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# Fitness components of avian migration: A dynamic model of Western Sandpiper migration

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## ABSTRACT

Western Sandpipers, *Calidris mauri*, one of the world's most abundant shorebird species, migrate from winter sites in the southern USA and Central and South America to breeding grounds in Western Alaska and Eastern Siberia. We describe a dynamic state variable optimization model for these migrations, assuming that individual female sandpipers employ migration strategies that maximize their expected lifetime reproduction. The principal environmental factors assumed to affect migration decisions are variable wind speeds, site-specific predation risks, and the timing of food availability on the breeding grounds and at the two most northerly stopover sites. The model's predictions, which agree closely with data collected in the field, are most sensitive to changes in wind conditions during the flight phase, rather than foraging opportunities at stopover sites en route. We also show how the model can be used to assess potential impacts of habitat degradation on the fitness of this species.

*Keywords*: avian migration, dynamic optimization models, habitat degradation and fitness loss, predation risk, Western Sandpipers.

## INTRODUCTION

Many environmental factors affect avian migration, including spatial and temporal variations in food availability, winds and weather, predator abundance, and breeding opportunities (Alerstam, 1990). Natural selection has presumably moulded migratory patterns so as to maximize individual fitness. Optimization models can help to assess our understanding, for particular species, of the relative importance of these multiple environmental factors.

Early optimization models of avian migration addressed isolated aspects of migration, such as flight speed and direction (Alerstam, 1979, 1991; Hedenström and Alerstam, 1995; Liechti, 1995) and fuel loads (Weber *et al.*, 1994; Weber and Houston, 1997). The need for more inclusive models has also been recognized (Alerstam and Lindström, 1990; Ens *et al.*, 1994).

The technique of stochastic dynamic programming (Mangel and Clark, 1988) allows the inclusion of multiple factors in a single model (Weber *et al.*, 1998; Farmer and Wiens,

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