BIODIVERSITY
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UNRAVELING OVER 2,000 YEARS OF ENVIRONMENTAL MYSTERIES USING ANCIENT BIRD DROPPINGS

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YOUNG REVIEWERS:

ASTRA NOVA
AGES: 11–14

MUHAMMAD
AGE: 14

Condors are amongst the largest flying birds in the world, nesting high up on cliffs and mountains and scavenging for prey below. Because condors live in remote locations, they are difficult for scientists to see and study. So, we used accumulated Andean Condor droppings to learn about them. After climbing up a mountain to collect samples, we learned that condors have responded to both natural and human-caused changes in their surroundings. We discovered that condors have been hanging out in the same nesting spot for about 2,200 years! However, around 1,700 years ago, the condors left because increased volcanic activity probably led to less

food. Around 700 years ago, condors returned to this nesting site, but their diet changed. Instead of scavenging for native animals, they started scavenging for dead sheep and cows introduced by colonizers. We continue to learn from the past to direct positive change for the future of these amazing scavengers.

CONDORS SOARING OVERHEAD

In 2014, our team was exploring the beautiful Andes Mountains in the Nahuel Huapi National Park in Argentina. Soaring high above were Andean Condors, one of the largest flying birds in the world. These amazing birds have glossy black feathers, topped with a bald, wrinkled head and a snow-white collar (Figure 1A). Their wingspan stretches to an impressive 3.3 m. That is longer than a basketball net is tall!

Figure 1

Figure 1

Sampling the Andean Condor nest. **(A)** A male Andean Condor patrolling the landscape (Photo by S. Lambertucci). **(B)** After the condor chick fledged, researcher Mercedes Tety Sahores climbed down the rockface to get into the nest. The nest is visible to the left (Photo by L. Sympson). **(C)** A young condor sitting in the nest. Notice how well the young bird is camouflaged in the nest! (Photo by L. Sympson). **(D)** Researcher Christopher Grooms sampling the nest with a saw (Photo by L. Sympson).

As we explored further, we saw something interesting: an adult condor gliding into a small cave. Intrigued, we followed, hoping to see their natural behaviors firsthand. We spent a few days observing the cave to see if they were nesting, since we did not want to disturb a condor with an egg. When we climbed into the cave from the cliff above (Figure 1B), what we discovered was unexpected: a young condor nestled snugly within a nest (Figure 1C). But even more remarkable was the nest itself—it was a donut-shaped structure about 1 m wide, tucked into the walls of the cave. The nest looked to be made from old condor droppings, which made sense since we had seen condors poop by squirting it away from where they sit. The *unique* smells confirmed our suspicions. The accumulation of poop was unexpected because condors typically lay their eggs directly on the ground instead of building traditional nests with sticks or other materials.

As scientists, we were curious to learn about the secrets that could be preserved in the nest. We wanted to know how long the condors had been using the nest, learn what they currently eat, and explore any other information that might be available. After the condor chick had **fledged**, we returned and carefully extracted a small portion of the dry, chalk-like nest using a hand saw, refilled the missing area, and went back to the lab to analyze the material (Figure 1D).

FLEDGE

The stage in a bird's development when it learns to fly. This is the time that the bird is no longer dependent on the nest.

THREATS TO THE ANDEAN CONDOR

Andean Condor populations face significant threats from habitat loss, poaching, and poisoning, among others, highlighting the urgent need for conservation efforts to ensure their survival [1]. However, it is difficult to effectively help the condor populations because there are gaps in our understanding of their behavior and **ecology**. Because condors nest high up in mountains and have very large territories spanning hundreds of kilometers, they are difficult to observe and track. The discovery of the nest provided a rare and exciting opportunity to learn about these birds.

ECOLOGY

The study of how living organisms interact with each other and the environment around them.

Condors, like many birds, leave evidence of their presence. Whether it is feathers, eggshells, leftovers of meals, or poop, bird wastes can provide valuable insights into their habits and habitat. Moreover, when animals repeatedly return to a favored site, such as a site that offers safety from predators, nesting habitat, or abundant food sources, their wastes can accumulate, creating a deposit that can be explored to learn about the past [2]. By analyzing the contents of these time capsules, we can learn about changes in diet, environmental conditions, and the overall health and behavior of the birds.

HOW OLD IS THE NEST?

Back in the lab with the nest section, our first step was to slice the nest into equal pieces (Figure 2). We knew that the top would contain the wastes from the condors currently there, and the deeper samples would be from condors in the past. Using microscopes, we found that the nest was mostly poop, with bits of condor feathers and plant leaves. We also saw that there were distinct layers, indicating that the nest has been accumulating for many years.

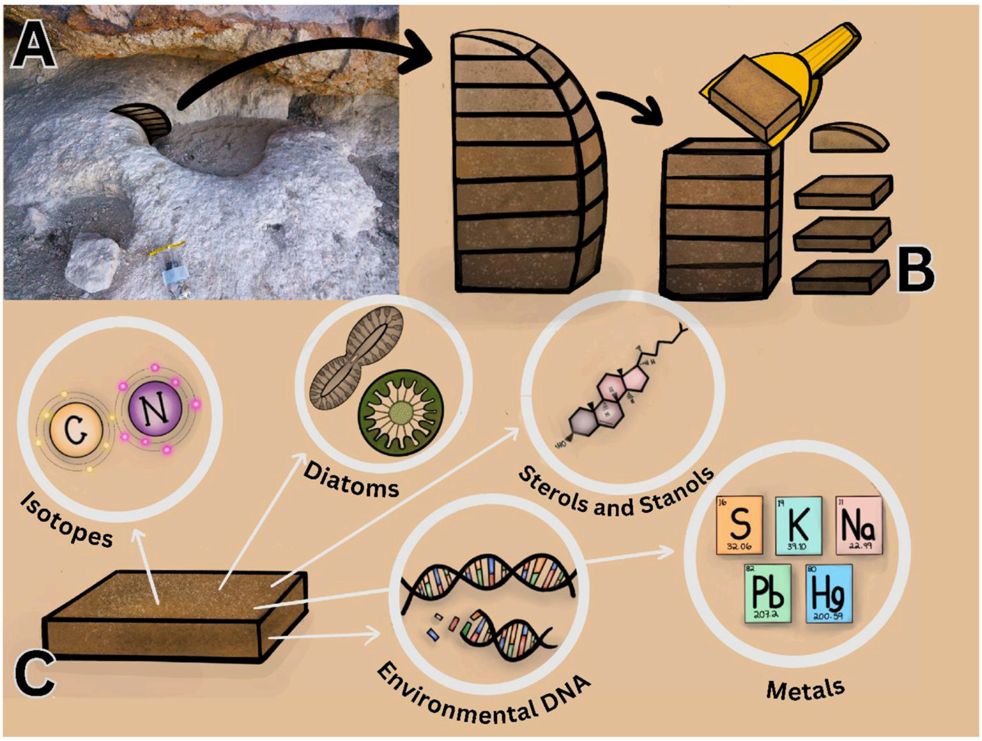

Figure 2

Figure 2

Measuring environmental indicators in the nest sample. **(A)** First, the sample was taken from the nest. **(B)** Back in the lab, we cut the nest sample into equal pieces from top to bottom. **(C)** For each slice, we measured isotopes, diatoms, sterols and stanols, environmental DNA, and metals.

We next measured the age of the nest using **carbon-14 dating**. Carbon-14 is a special way to understand how old something is by measuring the **isotopes** in a sample. When we looked at the age of the feathers and plant seeds in the nest, we found that the nest had been used for more than 2,200 years [3]! That means that the nest is older than the Roman Colosseum!

CARBON-14 DATING

A method to determine the age of organic materials by measuring the breakdown of the radioactive isotopes of carbon.

ISOTOPE

Atoms of the same element with different numbers of neutrons, meaning they have different weights. Isotope ratios can be used to understand environmental changes or to determine a sample's age.

Interestingly, we saw big changes in the rate that the nest accumulated droppings over time. In the beginning, around 2,200 years ago, the nest grew quickly, indicating frequent usage by many generations of condors. But for around 1,000 years, from ∼1,700 years ago to ∼700 years ago, the nest build-up slowed down significantly. Then, nest material accumulated faster again. This suggests that the condors nested less often in this spot for about 1,000 years.

AN ERUPTIVE PAST

We were blown away to find that the condors have been using the same site for so long, and we wanted to explore what could have caused the changes in nesting behavior. So next, we looked at substances that could indicate what was going on in the surrounding environment, called **environmental indicators**. For example, the

ENVIRONMENTAL INDICATOR

Clues found in nature, like chemicals or organisms, that help scientists understand the past and present conditions of the surrounding environment.

DIATOM

A type of algae with glass-like cell walls. Their remains can be used to reconstruct past changes in environmental conditions.

concentrations of metals in a sample will change through natural processes, like erosion, or human-caused processes, like mining and air pollution. Another indicator, **diatoms**, are algae with cell walls made of glass. Different diatom species can only survive in certain environmental conditions, so changes in the diatom communities over time can be used to reconstruct changes in the environment.

We discovered a correlation between sharp increases in elements such as sulfur, originating from volcanic eruptions, and the disappearance of condors at this site (Figure 3). At the same time, there was a shift in diatom species, indicating a trend toward dry weather when the condors disappeared. Together, our analysis suggested that multiple nearby volcanoes likely erupted at similar times, resulting in unfavorable conditions for condor survival.

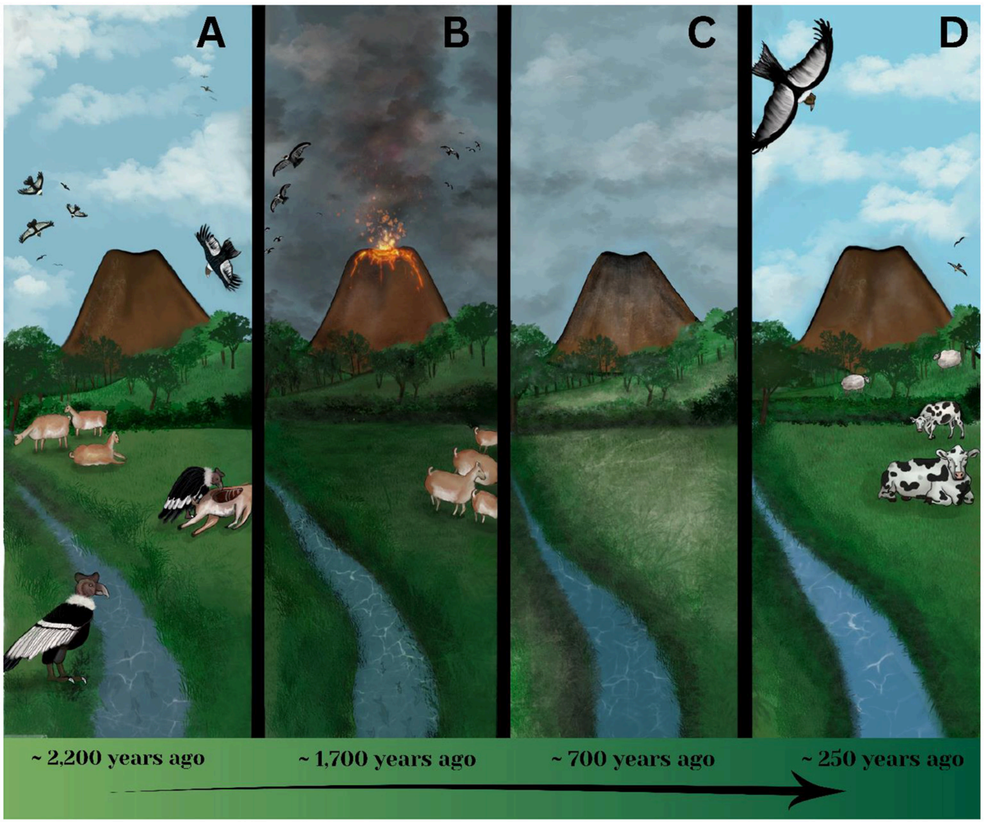

Figure 3

Figure 3

A timeline of changes preserved in the condor nest. **(A)** When the nest began accumulating about 2,200 years ago, the condors were eating fish, native animals, and scavenging dead whales. **(B)** There was a period of increased volcanic activity around 1,700 years ago, causing significant changes to the environment. **(C)** For 1,000 years, the ash from the volcanic activity changed the environment. **(D)** Around 700 years ago, condors began to return to the nest. Sheep and cows were introduced by European settlers and became the main food scavenged by condors.

The eruptions affected the whole environment. The ash from the volcanoes likely killed off much of the condor's prey and made it hard for the condors to find food. Consequently, it is likely that condors left the area, leading to a slowdown in the buildup of droppings on the nest.

WHAT HAVE THE CONDORS BEEN EATING?

After establishing that condors had been using the nest for about 2,200 years and that they were influenced by volcanic activity, we wanted to understand if there were broader environmental changes affecting their diet. To do this, we examined three key environmental indicators: **sterols and stanols**, isotopes of carbon and nitrogen, and DNA.

STEROL AND STANOL

Naturally occurring compounds found in all life forms. Different types of sterols and stanols are found in different types of organisms.

Sterols and stanols are molecules present in all living organisms, with variations in structure depending on the source, such as animals or plants. The types of sterols and stanols found in the nest can indicate if the sample is made from animal or plant material. Similarly, the ratios of different isotopes vary based on whether they originate from land-based or water-based environments. Additionally, analyzing animal DNA can reveal the prey species eaten by condors. By examining these environmental indicators together, we could track the composition of the nest material, the source of prey eaten (from the land or the sea), and the specific species eaten by condors.

Our findings revealed big dietary shifts before and after the volcanic eruptions. Before the period of increased volcanic eruptions, condors ate a higher proportion of ocean life, like dead whales and seals (Figure 3). Sometime after the eruptions, their diet shifted toward mostly land-based prey, notably sheep and cows, which were only introduced to South America in the last 150 years. Currently, sheep and cows are raised and protected by ranchers.

CURRENT THREATS TO CONDORS

By putting together all the results from the nest, we learned about the past conditions affecting condors, such as changes in their nesting behavior, diet, and responses to changes in the environment. The accumulating nest deposits serve as a time capsule, preserving a wealth of information for future generations to explore and understand.

Looking into the future, these amazing birds are facing another challenge—they are getting sick from ingesting metals like lead from hunting [4]. Hunters use lead bullets, which condors can eat in carcass and get sick. Condors are also being targeted due to misunderstandings people have about them [5]. For example, some people believe that condors hunt and eat livestock, like cattle and sheep, but condors are strictly **scavengers**, eating already dead animals. On top of that, Argentina continues to industrialize, increasing the amount of mercury and other contaminants in the environment. Condors now have elevated levels of mercury in their tissues, which may become a problem for their future health. Efforts are beginning to be made to protect the future of condors through public education and improved livestock management [6].

SCAVENGE

The search for dead animals or leftover food to eat. Condors are scavengers, exclusively eating already dead animals.

WHAT WE LEARNED

In this research, we discovered that Andean Condors have been using the same nesting site for over 2,200 years, with their presence and diet tied to changes in the environment, like volcanic eruptions and the arrival of people. By studying the condor poop and other clues in the nest, we learned how these important birds respond to changes in their environment, which helps us protect them today and into the future.

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ORIGINAL SOURCE ARTICLE

Duda, M. P., Grooms, C., Sympson, L., Blais, J. M., Dagodzo, D., Feng, W., et al. 2023. A 2200-year record of Andean Condor diet and nest site usage reflects natural and anthropogenic stressors. *Proc. R. Soc. B* 290:20230106. doi: 10.1098/rspb.2023.0106

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ASTRA NOVA, AGES: 11–14

We are students at an online middle school called Astra Nova. Our school is based in California but we live all over the world. We are all in a class called "Science Journal Club" where we are reading articles from Frontiers for Young Minds and learning how scientists share their ideas.

MUHAMMAD, AGE: 14

Hi, I am Muhammad and my curiosity for science originated when I secured first place in my grade 3 science project. It was about photosynthesis, which I chose after knowing the fact that plants are universal food makers. The science textbook of every grade always familiarized me about the magical wonders behind my daily life's surroundings.

AUTHORS

MATTHEW P. DUDA

Dr. Matthew Duda is an environmental scientist with broad interests in birds, fish, aquatic biology, and ecology. Much of his work is focused on using lake sediments to understand how animal populations changed in the past, so we can understand how to best conserve them moving forward. He hopes that his work inspires young scientists to help in exciting conservation work in the future. *mattpduda@gmail.com

CHRISTOPHER GROOMS

Chris Grooms is a research technician and laboratory manager at the Paleoecological Environmental Assessment and Research Lab (PEARL), Queen's University (Kingston, Ontario). He supports lab research that primarily focuses on tracking the effects of human impacts on lakes using environmental approaches. He is especially interested in how archives of bird and bat guano (poop) can help guide further conservation efforts.

LORENZO SYMPSON

Dr. Lorenzo Sympson is a retired large animal veterinarian and ornithologist (bird biologist), with a special interest in raptors. He has over 30 years of experience monitoring Andean Condor populations in Northern Patagonia, and has been involved in many documentaries about condor biology and behavior. Lorenzo is the co-founder of the SNAP-regional conservation NGO, and works hard to produce and manage environmental programs for rural schools.

SERGIO A. LAMBERTUCCI

Dr. Sergio Lambertucci is a principal researcher at CONICET and a professor at Universidad Nacional del Comahue, Argentina. As the head of the research group on conservation biology at INIBIOMA, his work focuses on understanding and addressing the environmental challenges posed by human activities on wildlife, with a specific emphasis on birds of prey. Working closely with his team, he conducts studies on various aspects of ecology and conservation biology. Dr. Lambertucci's main focus is on scavengers, particularly the Andean Condor—a species he has been studying and admiring since he was 20 years old.

ZOE A. KANE

Zoe Kane is a Ph.D. student supervised by Dr. John Smol at Queen's University. Her research focuses on understanding how the nutrients and deposits left behind by seabird colonies impact nearby pond ecosystems, through the lens of environmental biology. She studies the complex impacts of seabird on pond ecology, providing valuable insights into the broader ecological consequences of bird interactions with watery environments.

JOHN P. SMOL

Dr. John P. Smol is a professor at Queen's University (Kingston, Ontario) where he co-directs the Paleoecological Environmental Assessment and Research Lab (PEARL). His research and teaching, which has been conducted on all seven continents, primarily focuses on tracking the effects of human impacts on lakes using analyses of sediment. John is a frequent commentator on scientific issues with the print, online, radio, and TV media.