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Managing Phenotypic Variability with Genetic and Environmental Heterogeneity: Adaptation as a First Principle of Conservation Practice

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Seasons pass, succession proceeds, landscapes rise and erode. Species invade and disappear. All life experiences and is part of continual environmental flux. Environmental variation, coupled with the changing states of organisms themselves, generates tension between the design and performance of individuals. Across populations, we witness remarkable patterns of adaptation that emerge on brief timescales (see, for example, Benkman, this volume), yet no individual member of a population shows the best response to all circumstances. Many factors limit the degree and form of adaptation, including history, genes, environment, development, experience, decisions, and fortune. It follows then that a combination of variation—within individuals, among individuals, and among subpopulations—will determine a population's adaptability and resilience to environmental change (Boulding, this volume; Reed, this volume).

In contrast to predictably cyclic phenomena such as daily or seasonal rhythms, substantial and persistent shifts in environmental regimes have been comparatively rare (Vermeij, this volume). We are now in an epoch in which human-induced change is a force of extraordinary and enduring influence (Palumbi, 2001b). Altered climates, overharvesting, and introductions of exotic species have stressed many populations irretrievably. Population declines as well as local and global extinctions are sure signs of a failure to adapt (Gomulkiewicz & Holt, 1995), a consequence of which is the biodiversity crisis.

Recent discoveries in biology suggest that evolution is not best viewed as a strictly historical process, but rather as ongoing. Thus, evolution in response to global change phenomena, such as shifting seasonality and species introductions, changes the character of many organisms. Several well-known cases of "rapid evolution" during the middle 20th century, such as industrial melanism in peppered moths and heavy-metal tolerance in plants on mine tailings, were originally regarded as exceptional results of unnaturally high selection pressures. Although this interpretation may have been fair at the time, we now know that these cases were harbingers of the present. Such adaptive evolutionary events are now commonplace, occurring on timescales traditionally thought of as *ecological*. As examples accumulate, it remains clear that many cases of rapid evolution involve some degree of anthropogenic perturbation. Indeed, analyses by Hendry et al. (2008) indicate that human influences are especially potent agents of phenotypic change in contemporary animal populations.

The unanticipated fact of contemporary evolution in disturbed populations raises both interesting dilemmas and opportunities for biological conservation. Historically, protection and restoration of habitats and populations have been paramount and practiced in isolation from evolutionary concerns. Now, however, more and more species no longer genetically "match" their recent ancestral, less-disturbed habitats. Just as conservation biology