



FILM DOCUMENTATION OF THE PROBABLY EXTINCT IMPERIAL WOODPECKER (*CAMPEPHILUS IMPERIALIS*)

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ABSTRACT.—The Imperial Woodpecker (*Campephilus imperialis*) of Mexico—the largest woodpecker in the world—probably became extinct in the late 20th century, without known documentation of the species in life. We describe a recently discovered 16-mm color film of an Imperial Woodpecker taken in 1956 by William L. Rhein. The film documents climbing strides, launches, flights, and foraging of one female Imperial Woodpecker. For perches and foraging the woodpecker used dead or recently dead Durango Pines (*Pinus durangensis*). Trunks of perch and foraging trees were of the largest diameters available in this tree species. After allowing for possible inaccuracies in the frame speed of the film, we found that the Imperial Woodpecker had slow climbing strides and a fast wing-flap rate compared with other woodpeckers. Following landmarks documented during the 1956 expedition, we identified and surveyed the film site in 2010. The site was in coniferous forest in lightly undulating terrain at 2,700–2,900 m elevation. In 1956, the area was old-growth forest with abundant large and dead trees. By 2010, the area had been logged multiple times. Interviews with local people indicated that Imperial Woodpeckers had disappeared from the region by 1960 and that they were killed by hunting and perhaps through poisoning instigated by logging interests. Human persecution and the logging of large pines for timber and of dead trees for pulp were likely principal factors in the extinction process of the Imperial Woodpecker. Received 27 November 2010, accepted 13 May 2011.

Key words: body size, climbing, extinction, flight, hunting, logging, poisoning.

Documentación Fílmica de la Especie Probablemente Extinta *Campephilus imperialis*

RESUMEN.—La especie mexicana *Campephilus imperialis*—el carpintero de mayor tamaño en el mundo—probablemente se extinguió a finales del siglo XX, sin que haya documentación conocida de la especie en vida. Describimos una filmación de un individuo tomada en formato de 16 mm en color por William L. Rhein en 1956. La película documenta trepadas, lanzamientos, vuelos y forrajeo de una hembra. El carpintero usó como perchas y como sustrato de forrajeo pinos (*Pinus durangensis*) muertos o recientemente muertos. Los troncos de las perchas y los árboles de forrajeo fueron los de mayor diámetro disponible de esta especie. Luego de ajustar la velocidad de rodado de la película, encontramos que la especie daba zancadas lentas para trepar y presentaba una tasa rápida de batido de las alas en comparación con otros carpinteros. Siguiendo algunas marcas del paisaje documentados durante la expedición de 1956, identificamos e inspeccionamos el sitio de filmación en 2010. El sitio estaba ubicado en un bosque de coníferas en un terreno ligeramente ondulado a 2,700–2,900 m de elevación. En 1956, el área era un bosque antiguo con abundantes árboles grandes y muertos en pie. Entrevistas con personas locales indicaron que *C. imperialis* había desaparecido de la región para 1960 y que los carpinteros fueron cazados y tal vez envenenados respondiendo a intereses forestales. La persecución humana y la tala de los pinos grandes para madera y de los árboles muertos para pulpa fueron probablemente los principales factores en el proceso de extinción de *C. imperialis*.

THE IMPERIAL WOODPECKER (*Campephilus imperialis*) lived until recently in old-growth forests of pines and oaks in montane areas of northwestern Mexico. With a body mass of ~700 g, it was the largest woodpecker species in the world (Short 1982). Similar in appearance to the closely related Ivory-billed Woodpecker (*C. principalis*), the Imperial Woodpecker differed mainly in its larger size, narrower white stripes on its upper back, absence

of white on the neck and face, and longer crest. The crest was crescent-shaped and red with black in males, and forward-curling and black in females. Imperial Woodpeckers often occurred in groups of 5–10 individuals (Nelson 1898, Lammertink et al. 1996). They were associated with large areas of plateau forest at elevations >2,000 m with abundant mature and dead trees for food and cavities (Collar et al. 1992). Logging of large timber and extraction

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of dead trees for pulp had affected >99% of the species' range by 1995 (Lammertink et al. 1996). Imperial Woodpeckers were frequently hunted, primarily for their meat, for alleged medicinal properties of their feathers, and out of curiosity (Tanner 1964, Lammertink et al. 1996). From 1930 onward, population numbers rapidly declined. The disappearance of the Imperial Woodpecker has been attributed to a combination of hunting and logging by Collar et al. (1992) and Lammertink et al. (1996), but solely to hunting by Tanner (1964) and Snyder et al. (2009).

Search efforts for the Imperial Woodpecker in recent decades have failed to locate a bird (Tanner 1964, Plimpton 1977, Lammertink et al. 1996, D. G. Allen unpubl. data, R. Uranga-Thomas and D. Venegas-Holguín unpubl. data). Reports of Imperial Woodpeckers with accurate descriptions by local people indicated the possible survival of a few individuals into the early 1990s (Lammertink et al. 1996). However, high hunting pressure on wildlife in the Sierra Madre Occidental and a paucity of suitable breeding habitat make it unlikely that the species still exists.

Written records of the Imperial Woodpecker are scant, and the few firsthand accounts are more than a century old (Nelson 1898, Lumholtz 1903). About 160 mounted specimens and study skins exist in museums around the world (Snyder et al. 2009). Thus far, no photographic, film, or sound documentation of the species in life has been available.

We describe a recently discovered film of an Imperial Woodpecker taken in 1956 by William L. Rhein, a dentist and amateur ornithologist. We describe new information about the Imperial Woodpecker gleaned from the film, concentrating on climbing and flying movements and tree substrate use. We also report on field work in 2010 in southern Durango, where we located the Imperial Woodpecker film site, assessed current habitat conditions, searched for the species, and interviewed residents about the disappearance of the Imperial Woodpecker. We discuss the factors that contributed to the extirpation of the Imperial Woodpecker in the film area and its probable extinction throughout its range.

Although the existence of an Imperial Woodpecker film by Rhein was not known, Rhein has been widely attributed with the last sighting record of an Imperial Woodpecker (Tanner 1964, Plimpton 1977, Collar et al. 1992, Winkler and Christie 2002). However, the years of Rhein's first and last Imperial Woodpecker sightings have been inaccurately reported, his name has been spelled incorrectly, and conflicting accounts exist about whether the last bird he saw was alive or freshly killed. In the interest of accurately documenting the last records of a species that is probably extinct, we reconstruct the final Imperial Woodpecker records from unpublished correspondence and interviews.

METHODS

We examined documents in the folder "Correspondence of James T. Tanner on the Imperial Woodpecker 1941–1991" (collection no. 2665, Division of Rare and Manuscript Collections, Carl A. Kroch Library, Cornell University), including letters from 1962 by Rhein and Frederick H. Hilton indicating the existence of the film. On 17 November 1997, M.L. interviewed Rhein, at age 88, at his residence in Mechanicsburg, Pennsylvania, and viewed the film. Rhein passed away in 1999, and in 2005 his nephew, R. Thorpe, donated the film to the Macaulay Library at the Cornell Lab of

Ornithology, where the catalogue number of the film is 61027. Hilton, a member of Rhein's 1953 expedition, was interviewed by M.L. on 30 April 2010.

We scanned the individual frames of the original film in a telecline transfer using a Spirit HDTV Datacine. Footage was scanned at a rate of 24 frames s^{-1} (fps) at an image size of $1,436 \times 1,080$ pixels. To mitigate considerable camera shake in the Imperial Woodpecker footage, we stabilized two sequences using Adobe After Effects Professional software (films 2 and 3; Adobe, San Jose, California). In the automated stabilization process, frames were occasionally deleted and replaced with duplicated frames. For a frame-by-frame analysis, we recommend reviewing the original footage (film 1). The film clips are available online at www.birds.cornell.edu/imperial.

We calculated the duration of climbing hops and wing-flap rates of the Imperial Woodpecker for an estimated range of frame rates. Two sources of uncertainty affected estimations of the frame rate at which this film was shot. One was the target frame rate—that is, the frame-rate setting used by the filmer. The second was the inaccuracy or variation around the target frame rate resulting from the use of a spring-wound motor in Rhein's camera, a Ciné-Kodak Special (R. Heintzelman pers. comm., F. Hilton pers. comm.). Using Final Cut Pro software, we played the film at various frame rates and reviewed the Imperial Woodpecker material plus footage of other birds, people, and mules (film 4) that Rhein shot with the same camera. When played at the industry standard frame rate for 16-mm film of 24 fps (Malkiewicz 1992), the motions of the Imperial Woodpecker and other birds looked natural in most takes (film 1). Scenes with other birds, people, and mules earlier in the Rhein film also looked natural or occasionally slightly slow at 24 fps (film 4). When played at other possible frame rate settings of 16 fps and 32 fps (Eastman Kodak 1936), and at variations of less than 24 fps or more than 26 fps, motions looked decidedly unnatural. We concluded that the Rhein film was mostly shot at a target rate of 24 fps (with the exception of two takes, explained below) and met that target to within a 24- to 26-fps range. In the second take of the film (frames 212–395) and in the third take (frames 396–531), climbing and pecking movements of the woodpecker and the rhythm of camera shake were markedly slower than in other takes, and the exposure looked darker. These two takes were probably shot at a higher frame rate, capturing climbing movements and isolated pecks, but not foraging or flight. The ninth and final take (frames 1,842–2,041), which includes a third flight, is also rather dark at first but later becomes brighter. We made no inferences from takes 2, 3, and 9, which had uncertain target frame rates.

We measured the diameter of the trunk perches of the woodpecker in Photoshop CS3 software (Adobe) by using the folded wing of the Imperial Woodpecker for scale, assuming a wing length of 30.6 cm in this species (Winkler et al. 1995). We estimated a range of possible perch heights of the woodpecker from clues in the images and then used a tapering function for trunk diameter (Corral-Rivas et al. 2007) to arrive at an estimate of diameter at breast height (DBH) of perch trees. For comparative data on climbing hop (stride) duration in other woodpeckers, we searched for published studies using the Zoological Record database (apps.isiknowledge.com), and we measured stride duration in two videos of Great Slaty Woodpecker (*Mulleripicus pulverulentus*) in

the Internet Bird Collection (ibc.lynxeds.com). Those videos were taken by S. Behrens in 2000 and by C. Gouraud in 2009. The Great Slaty Woodpecker has a body mass of about 430–560 g and is the next largest woodpecker after the Imperial Woodpecker (Short 1982). Means are given \pm SD.

In 2009 and 2010, we interviewed Richard Heintzelman, a member of Rhein's 1956 expedition (film 4). Heintzelman provided 35-mm Kodachrome slides containing landmark clues about the location of the film site. During 3–11 March 2010, M.L. and T.G. visited the region where Rhein had worked, identifying the film site using these landmarks. We interviewed three elderly local people who had memories of the Imperial Woodpecker and knowledge of the logging and hunting history of the region. We surveyed a roadless forested area of 8.7 km² near the film site that we had identified in Google Earth (earth.google.com/). Roadless areas in the Sierra Madre Occidental are rare and small yet offer the best potential for harboring surviving Imperial Woodpeckers because they contain old-growth stands and are less accessible to hunters. We hiked 73 km during 76 daylight hours in and around this area, searching for birds, large woodpecker cavities, and signs of foraging behavior. We played recorded Ivory-billed Woodpecker calls that match the description of Imperial Woodpecker calls (Allen 1951) and made imitations of *Campephilus* double-knock drums with a custom-made hand-held tool at 18 points in the roadless area and at 5 points in the vicinity of the film site. The points were ≥ 500 m apart and at sites with an open view into the forest or across a valley.

RESULTS

Imperial Woodpecker film.—The Rhein film was shot on 16-mm color motion-picture film, without a sound track. It contains 2,041 frames or ~ 85 s of film, in nine takes, of one female Imperial Woodpecker (Fig. 1; films 1, 2, and 3). The film shows the bird in large Durango Pine trees (*Pinus durangensis*) and documents 18 climbing strides (13 vertical, 5 sideways), four pecks, one foraging scene, two flight launches, and one flight shortly after launching. Striking aspects of the film include movements during the initiation of climbing strides; the power stroke of the Imperial Woodpecker is slow

and deep compared with that of smaller woodpeckers. The long crest of the woodpecker sways and bounces markedly with abrupt head movements. In flight, the woodpecker shows long, narrow wings, long tail (Fig. 1), and a rapid wing-flap rate.

Assuming a frame rate that accurately meets the target of 24 fps in the six correctly exposed takes, vertical climbing strides of the woodpecker that are unobstructed in view have a duration of 0.35 ± 0.05 s ($n = 6$; 0.32 ± 0.05 if frame rate drifted to 26 fps). In two videos of the Great Slaty Woodpecker, we measured vertical climbing strides with a duration of 0.33 ± 0.05 s ($n = 6$). In two flight launches, the Imperial Woodpecker first leans in the direction of the flight, slightly relaxes and barely opens its wings, jumps, turns its tail and body horizontally, and only then fully opens its wings (film 1). As in other large woodpeckers, wing-flap rates slow progressively after launch. In one launch (starting at frame 635), assuming a rate of 24 fps, the woodpecker retains a wing-flap rate of 5.8 s⁻¹ (up to 6.2 s⁻¹ with frame-rate drift) through wing-flap 6, after which the bird is off frame. In the second launch (starting at frame 1,761), closer to the camera and perhaps an escape flight, the flap rate is 7.7 s⁻¹ (up to 8.3 s⁻¹) through wing-flap 8, and 7.3 s⁻¹ (up to 7.9 s⁻¹) through wing-flap 14. In the flight scenes, the bird performs two closed-winged swoops, accounting for 14% of total flight time.

Nine different perches of the Imperial Woodpecker appear in the film, four on branches and five on trunks (the perch trunks in takes 6 and 7 may be the same tree). Trunks measure 50 ± 15 cm (range: 31–63 cm) in diameter at perch height. The only foraging shown takes place on the largest of these trunks. From the viewing angle, the sky background, and the occurrence of branches near perches, we estimated that perch height of the woodpecker on these trunks was at midheight in the trees at 12–18 m. Maximum tree height of *P. durangensis* in the film environment was 28–31 m, as measured from still slides by Heintzelman, with people on mules as reference points for height. Taking into account the taper function for trunk diameter in *P. durangensis* (Corral-Rivas et al. 2007), the DBH of the perch trees was 71 ± 20 cm (range: 46–89 cm) if the woodpecker was perched at 12 m height, and the DBH was 88 ± 25 cm (range: 56–110 cm) if the woodpecker was perched at 18 m height. Of the nine perches, one is entirely covered in bark, one is entirely without bark,



FIG. 1. Details from four frames in a 16-mm motion-picture film of a female Imperial Woodpecker made by W. L. Rhein in 1956 in the Sierra Madre Occidental, Mexico. Diagnostic features, when perched (two panels on left): triangular white patch on folded wings, black neck and face, black, forward-curling crest; in flight (two panels on right): light-colored bill, white trailing edge in wings, long, tapering tail, and long wings.

and the remaining seven are beginning to lose bark with $21 \pm 17\%$ of bark missing, which indicates that these are recently dead trunks or branches. During foraging, three pieces of bark or wood are dislodged in a scene that lasts 9 s (film 3). Bark or wood pieces are worked loose with direct and lateral bill pecks. One piece is grabbed in the bill and then tossed (frames 1,721 and 1,722).

Imperial Woodpecker observations by Rhein.—William L. Rhein led expeditions to the Sierra Madre Occidental in the state of Durango in 1953, 1954, and 1956, all having the primary objectives of making motion pictures and sound recordings of the Imperial Woodpecker. Each expedition lasted ~6 weeks and was self-funded (Rhein letter, 1 March 1962). In June–July of 1953, Rhein, accompanied by Hilton and the brothers Walter and George Kohler, first explored the region between the towns of Tepehuanes and Topia. They failed to locate any Imperial Woodpeckers, but they found some old cavities that they attributed to the species. They then drove to the lumber camp of Los Laureles ($23^{\circ}17'41''\text{N}$, $104^{\circ}51'07''\text{W}$; INEGI 1983), 82 km south-southwest of the city of Durango. Los Laureles was situated on the west rim of the Rio Taxicaringa canyon and had just started logging operations in 1953. They observed, but did not film, several Imperial Woodpeckers between Los Laureles and the settlement of Carboneras, 6 km to the west-southwest of Los Laureles. They received reports that 12 Imperial Woodpeckers had been shot that year by the inhabitants of Los Laureles (Hilton letter, 19 February 1962). In June–July of 1954, Rhein returned to Los Laureles with Walter Kohler (F. Hilton pers. comm.). From there they traveled east by mule train, crossing the Rio Taxicaringa canyon to the highlands of what Rhein referred to as the “Guacamaya” mountains (Rhein

letter, 1 March 1962). In that area, in virgin pine forest, they found several Imperial Woodpeckers, apparently including a recent fledgling, but again they did not film the birds. Following the same route, in April–May of 1956 Rhein returned for a final visit, accompanied by Richard Rauch and Heintzelman (R. Heintzelman pers. comm.; film 4). That year, Rhein obtained “very poor footage” of an Imperial Woodpecker “with several short flight shots taken with a hand-held telephoto lens from the back of a mule” of “one lone female aimlessly flying about.” Further, Rhein stated that “In 1955 when I was unable to return to Mexico the local Indian shot the parent birds that I had localized the previous year” (Rhein letters, 1 March and 9 April 1962).

Rhein did not make sound recordings of the Imperial Woodpecker. The sound-recording equipment brought during the expeditions included a large metal parabola and a wire recorder powered by car batteries (F. Hilton pers. comm.; film 4). In the absence of finding an active nest or roost cavity, this equipment was probably too heavy to record a free-ranging Imperial Woodpecker. Describing the sounds of the Imperial Woodpeckers he heard, Rhein wrote: “the bird made cackling notes and the usual toy trumpet sounds” (letter, 1 March 1962). Rhein found cavities he ascribed to Imperial Woodpeckers at heights between 15 feet (5 m) and 90 feet (27 m) in trees, and found cavity trees with both single and multiple cavities (letter, 1 March 1962). Photos and film from the 1956 expedition show numerous big pines, and a forest that was open and park-like from periodic fires (Fig. 2).

Results of 2010 search.—During our field work in 2010, two of the landmarks visible in still photographs from the 1956 expedition were readily recognized by people living in the region: a



FIG. 2. (A) Old-growth pine forest with large pines, standing and downed dead trees, and a fire-maintained open understory in the area where the Imperial Woodpecker was filmed in 1956 in the Sierra Madre Occidental, Mexico (from a Kodachrome still slide by R. Heintzelman). (B) Approximately the same site in March 2010. Large pines had disappeared as a consequence of multiple rounds of logging, dense growth of young pines dominated, and standing dead trees were lacking (photograph by M. Lammertink).

rock formation known locally as Los Pilares, located at 23°18'23"N, 104°44'13"W (elevation: 2,800 m), and a pine flat 1.7 km to the east of there at 23°18'41"N, 104°43'18"W (elevation: 2,850 m) (Fig. 2). From route descriptions (R. Heintzelman pers. comm.) and habitat types shown in the Rhein film, it was clear that the Imperial Woodpecker was filmed within 2 km of these landmarks. The film site was 12 km east of Los Laureles and 3 km southwest of the village of Guacamayita.

Habitat at the film site consisted of flat and lightly undulating plateau (mesa) forest at elevations of 2,700–2,900 m, a mixed coniferous forest of *Pinus*, *Pseudotsuga*, and *Juniperus*, with only a few oaks (*Quercus*). By 2010, the forests around the film site, as well as all other similar plateau forests in the region, had been logged multiple times. A few large pines were left as seed trees, but most trees were in the 5–30 cm DBH range in dense stands, and few standing dead trees were present (Fig. 2).

The only roadless area at elevations >2,000 m near the film site, which we had identified in Google Earth on the basis of 2005 images, had never been logged and remained devoid of roads in 2010. This forest was located ~6 km west of the film site on the rim of the Rio Taxicaringa canyon. It was at elevations of mostly 2,000–2,400 m, with a few slopes up to 2,550 m. This environment differed from the film area, with mostly steep slopes, poor rocky soil, and mixed pine–oak forest. On slopes, pines rarely reached more than 40 cm DBH, although on ridges and in canyon bottoms we saw scattered pines of 80+ cm DBH. The frequency of large pines appeared to be much less than the historical frequency at the film site. We encountered scattered plots of illicit crops (both *Cannabis* and *Papaver*), created by slash and burn. On a foot trail in the roadless area we found a discarded box of .22 bullets, which are commonly used to hunt small game and birds. Thus, even in a rare roadless area, forest disturbance and hunting were evident.

We did not see or hear any Imperial Woodpeckers during our 2010 field work nor detect any responses at our 23 playback stations. We failed to locate any large woodpecker cavities or signs of foraging in suitable, recently dead pines. Young and middle-aged people living in the region reported no experience with Imperial Woodpeckers. We found three people aged 76, 68, and 72 who had lucid memories of the Imperial Woodpecker. All three reported that the species disappeared from the region by 1960, shortly after a sawmill opened near Guacamayita. Two of the interviewees said they were unaware of any hunting or killing of Imperial Woodpeckers. One said that the woodpecker needed old forest and left when the forest was logged. The third interviewee, however, recalled that people shot Imperial Woodpeckers. Moreover, he said that when the first logging operation moved into the region, the forester in charge believed that Imperial Woodpeckers were harmful to the valuable timber resources, and he gave villagers an agricultural poison to apply to foraging snags in order to kill the birds by ingestion of poison.

DISCUSSION

The information contained in this 85-s film is scant and must be interpreted with caution. Nevertheless, all of the previous information on Imperial Woodpecker biology is based on museum specimens, anecdotal accounts by 19th-century explorers (Nelson 1898, Lumholtz 1903), and interview data from local people (Fleming and Baker 1963, Lammertink et al. 1996). Therefore, film of a

live Imperial Woodpecker in motion in its wild habitat may be our last chance to gain substantial knowledge of the species.

Climbing and flight motions.—Vertical climbing hops (strides) of the Imperial Woodpecker appear to be rather slow and measure out at a duration between 0.32 ± 0.05 s and 0.35 ± 0.05 s. The strides of the Great Slaty Woodpecker that we measured were similar in duration at 0.33 ± 0.05 s. By comparison, in smaller vertical tree-climbing birds the following stride durations have been measured: 0.14 s in the 9-g Eurasian Treecreeper (*Certhia familiaris*); 0.14–0.21 s in the 21-g Japanese Pygmy Woodpecker (*Picooides kizuki*); 0.23 s in the 51-g Yellow-bellied Sapsucker (*Sphyrapicus varius*); and 0.23 s in the 74-g Black-backed Woodpecker (*P. arcticus*) (Spring 1965, Norberg 1986, Fujita et al. 2007). Climbing strides of the Imperial Woodpecker and the Great Slaty Woodpecker are the longest recorded in bark-climbing birds, and this slow pace is likely linked to these species being the heaviest birds in their foraging guild. Short (1973) commented on Great Slaty Woodpecker strides: “the apparent difficulty they seem to have in propelling themselves upward—almost in ‘slow motion’—on tree trunks.”

In the two launches captured in the film, the Imperial Woodpecker first leans in the direction of flight, jumps, turns its tail horizontal, and only then fully opens its wings. The bird maintains a fast wing-flap rate well into a flight. Data in this film contradict two arguments made about launch and flight behavior of large woodpeckers by Sibley et al. (2006), namely that in normal takeoff a woodpecker holds its tail against the trunk until after its wings are extended and ready for the initial down stroke and, secondly, that woodpeckers larger than the Pileated Woodpecker (*Dryocopus pileatus*) should flap more slowly than that species. In fact, whereas Pileated Woodpeckers have been documented to slow to flap rates of 3.9 to 6.7 s^{-1} through wing-flap 8 postlaunch (Collinson 2007), the film shows that the Imperial Woodpecker could maintain a flap rate of about 7.7 to 8.3 s^{-1} at that phase of flight, despite having a body mass $2.4\times$ larger than that of a Pileated Woodpecker.

Substrate use and selection.—Seven out of nine perches of the Imperial Woodpecker in the film were recently dead snags with some of the bark missing, consistent with interview data that the species primarily foraged by excavating and bark scaling of dead pines (Fleming and Baker 1963, Lammertink et al. 1996). Imperial Woodpeckers were also reported to use long-dead and fallen trees (Lumholtz 1903; Rhein letter, 1 March 1962; Lammertink et al. 1996). In the film, the Imperial Woodpecker is foraging on *P. durangensis* that are about 46–110 cm DBH. Because the maximum DBH attained by *P. durangensis* is about 70–100 cm (Eckenswelder 2009), the trees used by the Imperial Woodpecker in the film were evidently at the large extreme of sizes available in this tree species. In most natural forests, such as the old-growth pine forest at the filming site, frequency of tree diameters follows an inverse J-shaped frequency with large-diameter trees being rare (Newton 2007).

Factors in the decline of the Imperial Woodpecker.—Review of the film suggests that large-diameter trees were apparently sought out by the Imperial Woodpecker for perching and foraging. Widespread selective logging operations in the Sierra Madre Occidental during the second half of the 20th century took out pines >30 cm DBH and removed standing dead trees for paper pulp mills (Lammertink et al. 1996). Consequently, substrates similar

to those used by the Imperial Woodpecker in the film are now rare in most of the Sierra Madre Occidental, which likely contributed to the decline of the species.

The diet of the Imperial Woodpecker was reported to consist primarily of large beetle larvae (Fleming and Baker 1963, Lammertink et al. 1996). Other woodpecker species that specialize on beetle larvae—such as the White-backed Woodpecker (*Dendrocopos leucotos*), Black-backed Woodpecker, and Ivory-billed Woodpecker (Tanner 1942, Virkkala et al. 1993, Tremblay et al. 2010)—are often rare old-growth specialists and are sensitive to logging disturbance. It is therefore plausible that the Imperial Woodpecker, the largest woodpecker with correspondingly large energy demands, was similarly or perhaps even more dependent on old-growth forest for its foraging resources.

On plateaus with optimal Imperial Woodpecker habitat, with numerous old and dead trees, access for mechanized logging was relatively easy and the monetary incentive for logging was high. The roadless areas that remain today are mainly on steep slopes, at lower elevations than the highest tablelands, and have few large pines. In 1994–1995, an intensive search throughout the Sierra Madre Occidental found only small areas of 12 km² and 22 km² of never-logged plateau forest (Lammertink et al. 1996). A recent review that we made of Google Earth images yielded no overlooked areas of roadless (and hence uncut) forest in the range of the Imperial Woodpecker (M. Lammertink et al. unpubl. data).

From our 2010 interviews, we learned of commercially instigated persecution as a previously unknown element that perhaps contributed to the extinction process of the Imperial Woodpecker. In the mid-1950s, when logging started in the Guacamayita region, the forester in charge reportedly encouraged the local people to poison Imperial Woodpeckers by applying an agricultural chemical (which he supplied) on foraging trees, as a measure to stop the alleged damage to timber trees caused by Imperial Woodpeckers. The intent apparently was to poison woodpeckers when they pecked in treated wood or ingested poisoned insect prey. Because Imperial Woodpeckers foraged for up to 2 weeks on the same dead tree (Lumholtz 1903), and at times foraged at low heights, applying poison may have been a practical and effective method of killing these woodpeckers. The notion that large woodpeckers are harmful to timber was prevalent into the early 20th century in Europe and the United States (Fisher 1907, Gilmore 1910) and may have persisted in rural Mexico into the 1950s. In the Sierra Madre Occidental during the 1950s, another perceived pest species, the Mexican Wolf (*Canis lupus baileyi*), was being eradicated by poisoning (Lammertink et al. 1996, Parsons 1996). Consequently, adapting poisoning as a tool for eradicating woodpeckers is plausible in this time and place. Regardless of whether the poisoning of Imperial Woodpeckers actually worked, the important point is that people were encouraged to try. Hilton (letter, 19 February 1962) reported that 12 Imperial Woodpeckers were shot at Los Laureles in 1953, the first year that a lumbering operation began there, which suggests that these killings may also have been instigated. We were previously aware of Imperial Woodpeckers being killed for other reasons, such as curiosity, vandalism, as food, and for the birds' alleged medicinal purposes or use as a talisman (Lammertink et al. 1996). These were all killings that were motivated by individual hunters. The reported commercially instigated killings add a new dimension to the rapid decline of the Imperial Woodpecker at the logging frontier.

Although human persecution was clearly important in the decline of the Imperial Woodpecker, we disagree with Tanner (1964) and Snyder et al. (2009) that hunting was the sole driver of its extinction. After populations suffered reductions from persecution at the logging frontier and after operations moved to new areas, the loss of foraging and breeding habitat that resulted from logging likely prevented populations from recovering.

Last records of the Imperial Woodpecker.—Tanner (1964) cited several of Rhein's observations on Imperial Woodpecker biology that he received in the 1962 correspondence, but he did not mention that Rhein filmed an Imperial Woodpecker, nor did he include Rhein's descriptions of vocalizations and cavity trees of the woodpecker. Tanner incorrectly reported that Rhein first found an Imperial Woodpecker in 1954, when in fact this occurred in 1953. Plimpton (1977) introduced erroneous information about Rhein, including the spelling of his name ("Rheim"), the year of the last sighting (1958 instead of 1956), and a fictitious account that the last Imperial Woodpecker Rhein saw was a freshly shot individual in the hand of a hunter. The erroneous year of Rhein's last sighting as 1958 was adopted in Collar et al. (1992) and Winkler and Christie (2002) but has been corrected as 1956 in BirdLife International (2010).

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