporates a random variation value of 0.1, which produces the distribution of possible λ values as shown in the image on the right.

Set the model to run using these values:

Timespan = 200	**Starting Pop Size (N) = 40**
Mean Lambda = 1.1	**Variation (log SD) = 0.1**
Carrying Capacity (K) = 40	**Annual Fish Take = 1**
Iterations = 500	



(2d) 3 pts What is the probability of extinction over 200 years, and can you explain why it is not zero? I mean, we're fishing at MSY, right?

(2e) 3 pts Is the annual variation in this model likely representing environmental or demographic stochasticity?

- Be sure to demonstrate your understanding of the difference between these two types of stochasticity.
- Note that this model uses the logistic equation that we examined in class.

3. **(5 pts)** The following is an excerpt from an essay by Julian Simon entitled "Entropy and energy accounting: are they relevant concepts?". He uses this passage to suggest that evidence of increasing order runs counter to, and therefore undermines the relevance of the Second Law of Thermodynamics.

   But whereas the Second Law implies decreasing diversity, from the point of view of human beings, all our observations record an increase rather than a decrease in order, no matter what quantities we look at. The increase in complexity of living things throughout geological time, and of human society throughout history, are the most important examples, of course. Biologically -- as is suggested by the very word "evolution" -- the earth has changed from a smaller number of species of simple creatures toward a larger number of complex and ordered creatures. Geologically, the activities of human beings have resulted in a greater heaping up of particular materials in concentrated piles, e. g. the gold in Fort Knox and in gold jewelry compared to the gold in streams, or the steel in buildings and junk piles compared to the iron and other ores in the ground. The history of human institutions describes ever more complex modes of organization, a more extensive body of law, richer languages, a more ramified corpus of knowledge, and a greater range of human movement throughout the universe. All this suggests more order rather than less order with the passage of time.

   Critically evaluate Simon's excerpt and argument, making sure that you demonstrate your understanding of the Second Law of Thermodynamics in the process.

   (max 300 words)

4. The following data are from a study by the US Forest Service that examines even-aged loblolly pine forests planted at different densities in the southeastern US. The values show the change in total wood volume over time in one of the experimental forests.

   The image at right shows the different planting densities
   (the letters stand for different management treatments)

Year	Volume (m^3/ha)
2	4
4	37
6	104
8	179
10	246
12	289

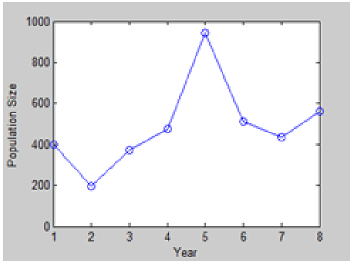
   (4a) 3 pts Assuming that you are managing this forest as a *normal forest*, when should you cut down the trees and plant anew in order to maximum the production of timber?

   (4b) 4 pts Briefly explain key differences in the conceptual framework for maximizing annual fish catch vs. wood volume over the long term.

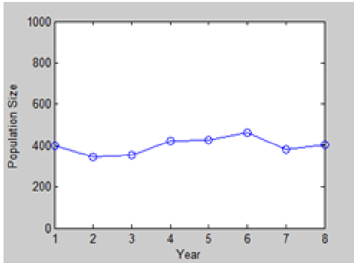
5. **(3 pts)** There are only two remaining populations in the world of the critically endangered web-toed hare. You have been monitoring both populations for the last eight years and have excellent data on changes in population size (below). From these data you have calculated the mean and standard deviation of population growth rates. You wrote a model in R to determine extinction probabilities, but unfortunately R caused your computer to catch on fire and you never got the answer.

The rare and elusive web-toed hare

Population A
Average $\lambda = 1.032$
Standard Deviation of $\lambda = 0.60$



Population B
Average $\lambda = 1.001$
Standard Deviation of $\lambda = 0.12$



In the absence of a population model, which population do you think has a greater chance of going extinct over the next several decades? Briefly explain your answer.

6. **(5 pts)** Although it has been more than 225 years since the publication of Malthus's *An Essay on the Principle of Population*, many of his arguments and conclusions have remained influential. Briefly highlight and describe (1) an area in which you think Malthus makes a useful point with remaining relevance, and (2) another where you think his conclusion is incorrect, unhelpful, and/or no longer relevant.

(max 400 words)