Augustin Birot

Causes and consequences of the Yellow-Bellied Marmot's body mass in the last half century.

Background: Natural selection shapes an organism's phenotype to optimize its fitness within its environment (Darwin 1859). When environmental conditions change, species typically respond in one of two ways: they either disperse or adapt (Gienapp and Brommer 2014). Adaptation occurs through **phenotypic plasticity**, where a genotype can express different phenotypes depending on environmental conditions, or through **microevolution**, which involves shifts in allele frequencies within the population. while plasticity often provides a short-term solution, microevolution drives more permanent changes. Understanding how much each mechanism contributes to phenotypic changes is critical, especially in the context of climate change, where the consequences for populations could vary dramatically over time.

Researchers have suggested that global warming could lead to a universal decrease in body size, in line with Bergmann's rule on heat dissipation (Bergmann, C 1847; Daufresne et al. 2009). However, long-term evidence supporting this pattern is scarce (Gardner et al. 2011), and studies at higher latitudes have often produced contradictory findings (Guillemain et al. 2010; Sheridan and Bickford 2011; Yom-Tov et al. 2008). In Yellow-Bellied Marmots (YBM), *Marmota flaviventris*, which are the subject of on of the longest-running wild mammal population studies (more details in Armitage 2014), we observe an increase in body mass in the last decades. Initially, this shift was attributed to phenotypic plasticity resulting from milder environmental conditions and longer active season (Ozgul et al. 2010).

However, recent work has raised question about the use of **Integral Projection Model** (IPMs) in making evolutionary inferences (Chevin 2015; Janeiro et al. 2017). My preliminary research, using quantitative genetic analysis with the **Animal Model** in a Bayesian framework (**MCMCglmm**, Hadfield 2010), reveals a strong evolutionary signal alongside phenotypic plasticity. While the lengthening of the active season provides an ecological explanation for the observed plasticity, it does not account for the evolutionary changes. A longer active season should reduce selective pressure for larger body mass. Thus the aim of my PhD is going to rethink the evolutionary drivers behind the observed body mass increase in the last half-century in a wild YBM population. Then study the consequences of significant change in a life-history trait such as body mass in a hibernating species.

Research Questions (RQ) and Methods:

Significance and Impact:

References

Armitage, K. B. (2014), "Marmot biology." https://doi.org/10.1017/cbo9781107284272.

Bergmann, C (1847), "About the relationships between heat conservation and body size of animals," *Goett Stud*, 1.

Chevin, L. (2015), "Evolution of adult size depends on genetic variance in growth trajectories: A comment on analyses of evolutionary dynamics using integral projection models," *Methods in Ecology and Evolution*, (S. Ramula, ed.), 6, 981–986. https://doi.org/10.1111/2041-210X.12389.

Darwin, C. (1859), *The Origin of Species: By Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, Cambridge University Press. https://doi.org/10.1017/CBO9780511694295.

Daufresne, M., Lengfellner, K., and Sommer, U. (2009), "Global warming benefits the small in aquatic ecosystems," *Proceedings of the National Academy of Sciences*, 106, 12788–12793. https://doi.org/10.1073/pnas.0902080106.

Gardner, J. L., Peters, A., Kearney, M. R., Joseph, L., and Heinsohn, R. (2011), "Declining body size: A third universal response to warming?" *Trends in Ecology & Evolution*, 26, 285–291. https://doi.org/10.1016/j.tree.2011.03.005.

Gienapp, P., and Brommer, J. E. (2014), "Evolutionary dynamics in response to climate change," in *Quantitative Genetics in the Wild*, eds. A. Charmantier, D. Garant, and L. E. B. Kruuk, Oxford University PressOxford, pp. 254–274. https://doi.org/10.1093/acprof:oso/9780199674237.003.0015.

Guillemain, M., Elmberg, J., Gauthier-Clerc, M., Massez, G., Hearn, R., Champagnon, J., and Simon, G. (2010), "Wintering French Mallard and Teal Are Heavier and in Better Body Condition than 30 Years Ago: Effects of a Changing Environment?" *AMBIO*, 39, 170–180. https://doi.org/10.1007/s13280-010-0020-9.

Hadfield, J. D. (2010), "MCMC Methods for Multi-Response Generalized Linear Mixed Models: The **MCMCglmm** *r* Package," *Journal of Statistical Software*, 33. https://doi.org/10.18637/jss.v033.i02.

Janeiro, M. J., Coltman, D. W., Festa-Bianchet, M., Pelletier, F., and Morrissey, M. B. (2017), "Towards robust evolutionary inference with integral projection models," *Journal of Evolutionary Biology*, 30, 270–288. https://doi.org/10.1111/jeb.13000.

Ozgul, A., Childs, D. Z., Oli, M. K., Armitage, K. B., Blumstein, D. T., Olson, L. E., Tuljapurkar, S., and Coulson, T. (2010), "Coupled dynamics of body mass and population growth in response to environmental change," *Nature*, 466, 482–485. https://doi.org/10.1038/nature09210.

Sheridan, J. A., and Bickford, D. (2011), "Shrinking body size as an ecological response to climate change," *Nature Climate Change*, 1, 401–406. https://doi.org/10.1038/nclimate1259.

Yom-Tov, Y., Yom-Tov, S., and Jarrell, G. (2008), "Recent increase in body size of the American marten Martes americana in Alaska: GLOBAL WARMING AND BODY SIZE OF THE AMERICAN MARTEN," *Biological Journal of the Linnean Society*, 93, 701–707. https://doi.org/10.1111/j.1095-8312.2007.00950.x.