ES 220 Final Systhesis

Linda Dominguez

1. Turtles

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 (Px, Gx, and Fx in the lifecycle diagram), but not the underlying vital rates.

(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.

Projection Matrix

	1st Year	Juveniles	Subadults	Adults
1st Year	0	0	0	E
Juveniles	S1	S2-(S2*M2)	0	0
Subadults	0	S2*M2	S3-(S3*M3)	0
Aduls	0	0	S3*M3	S4

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

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.)

Projection Matrix w/ Values

```
           1stYear juveniles subadults adults
1stYear      0.000    0.0000     0.000 2.0575
juveniles    0.706    0.3913     0.000 0.0000
subadults    0.000    0.2587     0.669 0.0000
adults       0.000    0.0000     0.081 0.8230
```

The lambda is .9863854

(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?

I'd calculate it by:

```
A[4,4]<- S4-(S4*P)
```

(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%)?

	1stYear	juveniles	subadults	adults
1stYear	0.000	0.0000	0.000	1.954625
juveniles	0.706	0.3913	0.000	0.000000
subadults	0.000	0.2587	0.669	0.000000
adults	0.000	0.0000	0.081	0.781850

Matrix Pop Adjusted

The new lambda is: 0.9618169. The adult to adult and adult to egg categories decreased.

(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.

Sensitivity = $\lambda(_{new}) - \lambda(_{original})/\alpha((_{new}) - \alpha(_{original})$

```
sensitivity <- (newLambda - originalLamb) / (P - 0)

sensitivity

#-0.4913699
```

The sensitivity associated with poaching is -0.4913699.

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

(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).

```
deforestationRate <- 0.012 # 1.2% decline per year
fractHabitatRemaining <- (1 - deforestationRate) ^ years
fractHabitatRemaining
# 0.7854868
```

The fraction of habitats remaining after t=20yr is 0.7854868.

(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).

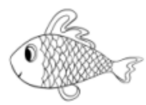
```
#question 1.7
after5 <- (1 - deforestationRate) ^ 5
after5

after5Rate <- .035
fractRemain <- (1 - after5Rate) ^ 15
fractRemain
#0.5860163
```

The remaining fraction of habitat would be 0.5860163.

2. Fisheries

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

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

(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?

The population would remain the same. It'll be constant because the fishing rate will stay the same, and hence the population won't suddely plummet or sky rocket. Ideally, the fishing rate should be kept under to increase the population if that's the goal.

(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 FMSY for these two species?
• Be sure to show your work

Exploitation rate = F
FMSY = exploitation rate = MSY/ carryng capacity

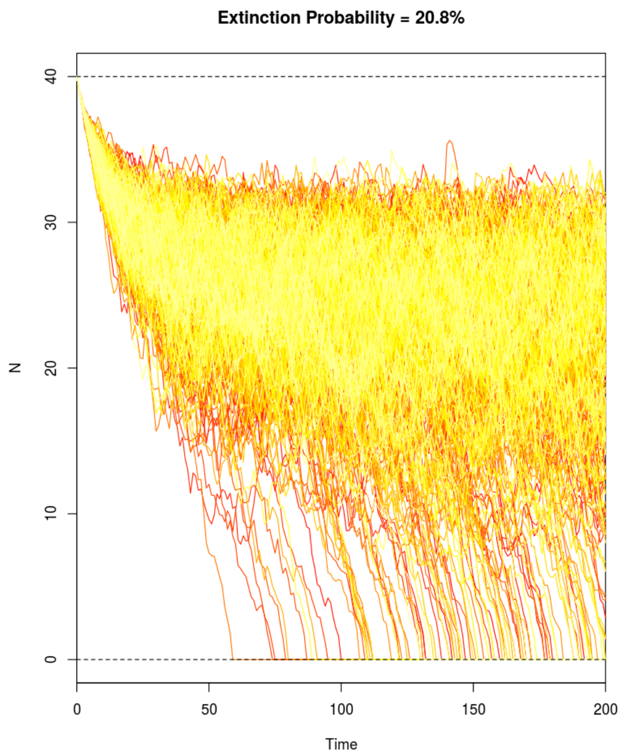
- Red bellied snarlfish: 300,000,000/500,000,000 = **.60**
- Barbed flobberfish: 1,000,000/40,000,000=**0.025**

(2c) 3 pts Briefly interpret the two FMSY 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 FMSY values?

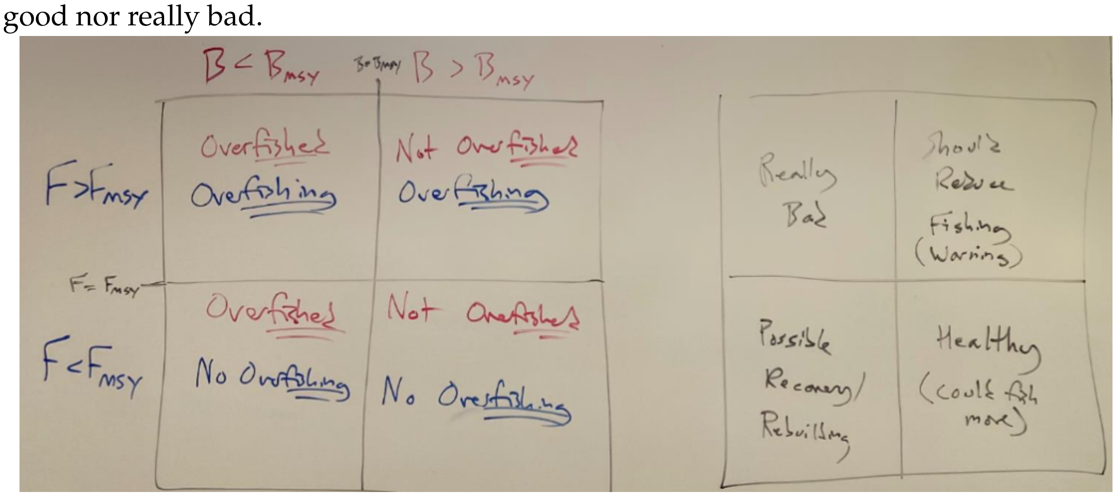
The MSY(Maximum Sustainable Yield) is the framework for how many fish we can catch. The FMSY is the exploitation rate when harvesting at MSY, so the maximum sustainable fishing.
The red bellied snarlfish has a higher FMSY at a rate of .6, while the barbed blobberfish has a rate of .025. These rates tell us that red bellied snarlfish can sustain a way higher level of exploitation than

the barbed blobberfish.
We can infer red bellied snarlfish perhaps can have higher reproduction rates, which makes them lambda higher. THey also have a higher starting population. They can also grow faster than the barbed blobberfish.

(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?



The extinction probability is 20.9%. The MSY is meant to be the max sustainable fishing rate, so if it's followed, populations won't go extinct. As we can see below, even if F=FMSY, the fish aren't being over or underfished. The population isn't suffering tremendously, nor is it flourishing. It's neither good nor really bad.



(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.

Environmental stochasticity refers to fluctuations in survival and reproduction through time as a result of environemtnal factors such as weather, food shortages, and other environmental factors. Demographic stochaticity refers to the deviations of survivals as a product of chance. I think the population variation is showing demographic stochasticity because the K is assumed to be the same through the years, which makes it have more random variation in fluctuation.

3. Entropy

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)

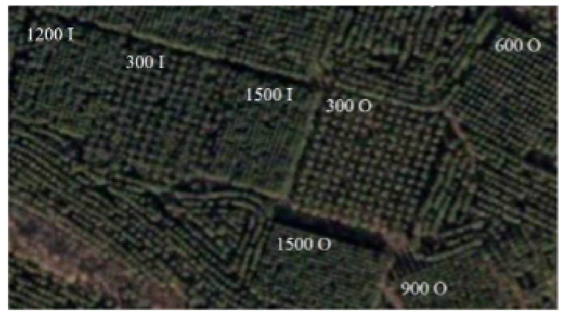
Entropy is a measure of the disorder of a given system. It's the way energy is distributed in the system. Entropy also shows the amount of energy avalible in the system to do work.The second law of thermodynamics states that natural processes tend towards an increase in entropy, aka disorder. An entropy of 0 means a system is completely balanced. As per the second law, heat can't be spontaneously converted to work, but work can be spontaneously converted to heat(this increases entropy). Low entropy states have high order and high entropy states have low order. **The second law states that in an isolated system, entropy increases and order decreases.** Simon claims that through time, order increases rather than decreases. Order refers to organization of molecules as in how they're arranged. He then attributes diversity to order and claims diversity has been increasing and thus order has been increasing. This argument is wrong because more diversity would allow order to decrease, not increase. I don't think he understands what order means, at least in this context.

4. Forest

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



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

(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

We want to maximize the timber. It's important to look at things like the maximum yield. To do this, we use the equation:

volume/yr = volume/years to produce

- 4/2 = 2
- 37/4 = 9.25
- 179/8 = 22.375
- 246/10 = 24.6
- 289/12 = 24.083

As we can see, the yield increases from year 2 through year 10 and begins declining in year 12. The max yield is in year 10, with a yield of 24.6.

We should cut down the trees at year 10.

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

- Wood:
  - Wood takes considerably longer to harvest.
  - The timescale to see results is in the magnitude of years.

  - Wood has a big consideration for economic discounting. Waiting may be more ideal than premmaturely cutting down trees, as seen by our example above, where 10 years had the highest volume/yr.

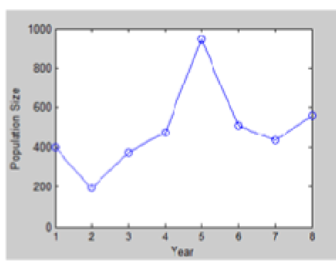
- Fish catch:
  - Must consider the year to year survival and hatch rates. Some years can have higher or lower survival rates.
  - Different stages of fish and their survival rates have different effects on the year to year survival. For example, if more adults survive, we can see a spike in hatchlings which could create a more positively skewed lambda.
  - The timescale of fish catch is on a shorter scale than that of trees, in terms of magnitude.

5. Web-toed Hare

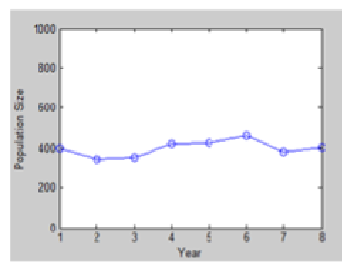
(3 pts) There are only two remaining populations in the world of the critically endangered web-toed hare. You have been monitoring both populations for the last eight years and have excellent data on changes in population size (below). From these data you have calculated the mean and standard deviation 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 λ = 1.032
Standard Deviation of λ = 0.60



Population B
Average λ = 1.001
Standard Deviation of λ = 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

Population A has higher fluctuation, as seen by the standard deviation of lambda PopulationA = .6, while the lambda PopulationB = .12. Although the average lambda of Population A is higher, I'd bet on Population A going extinct since it seems to be very sensitive to changes year to year. Population B apppears to be steadier, but had a lambda of 1.001, which is just enough for it to not go extinct, so truly either population could in theory go extinct. As long as it doesn't go below this lambda, it should be fine. Lambda of population A is better though, by .021 points.

6. Malthus

(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

In his essay, Malthus highlights that he believes population grows exponentially, but other resources don't. He specifically states that food grows arithmetically. This hence causes a disconnect between the exponentially population that's much more massive than the resources available per person. Malthus highlights his belief that population growth would outweigh the Earth's capacity to sustain all of its inhabitants and thus would cause a Malthusian catastrophe. One point Malthus made that I think is indubitably outdated is that there wouldn't be enough food or that the food would grow exponentially. As we discussed in class, this didn't account for the fast advances in technology that would allow for better farming and better yield of crops. Food isn't a scarce resource, except for those with extreme poverty, which isn't an environmental cause, but rather, a cause of sociopolitical and historical factors. A point Malthus made that I think still stands today is that factors like famine, war, and, disease would keep populations in check. As we saw in the 2020 pandemic, disease does still decrease populations, which aligns with Malthusian principles.