THE STUDY OF MIGRATION:
DISCOVERING HOW BIRDS FIND THEIR WAY

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The history of science is replete with cases in which the development of new technology (equipment or techniques) opened the door to rapid progress in some area of research. The invention of the microscope yielded access to a world which, though previously unseen, profoundly affected human existence. Techniques of electrophoresis were applied (in the 1950s) to questions of how much genetic variability exists in populations and gave rise to unforseen and revolutionary results. Likewise, in the study of bird migration, new methodology, some of it discovered quite by accident, has often led to explosive advances in our understanding of that subject.

In their broadest outlines, most of the basic descriptive facts about bird migration have been known for a long time. Some species (such as swallows, blackbirds, many finches, Blue Jays and soaring birds that take advantage of thermals) migrate by day, others (such as flycatchers, vireos, warblers, and sparrows) almost exclusively at night. The seasonal timing and routes taken have been determined for many populations through banding and recapture studies. The propensity for individuals of many species to return to precise breeding and wintering localities has been documented. In our attempts to understand the mechanisms responsible for these behaviors, however, we have often found ourselves limited, not by the ability to pose the right questions, but by the lack of efficient means to answer them.

Moonwatching. Most migratory birds perform their travels at night. This places obvious impediments in the path of a researcher who wishes to observe what they are doing. Over three decades ago, a window into this world was opened when George Lowery and Robert Newman of Louisiana State University elaborated on the old idea of watching birds pass in silhouette across the disc of the moon. Now, at least on clear nights around the full moon, one could estimate the flow of migration over an area and catalog the flight directions of the birds. If enough observers could be fielded simultaneously, a broad regional picture might be pieced together.

[1] When requested to contribute an article on migration for Bird Observer, Dr. Able suggested that we ask the Point Reyes Bird Observatory (PRBO) for permission to use this paper, published in the spring 1983 PRBO Newsletter under the title, "The Limits of Technology." PRBO, located at 4990 Shoreline Highway, Stinson Beach, CA 94970, is a non-profit, membership organization that conducts long-term research on birds and marine mammals, offers varied education programs, and works toward the solution of selected conservation problems. They have given BOEM permission to reprint this article.

Illustration by Denise Braunhardt

A rush of new information resulted. Direct empirical evidence was obtained that birds do indeed fly across the Gulf of Mexico. Observations made throughout the night showed that most birds destined to migrate on a given night take off shortly after dark. The number of birds aloft reaches a peak before midnight and gradually declines thereafter as individuals descend and land. By dawn virtually no birds remain in the sky.

Perhaps most illuminating were coordinated observations made over much of eastern North America. Regional similarities suggested that nocturnal migration did not concentrate along narrow flyways as previously thought, but rather occurred on a broad front. Without a means of directly observing nocturnal migration, this pattern would have been very difficult to discover. Moonwatching also added support to the conclusion emerging from field observation of migrants on the ground that the volume of migration on a given night is strongly related to weather conditions.

As revolutionary as the moonwatching data were, the technique had some significant limitations. The obvious constraints of cloud cover and moon phase limited the number of nights on which observations could be made. Enormous amounts of tiresome labor were required to collect the data and in those pre-computer days, analysis of the great mass of numbers was even more time-consuming. Some of these problems were overcome when Sidney Gauthreaux, then a student of Lowery and Newman, developed the portable ceilometer technique in which a beam of light is pointed vertically into the sky. Now, instead of being viewed in silhouette, the birds are dimly illuminated from below and observed with binoculars, telescope, or more sophisticated night vision equipment. The components involved are inexpensive, highly portable (the lights can be operated off a car battery), and the technique can be used on many more nights than moonwatching. Yet it gives comparable quantitative data on the magnitude of low altitude migration and flight directions.

Angels. Even with teams of cooperative observers, however, these visual methods gave one the feeling of peeping through a keyhole. If only we could walk into the room and see everything that is happening. A serendipitous discovery during World War II brought us as close to this possibility as we shall probably ever come. British radar surveillance technicians rather frequently observed echoes on their screens which could not be attributed to aircraft, weather, or ground targets. Because of their ephemeral nature and the inability of military personnel to identify them, the echoes were dubbed "angels," a term still applied to anomalous returns on radar scopes. But the appearance and movements of these original angels were not random. The great British ornithologist, David Lack, analyzed some radar films and realized that the timing and directions of the movements were remarkably coincident with those of migratory birds. This discovery opened the way for the era of radar ornithology in which such names as Sutter, Gehring, Lack, and Eastwood in Europe, and Bellrose, Drury, and Nisbet in North America were prominent.

Radar works much like a searchlight, but instead of a beam of light, a beam of microwave energy is emitted. A minute amount of this energy is reflected back from appropriate objects in the air space, and is detected as an "echo" by the receiving unit of the radar. Water is highly reflective of radar wavelength energy, and for that reason rain and birds (whose bodies contain much water) are readily detected. With long-range surveillance and weather radars, movements of birds could be seen in all directions and at ranges of tens or even hundreds of miles. Problems of estimating the number of birds seen by a radar scan have remained bothersome. A given blip on the screen might contain many birds, but at least it was now possible to view simultaneously the vast sweep of migration over an entire region. Another explosion of information ensued over the next twenty years or so.

The general validity of the broad-front view of night migration was confirmed. Unlike diurnal migrants which often follow coastlines, ridges, and other conspicuous landmarks, night migrants largely ignore such features on the ground. We could now estimate fairly precisely the height and flight speed of migrating birds, and there were surprises on both scores. The majority of night migrants fly at quite low altitudes; on most nights the bulk is below 3000 feet. And the speed at which they fly, without any wind effects, is often no more than 25 mph. The influences of weather now became abundantly clear. Even during peak season, the volume of migration often varies by three orders of magnitude from night to night. Some truly huge migrations have been witnessed. I well recall a late September night when Sid Gauthreaux and I were making radar and ceilometer observations at stations about eighty miles apart in Georgia and South Carolina. A cold front had passed and it was a clear, cool night with winds from the northwest, perfect for autumn migration. Birds were passing at the incredible rate of over 200,000 individuals per hour along a one-mile front.

From observations in several parts of the world, some general patterns have emerged. Tail winds usually accompany large flights of night migrants. In spring these southerly winds are normally accompanied by rising temperatures, while in fall north winds bring cooler air. Rain, strong winds, and stormy weather generally ground migrants, sometimes producing spectacular concentrations. So-called reverse migrations and flights in other, seemingly peculiar directions are relatively common, most often accompanied by winds blowing in the same directions. Perhaps the most important observation from the earlier radar studies was that even under solid overcast skies, migrating birds flew on straight and level tracks and as a group the birds were as well oriented as under clear skies. That finding was at odds with many of the general ideas emerging simultaneously from experimental studies of orientation mechanisms in migratory birds.

Sun and star compasses. Late in the 1940s, Gustav Kramer made a discovery in Germany that would revolutionize the study of migratory orientation. He found, first in the starling, a diurnal migrant, and later in several species of European night migrants, that during the appropriate seasons birds placed outdoors in round cages tended to hop and flutter in directions that corresponded to the migratory ones. This behavior enabled Kramer to perform experiments that demonstrated a sun compass in birds (in the same year, 1950, Karl von Frisch published the independent discovery of a sun compass in the honeybee). But most birds migrate at night. Further experiments by Kramer showed that such species also oriented appropriately in his cages so long as the birds had a view of a cloudless night sky. There was thus the clear hint that the birds might be using stars to determine direction.

Kramer's untimely death interrupted his pioneering studies, but the question of star orientation was taken up by other German investigators, Franz and Eleanore Sauer. They took Kramer's round cages into a planetarium where star patterns could be manipulated at will. Their work, later extended in this country by Stephen Emlen, showed that the migrants were indeed able to use star patterns as a nighttime compass. Emlen's extensive research on the Indigo Bunting revealed many details of how the star compass works and how it is learned by young birds prior to their first autumn migration. Thus at the time the first major radar studies were coming out, the

Illustration by Denise Braunhardt

primary hypothesis to explain the mechanism of orientation was based on visual cues, the sun by day and the stars at night. A naive prediction would have been that birds would either refrain from migrating on overcast nights or that they would become disoriented if they attempted to do so. Both were clearly false. Such conflicts in scientific data often result in unpleasant controversy, but they also usually mean that we are missing some important pieces of the puzzle. In this case, experiments being performed in Germany were soon to reveal one of those pieces.

Multiple cues. At the University of Frankfurt, Friedrich Merkel and his colleagues were using orientation cages to test night migrants, not under stars, but in covered cages in closed rooms. They reported weak orientation under these so-called "visually cueless" conditions and resurrected the old, largely discredited idea that the birds might be using magnetic information to orient. The climate of the times was not favorable to this idea and the birds' orientation data was far from impressive. Despite considerable criticism, Merkel and his student, Wolfgang Wiltschko, continued the work and were ultimately able to perform compelling manipulations of orientation cages.

At roughly the same time, undeniable magnetic effects on pigeon homing were being found, and these discoveries led to a new approach to orientation research. It was becoming clear that there was no single orientation mechanism but at least two and perhaps several. This meant that experiments had to be designed and interpreted very carefully. Just because a bird was still able to orient itself correctly in spite of the experimental elimination of a potential orientation cue did not mean that the bird never used that cue. It might simply have switched to another system in a highly redundant series. Our emphasis was forced in the direction of seeking the relationships among various types of orientation information. In the 1970s, field observations and manipulative experiments converged on this problem with some force.

Radar observations by Sid Gauthreaux and me in the southeastern states had revealed a major influence of wind direction on the flight orientation of migrating songbirds. Indeed, in that region wind direction seemed to override all other cues, with the birds almost invariably heading downwind regardless of wind direction. Wind direction is, of course, a critical factor for migrating birds and can significantly speed or retard their passage or drift them laterally. Wind is also a factor affecting free-flying birds that is entirely absent in the orientation cage experiments.

I continued to examine the orientation of free-flying night migrants in upstate New York with the aid of a renovated Korean War vintage tracking radar. Unlike the long-range surveillance units widely used in earlier studies, trackers are poorly designed to reveal broad regional patterns of migration. What they do superbly, however, is lock onto and follow individual birds, giving second-by-second positions of the bird in space. Its height, flight direction, and speed, even the pattern of its wingbeats, can be recorded with precision. The latter information gives a rough indication of the bird's identity - passerines fly with a characteristic bursting wingbeat pattern, a brief period of flapping alternating with a period of no flapping. At the outset of these studies, I assumed that I would observe the same relationship between wind and orientation that we had seen in the Southeast. That assumption turned out to be naive.

In the Northeast, wind still makes its mark. Many more birds embark on nights with favorable winds, and sometimes birds do head downwind in seasonally inappropriate directions but only under special conditions. When skies are clear enough for potential migrants to see either the sun late in the day or the stars at night, they orient in appropriate directions regardless of wind. When thick cloud cover prevents access to these visual cues, however, the birds head downwind even if that results in a reversed flight. These data clearly reveal a relationship between wind direction and the visual cues, the sun and stars. It is important to note that as yet neither my studies nor those of others have found a clear indication of the influence of a magnetic compass on free-flying migrants.

It may at first seem peculiar that nocturnal migrants should pay attention to the sun. After all, it is not visible to them when they are flying. On the other hand, it is a predominant feature in the sky at a time of day (dusk) when birds may well be making decisions about whether to fly and in what direction. Recall from the radar studies that most birds take off during this twilight period. In fact, at the same time these field studies were in progress, Frank Moore of Clemson University was able to show that Savannah Sparrows in orientation cages performed much better if afforded a view of the sky around sunset. These results brought us full circle back to Kramer, who had noticed that his orientation cage subjects did better if he allowed them to see the glow of sunset.

It is not yet clear exactly how the birds use the setting sun. Moore recently built an orientation cage equipped with mirrors placed so that he could shift the apparent position of the sun as the birds viewed it, a procedure identical to the one Kramer used to discover the sun compass. Indeed, Moore succeeded in shifting the orientation of his sparrows in the predicted way. However, it turns out that the clear sky contains other information related to the position of the sun. Sunlight is polarized as it passes through the atmosphere and the direction of the plane of polarization is a direct function of the position of the sun. Homing pigeons, like many invertebrates, have recently been found to be able to perceive polarized light, raising the possibility that migratory birds might make use of the orientation information contained in skylight polarization patterns. Although this seemed an unlikely prospect, I tested the idea by using some large sheet polarizers on top of orientation cages in which I placed White-throated Sparrows at dusk. By changing the polarization pattern viewed by the birds, I was able to alter their orientation predictably, suggesting that at least this one species of night migrant has another previously unknown trick in its already rather full bag of orientation capabilities.

The abandonment of the older, single-cue approach in the search for the mechanism of orientation opened the gates to the discovery of seemingly endless complexity. Much remains to be done in working out the relationships between the various cues used by birds, and it may well be that we do not yet even possess all the pieces of the puzzle. As if these problems were not vexing enough, there is reason to believe that migratory birds have navigational abilities similar to those of the homing pigeons discussed by Charles Walcott. Recently we have been equipping Wood Thrushes with tiny radio telemetry transmitters and displacing them from their nesting territories. For reasons as yet unclear, the thrushes are very slow to return, flying only a mile or two each day, nearly always at dawn. However, those short flights are well oriented in the homeward direction, implying that the thrushes know where they are going from the outset.

Great progress has been made in untangling the problems of bird orientation and navigation, but we still cannot explain in a mechanistic way how the birds do what we know they do. Much remains to be done and if the past is any harbinger of the future, there are some surprises in store for us.

KENNETH P. ABLE, a member of the faculty of Biological Sciences of the State University of New York at Albany, has studied migration with various techniques, including radar, for the past fifteen years. Most recently, he has been investigating the use of orientation cues by migrants. An avid birder since childhood, Dr. Able enjoys chasing rarities. His signature is one of the early ones (first page) of the Western Reef-Heron visitor's book.

NEW ENGLAND GULL PROJECT

In an effort to determine behavioral patterns and movements of an inland-feeding population of gulls and to estimate the numbers using an area, U.S. Fish and Wildlife biologists have color-marked and released gulls in the Manchester/Concord, New Hampshire area in May and June. The gulls have been dyed red and tagged with a numbered yellow leg marker.

IF MARKED BIRDS ARE SIGHTED, PLEASE REPORT DATE AND LOCATION to:
Rene Bollengier, Project Coordinator
U.S. Fish and Wildlife Service
Box 1518, Federal Building, Concord, NH 03301
Telephone: (603) 225-9621.