Trends in Ecology & Evolution

Review

Conservation Evo-Devo: Preserving Biodiversity by Understanding Its Origins

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Unprecedented rates of species extinction increase the urgency for effective conservation biology management practices. Thus, any improvements in practice are vital and we suggest that conservation can be enhanced through recent advances in evolutionary biology, specifically advances put forward by evolutionary developmental biology (i.e., evo-devo). There are strong overlapping conceptual links between conservation and evo-devo whereby both fields focus on evolutionary potential. In particular, benefits to conservation can be derived from some of the main areas of evo-devo research, namely phenotypic plasticity, modularity and integration, and mechanistic investigations of the precise developmental and genetic processes that determine phenotypes. Using examples we outline how evo-devo can expand into conservation biology, an opportunity which holds great promise for advancing both fields.

The Timely Merging of Evo-Devo and Conservation Biology

Contemporary rates of species extinction are unprecedented and are predicted to continue to increase [1,2]. Such high extinction rates are largely attributable to anthropogenic disturbances, with conservation biology providing the theoretical and practical framework underpinning actions for the mitigation of biodiversity loss [3,4]. Conservation is an integrative field and has been notably enhanced by beginning to adopt evolutionary biology. This was especially the case during the 1990s when population genetics emerged and allowed the examination of gene flow within and among populations [5–7]. However, since this time evolutionary biology has itself been extended with the emergence of evolutionary developmental biology (i.e., evo-devo) mostly also during the 1990s. Evo-devo emerged to describe and understand how developmental processes bring about variation and change through evolution. Because evo-devo was still being established in the 1990s its interaction with conservation was not a priority nor likely possible.

With evo-devo now firmly established we contend that it can be used to understand how anthropogenic forces that impact on environmental variation ultimately impact on populations [8–12] (Figure 1). What currently seems to be underappreciated in the context of short temporal timescales is that shifts in environmental conditions should directly alter development both within and between generations by modifying how the phenotype relates to the genotype [i.e., the **genotype–phenotype (G–P) map**; see Glossary]. Such developmental changes should therefore significantly impact on the efficiency, rate, and direction of contemporary evolution [13]. Therefore, understanding what drives and underlies these developmental shifts could provide predictive insights into the evolutionary effects of anthropogenic disturbance. Such insights could indicate to managers which heritable variation should be targeted for protection

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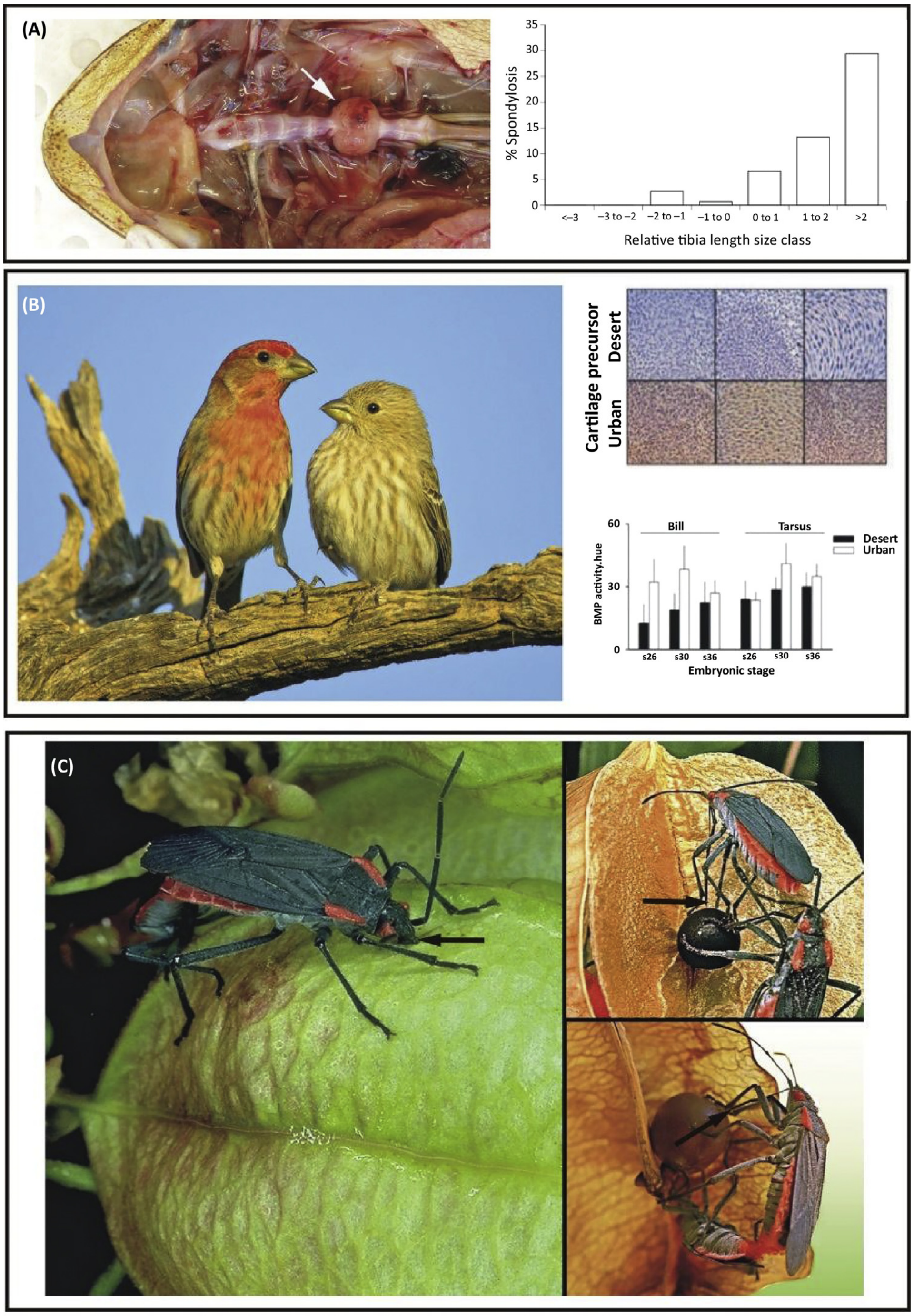

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Figure 1. Anthropogenic Change through the Lens of Evo-Devo. Environments induce evolution that can be measured through development. (A) Invasive cane toads (*Chaunus marinus*) develop spinal arthritis (left panel arrow) at far higher levels on the leading edge of the invasion where tibia length is significantly longer (right panel). This suggests an alteration of phenotypic integration between leg length and spines has a detrimental impact (photo courtesy of Greg Brown) [69]. (B) House finches (*Carpodacus mexicanus*) display divergence in bill morphology that corresponds to urban and desert habitats. The elevated levels of bone morphogenetic proteins (BMPs) during early bill morphogenesis, indicated by sections of bill primordia tissue with deeper staining in the upper right panel, are associated with the larger-beaked urban population. This is corroborated by quantitative measures of gene expression over development (lower right panel)

(See figure legend on the bottom of the next page.)

Glossary

Evolvability: the capacity of a population to produce adaptive variation through routes including mutation, standing genetic variation, and the input of environmental cues. Not to be confused with heritability, which is a measure of the total additive genetic variance.

Functional genetics: a branch of genetics which investigates the properties and functions of genes and gene variations often in relation to phenotypes.

Genotype–phenotype (G–P) map: a metaphor for how the genotype relates to the phenotype. The G–P map is dynamic and can change depending upon the environment or ontogenetic stage of an organism.

Modularity: a module is a group of tightly correlated traits which are relatively independent from other such modules.

Niche construction: refers to how an organism can modify a community and in turn their own niche or the niche of other organisms.

Phenotypic integration: the correlation between phenotypic traits. This can be the result of developmental and functional interactions between traits that evolve.

Phenotypic plasticity: the ability of a single genotype to create multiple phenotypes through developmental responses to environmental cues.