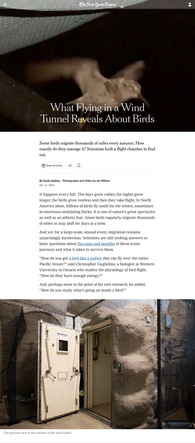

# What Flying in a Wind Tunnel Reveals About Birds

Some birds migrate thousands of miles every autumn. How exactly do they manage it? Scientists built a flight chamber to find out.

By Emily Anthes Photographs and Video by Ian Willms
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It happens every fall. The days grow cooler, the nights grow longer, the birds grow restless and then they take flight. In North America alone, billions of birds fly south for the winter, sometimes in enormous undulating flocks. It is one of nature's great spectacles and also an athletic feat. Some birds regularly migrate thousands of miles a day with no rest.

And yet, for all this seasonal event, migration remains surprisingly mysterious. Scientists are still seeking answers to basic questions about the costs and benefits of these avian journeys and what it takes to survive them.

"How do you get a bird like a pocket that can fly over the entire Pacific Ocean?" said Christopher Guglielmo, a biologist at Western University in Ontario who studies the physiology of bird flight. "How do they have enough energy?"

And, perhaps more to the point of his new research, he added, "How do you study what's going on inside a bird?"

The pressure hole in the ceiling of the wind tunnel.

Pablo Marcos Torres, a Ph.D. student, lining up the wind tunnel.

It is understandably difficult to monitor the internal workings of a bird in flight, let alone measure the energy it uses. For years, Dr. Guglielmo needs his avian test subjects as simulated journeys. At the Advanced Facility for Avian Research, he and his colleagues use a hyperbaric wind tunnel, which functions, in essence, as a treadmill for airborne birds.

Scientists can send air through the main test chamber at varying speeds, up to about 40 miles per hour. Not all birds take to the tunnel — "about half of them will be good flyers," Dr. Guglielmo said — but those that do can flap their wings for hours at a time while remaining, conveniently, in one place.

A monitor displaying a fire-bird at a sandpiper in the tunnel.

Researchers can adjust not only the wind speed inside the tunnel but also the temperature, humidity and air pressure to simulate various flight environments. Dr. Guglielmo, who is a bird physiologist, mapping how air flows around the bodies of different birds, or focus on avian physiology: How does a bird's breathing change at higher altitudes? How does diet affect flight performance?

Messages for visitors outside the tunnel's entrance.

Answering these questions will help scientists grasp what birds are capable of and what their limits are. It could also help to predict how climate change and environmental degradation and other human-caused warming might affect the ability of birds to survive long-haul journeys.

In one current study, Dr. Guglielmo's team is examining Western sandpipers, small shorebirds that spend their summers breeding in the Arctic tundra of Alaska and Siberia. "The family of birds that they're from, of shorebirds, are considered the champion migrators of the bird world," Dr. Guglielmo said. In the fall, Western sandpipers travel down the Pacific Coast, some flying as far as South America, stopping to rest and refuel at bays and wetlands along the way.

Western sandpipers in a simulated shorebird enclosure.

The researchers are studying how much energy it takes for the sandpipers to fly at different speeds. The relationship is not a linear one. Hovering in one place requires a lot of energy, Dr. Guglielmo said, as does flying at top speed. Somewhere between these extremes is a bird's most energy-efficient speed, one that allows it to cover a lot of ground while burning relatively few calories.

Pinpointing this speed will help scientists determine how far the sandpipers can fly without refueling — and what might happen if climate change or other factors make it harder to find dinner. "If we have this evidence and we can develop this observation, can they skip over and go somewhere else?" Dr. Guglielmo said.



Weighing a sandpiper mid-flight. A paper cone as part of the experiment to measure the bird's energy expenditure during flight.



Christopher Guglielmo, professor of biology at Western University in Ontario.

To measure how much energy the sandpipers expend while flying, the researchers analyze the chemical composition of the birds' breath. Just like humans, when birds use energy, they consume oxygen and produce carbon dioxide; the more energy a bird uses, the more carbon dioxide it exhales.

To measure a bird's carbon dioxide production while it is in flight requires outfitting it with a tiny respiratory mask. But that is a highly unnatural state that is likely to make flying even harder. "We try to use the least invasive methods that we can," Dr. Guglielmo said.



Dr. Tavares and Gabriella Fernandes, left, another Ph.D. student, prepared to measure a sonomer sandpiper's energy expenditure during a flight test.



Injecting a sandpiper with a metabolisable tracer of carbon-13 fatty acids to find a wind tunnel. It responds to a flight test.

So before the researchers put such bird in the wind tunnel, they inject it with a small amount of carbon-13, a heavy form of carbon that is relatively easy for scientists to trace. (Carbon 13 is not radioactive and does not harm the birds.) The more energy the birds use while flying, the more carbon 13 they expel, in the form of carbon dioxide. Less then remains in their bodies and breath when they are removed from the wind tunnel.

The scientists are charting the birds' energy expenditures at both ground level and a simulated altitude of about 10,000 feet. A sandpiper's ability to perform well at high altitudes, or low altitudes, where the air is denser but also thicker. Theoretical models suggest that the birds should have to work harder to fly in this thin air. "But we want to know how much harder," Dr. Guglielmo said, "so we have to measure it."

**Emily Anthes** is a science reporter, writing primarily about animal health and science. She also covered the coronavirus pandemic. More about Emily Anthes

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