Finding the genes that help kingfishers dive without hurting their brains

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A diving kingfisher. Credit: Richard Towell

If you've ever belly-flopped into a pool, then you know: water can be surprisingly hard if you hit it at the wrong angle. But many species of kingfishers dive headfirst into water to catch their fishy prey. In a new study in the journal *Communications Biology*, researchers compared the DNA of 30 different kingfisher species to zero in on the genes that might help explain the birds' diet and ability to dive without sustaining brain damage.

The type of diving that kingfishers do—what researchers call "plunge-diving"—is an aeronautic feat. "It's a high-speed dive from air to water, and it's done by very few bird species," says Chad Eliason, a research scientist at the Field Museum in Chicago and the study's first author. But it's a behavior that's potentially risky.

"For kingfishers to dive headfirst the way they do, they must have evolved other traits to keep them from hurting their brains," says Shannon Hackett, associate curator of birds at the Field Museum and the study's senior author.

Not all kingfishers actually fish—many species of these birds eat land-dwelling prey like insects, lizards, and even other kingfishers. Previously, co-authors Jenna McCollough and Michael Andersen, researchers from the University of New Mexico, led the team in using DNA to show that the groups of kingfishers that eat fish aren't each others' closest relatives within the kingfisher family tree. That means that kingfishers evolved their fishy diets—and the diving abilities to procure them—a number of separate times, rather than all evolving from one common fish-eating ancestor.

"The fact that there are so many transitions to diving is what makes this group both fascinating and powerful, from a scientific research perspective," says Hackett. "If a trait evolves a multitude of different times independently, that means you have power to find an overarching explanation for why that is."

For this study, the researchers—including co-authors Lauren Mellenthin currently at Yale University, who was an undergraduate intern at Field Museum at the time this research was conducted; Taylor Hains at the University of Chicago and Field Museum; Stacy Pirro at Iridian Genomes; and Michael Anderson and Jenna McCullough at the University of New Mexico—examined the DNA of 30 species of kingfishers, both fish-eating and not.

A kingfisher with a fish. Credit: Richard Towell

"To get all the kingfisher DNA, we used specimens in the Field

Museum's collections," says Eliason, who works in the Field's Grainger Bioinformatics Center and Negaunee Integrative Research Center. "When our scientists do fieldwork, they take tissue samples from the bird specimens they collect, like pieces of muscle or liver. Those tissue samples are stored at the Field Museum, frozen in liquid nitrogen, to preserve the DNA."

In the Field's Pritzker DNA Laboratory, the researchers began the process of sequencing full genomes for each of the species, generating the entire genetic code of each bird. From there, they used software to compare the billions of base pairs making up these genomes to look for genetic variations that the diving kingfishers have in common.

The scientists found that the fish-eating birds had several modified genes associated with diet and brain structure. For instance, they found mutations in the birds' AGT gene, which has been associated with dietary flexibility in other species, and the MAPT gene, which codes for tau proteins that relate to feeding behavior.

Tau proteins help stabilize tiny structures inside the brain, but the accumulation of too many tau proteins can be a bad thing. In humans, traumatic brain injuries and Alzheimer's disease are associated with a buildup of tau.

"I learned a lot about tau protein when I was the concussion manager of my son's hockey team," says Hackett. "I started to wonder, why don't kingfishers die because their brains turn to mush? There's gotta be something they're doing that protects them from the negative influences of repeatedly landing on their heads on the water's surface."

Kingfisher study skins in the collections of the Field Museum. Credit: Kate Golembiewski

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Hackett suspects that tau proteins may be something of a double-edged sword. "The same genes that keep your neurons in your brain in all nice and ordered are the things that fail when you get repeated concussions if you're a football player or if you get Alzheimer's," she says. "My guess is there's some sort of strong selective pressure on those proteins to protect the birds' brains in some way."

Now that these correlated genomic variations have been identified, says Hackett, "The next question is, what do the mutations in these birds' genes do to the proteins that are being produced? What shape changes are there? What is going on to compensate in a brain for the concussive forces?"

"Now, we know which of the underlying genes are shifting that help create the differences that we see across the kingfisher family," says Eliason. "But now that we know which genes to look at, it created more mysteries. That's how science works."

Tissue samples in cryogenic storage, kept cold with liquid nitrogren, at the Field Museum. Credit: John Weinstein, Field Museum

In addition to a better understanding of kingfisher genetics and potential implications for understanding brain injuries, Hackett says that this study is important because it highlights the value of museum collections.

"One of the specimens we got DNA from in this study is thirty years old. At the time it was collected, we couldn't do anywhere near the kind of analyses we can do today—we couldn't even do some of this stuff five years ago," says Hackett. "It traces back to the ability of individual specimens to tell new stories through time. And who knows what we'll be able to learn from these specimens in the future? That's why I love museum collections."

More information: Chad Eliason et al, Genomic signatures of convergent shifts to plunge-diving behavior in birds, *Communications Biology* (2023). doi.org/10.1038/s42003-023-05359-z

Provided by Field Museum

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