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FLIGHT MODIFICATIONS

Every year, billions of large moths and butterflies migrate seasonally from the Mediterranean basin to northern Europe and back again, using high-altitude winds to reach their destinations faster. But they don't ride along passively on wind currents; when necessary, they actively modify their flight by adjusting their heading with respect to the direction of travel. This is the conclusion of a study published in *Science* (5 February 2010) by a group of UK entomologists led by Jason Chapman, of Rothamsted Research, in Hertfordshire, United Kingdom.

These researchers track spring and fall insect migrations using vertical-looking radar (VLR), which detects insects passing 150 to 1200 meters (m) above the ground (for details, see *BioScience* 53: 503–511). When analyzed, the recorded signals provide data on insect size, shape, direction, speed, and orientation. From 2000–2007, during spring and fall months, the team collected and analyzed VLR signals from two locations in southern England, amassing data on more than 100,000 insects from 569 separate mass migrations.

Chapman and his colleagues identified four main participants in these migrations: two noctuid moth species (*Autographa gamma* and *Noctua pronuba*) and hawkmoths (Sphingidae), which all migrate at night, and butterflies, which travel during the day. The noctuids were the most abundant insects found traveling at night, and the hawkmoths were the largest. The most likely daytime migrants, yet to be confirmed, were red admiral (*Vanessa atalanta*) and painted lady (*Vanessa cardui*) butterflies.

The four insect groups were nearly always found to be moving directly north in spring, benefiting from strong southwesterly winds. The migrants on the whole were oriented downwind, but when winds were more than 20 degrees away from their preferred northerly direction, they shifted orientation to compensate. Likewise, fall migrants moved southward on prevailing easterly winds, and they made a similar shift in orientation to compensate for any strong (> 20 degree) crosswind drift. Travel speeds averaged 15 m per second (54 kilometers [km] per hour) and ranged as high as 28 m per second (100 km per hour), allowing the migrants to make their 800-km-plus trip in just a few days.

The scientists compared the trajectories of simulated *A. gamma*-like flight and windborne particle transport using an atmospheric dispersion model. The modeled moths were constrained to the altitude with the fastest wind speed, which is what live *A. gamma* moths have been demonstrated to choose, and had a 5-m-per-second southward vector, also typical of *A. gamma*, added to their flight. After an 8-hour flight, representing a single night for *A. gamma*, the simulated moths were less dispersed, had traveled 40 percent farther, and were significantly closer to the migratory track than the inert particles.

WING ADAPTATIONS

Monarch butterflies are renowned for migrating long distances, but what may be overlooked is that not all populations of monarchs migrate. Some travel relatively short distances, and some don't migrate at all. University of Georgia ecologists Sonia Altizer and Andrew Davis recognized the research opportunity this presents. They analyzed wild-caught and lab-reared representatives from these different populations and found that the wings of migratory monarchs are longer and larger than those of nonmigrants. Their study appeared in *Evolution*'s "Early View," published online 11 January 2010.

The largest population of monarchs *(Danaus plexippus)* breeds in eastern North America and travels thousands of kilometers to and from overwintering grounds in central Mexico. A smaller population in western North America migrates between the Rocky Mountains and the central California coast. Monarch populations in tropical and subtropical regions tend to stay put and breed year-round, although there may be some gene flow with migrants that pass through.

Altizer and Davis measured wing traits of wild adults from the two migratory North American populations (eastern and western) and from four nonmigratory populations (South Florida, Hawaii, Costa Rica, and Puerto Rico). They also analyzed butterflies from three North American populations (South Florida, eastern, and western) reared in captivity under identical conditions. They crunched these measurements into two variables, representing forewing size and shape, to run comparative analyses.

They found that forewings of eastern migrants were significantly larger than those of western migrants, and both of these groups had larger forewings than all four nonmigrant groups. In terms of shape, the breakdown was slightly different: the wings of eastern migrants and Hawaiian nonmigrants were the most elongated; South Florida nonmigrants and western migrants had slightly less elongated wings. The Costa Rica and Puerto Rico populations had the smallest, roundest wings of all.

Captive breeding experiments yielded similar forewing size and shape rankings for the three populations studied, showing that the differences in wing morphology have a significant genetic component. The experiments also examined body size to infer wing loading (the ratio of body mass to wing area) and energy storage. Eastern monarchs surpassed the other two groups in body size as well, suggesting that they utilize powered flight and are well adapted to traveling long distances. Although this study did not rule out other possible causes of size differences between populations, results indicate that North American migratory monarchs, currently threatened by habitat loss and climate change, are evolutionarily unique.

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