30-year puzzle solved: Light guides flight of migratory birds

Songbirds use multiple sources of directional cues to guide their seasonal migrations, including the Sun, star patterns, the earth's magnetic field, and sky polarized light patterns. To avoid navigational errors as cue availability changes with time of day and weather conditions, these "compass" systems must be calibrated to a common reference. Experiments over the last 30 years have failed to resolve the fundamental question of how migratory birds integrate multiple sources of directional information into a coherent navigational system.

Last autumn, Rachel Muheim, a postdoctoral associate in biology professor John Phillips' lab at Virginia Tech, captured Savannah sparrows in the Yukon before they headed south. She was able to demonstrate that the birds calibrate their magnetic compass based on polarized light patterns at sunset and sunrise.

The research appears in the Aug. 11, 2006, issue of *Science*, in the article, "Polarized Light Cues Underlie Compass Calibration in Migratory Songbirds," by Muheim, Phillips, and Suzanne Akesson. Muheim did her Ph.D. work at Lund University in Sweden with Akesson, who made the Alaska trip possible.

Polarized light is light that oscillates in one plane relative to the direction of propagation. At sunrise and sunset, there is a band of intense polarized light 90 degrees from the sun that passes directly overhead through the zenith and intersects the horizon 90 degrees to the right and left of the sun. Just as the sun location changes with latitude and the time of year, so does the alignment of the band of polarized light.

Muheim and Phillips argue that migratory songbirds average the sunrise and sunset intersections of the polarization band with the horizon to find the north-south meridian (geographic north-south axis), providing a reference that is independent of time of year and latitude. The birds then use this geographic reference to calibrate their other compass systems.

In other words, polarized light, the Sun and stars, and the geomagnetic field are all directional cues for migration, but polarized light appears to provide the primary reference system used to calibrate the other compass systems, said Phillips.

However, previous research had suggested a much more confusing picture.

Migratory birds are born with an innate magnetic compass preference that coincides with their species' migratory direction. Previous research suggested that before the migration period, songbirds are able to recalibrate the magnetic compass when exposed to a "conflict" between magnetic and celestial (including polarized light) cues, but during migration it appeared that the reverse was true, -- the magnetic field was used as the primary reference for calibrating the birds' other compass systems. But in a few experiments with birds during migration, the birds did recalibrate the magnetic compass.

When Muheim and Phillips did a literature review, they noticed a difference between the experiments of the few scientists who saw migratory birds recalibrate their compass and of those whose birds failed to recalibrate.

"It is important how you do the experiments. It turns out that the part of the sky that matters is just above the horizon," said Phillips. "In cue conflict experiments carried out before migration, birds were usually housed in outdoor aviaries in a rotated magnetic field, where they had a view of the whole sky, including the horizon. Once migration starts, however, scientists usually exposed birds in "funnel cages". This is so, after exposure to the cue conflict, the birds' directional preferences could be recorded; songbirds in migratory condition leave tracks or scratches on the sides of the funnel as they attempt to take flight in the migratory direction. A problem arises, however, because funnels block the lower 20 degrees of the sky. In the only two experiments (out of 30 or so) carried out during migration where birds were exposed to the cue conflict with a view of the horizon, they did recalibrate their magnetic compass -- just as was previously observed only in experiments carried out prior to migration."

Muheim's experiments proved that seeing polarized light cues near the horizon was the critical factor. "Once the right hypothesis came along, it all fit," said Phillips.

The research provides support for an observation Phillips had published 20 years ago. In the mid 1980s, he was doing research to determine how homing pigeons navigated. There was a theory that wind-borne odors provide pigeons with information about the locations of odor sources, which could then be used to determine their position relative to the home loft when they were released at an unfamiliar site. The birds were housed in a loft with a "pinwheel" arrangement of deflector panels attached to the four screened walls of the loft to rotate direction of the wind. Pigeons housed in the so-called "deflector lofts" showed the predicted (clockwise or counterclockwise) deflection of homeward orientation when released at a distant site. It turned out, however, that the panels influenced the distribution of polarized light patterns at sunset and sunrise, and it was the altered polarization patterns, rather than olfactory cues, that produced the directional biases. Moreover, the effect appeared to result from recalibration of the sun compass. Phillips published the research in the Journal of Theoretical Biology (1988, volume 131). "I've felt every since that this was the key to understanding the integration of compass information in migratory birds" he said.

Source: Virginia Tech