The Effect of Deforestation on Population Dynamics of Ring-Tailed Lemurs (*Lemur catta*) in the Unprotected Petriky Region of Southern Madagascar

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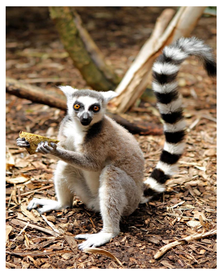
INTRODUCTION

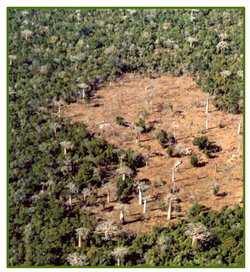
- Ring-tailed lemurs (*Lemur catta*) are one of the world's most endangered mammals, with roughly 2,000 in existence (Gould et al., 2016)
- Illegal human hunting and habitat loss due to deforestation contribute to the rapidly declining population (Nuwer 2011; Harper et al., 2007)
- The IUCN estimates that over 90% of lemurs face extinction in the next 20 years (Duke Lemur Center 2019).
- Understanding how environmental degradation influences population dynamics is crucial in predicting the future trajectory of the species
- Deforestation and *Lemur catta* population trends can be modelled using differential equations, lemur population data, and current deforestation rates (Big Green Differential Equation Machine)
- The Petriky region of southern Madagascar was used for the study because it was one of the few unprotected regions in Madagascar with remaining ring-tailed lemurs (Gould et al., 2016)

Research Objectives:

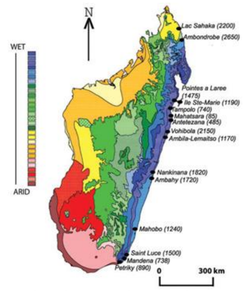
- To predict when the *lemur catta* population will go extinct
- To determine how to prevent the *lemur catta* from going extinct
- To discover how to prolong the survival of the *lemur catta* species by 20 years



Ring Tailed Lemur (Lemur catta)



Deforestation in Madagascar



Map of madagascar showing the major regions including Petriky

METHODS

I. Modeling Lemur Population

- Petriky region population density (D): 0.43 lemurs/km^2 (Sussman et al., 2006)
- Carrying capacity density (K): 197.2 lemurs/km^2
- Maximum intrinsic growth rate (r_{max}): 0.093

$$\frac{dP}{dt} = r_{max} \cdot P\left(1 - \frac{P}{K}\right)$$

$$\frac{dP}{dt} = 0.093 \cdot 0.43\left(1 - \frac{0.43}{197.2}\right) = 0.04 \text{ lemurs or } 9.3 \text{ percent per year}$$

I. The Effect Deforestation on Lemur Population Density (Modified Sussman et. al 2006)

$$D = \frac{P}{F} = \frac{197.2}{1+e^{-\frac{(F-75.336806)}{6.7818335}}}\ ;\ P = D \cdot F$$

- Forest canopy density (F): 100 percent
- Rate of deforestation (F'): –3.05 percent

I. Developing our Box Model

$$\frac{dP}{dt} = 0.093 \cdot 0.43\left(1 - \frac{0.43}{D}\right) \text{ where } D = \frac{P}{F} = \frac{197.2}{1+e^{-\frac{(F-75.336806)}{6.7818335}}} \text{ and substitutes for the original K.}$$

BOX MODEL

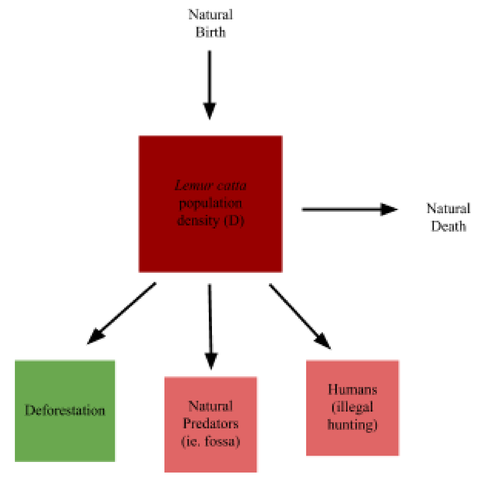


Figure 1. The box model focuses on *Lemur catta* population density (D) and thus size in Petriky.

dP/dt, the natural population density growth rate of 9.3 percent, includes natural birth and death rates, predation rates by fossa and other predators, and illegal human hunting

F describes deforestation and the remaining percentage of forest canopy in Petriky

RESULTS

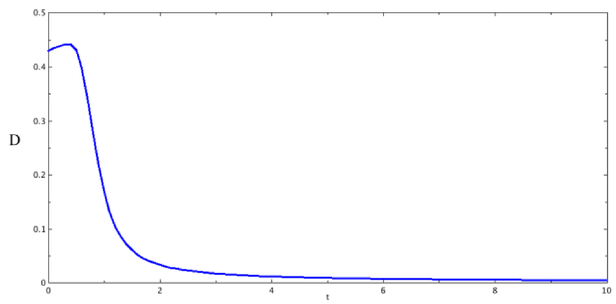


Figure 2. *Lemur catta* population density (D) in the Madagascar Petriky region over time in years (t), starting at 0.43 lemur/km^2 at time zero until extinction, affected by population growth and deforestation rates.

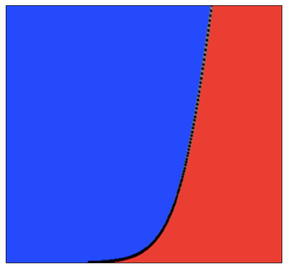


Figure 3. Bificuration diagram describing change change in *lemur catta* density (D) in the Petriky unprotected region and forest canopy density (F).

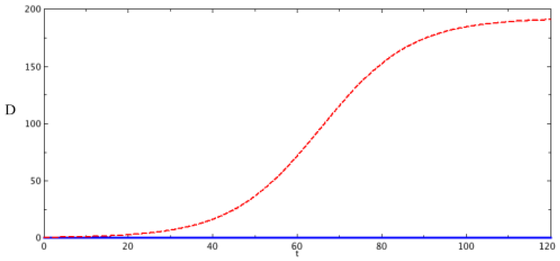


Figure 4. *Lemur catta* population density (D) in the Madagascar Petriky region over time in years (t) if deforestation stayed at the current rate of 3.05 percent where F'=3.05*F (blue) and if deforestation stopped where F'=0*F (dotted red).

RESULTS (cont.)

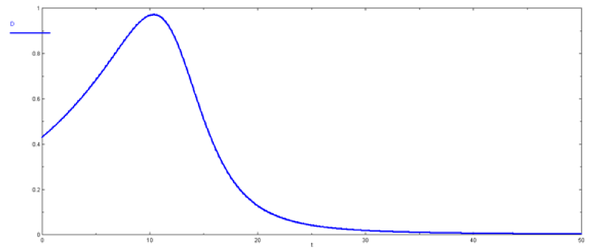


Figure 5. *Lemur catta* population density (D) in the Madagascar Petriky region over time in years (t), starting at 0.43 lemur/km^2 at time zero until extinction, affected by population growth and the proposed deforestation rates of -0.09 instead of the original -3.05 percent per year.

DISCUSSION

Determining Time of Extinction

- At current rates of deforestation, ring-tailed lemurs in this region will go extinct in approximately 1.18 years.

Preventing Extinction

- The only way to prevent ring-tailed lemurs from going extinct is to stop deforestation to allow for normal logistic growth of the ring-tailed lemurs to reach its carrying capacity.

Prolonging Survival by 20 years

- To prolong the life of the ring-tailed lemur population for another 20 years, the rate of deforestation needs to be reduced to a minimum rate of -0.09 percent per year.
  - The population will go extinct afterward, but 20 years may be enough time to find other solutions to preserve the ring-tailed lemurs.

Limitations to developed model:

- Assumed the population growth rate including natural births and deaths, predation, and illegal human hunting and the rate of deforestation to be constant, these processes are all dynamic.
- Study was only based on the Petriky region of southern Madagascar.

Future Direction:

- Application of model to any unprotected region in Madagascar for any lemur or animal that is at risk of extinction due to deforestation.

REFERENCES

"Kevbase Bifurcation Diagram Plotter." Bifurcation Diagram Plotter, kevbase.com/bifurcation/

"Ring-Tailed Lemur." Ring-Tailed Lemur: Lemur Catta, Duke Lemur Center, 2019, lemur.duke.edu/discover/meet-the-lemurs/ring-tailed-lemur/.

Big Green Differential Equation Machine. Digital file, Dartmouth College.

Gould, Lisa, and Michelle Sauther. "Going, Going, Gone…Is the Iconic Ring-Tailed Lemur (Lemur Catta) Headed for Imminent Extirpation?" Primate Conservation , vol. 30, 2016, pp. 89–101. green.blogs.nytimes.com/2011/12/15/madagascars-lemurs-sacred-no-more/.

Harper, Grady J., et al. "Fifty Years of Deforestation and Forest Fragmentation in Madagascar." Environmental Conservation, vol. 34, no. 04, 2007, doi:10.1017/s0376892907004262.

Nuwer, Rachel. "Madagascar's Lemurs, Sacred No More." The New York Times, The New York Times, 15 Dec. 2011,

Sussman, Robert W., et al. "A preliminary estimate of Lemur catta population density using satellite imagery." Ringtailed lemur biology. Springer, Boston, MA, 2006. 16-31.

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