ECOLOGY

Do Wandering Albatrosses Care About Math?

Repudiating a decade-old study of sea birds, a new report questions a popular model of how animals—as well as fishing boats and people—search for food

As its name suggests, the wandering albatross (*Diomedea exulans*) is a fabulous flyer, flapping its way around the world with the help of its 3-meter plus wingspan, the longest of any living bird. A 1996 report seemed to offer clear proof of the bird's endurance: It found that the birds sometimes soared for as many as 4 days before touching down on water, presumably to catch fish or other food. One of the first studies in which recording devices tracked animal movements, the work also brought a little-known mathematical tool to bear on the study of animal foraging. It showed ecologists that a model of random motion called a Lévy flight described the way albatrosses searched for food.

Inspired by the work of French mathematician Paul Lévy, Lévy flights are characterized by many short hops, with much longer jumps on rare occasions. Physicists have long used the mathematics behind Lévy flights to predict how particles move in liquids and how matter spreads in the universe, for example. And after analyzing the recorded albatross data, a team led by physicist H. Eugene Stanley of Boston University (BU) concluded in a 1996 *Nature* article that the tagged birds also followed Lévy flights.

This strategy could work well when food supplies are concentrated in a few places—say, in schools of fish or fields of flowers—with long stretches of empty sea or bare ground in between. Indeed, in a 1999 *Nature* article, Stanley's group outlined the theoretical benefits of foraging with the strategy and asserted that deer and bumblebees followed a Lévy flight search pattern.

Last week, however, a new study revealed flaws in both the 1996 and 1999 reports. In the initial albatross paper, Stanley's team misinterpreted key data on the birds, says Andrew Edwards of the Pacific Biological Station in Nanaimo, Canada. In the reanalysis by Edwards and colleagues, reported in the 25 October issue of *Nature*, the longest flight drops from 99 hours to 20 hours, for example. Moreover, using an arsenal of statistical tests on the 1996 and 1999 papers, the researchers show that the bird, bumblebee, and deer data support other search strategies equally well. Edwards goes so far as to say that none of the subsequent studies reporting animal Lévy flights that he has seen are "100% convincing."

Stanley's team apparently accepts this dramatic about-face. All the surviving authors from the 1996 and 1999 papers are co-authors on the new report. And Gandhimohan Viswanathan of the Federal University of Alagoas in Maceió, Brazil, who was the first author of the two earlier papers, agrees with Edwards that "the jury is out" on whether Lévy flights apply to any foraging animals. "One message that this new paper sends is clear: We must be more careful with data analysis," he says.

Wet and dry birds

Physicists first discussed the notion that animals perform Lévy flight searches in the 1980s, but obtaining data on large-scale movements of animals in a natural environment wasn't easy at the time. When the 1996 albatross report came out, the idea of Lévy flights in animals really took off among ecologists. That publication has been cited more than 100 times. Researchers have since described Lévy flights in jackals, spider monkeys, seals, microscopic zooplankton, and even by fishing vessels and hunter-gatherer tribes.

All this excitement piqued Edwards's curiosity in 2005. An ecological modeler, he had just landed a position with the British Antarctic Survey (BAS) in Cambridge, U.K., the source of the albatross data analyzed by Stanley, Viswanathan, and their colleagues. Edwards decided to take a closer look at the original study to understand the methods used.

In 1992, BAS researchers had gone to Bird Island in South Georgia and attached a newly designed detector that registered contact with saltwater to a leg of each of five birds, retrieving the detectors about 2 weeks later at the birds' nesting sites. After a BAS group member met someone on the BU team interested in modeling animal movements, BAS agreed to provide the detectors' data.

For their analysis, the BU team interpreted "wet" signals as moments when the birds stopped flying over open sea and grabbed a snack from the water. The time in between was considered to be flight time, with longer "dry" intervals signifying longer distances in the air. Viswanathan, then a BU graduate student, Stanley, and their co-authors found a "hop, hop … long jump, hop …" pattern among the albatross journeys. When they graphed these data a particular way, the probability for a jump of a specific distance seemed to follow a so-called power-law distribution, in which most jumps were very short, and the longer a jump was, the rarer its occurrence. This type

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of probability distribution fit the definition of a Lévy flight pattern.

Yet Edwards noticed that the first and last flights for each bird were suspiciously long. When he removed those flights from the original analysis, any evidence for Lévy flights vanished. The clincher came when, during a coffee break with a BAS albatross specialist, Edwards learned about data that the BU team didn't know about. For some of the recorded trips, some of the birds also wore rudimentary location trackers for a separate study. When Edwards and his colleagues at the survey pulled those data from the archives, they discovered that for much of the initial long "flights," the birds had never left their nests. Similarly, the last "flights" tended to be much longer because the birds had returned to their nests and were high and dry for hours. Flights recorded as 69, 67, 44, 26, and 23 hours in the original paper were actually all 4 hours or shorter, sometimes less than an hour.

Edwards and his colleagues also joined with the original BU authors to repeat the sea-bird study, drawing upon BAS data taken in 2004 from 20 Bird Island albatrosses equipped with more sophisticated tracking equipment. The new study confirmed that Stanley's team had been misled. "The birds aren't performing Lévy flights when foraging," Edwards says.

Edwards then took another look at the 1999 work on bumblebees and deer. He found other data of questionable relevance to Lévy flights: The deer "foraging" times analyzed by the BU team, for example, turned out to be the amount of time spent eating at a location rather than the time spent traveling between feeding sites.

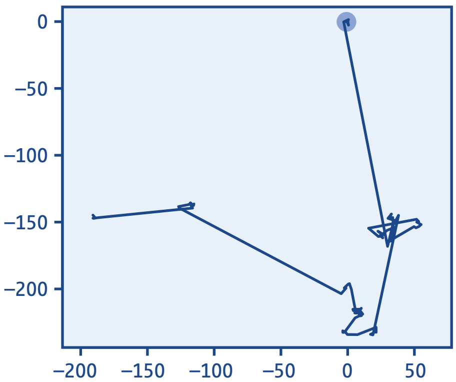
Moreover, in both the 1996 and 1999 studies, the BU team had used a simple graphical approach to demonstrate the power-law distribution that signified Lévy flights, one that has since been applied by others in their analyses of animals' movements. But, says Edwards, the strategy can often produce a spurious conclusion of Lévy flights. Indeed, when Edwards statistically compared whether a power-law distribution fit the bumblebee and deer foraging data better than non-Lévy flight distributions, it didn't.

This type of sophisticated statistical model comparison, note Edwards and Viswanathan, wasn't used in the 1990s. Still, the analysis removed from the two early papers the last bits of solid evidence for Lévy flights.

Those papers are not being retracted, however. Viswanathan says that he and the other original authors seriously considered retractions but decided that the new analysis serves as the needed public correction. Rory Howlett, an editor at *Nature* who handled the new paper, adds that its peer-reviewers didn't request retractions, either. "This is an unusual case in that new analytical methods and also new data became available that led to a re-evaluation of the original claims," he says.

From jackals to bees

Edwards's reappraisal of the two *Nature* papers isn't the only recent attack on biological Lévy flights. Behavioral ecologist Simon Benhamou of France's national research agency, CNRS, in Montpellier has also called into question the benefits of this foraging pattern. In the August issue of *Ecology*, he described computer simulations indicating that Lévy flight–styled movement is no more efficient at searching an area than is a variant of classical Brownian random motion. Moreover, it takes a very close analysis of the data to distinguish the two types of movements. "Both my paper and Edwards's paper show that [the Lévy flight] concept is not likely to be useful to analyze foraging movements in most situations," says Benhamou.



Flight paths. Scientists have suggested that foraging jackals and bees and even fishing boats follow a Lévy flight pattern (computer simulation, *above*), which is random motion marked by short spurts and occasional longer jumps.

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To statistician Stephen Buckland of the Centre for Research into Ecological and Environmental Modelling at the University of St. Andrews in Fife, U.K., the application of the Lévy flight concept to ecology was always "a bit far-fetched." "It's mathematicians taking a simplistic tool and pretending it is relevant to the real world," he says. The idea that foraging animals conduct Lévy flight searches, or any similar random search strategy, ignores that animals use their intelligence and experience to guide them, Buckland adds.

But not all ecologists share that dismissive view. They maintain that some Lévy flight studies may be valid. "My view is that the albatross work may well be flawed, but it has played a big role in stimulating some really good subsequent work on the whole issue of search strategies and animal behaviors," says Christopher Rhodes of Imperial College London, who has reported that foraging jackals perform Lévy flight searches.

Andy Reynolds of Rothamsted Research in Harpenden, U.K., is equally adamant that Lévy flights are a useful tool for ecologists. "Theory shows that Lévy flights are a good way to search. My feeling is that animals evolved to do the best possible searches," he says. Reynolds has found Lévy flight activity in starved flies searching for food in a container and in honeybees—tracked by radar—looking for food or hives in fields. He's also applied several statistical techniques to analyze his data. "I have used many methods to show Lévy flights rather than one method," says Reynolds.

Reynolds has been corresponding with both Benhamou and Edwards about his evidence for Lévy flights, but both remain unconvinced. Benhamou doesn't insist that ecologists abandon Lévy flights just yet. But he, like Edwards, argues that researchers must realize that there could be other, equally plausible explanations for how animals search: "Showing that data are well accounted for by a Lévy process is not enough." **–JOHN TRAVIS**