**ENVIRONMENTAL PREDICTABILITY AND LIFE HISTORY TRAIT EVOLUTION**

**Broad concept**

Fluctuating environments represent a major challenge for all organisms, because different environmental conditions impose varying and sometimes opposing demands on morphology, physiology and behaviour. This complicates reproductive decisions and sometimes heavily constrains life history strategies. Fluctuations in environmental conditions can be separated into regular changes (such as seasonal variation) and stochastic changes. To date, our understanding of the relative importance of these two types of environmental fluctuations in shaping life histories is limited. With this project, we (PI Nathalie Pettorelli, CoI Max Reuter and project partners Bram Kuijper, Hanna Kokko and Per Lundberg) will develop an integrated research programme that includes theory development, large-scale data analysis and experimentation to obtain a clear understanding of how seasonal and stochastic fluctuations in environmental conditions can shape life history traits of iteroparous species, paying particular attention to possible interactions between seasonal and stochastic fluctuations. This understanding is key for predicting species’ response to climate change, which incorporates both types of environmental variability.

**Background**

Seasonal and stochastic fluctuations represent two distinct types of environmental fluctuations; together, they shape environmental predictability. To some extent, both have been considered in studies of life history adaptations to environmental fluctuations, but typically the two types are considered in isolation. Work on life histories in seasonal environments mostly ignores stochastic environmental fluctuations, while studies focused on stochastic fluctuations and bet-hedging strategies (strategies that reduce the variance in fitness at the expense of a lowered arithmetic mean fitness) assume the absence of seasonal variation and have failed to incorporate the demographic effects that are crucial for understanding the evolution of life histories. As a consequence, we are still to assess the factors shaping the relative importance of these two components of environmental predictability in determining life reproductive strategies of iteroparous species. Filling this gap in our knowledge is crucial for understanding the fundamental forces that shape life organismal histories, as well as for our capacity to predict how species will respond to the shifts in the patterns of environmental fluctuations that are caused by climate change.

**Objectives**

This project addresses the above questions by investing how seasonality, stochastic environmental variations and their interaction shape life history strategies. This will be achieved through the completion of 3 interlinked Work Packages (WPs): WP1 will develop a unified theoretical framework that allows us to derive a clear set of predictions with respect to how seasonal and stochastic variation determine optimal life history traits. This set of predictions will then be tested using both correlative (WP2) and experimental (WP3) approaches.

**Methodology**

***WP1:* Environmental fluctuations and life history evolution - theoretical formulation.** Building on classical life-history theory and and more recent work on trait evolution under environmental fluctuations [e.g., 1] we will build models of life history evolution under varying degrees of seasonality and stochastic environmental fluctuations. Using both analytic approximations and stochastic simulations, WP1 will predict optimal life history traits (particularly, breeding synchrony, body size, litter size, generation time, and lifespan) in response to patterns of environmental variation. BRAM: ADD MORE

***WP2:* Environmental fluctuations and life history evolution - empirical exploration.** WP2 will empirically assess the relative role of seasonal and stochastic fluctuations in resource availability as factors shaping life history trait evolution (particularly body size, litter size, generation time, and lifespan) in iteroparous organisms. Based on the few empirical studies published so far, it is expected that, for a given level of seasonality, increased levels of stochastic fluctuations in resource availability will be associated with increased lifespan, increased adult body size and increased generation time, as well as reduced litter size. It is also expected that lifespan, adult body size, litter size and generation time will be more sensitive to changes in the level of stochastic fluctuations in resource availability as the level of seasonality in resource availability increases [2-4]. To test these predictions, a systematic literature search will first be performed using ISI Web of Knowledge. This survey will focus on mammals (due to the expected poor data availability on life history and phylogeny for other taxa) and gather population-level information on body size, litter size, generation time and lifespan. Resource availability dynamics will be indexed using the Normalised Difference Vegetation Index. Levels of seasonality and predictability in NDVI dynamics will be inferred using Colwell’s framework (as per [4]) and statistical decomposition of environmental variance into seasonal and stochastic components.

***WP3:* Environmental fluctuations and life history evolution - experimental validation.** WP3 will experimentally test the predictions generated in WP1 by assessing how environmental fluctuations drive adaptation in life history traits in the fruitfly *Drosophila melanogaster*. We will use an experimental evolution approach that imposes different levels of stochasticity in resource availability for adults (ranging from purely seasonal variation to completely stochastic resource levels) as well as varying correlations between adult and larval resource availability. We will investigate the evolutionary responses of replicated experimental populations to the above treatments, focussing on environment-dependent daily fecundity, egg size, adult body size, development time and lifespan. These life history traits are known to be highly associated with fitness in flies and are closely linked to the traits considered in WP1 and WP2. Data from experimental lines will be analysed to infer changes in the mean and variances of the different life-history traits, as well as their underlying genetics (heritabilities and genetic correlations, as well as the extent of parental effects). The results will be contrasted to the predictions of the models produced in WP1 as well as the large-scale associations observed in WP2.

**Research Plan & Project management**

The PI will have overall project management responsibilities and will be responsible for day-to-day supervision of the recruited post-doc for WP1 & WP2. The Co-I will have overall management of animal experiments and will be responsible for day-to-day supervision of the recruited post-doc for WP3; two technicians will be recruited to support W3. Project partners will be involved in all of the key project management aspects. We will schedule regular meetings (online and in-person) with them. The project partners will also provide technical support to the recruited post-doc during WP1 implementation.

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| **Hypothesis tested/Task** | **Year 1** | | | | **Year 2** | | | | **Year 3** | | | |
| Modelling work & publication (WP1) |  |  |  |  |  |  |  |  |  |  |  |  |
| Literature search and data compilation (WP2) |  |  |  |  |  |  |  |  |  |  |  |  |
| Life History Trait Modelling & publication (WP2) |  |  |  |  |  |  |  |  |  |  |  |  |
| Experimental calibration (WP3) |  |  |  |  |  |  |  |  |  |  |  |  |
| Experimentation (WP3) |  |  |  |  |  |  |  |  |  |  |  |  |
| Data analyses & publication (WP3) |  |  |  |  |  |  |  |  |  |  |  |  |

**References:** [1] Tufto (2015) Evolution 69: 2034-2049; [2] Roff (2002) Life history evolution, Sinauer Associates; [3] Stearns (1992) The evolution of life histories, Oxford University Press; [4] English et al. (2012) PLOS ONE 7(7), e41444;