Podcast Interview: Amanda Rodewald, Ivan Rudik, and Catherine Kling

PNAS: Welcome to *Science Sessions*, the podcast of the Proceedings of the National Academy of Sciences, where we connect you with Academy members, researchers, and policymakers. Join us as we explore the stories behind the science. I'm Paul Gabrielsen.

Air pollution is a known hazard to human health and can likewise impact birds, which have suffered dramatic population declines in recent decades. I'm speaking with Amanda Rodewald, Ivan Rudik, and Catherine Kling of Cornell University. In a recent PNAS article, they and their colleagues estimated the impacts of air pollution, particularly ozone pollution, on birds, and also estimated the bird deaths averted by environmental regulations limiting ozone.

In your study, you identified ozone as a particularly harmful pollutant for birds. Amanda, how does ozone impact birds and their habitats?

Rodewald: So there are a number of ways that ozone can impact birds. And so some of those ways are directly, right? So, ozone can actually cause physical damage to birds. It can damage their respiratory systems, which are inherently more vulnerable to pollutants than ours. It can also increase physical stress to them, reduce immune function. So in addition to those direct impacts, birds can also be indirectly affected by ozone. There were some recent studies that reviewed the literature and found that elevated ozone can inhibit plant health, quality, and growth rates. It can actually reduce species richness of plants within the environment, and it can reduce the number of insects that birds eat. One study actually reported that there were almost 20% fewer insects when ozone levels were elevated in a habitat.

So if we think about it then, whenever we reduce the access to high-quality habitat or food resources, what we're doing is we're actually making it more difficult for individual birds to survive and to reproduce successfully. And that's especially true if we think about migratory birds because they're traveling such enormous distances over the course of a year. And so they're already under incredible physical stress, you know, and facing these really high energetic demands. Even in less severe cases, you know, an individual may just produce fewer young that it would have otherwise if it's in poor condition.

PNAS: Your estimates of relative abundances of birds came from a database of bird observations called eBird. What is eBird, and why is it a valuable resource for researchers?

Rodewald: eBird is an amazing resource. So the Cornell Lab [of Ornithology]'s eBird program has become the world's fastest growing biodiversity database. It truly is unparalleled in terms of the global coverage and the year-round coverage, and it does this at really fine spatial and temporal scales. So, right now, we have over a half a million volunteers that are submitting observations from literally around the world, and we're nearing 1 billion observations within the eBird database. We just do not have sufficient

resources to hire biologists to go out there and collect the data, and so that's why citizen science projects like eBird have becomes so valuable and really essential for us to use with environmental protection, to advance science—all sorts of uses. It helps us to fill the gaps that we otherwise would not be able to fill.

PNAS: Ivan, how did you connect ozone levels to bird mortality?

Rudik: Right. So, I'll answer this one. And I'll start off with something I learned from Amanda when we started this project, which is that what we're picking up on is even broader than mortality, kind of following up with what she said earlier, where it's not just these direct impacts where the ozone is directly harming the bird, or it might not even be killing them, but it might be making sure that they're not able to reproduce in the next year—and so that we see fewer birds in the future. So what we're doing is first we're gonna be taking this eBird data that Amanda described, and then we're going to be linking it up with the US Environmental Protection Agency's ozone air monitoring network, which is pretty extensive across the United States.

And the first thing that we do in the paper is we're just looking at, essentially, the association between the two. So we're going to be controlling for as many things as we possibly can. So important stuff like weather—that's going to be important for bird activity and also for the formation of pollution, especially ozone. But what we're ultimately doing is just looking at, on high-ozone days, do people report a lot of birds on their eBird checklists? And that's just kind of like the first quick cut that we just take with the data. And the second thing that we do is we're going to be actually using an environmental regulation called the NOx Budget [Trading] Program to look at what ozone is actually doing in terms of causing changes in bird abundance.

PNAS: How did seasonal ozone regulations allow you to refine your estimates of ozone's effect on birds?

Rudik: Yeah, so the NOx Budget Program is really a nice thing for trying to understand the effect of ozone. So how it works is in the Eastern United States in the 2000s, the EPA set a cap, essentially, on precursors to ozone. So these are nitrogen oxides. So what we have just kind of all of a sudden—that happens in 2003—is in the summer in the Eastern United States, ozone just kind of sharply dropped. And it was only in the east and only during the summer. It's kind of like this natural experiment that just happened and just ozone concentrations, right? Like [if] we were trying to come up with an experiment in a lab, it might look something like this. So what this does is it lets us compare what's happening in these Eastern United States in the summer to the Eastern United States in other months, or in the Western United States in the summer.

And so we can look at how the trends in bird abundance are changing over time. And what we actually see is once those ozone regulations kick in, in the Eastern United States, you get this jump up in bird populations when the ozone is a lot lower.

This is allowing us to really just nail the causal impact of this, while controlling for most of the things that we think would be confounding how we would think about how ozone is actually affecting birds. If you just, like, took a really naive approach, people probably like to go birding on nice warm days. So they're going to be reporting more birds on

those kind of days. But ozone is also a lot higher on nice warm days, too. So if you just, like, looked at the raw data, it would all of a sudden look like ozone is good for birds, right? Like it's been boosting bird abundance, but that's obviously not true. It's just something that you have to address with these statistical methods.

PNAS: Catherine, what is the value of the size of the eBird database?

Kling: What allows us to do that sort of control that Ivan just explained is the huge amount of data. So, because there are so many observations, both in a given state, in lots of different areas in this state, we can add variables that account for "this was seen in this location in this year," and that's the way in which all of this gets controlled for. And that would simply not be possible without the enormous amount of detailed, spatially rich data that comes from eBird and can be matched with the ozone data. So lots of studies can't do this kind of thing because they don't have that level of rich data. The key point here is that the statistical methods are only possible because of the availability of this really remarkable database.

PNAS: Tell us about the declines in ozone pollution since 1980, and how that's benefitted birds.

Rudik: Right. So, ozone has declined by quite a bit since 1980. So the number of very bad days on average—so these would be ones that are about, like, unhealthy for sensitive groups is how the EPA would classify it—has been cut by about half, and average concentrations have fallen by about a third over that timeframe. And this has been mostly in the Eastern United States where this NOx Budget Program was in effect. All of these regulations are kind of falling under the Clean Air Act, which is the major driver behind these declines in pollution, and we're seeing that this has avoided the loss of about 1.5 billion birds is our best estimate. And what we're seeing is that most of this actually happened very recently, starting in the 2000s. There were gains, or avoided losses, before then, but it actually is increasing over time. And that is something that we're actually seeing happen right as when ozone starts declining even more rapidly with the introduction of these ozone-specific programs. So what this means is that this has particularly benefited birds in the Eastern United States, where we were seeing these precipitous ozone declines.

PNAS: What would we have lost without those estimated 1.5 billion birds saved by environmental regulations?

Rodewald: We would have lost enormously. So we know, for example, that many birds, about three-quarters of birds actually, eat insects at one time or another. In some cases, too, the economic value of those pest control services are really meaningful. They can be even thousands of dollars per acre that are saved, and birds also play roles in ecosystems by helping to disperse seeds.

Birds can be really valuable scavengers that remove waste and help to support nutrient cycling. Examples of those kinds of species are vultures and ravens and crows and seabirds. Even for those people who really could care less about birds in particular, they

might care very much about the revenue that bird-related recreation infuses into local economies. We know that over a hundred million people participate in wildlife-related recreation activities every year, and that number keeps growing. Overwhelmingly, most of that recreation is focused on birds. And what this does is it contributes, the estimates are, over $150 billion each year added to the US economy because of these activities. So again, no matter how you look at it, really what's good for birds is usually good for people too.

PNAS: Why is it important to recognize the co-benefits of air pollution mitigation for conservation?

Rodewald: From my perspective, we're facing so many challenges in the US today that we are compelled to do more with less. We just don't have the luxury of really enacting policies or having interventions that address one problem at a time. We need to find creative ways to really tackle multiple problems at once.

Rudik: One of the big things in environmental regulation—to do it right—is you have to add up all of the costs and benefits. It's not just the one thing that you're interested in; but if we want to design good policy, we have to take into account all of its impacts. These impacts that we're seeing on birds are things that have not been quantified or captured before in environmental regulation, and what that's saying is that the benefits of these regulations are higher than we thought. And what this means is that we could do more in terms of regulation in the future; if these benefits are larger, it means that we could incur some more costs to improve environmental quality and still be better off and potentially even be more better off.

Kling: We've learned a lot in the last six to nine months about the value that people place on having access to healthy and enjoyable outdoor recreation amenities.

The data is remarkable. Cell phone data and simple observations. People have flooded outdoors where it's safe during this pandemic. People have taken up birdwatching in quantities previously unknown. People have invested in bird feeders in their backyard. This is improving the quality of their life during this difficult time. That's economic value above and beyond the amount spent on bird seed, above and beyond the amount spent on gasoline and sandwiches. That value is what economists primarily refer to when we mean economic value: it's the enjoyment; it's what we'd be willing to give up in exchange for preserving birds, so that we can see them. It's critically important for good governance and good government decisions for us to be able to understand what the benefits are of interventions for public health. Do they go beyond just human health?

A lot of people contribute to the eBird database. They do it because they enjoy it. They like to have their own accounting. It's a really snazzy tool. You download it for free. It gives you all kinds of information. Merlin is this app that helps you identify birds, like identifying what birds in your area you're most likely to see, so you don't make up ridiculous things and then get in a big argument with your spouse. When they submit their lists, it provides information that we can then use for research purposes. So this is research-quality data once it has gone through a number of statistical filters and checks, and that is what provides the basis. This is citizen science at its very best.

Rodewald: Yeah. And I guess even more broadly, too. So eBird, as Cathy says, that provides a platform when people submit their observations and their checklists, right? They're not only contributing to sort of their own enjoyment because they have their lists, you know; they're actually helping other people make the most of their bird watching trips because now they know where to go and where hotspots are. So in terms of sort of the recreational value, it's enormous. In terms of educational value, eBird is increasingly used in classrooms and also in informal education settings to inspire, to help engage new audiences in understanding the environment and the species that live on the planet with us. It advances science in the ways that we've been sharing today because it provides this unparalleled resource.

And increasingly it's used in decision-making not only related to trying to figure out, well, where should we be focusing our efforts if we want to conserve birds—that's really important—but also in terms of using birds as indicators of other things we care about in the environment, so whether it's pollinators; whether it's, yeah, maybe human health concerns; whether it's trying to use birds as an indicator for how forest restoration is playing out, you know, in other parts of the world. So the uses are incredibly diverse and they're growing all of the time. We have more demand right now for eBird data products than we even have capacity to provide right now. So it's an exciting time because individual people are spending the time and they're contributing. This all comes from the collective efforts of, yeah, half a million individuals around the planet.

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