Life-history, Selection and Effective Population Size shaping Evolution during Colonization – Lessons from *Drosophila melanogaster*.

Marta Santos [1,2] , Marjan Koosha [2] , Laurel K. Dang [2], Margarida Matos [1] & Michael R. Rose [2]

1 – Centro de Biologia Ambiental / Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa. Campo Grande, Lisboa. Portugal

2 – Department of Ecology & Evolutionary Biology, School of Biological Sciences, University of California, Irvine. Irvine, CA. USA

ABSTRACT

Consider the scenario where a population migrates to a new environment: it encounters qualitatively novel nutrition (possibly including periods in which it starves) and its effective population size is reduced in the course of migration or as a result of an initial lack of adaptation. How will the population's life history evolve and how will effective population size affect its evolutionary response to this new environment? If this population survives and its descendants migrate back to their ancestral environment, how will this preceding period of adaptation to a new environment affect its initial life history, upon return to ancestral conditions? To tackle these issues we used a highly replicated system of *Drosophila melanogaster* populations of known differentiated histories on which selection (both forward and reverse) was imposed with contrasting population sizes.

BACKGROUND

Natural Selection is able to produce rapid adaptive response to sustained environmental change under propitious conditions: intense **Directional Selection**, (Figure 1) abundant genetic variation, and large population sizes.

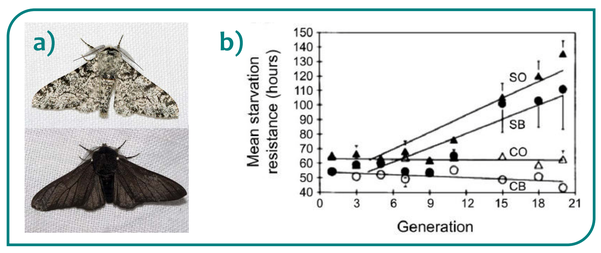


Figure 1. Examples of directional selection: a) In nature: melanism in *Biston betularia* during the industrial revolution [1, 2]; **b)** In the laboratory setting: clear increase in starvation resistance in response to selection of two independent, five-fold replicated outbred stocks of D*rosophila melanogaster* [3].

Reverse Evolution is the reacquisition by derived populations of the same character states as those of the ancestor population [4]. Figure 2 shows a 50-generation long reversion experiment by Teotónio & Rose (2000) with 4 different selective regimes of *D. melanogaster*, each 5-fold replicated.

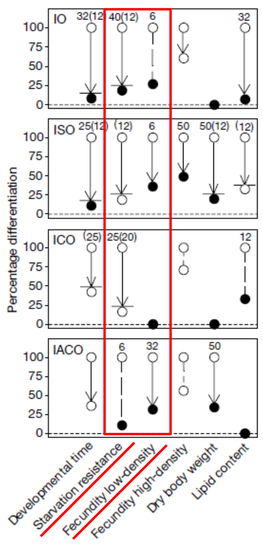


Figure 2. Teotónio & Rose experiment on reverse evolution, showing the percentage of differentiation from controls in several life-history traits. Notes: ● full convergence to the ancestral state; ○ non-convergence. Numbers above the character show the generation of convergence to the control levels, and numbers in parentheses show the generation at which a plateau was reached [5].

For starvation resistance and low-density fecundity, **reverse evolution occurred** despite the selection regime. Furthermore, populations selected for starvation resistance (*SO* regime) reached a plateau after 12 generations of reverse selection.

The **Effective Population Size** is a major factor affecting the evolutionary dynamics of fitness (Figure 3) and its components, being a constraint factor to adaptation to a new environment, namely during **COLONIZATION**.

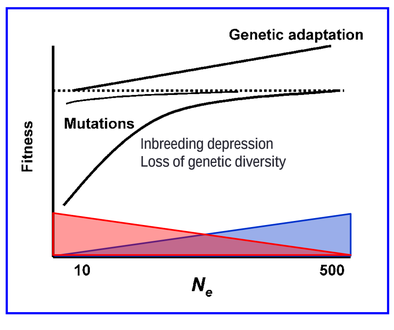


Figure 3. Relationship between fitness and population size (N_e) due to different genetic factors [6].

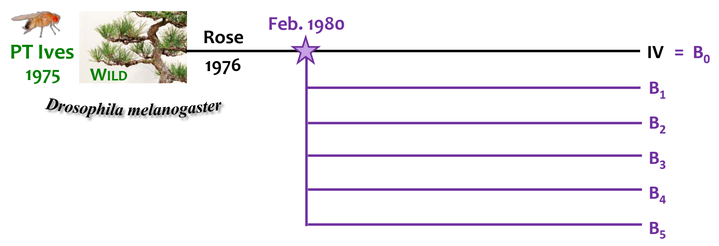
A population's performance and fate will depend on the establishment of an equilibrium between **Genetic Drift** and **Natural Selection**.

AIM OF THE PROJECT

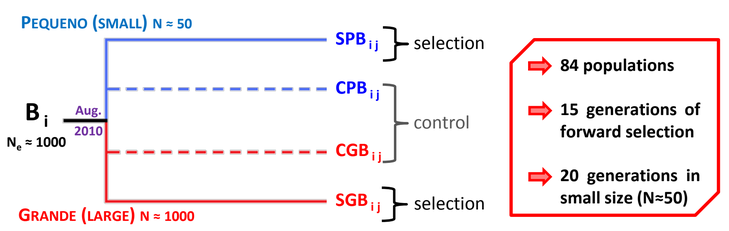
To study the **evolutionary dynamics** of sexual populations in a **colonization scenario** by:

- Analyzing the effect of **population size** on the rate of direct and indirect response to **forward selection**.
- Monitoring the effect of **sustained small population size** on the rate of response to **reverse selection**.

EXPERIMENTAL DESIGN

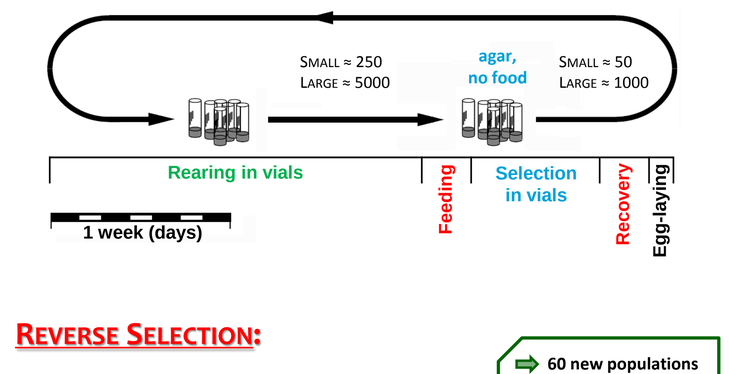


Forward Selection:



Selection Protocol:

© Gibbs, Chippindale & Rose, 1997 (adapted) [7]



Reverse Selection:

RESULTS

Both small and large-sized populations responded to **Forward Selection** for starvation resistance, showing evolutionary rates significantly different ***(p<0.02)*** between population size regimes, with a **lower** response in **small-sized populations** (Figure 4).

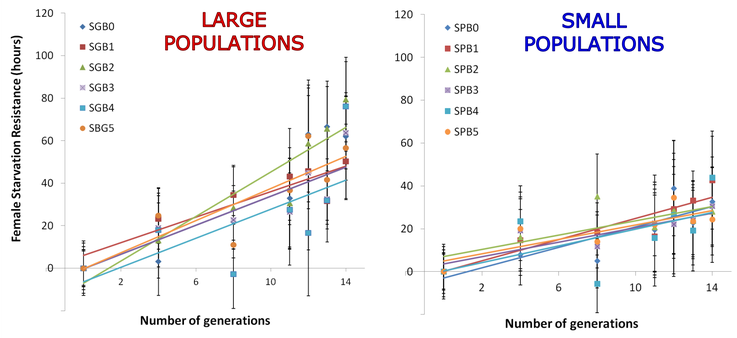


Figure 4. Direct response to forward selection for starvation resistance: a) In large populations and **b)** In small populations. Data shows the average values per B_i ancestor (difference to CGB_i controls). Vertical bars denote standard deviation of mean.

Early fecundity was used to measure the indirect response to selection (Figure 5). Small populations (**SPB**) showed significantly **higher fecundity rate** *(p<0.04)* than the large ones (**SGB**). This difference disappeared when the effect of inbreeding was removed by using a small-sized control (**SPB-CPB$_i$**).

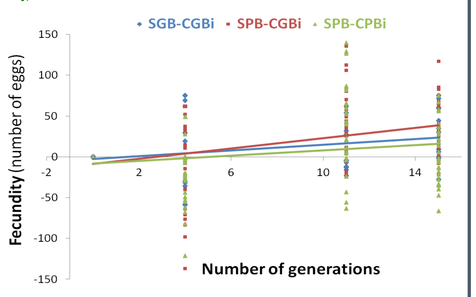


Figure 5. Indirect response to starvation resistance selection, in terms of early fecundity. Data shows the mean population value, using CGB_i and CPB_i controls.

The effect of sustained small population size on the response to **Reverse Selection** is shown on Figure 6. In every generation assayed, the selection lines were significantly different from the controls *(p<0.04)*, and this differentiation between regimes did not significantly change *(p>0.1)*.

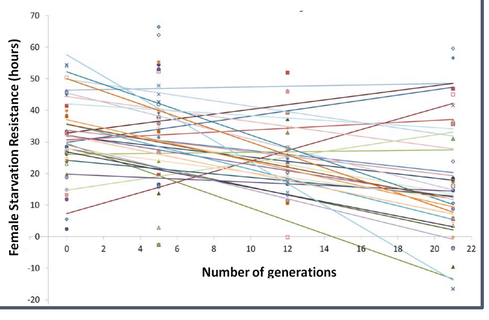


Figure 6. Direct response to reverse selection. Data shows the average value for each $RSPB_{ij}$-$RCPB_{ij}$ combination.

REFERENCES

[1] Tutt, J.W. (1896) British Moths. London. George Routledge and Sons

[2] Photo by Olaf Leillinger, 2006

[3] Rose, M.R., Vu, L.N., Park, S.U. & Graves, J.L. (1992) Selection for stress resistance increases longevity in *Drosophila melanogaster*. Experimental Gerontology **27:** 241-250

[4] Bull, J.J. & Charnov, E.L. (1985) On irreversible evolution. Evolution **39:** 1149-1155

[5] Teotónio, H. & Rose, M.R. (2000) Variation in the reversibility of evolution. Nature **408:** 463-466

[6] Woodworth, L., Montgomery, M., Briscoe, D. & Frankham, R. (2002) Rapid genetic deterioration in captive populations: Causes and conservation implications. Conservation Genetics **3:** 277-288

[7] Gibbs, A.G., Chippindale, A.K. & Rose, M.R. (1997) Physiological mechanisms of evolved desiccation resistance in Drosophila melanogaster. Journal of Experimental Biology **200:** 1821-1832

ACKNOWLEDGEMENTS

This study was partially financed by Marta Santos' PhD grant (SFRH/BD/46363/2008) from *Fundação para a Ciência e Tecnologia* and *University of California, Irvine*, UROP grants awarded to Marjan Koosha and Laurel K. Dang.

FINAL REMARKS

It is here demonstrated at a higher level of replication than ever before achieved, that:

- Effective population size limits the rate of response to **forward selection** – both directly (starvation resistance) and indirectly (fecundity).
- Sustained effective size also limits the response to **reverse selection**.

Experimental designs that use small laboratory populations should be confined to cases where the effects of low population size are of scientific interest.