Lower Predation Risk for Migratory Birds at High Latitudes

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Quantifying the costs and benefits of migration distance is critical to understanding the evolution of long-distance migration. In migratory birds, life history theory predicts that the potential survival costs of migrating longer distances should be balanced by benefits to lifetime reproductive success, yet quantification of these reproductive benefits in a controlled manner along a large geographical gradient is challenging. We measured a controlled effect of predation risk along a 3350-kilometer south-north gradient in the Arctic and found that nest predation risk declined more than twofold along the latitudinal gradient. These results provide evidence that birds migrating farther north may acquire reproductive benefits in the form of lower nest predation risk.

Life history theory predicts that the costs of migration must be compensated for by benefits to lifetime reproductive success (1, 2). Costs of migration include the metabolic and energetic requirements of flight (3), high mortality risk (4, 5), and exposure to extreme weather events (6, 7). Such negative effects are expected to be important for migrant birds that breed in the Arctic, where severe weather events during migration or upon arrival at the breeding grounds can lead to poor body condition, breeding failure, complete reverse migration, and even death (8). Bird migration patterns have been thought to be determined mainly by food availability (9), habitat-related parasite pressures (10), and predation risk during migration (4).

Arctic-nesting birds exhibit some of the most impressive migratory strategies, such as flying from wintering areas at the southern tip of southern America, southern Africa, and Oceania to their breeding grounds in the Arctic (11, 12). The physiological costs of migrating to and breeding at these arctic sites have been well documented for species such as shorebirds (7, 13, 14). Birds could reduce these costs by breeding at more southerly latitudes, thereby decreasing both migration costs and the metabolic costs of breeding in the extreme Arctic environment. However, if competition for food resources, risk of parasite infection, and predation at southern sites are high, then increasing migration distance could have reproductive and survival benefits. Potential fitness benefits of breeding at higher latitudes have been quantified in terms of reduced parasite loads (15) and greater food availability due to longer daylight hours (16). Reduced predation at higher-latitude sites has yet to be quantified. Predation risk has emerged as a dominant force in the evolution of avian life history, influencing the selection of nest sites and underlying latitudinal clines in the clutch size of passerines (17). We thus predicted that the risk of nest predation could also play a key role in balancing the costs of long-distance migration. If so, we would expect a negative relationship between nest predation risk and latitude in Arctic ground-nesting shorebirds. To test for this relationship, we systematically measured predation risk by monitoring predation on eggs placed in 1555 artificial nests for a minimum of two summers at seven shorebird breeding sites (table S1) (18) over a latitudinal gradient of 29° (~3350 km) from sub-Arctic to high-Arctic regions of Canada (Fig. 1).

As predicted, nest predation risk was negatively correlated with latitude. For an increase in 1° of latitude, the relative risk of predation declined by 3.6% (coefficient –0.0360, SE 0.0045, χ² = 63.77, P ≤ 0.0001; Figs. 1 to 3). This equates to a decrease in predation risk of 65% over the studied latitudinal transect of 29°. Previous studies investigating latitudinal trends in predation risk on the nests of temperate-breeding neotropical migrants failed to detect any clear south-north gradient (21). These differences in results could be attributed to differences in real patterns of predation risk between temperate versus Arctic environments, or they could be due to differences in...
methodological approaches. In our study, artificial nests enabled us to measure a standardized predation risk, as opposed to the nest success of real nests, which is affected by several factors other than predation pressure (for example, parent birds can compensate for an increased risk of predation by increasing the defense of their nest (12)).

These results provide evidence that the costs of migrating farther north could be compensated for by decreases in predation risk at higher latitudes. However, a lower predation risk at higher latitudes really compensate for the increased migration distances and increased metabolic harshness experienced by high-Arctic-nesting species? Though we may have good estimates of the energetic costs of flying (23) and how standard metabolic rates change with latitude (they increase by 1% per degree of latitude) (24), we still lack the basic understanding of how these variables affect adult survival. The apparent cost associated with migrating to Arctic breeding areas is indicated by the reduced survival of adults that fail to achieve adequate condition before leaving the last spring staging area (7, 13); however, it is not known whether the increased mortality is associated with migration, breeding, or both. To explore these trade-offs, we require better estimates of demographic parameters for birds breeding at various latitudes, so that we can model the contrasting effects of adult survival versus reproductive components. By combining studies on marked individuals with systematic sampling of ecological conditions experienced on the breeding grounds, we will be better able to link individual itineraries with life history events, thus improving our theoretical understanding of the ecology and evolution of long-distance migration.

Fig. 2. Kaplan-Meier survival probabilities over 9 exposure days for artificial nests by site for all years during early (A) and late (B) shorebird incubation periods. Each data point on the curve represents the Kaplan-Meier survival estimate at time t (±SEM), which provides the probability that eggs in a nest will survive past time t. Survival probabilities are based on 2 to 4 years of data per site (see table S1 for details (18)).

Fig. 3. Mean failure time in days (±SEM) for depredated artificial nests by latitude for all years during early (open circles) and late (solid circles) shorebird incubation periods. Low mean failure times indicate rapid nest loss (high predation risk). Each data point is based on 2 to 4 years of data per site [see table S1 for details (18)]. Overlapping data points for Bylot Island (73° N) have been offset by ±0.2°.

References and Notes

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