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Additions and updates to the list of specimens of Imperial Woodpecker *Campephilus imperialis* (Gould, 1832), including genetic analysis of a putative clutch of eggs

by Benjamin E. Leese, Lars Erik Johannessen, Audun Schrøder-Nielsen, Jiří Mlíkovský, Don Gorney, Leon Schreffler & Jane Schreffler

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Summary.—We present an addendum to the list of known specimens of Imperial Woodpecker *Campephilus imperialis* published by Brown & Clark in 2009. The addendum adds a total of 31 specimens, comprising 15 mounts, ten study skins, three skeletons, two skulls and one not extant specimen, bringing the total number to 189 specimens. It also offers clarification of some of the records presented in Brown & Clark, as well as revisions of several specimens previously registered as *C. imperialis* but later found to be of other species. The latter includes a putative clutch of Imperial Woodpecker eggs, which was found via genetic analysis to belong to Burrowing Owl *Athene cunicularia*.

Almost certainly extinct, the Imperial Woodpecker *Campephilus imperialis* (Gould 1832) leaves many unanswered questions about its natural history. Details about its degree of specialisation, group-living strategy, and other basic natural history are open questions which were carefully framed by Brown & Clark (2009) and Clark & Brown (2020) but can be answered only through scraps of evidence preserved from the past. Specimens of the species will likely be the most useful tool in any future studies, and their rarity makes each even more valuable as a source of information. Brown & Clark (2009, Appendix 2; hereafter 'B&C') provided a helpful table recording all specimens known to them in private and public collections throughout the world. Of the 158 unique specimens with confirmed location listed by them, only 16 are preserved as taxidermic mounts; the rest are more or less complete study skins or skeletons.

The present addendum (Table 1) adds a total of 31 specimens to the list: 15 mounted specimens, nine full and one partial study skins, two full and one partial skeletons, two skulls, and one no longer extant specimen. These include specimens published by various authors, mostly since B&C in 2009 (Violani *et al*. 1984, Mlíkovský & Sutorová 2010, Prŷs-Jones 2011, Mlíkovský 2012, Nicolai 2018, Prŷs-Jones *et al*. 2021), and previously unpublished (to our knowledge) specimens in various museums and collections. The total number is brought to 189 known specimens. Table 2 clarifies the current location, and adds or corrects catalogue numbers and other information, of several specimens included in B&C. Table 3 corrects the species identity of two specimens and three clutches of eggs previously assumed to belong to Imperial Woodpecker.

Specimens from the Lumholtz expeditions

Six specimens currently held in the Natural History Museum of the University of Oslo (NHMO), and a skin and a skeleton in the American Museum of Natural History collection in New York (AMNH), are probably all from Carl Lumholtz's (1851–1922) famous expeditions to the Sierra Madre in the 1890s. Two of the NHMO specimens, a mounted pair

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TABLE 1
Specimens of Imperial Woodpecker *Campephilus imperialis* not included in Appendix 2 in Brown & Clark (2009). F = female; M = male; CH = Chihuahua; DU = Durango; SO = Sonora.

Date	Institution	Collection code	Catalogue number	Sex	Locality	State	Collector	Object type	Notes	Reference
5 Nov 1896	AMNH	Birds	Skel 1081		Sonora, Mexico	SO	Carl Lumholtz	Skeleton		Prŷs-Jones *et al.* (2021), AMNH (2021)
	CLEV			F				Mount		
	CLEV			M				Mount		
	DESM-PSU	BMC		F				Mount		
	HNS	Aves	D-02315	M				Mount	May have belonged to the Behrens Collection	
	IBUNAM	CNAV	27010	F		DU		Skin	Key number 1665. Relaxed mount.	
	IBUNAM	CNAV	27011	M		DU		Skin	Key number 1665. Relaxed mount.	
	IBUNAM	CNAV	27012	F		DU		Skin	Key number 1668. Relaxed mount.	
	IBUNAM	CNAV	27013	M		DU		Skin	Key number 1668. Relaxed mount.	
21 Nov 1932	LACM	Birds	87480				Leonard Brown	Skeleton (partial)	Cranium, mandible and ramphotheca, radii (2), ulnae (2), carpals (2), tarsometatarsi (2), toe bones and claws, some vertebrae, portions of hyoid bones, radiale/scapholunar (2). Accession no. A3130; previous cat. no. Bi 694.	
<1919	MCM		1919.021.0033.2	F			Charles F. Fite?	Mount	Donated by Pearl Fite. Probably collected by her husband, Charles F. Fite.	
8 Sep 1905	MCZ	Orn	114749	M	Mound Valley	CH	Wilmot W. Brown, Jr.	Mount	Previous cat. no 14749. John E. Thayer Expedition of 1904–05	
≤1863	MHH		7735	M	(West-) Mexico			Mount	Previous cat. no. N 07735. Bought from G. A. Frank, Amsterdam.	Prŷs-Jones (2011), Nicolai (2018)

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Date	Institution	Collection code	Catalogue number	Sex	Locality	State	Collector	Object type	Notes	Reference
<1860	MSNM	Av	27993	F	'*California*' [Mexico]			Mount	Originally Alfred Malherbe collection, later Ercole Turati collection (cat. no 4386)	Violani *et al*. (1984), Prŷs-Jones (2011)
<1860	MSNM	Av	31059	M	'*California*' [Mexico]			Mount	Originally Alfred Malherbe collection, later Ercole Turati collection (cat. no 4385)	Violani *et al*. (1984), Prŷs-Jones (2011)
9 Feb 1900	MZMB		26189	M	Sierra Madre, Mexico			Mount	Prepared by Jindřich Mrázek.	Mlíkovský & Sutorová (2010)
≤1898	NHMO	BI	61382	M	Mexico		Carl Lumholtz	Skin	Previous cat. no. 19115.	
≤1898	NHMO	BI	61383	M	Mexico		Carl Lumholtz	Skin (partial)	Piece of head skin, including crest. Previous cat. no. 19116.	
10 Jan 1891	NHMO	BI	62037	M	Rancheria de los Apaches; Camp 45 30.00ºN, 108.55ºW	CH	F. Robinette (Carl Lumholtz)	Mount	From AMNH (56574). Mounted together with NHMO-BI-62038. Previous cat. no. 19836. Collectors ID: no. 9.	
24 Dec 1890	NHMO	BI	62038	F	Bavispe River; Camp 40 29.890ºN, 108.637ºW	SO	F. Robinette (Carl Lumholtz)	Mount	From AMNH (56573). Mounted together with NHMO-BI-62037. Previous cat. no. 19837. Collectors ID: no. 2.	
≤1891	NHMO	BI	104430		N. Mexico [north Mexico?]		Carl Lumholtz	Skull	Previous cat. no. 7177 (two skulls reg. together).	
≤1891	NHMO	BI	104431		New Mexico [north Mexico?]		Carl Lumholtz	Skull	Previous cat. no. 7177 (two skulls reg. together).	
1882	NHMUK	ZOO	1886.9.9.1	F	La Ciudad, Durango	DU	Alphonse Forrer	Skeleton		Prŷs-Jones *et al*. (2021)
Sep 1906	NMNSL		689	M	Old Mexico		Aaron C. Kepler?	Mount	Donated by Kepler. His journal says that he 'acquired' three specimens, so it is not clear if he collected them.	
17 Feb 1910	NMP		P6V-041194	M	Chihuahua, Mexico	CH	Filip Oberländer	Mount	Mounted together with P6V-041195. Accession no. 2743/1910. Previous cat. no. B-16443.	Mlíkovský (2012)
17 Feb 1910	NMP		P6V-041195	F	Chihuahua, Mexico	CH	Filip Oberländer	Mount	Mounted together with P6V-041194. Accession no. 2743/1910. Previous cat. no. B-16443.	Mlíkovský (2012)

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Date	Institution	Collection code	Catalogue number	Sex	Locality	State	Collector	Object type	Notes	Reference
	OMNH	Birds	15218.0	M				Skin		
<1849	SMTD (SNSD)		2774	M	'*California*' [Mexico]). Possibly Bolaños area, Mexico.		Possibly Damiano Floresi	Likely a mount; not extant	Probably lost during World War II.	Prŷs-Jones (2011), current paper
1901	YPM	VZ	ORN 084885	M	Sierra Madre 200 miles south of Chihuahua 25.715ºN, 106.069ºW	CH		Skin	Relaxed mount. Donated by Charles Sheldon's wife but probably not collected by him.	
1901	YPM	VZ	ORN 084886	F	Sierra Madre 200 miles south of Chihuahua 25.715ºN, 106.069ºW	CH		Skin	Relaxed mount. Donated by Charles Sheldon's wife but probably not collected by him.	
1901	YPM	VZ	ORN 084887	M	Sierra Madre 200 miles south of Chihuahua 25.715ºN, 106.069ºW	CH		Skin	Relaxed mount. Donated by Charles Sheldon's wife but probably not collected by him.	

Acronyms, names and location of institutions included in the tables

AMNH	American Museum of Natural History, New York, New York, USA
CLEV	Cleveland Museum of Natural History, Cleveland, Ohio, USA
DESM-PSU	Bird and Mammal Collection, Department of Ecosystem Science and Management, Pennsylvania State University, Pennsylvania, USA
HNS	Haus der Natur, Salzburg, Austria
IBUNAM	Colección Nacional de Aves, Instituto de Biología de la Universidad Nacional Autónoma de México, Mexico City, Mexico
KU	University of Kansas Biodiversity Institute, Lawrence, Kansas, USA
LACM	Natural History Museum of Los Angeles County, Los Angeles, California, USA
MCM	Miami County Museum, Peru, Indiana, USA
MCZ	Museum of Comparative Zoology, Harvard, Cambridge, Massachusetts, USA
MHH	Museum Heineanum, Halberstadt, Germany
MPM	Milwaukee Public Museum, Milwaukee, Wisconsin, USA
MSNM	Storia Naturale di Milano, Milan, Italy
MZMB	Moravian Museum, Brno, Czech Republic
NHMO	Natural History Museum, University of Oslo, Norway
NHMUK	Natural History Museum, Tring, UK
NMNSL	North Museum of Nature and Science, Lancaster, Pennsylvania, USA
NMP	National Museum, Prague, Czech Republic
OMNH	Sam Noble Oklahoma Museum of Natural History, University of Oklahoma, Norman, Oklahoma, USA
SDM	State Darwin Museum, Moscow, Russian Federation
SMTD	Staatliches Museum für Tierkunde, Dresden, Germany (currently part of SNSD)
SNSD	Senckenberg Naturhistorische Sammlungen Dresden, Germany (currently including SMTD)
UCLA	University of California, Los Angeles, California, USA
YPM	Yale Peabody Museum, New Haven, Connecticut, USA
WFVZ	Western Foundation of Vertebrate Zoology, Camarillo, California, USA
WML-VZ	National Museums Liverpool, Liverpool, UK
ZIN	Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russian Federation

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TABLE 2
Amendments and corrections to specimens included in Appendix 2 of Brown & Clark (2009). Information added by the present work shown in **bold**; all other data, shown in *italics*, are from Brown & Clark (2009, Appendix 2). F = female; M = male; CH = Chihuahua; DU = Durango; SO = Sonora. See Table 1 for institution acronyms.

Date	Institution	Collection code	Catalogue number	Sex	Locality	State	Collector/provider	Object type	Notes
25 Dec 1921	*AMNH*	**Birds**	**Skin 188856**	*F*	*Mound Valley*	*CH*	*Wilmot W. Brown, Jr.*	*Skin*	**Listed with cat. no. '958881' (i.e., the number had been read upside down).**
29 Jun 1934	*AMNH*	**Birds**	**Skin 300518**	*F*				*Skin*	**Listed with cat. no. '300158'.**
20 Feb 1904	*AMNH*	**Birds**	**Skin 363844 bis**	*F*	*125 m w. of Durango*	*DU*	C. K. Worthen	*Skin*	**Listed with cat. no. '363844615'.**
10 Jan 1891	*AMNH*	**Birds**	**Skin 56575**	*M*	**Rancheria de los Apaches; Camp 45 30.00ºN, 108.55ºW**	**CH**	**F. Robinette (Carl Lumholtz)**	*Skin*	**Listed without cat. no. and thereby also most other data; see details in text.**
10 Jan 1891	*AMNH*	**Birds**	**Skin 56576**	*F*	*Rancheria de los Apaches at 2,020 m*	**CH**	*F. Robinette*	*Skin*	**Listed with cat. no. '56596(?)' and state SO; see details in text.**
25 Jan 1892	*AMNH*	**Birds**	**Skin 56850**	*M*	*Col. Chuhuichupa*	*CH*	*Meeds*	*Skin*	**Listed with cat. no. '56820'.**
	KU	**Birds**	*43123*	*M*	*8000' mtns.; 50 mi. s. of Durango*	*DU*	*C. C. Lamb*	*Skin*	**Listed as being at the Moore Lab of Ornithology ('MLZ 46338'), albeit with a note that it had been *'Exch to MNHUK #43123'*.**
1912	**LACM**	**Birds**	**16524**	*M*	*Mtns. of Durango*	*DU*	*W. J. Hale*	**Relaxed mount**	**Listed with a different, probably older number ('1497') and as a skin; acronym adjusted to current version.**
1906	**LACM**	**Birds**	**16525**	*M*	*35 mi. w. of Casas Grandes*	*SO-CH*	*W. L. Neely*	**Relaxed mount**	**Listed with a different, probably older number ('944', i.e., same as current 16526) and as a skin; acronym adjusted to current version.**
1906	**LACM**	**Birds**	**16526**	*F*	*35 mi. w. of Casas Grandes*	*SO-CH*	*W. L. Neely*	**Relaxed mount**	**Listed with a different, probably older number ('944', i.e., same as current 16525) and as a skin; acronym adjusted to current version.**
14 April 1880–1910	*MCZ*	**Orn**	*237908*		**Mexico**	*CH*	**C. M. Barber**		**Listed with date as 'April 14, no year' and without collector**
14 April 1880–1910	*MCZ*	**Orn**	*237909*	*F*	**Mexico**	*CH*	**C. M. Barber**		**Listed with date as 'April 14, no year' and without collector**
≤1832	*NHMUK*	**ZOO**	**1838.5.12.108**	*M*	**Bolaños area**	*JA*	**Damiano Floresi, via John Gould**	*Skin*	**Listed with a different, newer number ('BMNH 1988216'), with incomplete collector information, and not identified as part of the type series; original number restored by Prŷs-Jones (2011). SYNTYPE.**

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Date	Institution	Collection code	Catalogue number	Sex	Locality	State	Collector/provider	Object type	Notes
≤1832	*NHMUK*	**ZOO**	**1855.12.19.325**	F	**Bolaños area**	**JA**	**Damiano Floresi, via John Gould and Zoological Society's Collection**	*Mount*	**Listed as *'Mounted specimen on display'* without cat. no., with incomplete collector information, erroneous date and locality information, and not identified as part of the type series. SYNTYPE.**
≤1832	*NHMUK*	**ZOO**	*1888.8.5.60*	*F*	*Sierra Bolaños*	*JA*	**Damiano Floresi, via John Gould and Salvin & Godman**	*Skin*	**Listed without collector. SYNTYPE.**
≤1832	*NHMUK*	**ZOO**	*1888.8.5.61*	*M*	*Sierra Bolaños*	*JA*	**Damiano Floresi, via John Gould and Salvin & Godman**	*Skin*	**Listed without collector. SYNTYPE.**
<1868	*NHMUK*	**ZOO**	**Unregistered**	*M*	*'California'* [Mexico]			*Mount*	**Listed as *'Mounted specimen on display'* without cat. no., and with erroneous date and locality information.**
c. 1900	*SDM*	**OF**	**4375**	M					**Listed without cat. no. and date.**
5 Sep 1905	*UCLA*	**Birds**	**37961**	*M*	*Mound Valley*	*CH*	*Wilmot W. Brown, Jr.*	**Skin**	**Listed without cat. no.; noted to come from MCZ, where it had cat. no. 302877. Previously numbered 3948 in the L. H. Miller collection.**
10 Sep 1905	*UCLA*	**Birds**	**37962**	*F*	*Mound Valley*	*CH*	*Wilmot W. Brown, Jr.*	**Skin**	**Listed without cat. no.; noted to come from MCZ, where it had cat. no. 302880. Previously number 3449 in the L. H. Miller collection.**
	WFVZ	**Bird**	**55279**	*M*		CH		**Skin**	**Listed without cat. no. and as a mount.**
≤1832	*WML-VZ*	*D*	*3868*	*M*	**Bolaños area**	**JA**	**Damiano Floresi, via John Gould and 13th Earl of Derby**	*Skin*	**Listed with institution acronym NML without collection date, locality and collector, and to be of potential syntype status. SYNTYPE.**
≤1832	*WML-VZ*	*D*	*3868a*	*F*	**Bolaños area**	**JA**	**Damiano Floresi, via John Gould and 13th Earl of Derby**	*Skin*	**Listed with institution acronym NML without collection date, locality and collector, and to be of potential syntype status. SYNTYPE.**
14 Sep 1905	*ZIN*		*112329*	*F*	**'Chuechupa' [sic]** *Col. Chuhuichupa 29°35'N, 108°25'W*	*CH*	*Wilmot W. Brown, Jr.*	*Skin*	*Received 1932: #108-932.* **Received from MCZ, where it had cat. no. 2889. Collected by the 1904–05 John E. Thayer Expedition.**
16 Sep 1905	*ZIN*		*112330*	*M*	**'Chuechupa' [sic]** *Col. Chuhuichupa 29°35'N, 108°25'W*	*CH*	*Wilmot W. Brown, Jr.*	*Skin*	*Received 1932: #108-932.* **Received from MCZ, where it had cat. no. 2890. Collected by the 1904–05 John E. Thayer Expedition. Accidentally duplicated in B&C.**

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TABLE 3
Revisions of erroneous identifications; specimens originally identified as Imperial Woodpecker *Campephilus imperialis* but now known to belong to other species. See Table 1 for institution acronyms.

Institution	Collection code	Catalogue number	Object type	Notes	Source	Revised
KU	Birds	4613	Skin	Determined as *Campephilus principalis* by morphology (Jerome A. Jackson)	University of Kansas Biodiversity Institute (2022)	Current paper
MCZ	Orn	361680	Eggs (n = 2)	Confused with *Campephilus principalis* in publication's table	Kiff & Hough (1985)	Current paper
MPM	BI	338	Eggs (n = 3)	Confused with *Campephilus principalis* in publication's table	Kiff & Hough (1985)	Current paper
OMNH	Egg	1825	Eggs (n = 5)	Determined as Burrowing Owl *Athene cunicularia* by genetic analyses	Kiff & Hough (1985)	Current paper
ZIN		1791	Skull	Determined as *Campephilus principalis* by morphological analyses	Wood & Schnell (1986)	Prŷs-Jones *et al.* (2021)

(Fig. 1), must have been received from AMNH, as they still bear original AMNH labels, although neither NHMO nor AMNH (P. Sweet *in litt*. 2021) has any records of this transfer. They are both from Lumholtz's first expedition, in 1890–91, which was documented in depth in his book *Unknown Mexico* (Lumholtz 1902). Based on the detailed information in this travelogue, in combination with the collecting dates, the geographical location of the collecting localities has been established quite accurately (i.e. +/- a few kilometres), confirming that they are close to, but on either side of, the Sonoran / Chihuahuan border. The complete mitochondrial genome of the male specimen was sequenced as part of a study by Anmarkrud & Lifjeld (2017).

The origin of two skulls in NHMO is less certain, as the only information available is the text written directly on them by museum personnel. '*Campephilus imperialis* Ltz 91' is written on both, whereas the locality is indicated as 'N. Mexico' on one but 'New-Mexico' on the other. 'Ltz 91' is an abbreviation often seen in the NHMO collection, meaning that the specimen was provided by Carl Lumholtz and probably that it arrived at the museum in 1891. As for the locality, 'New-Mexico' probably does not refer to the current American state of New Mexico but rather to a more loosely defined region that may well have included northern parts of the Mexican states of Chihuahua and Sonora. However, most likely, 'N. Mexico' was the originally provided name for the locality (by Lumholtz), and this has been misinterpreted as 'New' rather than 'North' Mexico, probably by the person who added the text to the skulls. It is therefore probable that these two specimens are also from the same expedition as the two mounts, but this has not been possible to verify.

The two last specimens in the NHMO collection are both labelled 'Lumholtz 01'. Like the skulls, this probably indicates when they arrived at the museum, not when they were collected. This fits well with the fact that Lumholtz was not in Mexico between 1898 and 1909, and subsequently he only visited the Sonoran Desert, not the Sierra Madre. These two specimens were therefore almost certainly collected before the end of the 19th century, probably in or before 1898, when Lumholtz went on his last expedition in the Sierra Madre (Lumholtz 1902). The collecting locality of these two specimens is recorded only as 'Mexico,' and it has not been possible to refine this further. While one is a full male study skin in good condition, the other is just a piece of skin from the head, including the red crest, indicating a male.

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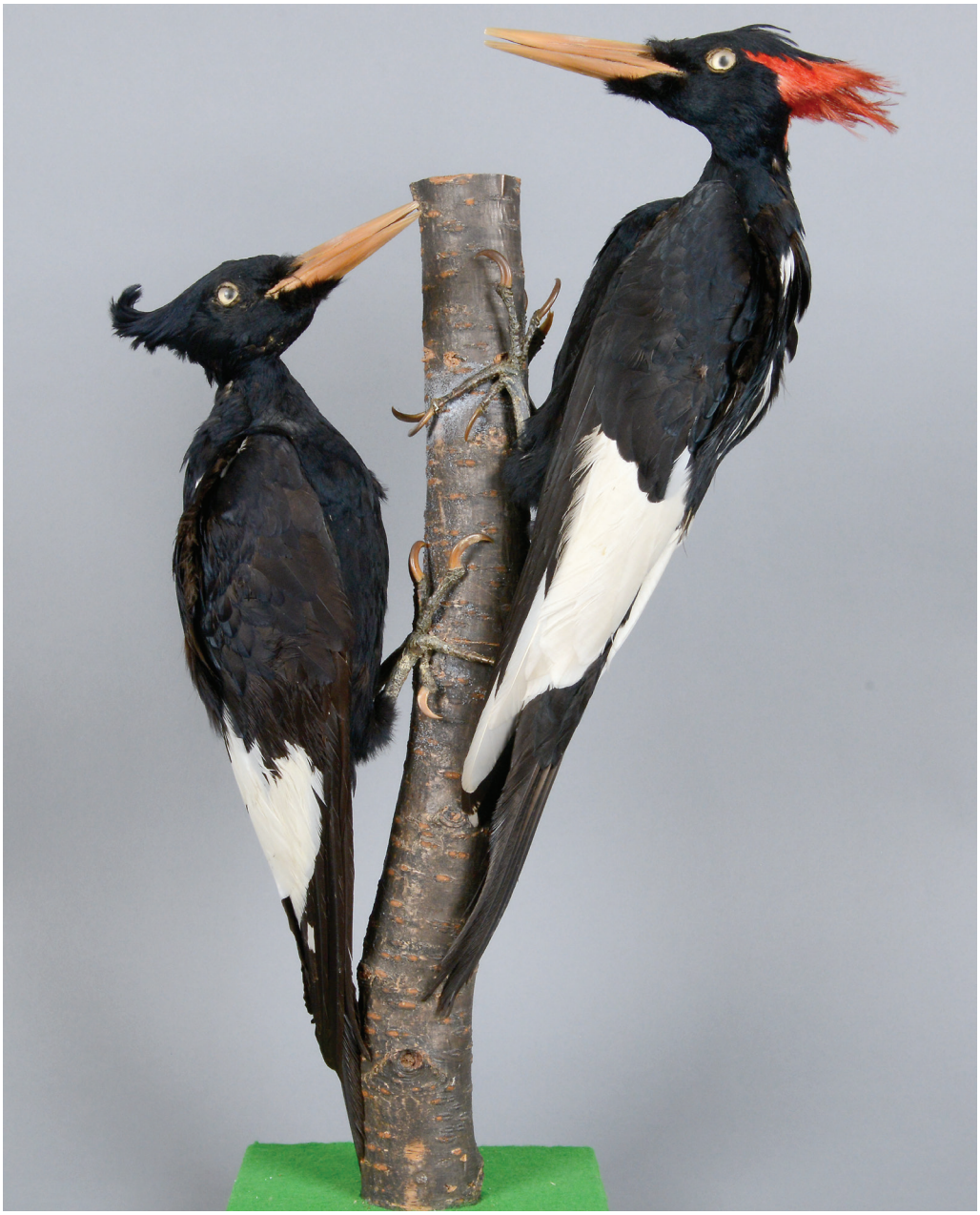

Figure 1. Mounted pair of Imperial Woodpeckers *Campephilus imperialis* collected by Carl Lumholtz around New Year 1890–91, at the Sonora / Chihuahua border; male NHMO-BI-62037; female NHMO-BI-62038 (© Lars Erik Johannessen, Natural History Museum, University of Oslo)

As the piece of skin, based on its appearance, could be from an Ivory-billed Woodpecker *Campephilus principalis*, it was subjected to a genetic barcoding analysis. DNA from a small tissue sample was extracted in replicate in the sensi-lab at the NHMO DNA lab using DNeasy Blood and Tissue kit (Qiagen), followed by amplification in replicates and sequencing of a 287 base pair fragment of cytochrome C oxidase subunit I. Both PCR and sequencing primers were Minibar-mod-f 5′- TCC ACT AAT CAC AAA GAY ATY GGY

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AC -3′ (Berry *et al*. 2015) and PicidaeCOI362-R 5′- GCT TCT ACT GTA GAG GAG GCT A -3′ (designed for this paper, based on Anmarkrud & Lifjeld 2017). PCR thermal profile was three minutes at 95°C (30 seconds at 95°C; 30 seconds at 60°C, -0.5°C/cycle; 30 seconds at 72°C) × 15; (30 seconds at 95°C; 30 seconds at 52°C; 30 seconds at 72°C) × 25; five minutes at 72°C; 8°C hold. Negative controls were included in extraction and PCR steps. Blasting of the resulting sequence against the NCBI database produced a 100% match with the previously published *C. imperialis* complete mitogenome (Anmarkrud & Lifjeld 2017) and >3.16% dissimilarity compared to other *Campephilus* sequences available in the NCBI-database (including *C. principalis*). The specimen is therefore indeed from *C. imperialis* (GenBank accession no. OK336065.1).

The presence of any of these specimens in Norway is surprising, given that Lumholtz's Mexico expeditions were funded by American benefactors, including the AMNH and American Geographical Society of New York. Most of the birds and other objects collected therefore probably initially ended up in the AMNH, as did at least two specimens currently in NHMO. However, in addition to being Norwegian, Lumholtz had been collecting in Australia for NHMO before he went to Mexico, and it is thus quite possible that he arranged for the specimens' transfer to NHMO as a gift to a previous employer or a courtesy to his home country.

One of the two Lumholtz specimens in AMNH was listed by B&C, but without a catalogue number, and most other data were also lacking. B&C noted that the specimen was 'on display in exposition' and that it is 'likely the same as mounted male seen in a photo by H. S. Rice taken in March 1933 (AMNH Negative #103797)'. The bird on the mentioned negative is identical with a mounted, unnumbered bird, located during a full inventory of Imperial Woodpeckers in the collection performed in 2021 (P. Sweet *in litt*. 2021). The inventory also revealed that all specimens recorded in the ledgers were present, except AMNH 56573–56575, of which 56573 and 56574 are in NHMO (see above). The unnumbered bird can therefore be concluded to be AMNH 56575, i.e. one of the Lumholtz specimens, from the same locality as one of the specimens in the NHMO collection.

The Lumholtz skeleton in AMNH was not listed by B&C, but was mentioned by Prŷs-Jones *et al*. (2021). This is reported as an unsexed specimen collected by Carl Lumholtz in Sonora, Mexico, on 5 November 1896 (AMNH 2021). This combination of collecting date and locality appears contradictory, as Lumholtz was travelling much further south in Mexico than the state of Sonora in November 1896, probably in the state of Michoacán (Lumholtz 1902). Nevertheless, as the original entry in the AMNH catalogue and the label accompanying the skeleton both clearly state the listed date and locality (P. Sweet *in litt*. 2021), these will have to be accepted as correct unless additional information becomes available. It should, however, be kept in mind that the skeleton is potentially from a more southern part of the species' distribution (if only the date but not locality should prove correct), or alternatively that Lumholtz may have obtained it from someone else who did collect it in Sonora on the specified date.

Other specimens not noted by Brown & Clark (2009)

Two museums in the Czech Republic contain three specimens. The Moravian Museum in Brno (MZMB) holds a male collected by an unknown person on 9 February 1900 in 'Sierra Madre', Mexico. The museum's catalogue states that it was from the J. Mrázek Collection, but it appears more likely that it was simply prepared by Jindřich Mrázek (1886–1948) during his tenure at the museum (Mlíkovský & Sutorová 2010). The other two specimens are in the National Museum in Prague (NMP) and are among the most beautiful mounts of the species (illustrated in Mlíkovský 2012: 112). These specimens, a male and female,

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were collected by Filip Oberländer (1875–1911), a Czech businessman and avid hunter, on 17 February 1910 in 'Chihuahua, Mexico', and subsequently donated by him to NMP (Mlíkovský 2012).

Whilst B&C listed nine specimens in the Natural History Museum, Tring (formerly BMNH, now NHMUK), another was added by Prŷs-Jones *et al*. (2021). A rare skeleton (one of only three known) was identified and found to probably be the specimen registered as NHMUK 1886.9.9.1, a female collected by Alphonse Forrer (1836–99) in La Ciudad, Mexico, in 1882. As documented by Prŷs-Jones *et al*. (2021), Forrer also had a second Imperial skeleton, but nothing is currently known about the whereabouts of that specimen.

The Miami County Public Museum in Peru, Indiana (MCM), has a mounted female specimen (Fig. 2). It had been mislabelled as an Ivory-billed Woodpecker or a Pileated Woodpecker *Dryocopus pileatus* since its donation to the museum by Pearl Fite (1882–?) on 31 July 1919. However, careful examination reveals it to be an Imperial Woodpecker (identified by Don Gorney), albeit with a painted bill. There are unfortunately no other data available concerning its provenance. It apparently belonged to the collection of Charles Frederick Fite (1850–1918; V. Roosevelt Fite *in litt*. 1986 to MCM), but it is not certain that he collected the specimen himself.

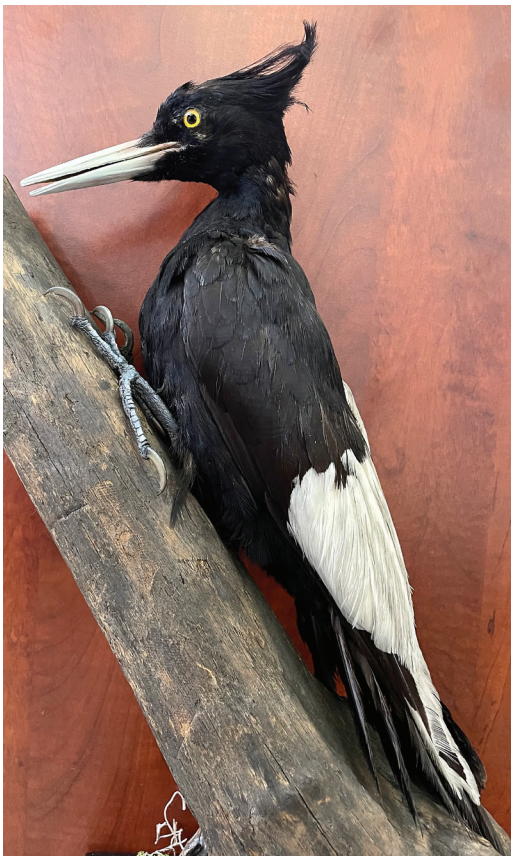

Figure 2. Female Imperial Woodpecker *Campephilus imperialis* in the Miami County Museum in Peru, Indiana (MCM-1919.021.0033.2); previously misidentified as Ivory-billed Woodpecker *C. principalis* (© Anna Pohlman, Miami County Public Museum)

Figure 3. Male Imperial Woodpecker *Campephilus imperialis* in the North Museum of Nature and Science in Lancaster, Pennsylvania (NMNSL-689) (© Molly Wolanski, North Museum of Nature and Science, Lancaster)

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The North Museum of Nature and Science in Lancaster, Pennsylvania (NMNSL), holds another unreported specimen (Fig. 3), a fine male obtained by Aaron C. Kepler (1841–1921), a local hardware store mogul, in September 1906. Collecting locality is listed only as 'Old Mexico'. Kepler's journal for the relevant period says that he 'acquired' three specimens of this woodpecker during a trip. While it is not entirely clear if he collected the specimens himself, his status as an avid hunter and naturalist (Kepler *c.*1921) makes that more than likely. The disposition of the two other specimens referred to in his journal is unknown.

Another previously unlisted specimen, an adult male from '(West-) Mexico', is in the Museum Heineanum in Halberstadt (MHH; Prŷs-Jones 2011, Nicolai 2018). There is no information about the exact locality, year or collector, but it was obtained from Gustav Adolph Frank (1809–80), a natural history dealer in Amsterdam. However, the specimen is among the oldest of the species, as it is mentioned in the museum's catalogue in 1863 (Cabanis & Heine 1863). Its age may prove useful in the future, e.g. for genetic analysis of diversity within the species as it headed towards extinction.

The Yale Peabody Museum in New Haven, Connecticut (YPM), holds three relaxed mounts attributed to Charles A. Sheldon (1867–1928), in addition to the two noted in B&C (collected by Lois T. Ledbetter). Sheldon observed Imperials in the wild and provided much of the available natural history evidence. It is not clear if he actually collected the specimens or purchased them. B&C believed that he never collected any specimens, and Sheldon's own journal appears to support that (Sheldon 1925). The three specimens came to Yale via the Montshire Museum, Norwich, Vermont, which obtained them from the Dartmouth College Museum, Hanover, New Hampshire, in 2005. According to the collection catalogue from Dartmouth, they were donated by Charles Sheldon's wife, Louisa Gulliver Sheldon (K. Zyskowski *in litt*. 2021). They were collected or obtained in 1901 in the 'Sierra Madre 200 miles south of Chihuahua' (the original ink entry said '40 miles', but this was corrected in pencil to 200 miles).

The Museum of Comparative Zoology at Harvard University, Cambridge, Massachusetts (MCZ) boasts 18 specimens in B&C, and a 19th can now be added. Wilmot Wood Brown, Jr. (1870?–1953), a prolific collector (Clark 2020), took the specimen on 8 September 1905 in Mound Valley, Chihuahua state. It may have been on display, and thus overlooked, during the original inventory (J. Trimble *in litt*. 2021).

The Natural History Museum of Los Angeles County, Los Angeles, California (LACM), contains a partial skeleton of the species, collected on 21 November 1932 by Leonard Brown and identified by LACM preparator George Cantwell. It was accessioned as A3130 and first catalogued in the Vertebrate Palaeontology comparative osteology collection as Bi 694, before it was registered in the regular modern bird collection as LACM 87480. The specimen is mostly skull and limb bones; the bones of the trunk, which would normally be disposed of when preparing a mount or skin, are missing from this partial skeleton. These bones may therefore have been salvaged from a mount or skin that was being discarded.

Museo di Storia Naturale di Milano in Milan (MSNM) holds two specimens; a male and female (Violani *et al*. 1984). Both originated from the Ercole Turati (1829–81) collection, which was bequeathed to MSNM in 1884, after Count Turati's death. They were originally part of Alfred Malherbe's (1804–65) woodpecker collection, which was sold to Turati in 1860. The specimens may have come to Europe along with those in Victor Massena's collection, which is now at the Academy of Natural Sciences of Drexel University in Philadelphia (Stone 1899, Brown & Clark 2009, Prŷs-Jones 2011). The collection locality for both specimens is given enigmatically as 'California'. Whilst the state of California was part of Mexico from 1821 to 1848, it is outside the known range of the species, as is the Baja California Peninsula, which could be an alternative interpretation of the locality name. However, the earliest specimens

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Figure 4. Pl. DCXLVI from Reichenbach (1854), depicting in the upper half (no. 4314) the possible syntype once held in the Staatliches Museum für Tierkunde in Dresden (image reproduced from the Smithsonian Libraries version of Reichenbach 1854, available from the Biodiversity Heritage Library; https://www.biodiversitylibrary.org/)

were also recorded as originating from 'California', despite Bolaños in Jalisco, Mexico, being the species' probable type locality (Nelson 1898, Brown & Clark 2009: 68–69, Prŷs-Jones 2011). Perhaps this is just an example of vague knowledge of American geography at the time, as suggested by Nelson (1898). Another possibility, also mentioned by Prŷs-Jones (2011), is that the specimens might have been shipped from or through (Baja) California. Shipping ports have become *de facto* type locations in the past (Turner 2011, Black 2013), so this hypothesis is quite plausible.

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Colección Nacional de Aves at the Universidad Nacional Autónoma de México in Mexico City (IBUNAM) houses four specimens, two male and two female skins. They are all from Durango, but no other information is available (P. Escalante *in litt*. 2020).

Prŷs-Jones (2011) considered the possibility that a specimen once held in the Staatliches Museum für Tierkunde, Dresden (SMTD; currently part of Senckenberg Naturhistorische Sammlungen Dresden; SNSD) was a syntype of the species. Heinrich Gottlieb Ludwig Reichenbach (1793–1879), who curated the SMTD collections between 1820 and 1874, noted in his *Die vollständigste Naturgeschichte* (Reichenbach 1854: 390) that a single male came to the museum 'zu derselben Zeit erhielt, als Gould zuerst diese neue Art beschrieb' [at the same time as when Gould described this new species for the first time], i.e. about 1832, and noted that this specimen was probably the only one in continental Europe at the time. The bird appeared on pl. DCXLVI, fig. 4314 (Reichenbach 1854). The illustration (Fig. 4) is based on the Dresden specimen, for which Reichenbach provided measurements. Since study skins came into use only during the second half of the 19th century, the specimen was presumably a mount.

Entries in SMTD catalogues (T. Töpfer *in* Prŷs-Jones 2011) show that the specimen survived the fire at Dresden in May 1849, but that it was probably destroyed during World War II. Reichenbach (1854) did not state explicitly where the specimen was collected nor who obtained it. As Reichenbach received the specimen at the same time as Gould described the species (1832), it is probable, but not proven, that the collector of all these specimens was Damiano Floresi (1799?–1853?; see Prŷs-Jones 2011). If so, it was probably collected in Jalisco, Mexico. Reichenbach may have received the specimen directly or indirectly from Floresi, perhaps via Gould. This leaves the type status of the SMTD specimen open; if Gould was aware of it by 1832 it should be considered a syntype, otherwise the specimen has no type status.

Five other specimens lack any provenance data: a male and a female, both mounted, in the Cleveland Museum of Natural History in Cleveland (CLEV); a male skin in the Sam Noble Oklahoma Museum of Natural History at the University of Oklahoma (OMNH); a mounted female in the Bird and Mammal Collection at the Department of Ecosystem Science and Management, Pennsylvania State University (DESM-PSU); and a mounted male in Haus der Natur in Salzburg (HNS), which may have belonged to the Behrens Collection but is not mentioned by Duncker (1953; see also Koch 2018). This latter specimen appears in the Global Biodiversity Information Facility (GBIF; GBIF.org 2022) with catalogue number 1395064, but that is erroneous (R. Lindner *in litt*. 2022).

Putative eggs of Imperial Woodpecker

Almost nothing is known of the eggs of this species, with just two trustworthy field reports. Lumholtz (1902: 212) reported that the Tarahumara (Rarámuri) considered the 'one or two young' of the species a delicacy and would cut down large trees to get at them. Nelson (1898: 222) related that his co-worker, George B. Winton (1861–1938), nearly managed to secure two eggs, but the boy who climbed the tree to get them broke one while descending the tree and the other while driving cattle. Two putative nest cavities are in existence, one at La Sierra University, Riverside, California, and the other at MCZ (occupied by a pair of Thick-billed Parrots *Rhynchopsitta pachyrhyncha* when collected by Wilmot W. Brown, Jr., but reported to have been abandoned or previously used by a pair of *C. imperialis*; J. Trimble *in litt*. 2021), but no eggs are associated with either.

Despite Nelson (1855–1934) and Winton's unsuccessful attempt to secure eggs, Kiff & Hough (1985) reported three sets of Imperial Woodpecker eggs in three different collections, but two were confused with Ivory-billed Woodpecker when the list was prepared (Table 3).

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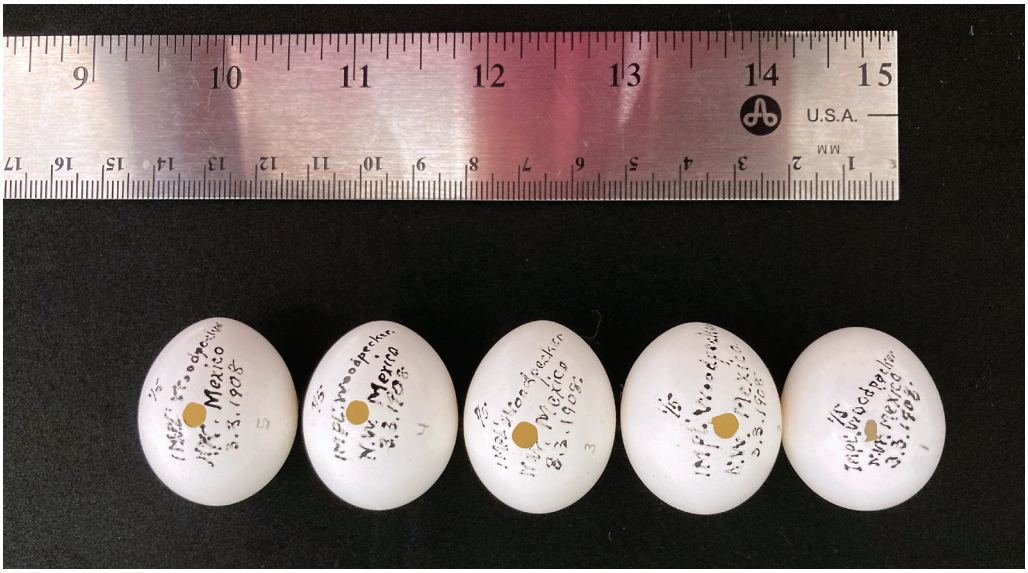

Figure 5. Five eggs (OMNH-1825) putatively of Imperial Woodpecker *Campephilus imperialis*, but found through genetic analysis to belong to Burrowing Owl *Athene cunicularia* (© Brandi S. Coyner, Sam Noble Oklahoma Museum of Natural History)

They listed one set of Imperial eggs, but none of Ivory-billed, for both MCZ and the Milwaukee Public Museum in Milwaukee (MPM), but these collections currently hold the opposite (J. Trimble and J. Colby *in litt*. 2021). The only presumed set of Imperial Woodpecker eggs is therefore that in OMNH (Fig. 5). This is a clutch of five eggs, and according to information written on the eggs they were collected in 'N. W. Mexico' on 3 March 1908. No further data exists for these eggs.

The eggs measure 32.3 × 26.5 mm on average and are pure white and somewhat glossy. Their physical appearance is thus similar to, and their size within the range of, other large woodpeckers in Mexico and North America (*C. principalis*, Pale-billed Woodpecker *C. guatemalensis*, *D. pileatus*, and Lineated Woodpecker *D. lineatus*). However, they do not match any of the species exactly (Bendire 1895, Malekan 2020; pers. obs. from OMNH and WFVZ). The clutch size of five is large compared to most *Campephilus*, which tend to lay only two eggs (Bendire 1895, Nelson 1898, Lumholtz 1902, Winkler *et al*. 1995, Ojeda 2004), but the Imperial's closest relative, Ivory-billed Woodpecker, regularly laid three to four, and sometimes as many as six, eggs (Jackson 2020). Apart from closely related woodpeckers, there are other groups of birds with eggs of similar size and appearance, e.g. Strigidae (owls), Columbidae (pigeons and doves) and Psittacidae (parrots) (e.g. Reed 1904). The eggs could therefore not be identified based on morphology alone, and genetic analysis, which previously has been successfully used to identify old museum eggs (e.g. Chilton & Sorenson 2007, Fossøy *et al*. 2016, Grealey *et al*. 2021), was the only option to determine their identity.

We obtained permission from OMNH to sample the eggs for genetic analysis. Sampling was performed by OMNH personnel, following Fossøy *et al*. (2016), by gently enlarging the already existing blow hole and collecting the resulting fine eggshell dust for DNA extraction. Two separate samples were taken from each egg. The samples were analysed genetically using the same protocol as described above for the piece of head skin, with multiple replicates per sample and negative controls in the extraction and PCR steps.

While the amount and quality (fragment size) of the extracted DNA was low, as expected for this type of sample, DNA of sufficient quantity and quality for sequencing

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was obtained from four of the five eggs (GenBank accession nos. OK336060.1–OK336063.1). Blasting against the NCBI and BOLD databases identified at least one, but mostly several, of the replicates from each of the four eggs as Burrowing Owl *Athene cunicularia*, with >98% sequence similarity. The remaining replicates were identified either as Wolf *Canis lupus*, i.e. probably domestic dog, or Andean Condor *Vultur gryphus*, but as neither of these can be the origin of the eggs these sequences must represent contamination. Importantly, none of the samples or replicates showed any evidence of woodpecker DNA.

It therefore seems safe to conclude that these eggs: (a) are not from Imperial Woodpecker, and (b) probably pertain to Burrowing Owl. One can only speculate as to why they have been labelled as Imperial Woodpecker eggs, but deliberate falsification of museum specimen data is not unknown (e.g. Rasmussen & Prŷs-Jones 2003, Boessenkool *et al*. 2010). Identification of this type of egg out of context can be difficult or impossible even for the most skilled oologist. In conclusion, eggs of Imperial Woodpecker are still not known in any museum collection.

Amendments and revisions

Table 2 lists a number of amendments and revisions of information relating to specimens included in B&C. Two of the specimens listed for BMNH (now NHMUK) by B&C, a male and a female, lacked catalogue numbers, but were both referred to as 'Mounted specimen on display'. These two are identical with the data-less male and 'Zoological Society' female discussed by Prŷs-Jones (2011). The only known data for the male is that it, like the female, was noted by Gray (1868) to be from 'California' (i.e. probably Mexico, as discussed above). Based on its mention in Gray (1868) it can, however, be concluded that it must be at least from before 1868, and probably well before that. The female was concluded by Prŷs-Jones (2011) to 'almost certainly' be one of the syntypes of the species, with catalogue number 1855.12.19.325, and, like all of the syntypes, probably collected by Damiano Floresi near Bolaños, Jalisco, in or before 1832. The date and locality information provided by B&C must therefore be considered erroneous. Further, Prŷs-Jones (2011) restored the original catalogue number, 1838.5.12.108, to the specimen listed in B&C as BMNH 1988216 and identified it as a syntype. The latter should be written 1988.21.6, but this was assigned by Knox & Walters (1994) as they were not aware of the original catalogue number. Finally, collector and later owners are added to two of the other syntypes in NHMUK, viz. 1888.8.5.60 and 1888.8.5.61.

Two specimens listed by B&C at the World Museum Liverpool (WML-VZ D3868 and D3868a) lacked information about collecting date, locality and collector, but were indicated as potential syntypes. Prŷs-Jones (2011) identified them as syntypes and thereby established details about their collection, and also clarified their likely history of subsequent ownership.

Brown & Clark (2009) listed six specimens in the Moore Laboratory of Zoology, Occidental College, Los Angeles (MLZ). However, they noted that one of those specimens (MLZ 46338) was exchanged to 'MNHUK #43123', without explanation. It is currently in the Biodiversity Institute and Natural History Museum at the University of Kansas (KU).

Another *C. imperialis* specimen has also been reported at KU (see, e.g., University of Kansas Biodiversity Institute 2022; Table 3), but was previously misidentified until examined by Jerome Jackson (M. Robbins *in litt*. 2019). Similarly, a skull held at the Zoological Institute, Russian Academy of Sciences in St. Petersburg (ZIN) was previously identified as *C. imperialis* (see, e.g., Wood & Schnell 1986; Table 3) but, based on morphological analysis, Prŷs-Jones *et al*. (2021) concluded that it also represents *C. principalis*.

Finally, institution, catalogue numbers, collector or provider, locality, state, collecting date and/or object type have been added or corrected for 17 additional specimens (see Table 2).

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Conclusion

We present an overview of a total of 31 specimens of Imperial Woodpecker, including one no longer extant, that have become known since the publication of Brown & Clark (2009). Several of these have been included in previous publications (see Table 1), but are presented collectively for the first time here. They represent a 20% increase in the number of known specimens, bringing the total to 189 (GBIF.org 2022 currently lists 274, but this includes a large number of duplicated data points). Taken with the comprehensive overview provided by B&C, the current publication will hopefully facilitate novel studies on various aspects of this enigmatic and probably extinct species. Additional specimens may provide more data to understand the species' breeding biology, or to test if it was already experiencing a genetic bottleneck at the start of the collecting era (Thomas *et al*. 2019).

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