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Materials and Methods
Figs. S1 to S3

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Ivory-billed Woodpecker (*Campephilus principalis*) Persists in Continental North America

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The ivory-billed woodpecker (*Campephilus principalis*), long suspected to be extinct, has been rediscovered in the Big Woods region of eastern Arkansas. Visual encounters during 2004 and 2005, and analysis of a video clip from April 2004, confirm the existence of at least one male. Acoustic signatures consistent with *Campephilus* display drums also have been heard from the region. Extensive efforts to find birds away from the primary encounter site remain unsuccessful, but potential habitat for a thinly distributed source population is vast (over 220,000 hectares).

The ivory-billed woodpecker is one of seven North American bird species that are suspected or known to have become extinct since 1880 (1). One of the world's largest woodpeckers, this species of considerable beauty and lore was uncommon but widespread across lowland primary forest of the southeastern United States until midway through the 19th century (2, 3). Its disappearance coincided with the systematic annihilation of virgin tall forests across the southeastern United States between 1880 and the 1940s. Relentless pursuit by professional collectors accelerated the species' decline from 1890 to the early 1920s. The last well-documented population occupied a stand of old-growth bottomland hardwood forest in northeastern Louisiana (the

Singer Tract) during the late 1930s (3–6). That population disappeared as the Singer Tract was logged amid cries for protection of both forest and bird. The final individual in the Singer Tract, an unpaired female, was last seen in cut-over forest remnants in 1944 (7).

A resident subspecies of ivory-billed woodpecker (*Campephilus principalis bairdii*) occupied tall forests throughout Cuba, and a small population was mapped and photographed in eastern Cuba as late as 1956 (8). Fleeting observations of at least two individuals in 1986 and 1987 by several experts are widely accepted as valid (9), but repeated efforts to confirm the continued existence of that population have failed (10).

Anecdotal reports of ivory-billed woodpeckers in the southern United States continue to this day. Such reports are suspect because of the existence and relative abundance throughout this region of the superficially similar pileated woodpecker (*Dryocopus pileatus*). Three reports were accompanied by physical evidence, but their veracity continues to be questioned [supporting online material (SOM) text]. Thus, no living ivory-billed woodpecker has been conclusively documented in continental North America since 1944.

At approximately 13:30 Central Standard Time (CST) on 11 February 2004, while kayaking alone on a bayou in the Cache River National Wildlife Refuge, Monroe County,

Arkansas, G. Sparling spotted an unusually large red-crested woodpecker flying toward him and landing near the base of a tree about 20 m away. Several field marks suggested that the bird was a male ivory-billed woodpecker (SOM text), and Sparling hinted at his sighting on a Web site. T. Gallagher and B. Harrison were struck by the apparent authenticity of this sighting and arranged to be guided through the region by Sparling. At 13:15 CST on 27 February 2004, within 0.5 km of the original sighting, an ivory-billed woodpecker (sex unknown) flew directly in front of their canoe with the apparent intention of landing on a tree near the canoe, thereby fully revealing its dorsal wing pattern. The bird instead veered into the forest, apparently landed briefly several times (each time blocked from the observers' sight by trees), and then flew off (SOM text and fig. S1). Efforts to locate the bird over the next several days failed, but subsequent surveys by teams of experienced observers yielded a minimum of five additional visual encounters between 5 April 2004 and 15 February 2005 (SOM text). All seven convincing sightings were within 3 km of one another.

At 15:42 Central Daylight Time on 25 April 2004, M. D. Luneau secured a brief but crucial video of a very large woodpecker perched on the trunk of a water tupelo (*Nyssa aquatica*), then fleeing from the approaching canoe (fig. S2 and movie S1). The woodpecker remains in the video frame for a total of 4 s as it flies rapidly away. Even at its closest point, the woodpecker occupies only a small fraction of the video. Its images are blurred and pixilated owing to rapid motion, slow shutter speed, video interlacing artifacts, and the bird's distance beyond the video camera's focal plane. Despite these imperfections, crucial field marks are evident both on the original and on deinterlaced and magnified video fields (11) (fig. S3). At least five diagnostic features allow us to identify the subject as an ivory-billed woodpecker.

1) Size. When the woodpecker first begins to take flight from the left side of a tupelo trunk, two video fields reveal the dorsal surface of the right wing and a large black tail (Fig. 1). The minimum distances between the "wrist" and the tip of its tail—measured independently on each of the two video fields and compared to known scales (the diameter of the tupelo trunk at two places)—are 34 to 38 cm. These values exceed comparable values for the pileated woodpecker and correspond to the upper range for the ivory-billed woodpecker (fig. S4).

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2) Wing pattern at rest. These same two video fields (Fig. 1) reveal an extensive posterior white region on the opening wing, sharply bordered by an anterior black patch that corresponds to upper wing coverts and wrist area. Such extensive white on the secondary flight feathers is consistent with both sexes of ivory-billed woodpecker. The only comparably large white patch anywhere on a pileated woodpecker is the underwing lining, which would be obscured at this early stage of wing extension, and any barely visible portion of the white underwing should appear anteriorly, not posteriorly, on the wing.

3) Wing pattern in flight. During the first 1.2 s of flight, the fleeing woodpecker completes 10 full wingbeats before being obscured temporarily by a tupelo trunk (fig. S3). All visible wingbeats reveal extensive white patches on the posterior dorsal and ventral wing surfaces, representing entirely white secondary and innermost primary flight feathers. Body and wing tips are black. Video images of flying pileated woodpeckers, including our model during reenactment (11), consistently reveal a different pattern: Ventrally, white wing-linings are bordered by a dark trailing edge. Dorsally, a white band (proximally narrow, distally broadening into a wide spot along the base of the inner primaries) is surrounded by an otherwise all-dark upper wing surface (Fig. 2).

4) White plumage on dorsum. As the fleeing woodpecker gains elevation (video fields 966.7 to 1016.7 in fig. S3), white plumage is clearly evident on the back between the wings. Ivory-billed woodpeckers have a pair of longitudinal dorsal stripes that approach one another on the middle and lower back (Fig. 2), producing a white area

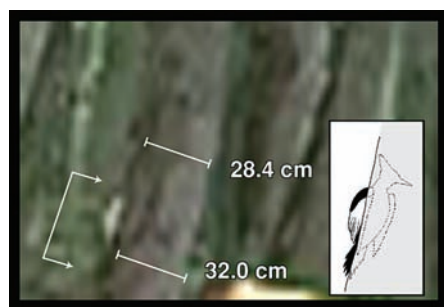


Fig. 1. Zoomed segment of frame 33.3 from the Luneau video (fig. S3), one of two consecutive frames in which the woodpecker's right wing is revealed immediately before flight. The large white area represents a dorsolateral view of the secondary flight feathers. Bracketed arrows mark the exposed distance between a spot near the bird's wrist and the tip of its tail, which is thrusting laterally upon takeoff. Parallel white bars identify two diameters of the tree trunk, measured later for scale. The inset sketch (by J. Fitzpatrick) interprets the approximate position of the bird, including unrevealed portions (dotted lines and shaded background).

that is visible on a dorsal view of a fleeing bird. Pileated woodpeckers have lateral white marks on the sides of the head and neck but lack any trace of white on the dorsum.

5) Black-white-black pattern of the perched bird. In the Luneau video (26 to 21 s before the zero point in fig. S3), a blurry white object bordered above and below by black is visible on a distant tupelo trunk (fig. S5). The object was not present during subsequent inspections of the site, when we determined that it had been situated 4 m above

the water, on a tree located 3 m from the trunk from which the woodpecker flew 21 s later. We interpret the object to be a large perched woodpecker. Among candidate species, the observed pattern fits only that of the ivory-billed woodpecker. Placing a life-sized model on the same tree trunk produced a similar image (fig. S5).

Two other features suggesting the ivory-billed woodpecker are evident on the Luneau video, but we do not currently regard them as diagnostic, in part because we lack suf-

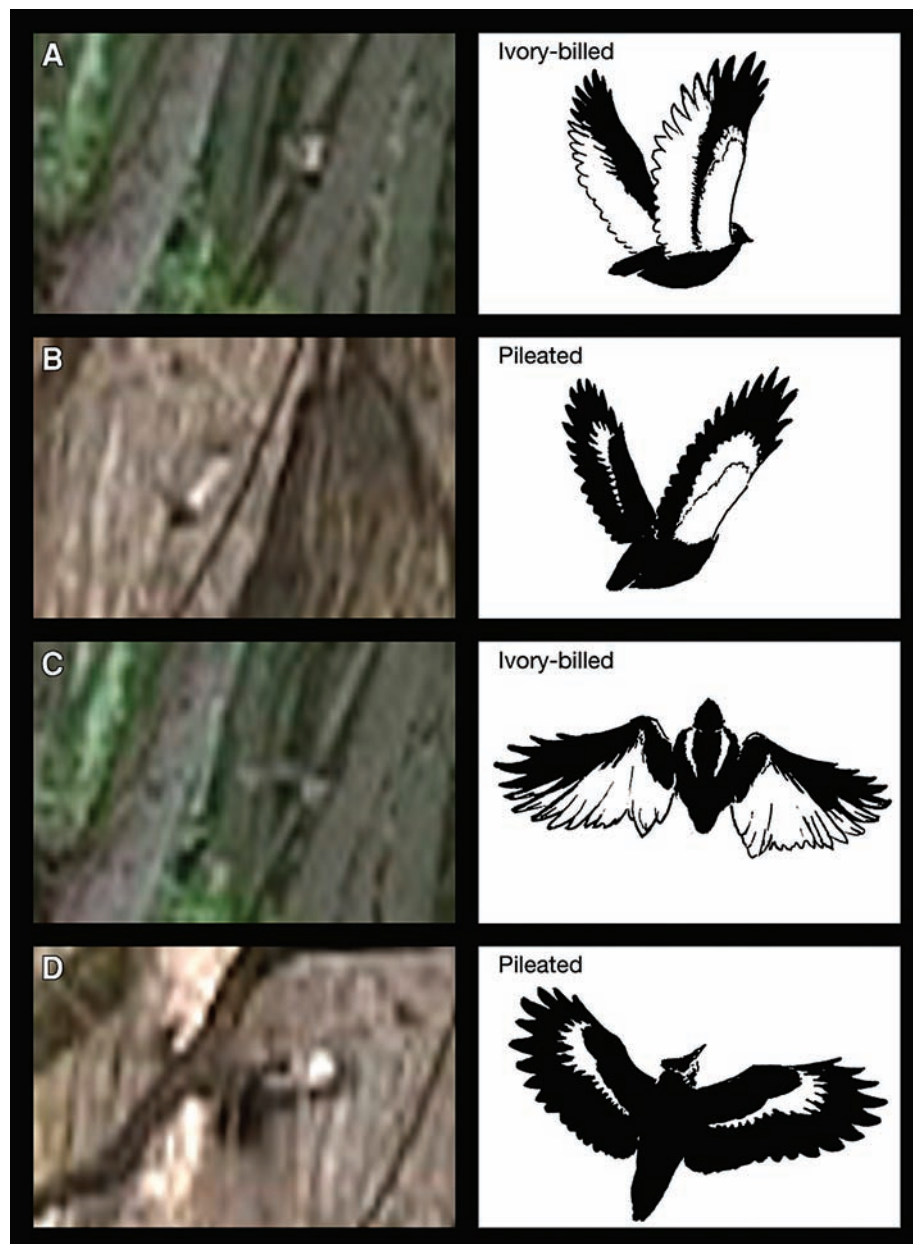


Fig. 2. Selected video frames of the woodpecker in the Luneau video [(A and C), left column], comparably distant and imperfect video frames of a pileated woodpecker recorded in the study area in similar postures [(B and D), left column], and interpretative sketches by J. Fitzpatrick (right column). With these distances and light conditions, bleeding tends to exaggerate the apparent extent of white in the wings. However, careful study of these and numerous other video examples consistently reveals dark trailing edges on both upper and lower wing surfaces of pileated woodpeckers—features not present on the bird in the Luneau video.

ficiently comparable data for objective comparison with the pileated woodpecker. First, the estimated wingspan of the fleeing woodpecker exceeds 71 cm (11), a value that is within the published range for the ivory-billed woodpecker and at or above the maximum published wingspan of the pileated woodpecker. Second, the video shows a woodpecker on a sustained escape flight that is rapid (nine wingbeats per second) and direct for at least 4 s. This flight pattern matches many anecdotal descriptions of the ivory-billed woodpecker (2–5) and is atypical for the pileated woodpecker.

We considered and rejected the hypothesis that the sightings and video can be explained by a “piebald” or partially leucistic pileated woodpecker with symmetric white patches on wings and back approximately matching the pattern of an ivory-billed woodpecker. Several observers described the bird they saw as conspicuously larger than a pileated woodpecker, and the video bears this out (fig. S4). We are unaware of any examples of extensively and symmetrically piebald pileated woodpeckers in museum collections or the literature (12, 13). During 14 months of nearly continuous fieldwork by dozens of observers, pileated woodpeckers were encountered virtually daily throughout the study region, where they are common and noisy residents occupying permanent territories. We would expect any strikingly plumaged leucistic individual in the study area to have been observed regularly.

Despite substantial survey efforts by skilled observers after the original sightings, we obtained minimal acoustic evidence of the ivory-billed woodpecker in the region. Distinctive “double-knock” display drums characteristic of most members of the genus *Campephilus*, including the ivory-billed woodpecker, were heard sporadically by seven different observers between March 2004 and March 2005, and series of these display drums were heard on three occasions (SOM text). No observer has positively heard or recorded nasal “kent” notes that are typical of the species (5). During late spring 2004, and again from 16 December 2004 through the present, we acoustically monitored a 20-km² region of forest in the vicinity of the sightings and potential habitat elsewhere in the White River and Cache River refuge complex (11). Recordings of series of “kent” notes exist in these data but cannot be positively distinguished from exceptional calls by blue jays (*Cyanocitta cristata*).

Our field surveys (11) to date have revealed little about population size or breeding. Work covering substantial portions of the Cache River and White River National Wildlife Refuges from December 2004 through April 2005 yielded remarkably few encounters. Except for the flurry of sightings and the video in April 2004, our surveys have

provided no evidence for the predictable occurrence of ivory-billed woodpeckers in a localized area and no evidence of a mated pair. Indeed, we cannot rule out the possibility that all of our fleeting encounters involved the same bird. In three sightings (including the initial one of a perched bird), the observer saw red on the hindcrest, which indicates that at least one male exists (the female’s crest is all black). The life spans of large woodpeckers rarely exceed 15 years (14). Hence, the individual(s) documented here probably hatched no earlier than the 1990s and could even represent dispersing nonbreeders hatched in the 21st century.

The difficulty of detecting ivory-billed woodpeckers in the Big Woods may be a consequence of extremely low population density. In the Singer Tract’s mature bottomland hardwoods, Tanner documented only one pair per 16 km² of forest (5). The present Big Woods landscape consists of patches of mature forest amid a matrix of regenerating trees of various ages; its resource base for ivory-billed woodpeckers is much reduced as compared to that of the Singer Tract. Although we failed to find occupied roost holes in an intensive search of over 41 km² of forest around the sighting area (11), we have covered only a small part of the available potential habitat. Individuals may roost far from where our encounters have been concentrated. Large woodpeckers are known to adapt to fragmented forest landscapes by expanding their home range sizes (15, 16) (SOM text). Ivory-billed woodpeckers are capable of rapid and sustained flight and were known to move widely in search of recently dead large trees (2–5). Individuals in the Big Woods could cover hundreds of square kilometers to accommodate their resource requirements. Such low densities would, in turn, explain the paucity of vocalizations and drumming signals we encountered.

The Big Woods (fig. S6) (at 220,000 ha, the second-largest contiguous area of bottomland forest in the Mississippi River basin) includes 20 distinct types of swamp and bottomland hardwood forests (17). About 40% of the forest is currently approaching maturity (with the oldest trees being over 60 years old). The remainder, although younger (20 to 60 years), is growing rapidly. An additional 40,000 ha of adjacent or nearby land has been reforested in the past decade and is in early successional stages. If a few breeding pairs do exist, most of the conditions believed to be required for successful breeding and population growth (5) are becoming more available to them. Strategic additions to the public refuge system and successful restoration efforts by both public and private landowners are reestablishing mature hardwood forest, the crucial foraging habitat for ivory-billed woodpeckers (5). Increasing the extent and diversity

of genuinely mature bottomland forest with large, very old trees and substantial standing dead and dying timber may allow future generations to see the awe-inspiring woodpecker again gracing old-growth treetops.

References and Notes

- The other species are the Labrador duck (*Camptorhynchus labradorius*), Eskimo curlew (*Numenius borealis*), Carolina parakeet (*Conuropsis carolinensis*), passenger pigeon (*Ectopistes migratorius*), Bachman’s warbler (*Vermivora bachmanii*), and dusky seaside sparrow (*Ammodramus nigrescens*).
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Supporting Online Material

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Materials and Methods

SOM Text

Acknowledgments

Figs. S1 to S6

Movie S1

References and Notes

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