Role of Gut Microbiome in Rock Ptarmigan Health and Population Cycles

Michelle Ramirez[1,2], Amanda Stromecki[2], Mario Muscarella[2,3,4]
[1]Biomedical Learning and Student Training [2]University of Alaska Fairbanks [3]Institute of Arctic Biology [4]Department of Biology and Wildlife

Objectives

- Examine microbial diversity in the Icelandic rock ptarmigan ceca.
- Explore the relationship between rock ptarmigan's microbiome and their health and population cycles.

Hypothesis

We hypothesize that the cecal microbiome plays a vital role in the overall health of Icelandic rock ptarmigan.

Preliminary Findings

- Some temporal shifts in species richness in cecal microbiome may relate to diet and body condition.
- Ptarmigan weight is independent of cecum length.
- Longer ceca length may relate to lower body condition and health

Introduction

Rock Ptarmigan (*Lagopus muta)*

- Medium-sized game bird found in sub-Arctic and Arctic regions.
- Lives in rocky habitats above the tree lines desolate of shrubs and vegetation in high Arctic or high-alpine tundra.
- Diet consists of catkins, seeds, insects, buds, and berries.
- Sometimes digest **chemically defended plants** that contain toxic plant secondary metabolites (PSM).

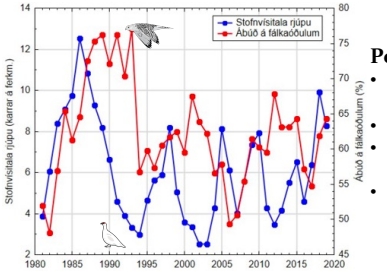

Figure 1: Ptarmigan and gyrfalcon population cycles in North-east Iceland (Nielsen 2023)

Population Dynamics

- May vary in cycle periods depending on geography and their ecological interactions.
- Multiannual cycles that fluctuate every 10-12 years.
- **Overall negative trend** in their cyclic patterns, especially in recent years in Iceland.
- Small game hunters and the gyrfalcon (*Falco rusticolus)* contribute to pattern, but ptarmigan health may also.

Cecal Microbiome (Gut)

- Ferments or breaks down the complex food molecules from the small intestine to the large intestine.
- Rich in microbes that play an essential role in processing of food in herbivores, especially ptarmigan.. Some help degrade PSMs.
- The efficiency depends on factors like food quality, cecum size, and residence time of dry matter, which controls how much energy used.
- There **is little known about the cecum's multifunctionality** and how it differs between species, ecological exchanges, and gut morphology.

Methods

Collect cecal samples (100 per yr.) for 10 years

Record health, demographic, and morphology measurements: weight, cecum length, age, etc.

Amplify 16s rRNA V3/V4 region using amplicon sequencing (DNA extraction, PCRs, library pools)

Quality checks and assessments with Mothur

Bioinformatics using R programming

Results

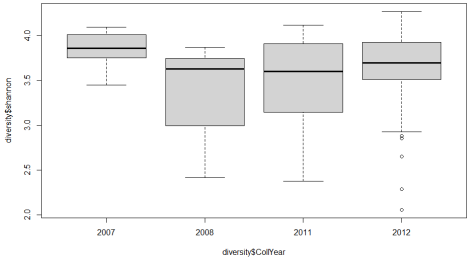

Figure 2: Using Shannon-Weiner diversity index: species diversity in each cecal content sample taken from collecting years of 2007, 2008, 2011, 2012.

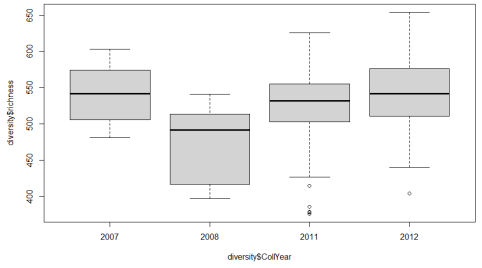

Figure 3: Total bacterial species in each cecal content sample taken from collecting years of 2007, 2008, 2011, 2012

References

Al Hakeem W, Acevedo Villanueva K, Selvaraj R. (2023). The Development of Gut Microbiota and Its Changes Following *C. jejuni* Infection in Broilers. *Vaccines*, 11(3), 595. doi.org/10.3390/vaccines11030595
Clench M, & Mathias J. (1995). The Avian Cecum: A Review. *The Wilson Bulletin*, 107(1), 93-121, https://sora.unm.edu/sites/default/files/journals/wilson/v107n01/p0093-p0121.pdf
Fuglei E, Henden J, Callahan C, Gilg O, Hansen J, Ims R, Isaev A, Lang J, McIntyre C, Merizon R, Mineev O, Mineev Y, Mossop D, Nielsen O, Nilsen E, Pedersen Å, Schmidt N, Sittler B, Willebrand M, & Martin K. (2020). Circumpolar status of Arctic ptarmigan:Population dynamics and trends. *Ambio*, 49(3), 749–761. doi.org/10.1007/s13280-019-01191-0
Gasaway W, Holleman D, & White R. (1975). Flow of Digesta in the Intestine and Cecum of the Rock Ptarmigan. *The Condor*, 77(4), 467–474. doi.org/10.2307/1366093
Nielsen, O. (2023). Rock ptarmigan. Icelandic Institute of Natural History. https://www.ni.is/en/fauna/birds/breeding-birds/rock-ptarmigan
Nielsen, Ó. (2011). Harvest and population change of Rock Ptarmigan in Iceland. Abstract. In *Gyrfalcons and ptarmigan in a changing world*, vol. II, ed. R.T. Watson, T.J. Cade, M. Fuller, G. Hunt, and E. Potapov, 71. Boise: The Peregrine Fund
Nielsen O, & Pétursson G. (1995). Population fluctuations of gyrfalcon and rock ptarmigan: analysis of export figures from Iceland. *Wildlife Biology*, 1(2), 65-71. doi.org/10.2981/wlb.1995.0011
Salgado-Flores A, Tveit A, Wright A, Pope P, & Sundset M. (2019). Characterization of the cecum microbiome from wild and captive rock ptarmigans indigenous to Arctic Norway. *PloS one*, *14*(3), doi.org/10.1371/journal.pone.0213503

Discussion

- No major significance between cecum length and alpha species diversity or weight and alpha species diversity.
- No significant difference in alpha diversity across years, which may indicate cecal microbiome structure is highly specialized.
- The lack of diversity in our findings seem to support other research that the cecum has less variability compared to other gut regions (Drovetski et al. 2019).
- Some temporal shifts in species richness in cecal microbiome may relate to diet and body condition.
- We've found that cecum length varies, while ptarmigan weight stays relatively the same for some samples.
- In juveniles, their ceca, on average, were longer compared to adults. They also had lower body condition and health metrics.
- The beta diversity of some samples did not have any differences between collection years.
- Without a complete analysis, our hypothesis is not supported yet, but foresee it being proven when finished.
- Analysis of the full dataset may reveal possible health factors that may relate to the cecal microbiome.

Future Directions

- More studies conducted on rock ptarmigan of other regions of the world that are seeing declines like Greenland.
- Use geographic information system(GIS), to track their scavenging patterns and relate the diet and habitat to the changes in the gut microbiome.
- Improve and run data for this large of a sample size at UAF. We would experience crashes, when trying to process more than 400 samples.
- Research the environment of rock ptarmigan and whether climate change impacts are affecting them or other bird species.
- Study further microbial communities in other parts of the gut microbiome.
- Better understanding of how the ceca fermentation process.

Acknowledgements

- Thanks to BLaST in mentoring my research journey.
- Thanks to Ólafur Karl Nielsen and Kristinn Pétur Magnússon from the Icelandic Institute of Natural History for the samples and processing.
- Thanks to Jennifer Forbey and Stephanie Galla at Boise State University with the GUTT project support of National Science Foundation grants.