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Quantifying individual variation, selection, and additive genetic variance in migration versus residence with full-annual-cycle capture-recapture models

Seasonal migration is a key trait that underpins spatio-seasonal population dynamics and allows individuals to escape from temporarily hostile environments. Global changes are altering patterns of spatio-seasonal environmental variability, including increasing frequencies of extreme climatic events ('ECEs'). Yet, the potential for changing migration to mediate rapid eco-evolutionary responses remains largely unknown. In "partially migratory" populations, different individuals may undertake different tactics, such that they are resident or migrant throughout the non-breeding season, or express a mix of both phenotypes given late migration and/or early return to residence. Further, individuals may repeat or change their tactic across years. Phenotypes expressed within years and resulting annual tactics may be subject to survival and reproductive selection, and eco-evolutionary consequences will depend on the magnitude and form of phenotypic plasticity and additive genetic (co)variances. Quantifying all these components of variation in migration versus residence can be achieved using multi- year year-round resightings of marked individuals within partially migratory populations. Such data require advanced capture-recapture models to allow inference on parameters underlying phenotypic dynamics while accounting for spatio-temporal heterogeneity in re-encounter probabilities. Accordingly, we devised a suite of novel discrete-time full-annual-cycle models. Depending on the target parameters, we represented phenotypic variation as resulting from either a simple first-order Markovian multistate process, a dynamic finite mixture of annual tactics, or threshold-trait expression underlaid by continuous variation in latent individual liability. We fitted these models to large-scale ring-resighting, breeding success and pedigree data from adult European shags (Gulosus aristotelis) monitored over 12 years encompassing three winters with ECEs. We show patterns of substantial individually varying within- and between-year plasticity in migration versus residence. Yet, we found high phenotypic repeatability dominated by permanent environmental effects but also due to non-negligible additive genetic variation. Further, we demonstrate strong fluctuating selection caused by episodes of opposing survival and reproductive selection. Residents typically had higher fitness than migrants due to higher breeding success, but they had lower fitness in ECE years due to lower survival. ECEs also caused large year- and sex-specific variation in selection on within-year plasticity. Overall, our results highlight the potential for seasonal migration to shape complex eco-evolutionary dynamics.