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Radiocarbon dating redefines the timing and circumstances of the chicken's introduction to Europe and northwest Africa

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Abstract

Astonishingly little is known about the early history of the chicken (*Gallus gallus domesticus*). To better understand their spatiotemporal spread across Eurasia and Africa, we radiocarbon dated presumed early chicken bones. The results indicate chickens were an Iron Age arrival to Europe and that there was a consistent time-lag of several centuries between their introduction to new regions and incorporation into the human diet. Well-dated evidence for Britain and mainland Europe suggests chickens were initially considered exotica and buried as individuals, were gradually incorporated into human funerary rites, and only much later came to be seen as just 'food'.

1. Introduction

The chicken (*Gallus gallus domesticus*) is the most widely distributed domestic animal on the planet (Nicol 2015). Transported around the world by people, the species is now established across a broad range of ecosystems and societies, providing humans with an increasing quantity of both meat and eggs (Bennett *et al.* 2018). Given their modern ubiquity in the human food chain, it is easy to assume that chickens were domesticated primarily as a food source (e.g. Marino 2017), though there is little evidence to support this hypothesis. In fact, despite the chicken's global economic and cultural significance, its early history is poorly understood.

The existing academic literature is largely speculative. For instance, West & Zhou (1988) summarised, but did not challenge, claims regarding chicken domestication and diffusion. From their survey of the literature, they proposed that chickens were domesticated in Southeast Asia *c.*6,000 BC, became established in China shortly afterwards, and spread rapidly into Western Eurasia. They also suggested that chickens arrived into eastern Europe by the Neolithic, before becoming established throughout the Mediterranean during the Bronze Age and reaching temperate Europe in the Iron Age. Other studies (*e.g.* those cited by Ledogar *et al.* 2019) have proposed that chickens were not only established in eastern

Europe by the Neolithic, but that the species may even have been native to the region (Boev 1995).

West & Zhou (1988) continues to be cited frequently though several recent studies have questioned the validity of the evidence presented within it (Eda *et al.* 2016; Peters *et al.* 2016; Huang *et al*. 2018; Peters *et al.* in prep). Based on comprehensive zooarchaeological re-analyses and ecological modelling, these publications have argued that chickens could not have been domesticated in the seventh millennium BC, and that the third millennium BC is more probable. These refined dates have significant ramifications for diffusion models (Pitt et al. 2016), yet many publications (e.g. Bennett *et al.* 2018; Sykes 2018) continue to cite some of West & Zhou's (1988) conclusions without questioning the underpinning archaeological data.

There are numerous reasons why these archaeological data should be questioned. Issues of taphonomy and recovery bias can lead to an under-representation of archaeological chicken bones, making it difficult to accurately reconstruct ancient distributions (Serjeantson 2009; Dirrigl *et al.* 2020). This is compounded by problems of identification: for example, re-analyses by Eda *et al.* (2016) and Peters *et al.* (2016) revealed that several bones identified as early chicken remains were actually pheasants (*Phasianus* sp).

The most significant factor obfuscating the chicken's bio-cultural history is imprecise dating. Chicken bones are prone to stratigraphic movement via bioturbation or through building and agricultural activities. For instance, Flink *et al.* (2014) directly dated a chicken bone from an Iron Age context (280–15 BC) at Altenburg, Germany, and found it to be a recent intrusion (150±30 BP, 1667-1903 cal AD, 95.4%). Similarly, Ledoger *et al.* (2018) demonstrated that proposed Neolithic specimens from a Ukrainian cave were also intrusive. Such examples of direct dating are rare, yet they have consistently highlighted the fallibility of assigning chicken remains to stratigraphic dates. To test whether other early chicken bones are also intrusive, we directly radiocarbon dated many of the earliest claimed specimens in Europe and Northwest Africa. The results allowed us to re-evaluate the arrival and spread of chickens across these regions and discuss the shifting relationships between humans and chickens through time.

2. Materials and Methods

Twenty-three chicken bones were selected from 16 archaeological sites for direct radiocarbon dating (Figure 1, Table 1, Table S1, and Online Supplementary Material - OSM). Those from Bulgaria were suggested to date to the Neolithic/Bronze Age, and those from Turkey and Greece were supposedly Bronze Age. For France, purportedly Bronze Age/Early Iron Age specimens were dated. We also targeted Iron Age sites in Italy, Morocco and England where claims have been made for early chickens. Lastly, we chose Iron Age chickens from Scotland, although here the Iron Age extends to AD 800.

Detailed methods are provided in the OSM. In brief, radiocarbon dating was undertaken by three separate laboratories (Oxford Radiocarbon Accelerator Unit: n= 20; Kiel AMS: n=2; and Beta Analytic: n=1). Carbon and nitrogen isotope data derived from the dating process were incorporated into our wider project dataset. Prior to destruction, specimens were measured and examined for evidence of butchery, sex and age.

These approaches help ascertain a specimen's archaeological status. Bennett *et al.* (2018) demonstrated that ancient and modern chickens can be differentiated morphologically since modern chickens grow much faster and their bones are larger in every dimension than ancient specimens. This is due to advances in poultry feeding and selective breeding that have resulted in significant genetic changes (Flink *et al.* 2014; Loog *et al.* 2017). Dietary differences can also be observed isotopically: modern chicken diets contain higher quantities of C4 plants, notably maize, and far lower levels of protein relative to their ancient counterparts (Bennett *et al.* 2018).

Contextual information, and whether specimens were recovered as isolated bones or complete skeletons, can indicate risk of intrusion, whilst also revealing human attitudes towards chickens.

3. Results

Of the 23 dated chicken bones, only five were consistent with their reported stratigraphic phasing. The radiocarbon dates associated with the remaining 18 were more recent than their reported dates (Table 2 and Figure 2).

Radiocarbon dates for the chicken bones derived from Neolithic/Bronze Age Hotnitsa (Bulgaria: CKN4), Bronze Age Tiryns (Greece - CKN22) and two of the bones from Iron

Age/Roman Mogador (Morocco: CKN18 and CKN19) were modern (post-bomb). This explains the morphological and isotopic results derived from the same bones which appeared closer to those for modern broilers (commercial meat birds) and not ancient chickens (Figures 3 and 4).

Differences between ancient and modern poultry production are exemplified by the chickens from Mogador. The two modern individuals (CKN18 and CKN19) had more positive $\delta^{13}C$ values and more negative $\delta^{15}N$ values relative to the two medieval-dated specimens (CKN20 and CKN21), whose isotope values plot within the distribution of other ancient chicken remains (Fig 4).

Other intrusive chicken bones include specimen CKN23 from Tiryns (Greece) which was *c.*1300 years younger than its Bronze Age context. Two specimens from Galabovo (Bulgaria) were over 3500 years younger than originally claimed (CKN3: 215-338 cal AD and CKN2: 436-605 cal AD), and specimen CKN1 from Yabalkovo (Bulgaria) was *c.*5,000 years younger and dated to the eleventh-twelfth centuries AD.

Both proposed Late Bronze Age specimens from Korucutepe in Turkey (CKN16 and CKN17) dated to the thirteenth century AD, and CKN13 from Boulancourt, le Châtelet (France) was also medieval rather than Bronze Age. Specimen CKN14 from Marseille (France), thought to be from a secure Iron Age context, was found to be Roman. At Covesea Cave 2 (Scotland) specimen CKN15 was shown to be seventeenth-twentieth century AD rather than Iron Age (800 BC – AD 800). Finally, the two chicken bones selected from Howe, Orkney, though supposedly dating between 200-800 AD returned direct dates of fourteenth-fifteenth century AD (CKN11) and seventeenth-twentieth centuries AD (CKN12), respectively.

Articulated skeletons are generally acknowledged to be reliable indicators of a secure context (Baker & Worley 2019: 18). Despite this, the purportedly Iron Age skeleton from Winklebury (CKN10, England) returned a post-medieval/modern date. The skeletons from Weston Down (CKN8) and Houghton Down (CKN9) were, however, consistent with their fourth/third century BC contexts. The isolated chicken bone from Stonehenge Road Improvement (CKN7) appears slightly earlier, extending into the late fifth century BC.

The earliest radiocarbon dates were from two Italian sites: Forcello (CKN5) and Orvieto (CKN6), both of which were consistent with their sixth and fifth century BC contexts. Their broadest radiocarbon date range extends to the mid-eighth century BC but this likely reflects the Hallstatt plateau, a flat area of the calibration curve that reduces the precision of determinations during this period. The specimen from Forcello (CKN5) again derived from an articulated skeleton.

4. Discussion and Conclusion

This programme of radiocarbon dating redefines the established chronology for the arrival and dispersal of chickens across Europe. Specifically, we found no evidence for chickens in Europe during the Neolithic, Chalcolithic or Bronze Age, nor do our results support claims of an autochthonous Holocene population of junglefowl in Eastern Europe. Instead, our results suggest that all claims for the presence of pre-Iron Age European chickens should be rejected unless supported by direct radiocarbon dating of the bones themselves.

4.1 A revised spatiotemporal pattern of the spread of chickens

Our results undermine claims of a seventh century BC presence in northwest Africa (Mogador, Morocco) but specimens from this site did date to ninth-twelfth centuries AD. This is consistent with current models suggesting that, following their ninth-sixth century BC introduction in the Horn of Africa (Woldekiros & D'Andrea 2016: 334), chickens spread across the continent slowly. Mwacharo *et al.* (2013) argue chickens were not established in the northwest until the medieval period, whereas Oueslati *et al.* (2020) propose a 1st century BC arrival but neither of these studies are based on directly dated specimens.

Our results also support the accepted chronology that chickens were present in Italy by the eighth century BC (Corbino et al. in press; Trentacoste 2020). It seems likely that chickens were transported throughout the Mediterranean along routes ecologically suited to them (Pitt *et al.* 2016), likely via early Greek, Etruscan and Phoenician maritime trade (Peters *et al.* in prep).

Human-assisted movement of chickens into central and northern Europe took place over the following centuries. Directly dated chicken bone from the Czech Republic (Kyselý 2010), alongside zooarchaeological and iconographic data from Bulgaria indicate arrival in the sixth-fifth centuries BC (Boev 1995), whilst chickens were introduced into France and southern Britain by the sixth-fifth century BC (Peters *et al.* in prep.)

It took almost 1,000 years longer for thermophilic chickens to become established in the colder climates of Scotland, Ireland, Scandinavia and Iceland (Best 2014; Best & Mulville 2014; Sykes 2018; Walker & Meijer 2020). Our direct dates also support the suggestion that chickens were not introduced to the Scottish Isles until the Norse arrivals from *c*.AD 800 (Best 2014). The same appears to be true for mainland Scotland where, rather than being introduced from the south, chickens may have arrived via Scandinavia or Ireland.

4.2 The Movement of Chicken Bones through Archaeological Stratigraphies

With one exception, all of the specimens that did not match their contextually assigned dates were isolated bones. This result highlights the ease with which chicken bones migrate through contexts, thus necessitating confirmation by direct dating. This is also true for articulated skeletons, since the purportedly Iron Age skeleton from Winklebury (England) proved to be modern. However, direct dates from the other articulated remains corroborated their stratigraphic phasing, and they are among the earliest regional specimens in our European dataset.

One possible explanation for why many of the earliest dated chicken remains are complete or nearly complete skeletons is because they have been preferentially targeted for radiocarbon dating programmes (Baker & Worley 2019: 18). A more intriguing possibility is that the deposition of complete chickens reflects how the species was perceived and treated by humans during the earliest stages of their human-mediated dispersal.

4.3 The Dynamics of Human-Chicken Relationships

Globally, the first convincing evidence for domestic chickens comes from complete skeletons placed within Bronze Age human burials in Thailand (e.g. Ban Non Wat *c*.800 BC) and China (Dasikongcun royal cemetery, 1320-1046 BC) (Peters *et al.* in prep). The same is true for Italy, where the earliest identified chicken is from a tenth-ninth century BC tomb (Corbino et al. in press), with other possible eighth century examples (see OSM) (De Grossi Mazzorin & Minniti 2019; Trentacoste 2020), although none of these have been directly dated. It is possible that this pattern could be the product of research bias, resulting from preferential excavation of funerary contexts. Earlier evidence for chickens may be awaiting discovery on other site types.

To understand how human–chicken relationships evolved from the point of introduction and as their populations increased, it is necessary to focus on the evidence from regions for which there is an extensive (zoo)archaeological record covering a variety of site types. For northern Europe, and in particular Britain, there is a sufficient body of securely dated evidence to propose a model for how attitudes to chickens changed through time (Fig 5A-E). In many areas, chickens appear initially not in human burials, but as individually buried skeletons. In addition to those dated from Weston Down (CKN8) and Houghton Down (CKN9) in Britain, articulated remains have been recovered from Iron Age sites across Europe (e.g. Peters *et al.* in prep). For the Czech Republic, Kyselý (2010) reported an adult cockerel skeleton from Rubín radiocarbon dated to 2380±30 BP (542-393 cal BC, 93.9%). It is possible that isolated early specimens could have also been buried as complete animals but became disarticulated through taphonomic processes.

Importantly, none of these skeletons show evidence of butchery or human consumption. Instead, they are often older animals: the long spurs on the Houghton Down cockerel (Fig 5B) suggest it was over two years old (Doherty et al. 2021). Similarly, the hen from Weston Down (CKN8) was mature and had a well-healed leg fracture (Fig 3C) which could indicate evidence of human care.

Rather than being considered 'food', these early arrivals to northern Europe were more likely viewed and treated as exotica, especially given their limited population size at the time (Fig 5A). The idea that chickens were too rare or too important to be slaughtered for meat is consistent with Caesar's *De Bello Gallico* that states "The Britons consider it contrary to divine law to eat the hare, the chicken, or the goose". Helms (1993) suggested that, in many cultures, animals and things derived from the 'outer realms' are often attributed with cosmological powers. Given the exotic nature of chickens, this could explain their depiction on Late Iron Age coins (themselves artefacts of power) recovered from southern Britain and northern France (Feider *et al*. 2020).

Through Late Iron Age and Early Roman Britain, there is an observable shift not only in the frequency of chicken remains within zooarchaeological assemblages (Fig 5A), but also towards human–chicken co-burials (Fig 5C), a phenomenon seen in other areas of northern Europe (Lauwerier 1993; Kunst & Doneus 2013; Sykes 2012). Our survey of British co-burials indicates that these funerary rites were often strongly gendered: males were buried with cockerels, females with hens (as at Broughton, Yorkshire, Fig 5B). Chickens may have been included within human graves as psychopomps, leading human souls to the afterlife. Such a role would have befitted their association with Mercury (god of communication and travel) to whom large quantities of cockerels were sacrificed at the Temple of Uley, Gloucestershire (Woodward & Leach 1993). On other occasions, the inclusion of chickens in graves is more obviously a food offering, a practice that becomes more common through the course of the Roman period (White 2007).

The spread of the Roman Empire popularised chickens and eggs as a foodstuff (e.g. Maltby *et al*. 2018; Peters 1998). In Britain, the earliest evidence for high levels of chicken consumption comes from the 'Romanized' site of Fishbourne Palace, Sussex, where Allen (2010) demonstrated that exceptional numbers of chickens were eaten as early as the first century AD (indicated by two direct dates: 1970±30 BP and 1920±30 BP). Here, chickens comprised 8% of the total assemblage, far higher than on other Iron Age/Roman sites (Fig 5A). Elsewhere in Britain, chickens were not regularly consumed until the third century AD, again primarily on highly Romanized towns and military sites (Maltby *et al.* 2018).

This evidence suggests that, in Britain, 700-800 years elapsed between their initial introduction as newly arrived exotic (whose flesh was prohibited for consumption), and the acceptance of chickens as a source of dietary protein. An equivalent time-lag appears to also be true in Italy, where chickens were sporadically represented in tombs and cult places for the first few centuries after their arrival (tenth/ninth to sixth centuries BC), became more abundant and occasionally eaten on settlements around the sixth-fifth centuries BC (at Forcello [Bagnolo San Vito] chickens were butchered) and only became a more frequent dietary component from the fourth century BC (De Grossi Mazzorin & Minniti 2019; Trentacoste 2020). Similarly, in the Levant, though chickens were present in the ninth/eighth century BC (Peters *et al.* in prep.) it was not until the fourth/third century BC that they became a common meat resource (Perry-Gal *et al.* 2015).

The trend toward perceiving chickens solely as dietary protein has accelerated to the present day. Whereas the earliest chickens in Europe were rare and lived into maturity, today this is often inverted. Of the >70 billion chickens now on the planet, most are commercial broilers that grow exceptionally quickly during their short lives (the average slaughter age is 42 days - EFSA 2010). They are seldom buried as individuals or together with people, and instead are often disposed of as fast-food refuse, littered in the street (Fig 5E). Though recent changes in chicken size, shape, genetics, and diet allow for a more robust assessment of their intrusive status (Figs. 3 & 4), these characteristics are also an eloquent expression of how dramatically human-chicken relationships have changed over the last three millennia.

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Figure 1: *Map of sample locations by sample numbers CKN1-23 (see Table 1, Table S1 and OSM).*

Figure 2: *Calibrated radiocarbon results for each specimen with stratigraphically proposed dates in brackets (see Tables 1, 2 and S1, and OSM for further information). CKN22 (thought to date to 1250-1100 BC) was determined to be 'post-1954' and is not included.*

Figure 3: *Comparison of chicken tarsometatarsi from A) Mogador (Becker 2013), B) modern broiler, C) Iron Age Weston Down, showing healthy bone on the left and injured bone on the right (CKN8)*

Figure 4: *Isotope values for the dated specimens (Table 2) against broader isotope dataset for ancient and modern chickens.*

Figure 5: *The association between A) zooarchaeological representation (Skelton 2019) and depositional context. From individual burial as at B) Middle Iron Age Houghton Down (CKN9), to gendered human-chicken co-burial as at C) Roman Broughton (Yorkshire) to foodstuff as at D) Fishbourne Roman Palace; and finally E) litter on modern streets.*

Table 1: *Site and location data for dated samples (see Fig. 1)*

SNO	Archaeological site	Country
CKN1	Yabalkovo	Bulgaria
CKN2	Galabovo	Bulgaria
CKN3	Galabovo	Bulgaria
CKN4	Hotnitsa	Bulgaria
CKN5	Forcello (Bagnolo San Vito)	Italy
CKN6	Orvieto	Italy
CKN7	WA50157: A303 Stonehenge	England
CKN8	Weston Down	England

CKN9	Houghton Down	England
CKN10	Winklebury	England
CKN11	Howe, Orkney	Scotland
CKN12	Howe, Orkney	Scotland
CKN13	Boulancourt Le Châtelet	France
CKN14	Marseille	France
CKN15	Covesea Cave 2	Scotland
CKN16	Korucutepe/Elazig	Turkey
CKN17	Korucutepe/Elazig	Turkey
CKN18	Mogador	Morocco
CKN19	Mogador	Morocco
CKN20	Mogador	Morocco
CKN21	Mogador	Morocco
CKN22	Tiryns	Greece
CKN23	Tiryns	Greece

Table 2: Sample details and results for the new series of AMS dates.

SNO	Archaeological site	Lab code	Proposed date	14C age (BP)	Calibrated date: 95.4%	Calibrated date: next highest % probability	$\delta^{13}C$	$\delta^{15}N$	C:N
CKN1	Yabalkovo, Bulgaria	OxA34654	4500 BC	957±24	1029-1158 cal AD	76.4%: 1060-1158 cal AD	-17.2	7.6	3.2
CKN2	Galabovo, Bulgaria	OxA34655	3550 BC	1525±25	436-605 cal AD	82.2%: 530-605 cal AD	-18.9	11.0	3.2
CKN3	Galabovo, Bulgaria	OxA34656	3550 BC	1789±25	215-338 cal AD	59.3%: 277-338 cal AD	-17.1	4.7	3.2
CKN4	Hotnitsa, Bulgaria	OxA34657	5500 BC	1.22391±0.00312	1959-1985 cal AD	49.9%: 1959-1962 cal AD	-12.1	4.7	3.2
CKN5	Forcello, Italy	OxA34658	530-520 BC	2495±26	775-540 cal BC		-20.0	10.4	3.2
CKN6	Orvieto, Italy	OxA34659	500-400 BC	2499±26	775-541 cal BC		-20.1	7.1	3.2
CKN7	WA50157: A303 Stonehenge, England	OxA34660	800-100 BC	2303±27	407-232 cal BC	77.6%: 407-356 cal BC	-20.1	8.2	3.3
CKN8	Weston Down, England	OxA34661	400-100 BC	2240±25	387-204 cal BC	70.0%: 315-204 cal BC	-20.3	9.3	3.2
CKN9	Houghton Down, England	OxA34662	470–360 BC	2242±26	388-204 cal BC	69.0%: 315-204 cal BC	-20.4	8.1	3.2
CKN10	Winklebury, England	OxA34663	800-100 BC	188±23	1656-1920+ cal AD	57.2%: 1727-1810 cal AD	-20.3	7.5	3.2
CKN11	Howe, Orkney, Scotland	OxA34664	AD 0-400	601±24	1302-1405 cal AD	73.6%: 1302-1368 cal AD	-21.7	11.7	3.2
CKN12	Howe, Orkney, Scotland	OxA34665	AD 400-800	82±23	1694-1917+ cal AD	68.5%: 1811-1917 cal AD	-21.8	8.3	3.2
CKN13	Boulancourt Le Châtelet, France	OxA34666	920-800 BC	982±24	996-1157 cal AD	58.9%: 1076-1157 cal AD	-20.4	7.7	3.4
CKN14	Marseille, France	OxA34667	580-560 BC	1938±25	16-203 cal AD	92.3%: 16-170 cal AD	-20.5	11.9	3.2
CKN15	Covesea Cave 2, Scotland	Beta-460769	800 BC-AD 800	170±30	1660-1908+ cal AD	46.4%: 1721-1816 cal AD	-20.2	10.5	3.2
CKN16	Korucutepe/Elazig, Turkey	OxA-X-2504-43	1400-1200 BC	754±27	1225-1286 cal AD		-15.1	6.1	3.2
CKN17	Korucutepe/Elazig, Turkey	OxA-27436	1800-1600 BC	738±24	1229-1298 cal AD	89.6%: 1255-1298 cal AD	-18.0	5.9	3.2
CKN18	Mogador, Morocco	OxA-27435	650 BC	1.28372±0.00326	1959-1980 cal AD	78.7%: 1979-1980 cal AD	-17.9	9.1	3.2
CKN19	Mogador, Morocco	OxA-27588	AD 0-300	1.12172±0.00631	1957-1997 cal AD	89.8%: 1992-1997 cal AD	-18.1	7.8	3.2
CKN20	Mogador, Morocco	OxA36658	700-400 BC	1077±27	893-1024 cal AD	67.9%: 943-1024 cal AD	-19.2	10.9	3.2
CKN21	Mogador, Morocco	OxA36659	700-400 BC	937±26	1031-1167 cal AD		-19.5	12	3.2
CKN22	Tiryns, Greece	KIA42955	1250-1100 BC	Unknown	Post-1954 cal AD		-13.8		
CKN23	Tiryns, Greece	KIA42956	1250-1100 BC	1675±28	256-433 cal AD	83.9%: 328-433 cal AD	-17.9		

Supplementary Data

This section outlines the rationale for the samples selected for dating in this study. For publications relating to the specimens selected please see Supplementary Table 1 (S1) below.

1. Materials

Morocco

Evidence for the chicken's introduction and spread through Africa has been reviewed by a number of researchers (e.g. MacDonald 1992; Mwacharo *et al*. 2013; Woldekiros and D'Angela 2016; Peters *et al*. in prep). It is generally accepted that whilst the birds were present in the Horn of Africa by the eighth century BC, it took approximately 1000 years for them to become established across the whole continent, especially the northwest. Several finds from Mogador in Morocco are of considerable interest, given their contextually assigned dates of mid-seventh century BC, with other specimens attributed to the first-third centuries AD. For this reason, four were selected for direct dating covering both proposed periods (see Table S1, Table 1 and Figure 1).

Turkey

The original report for Korucutepe suggests that one chicken bone was found in Middle Bronze Age deposits, with a further 16 from Late Bronze Age layers (Boessneck & von den Driesch 1975). These finds have been cited as evidence that chickens entered Europe via the Turkish bridge (e.g. West & Zhou 1988) even though Boessneck & von den Driesh (1975) dismissed some of the specimens as intrusive. To test the status of these key specimens, two bones derived from contexts dated stratigraphically to *c*. 1800-1200 BC were selected for dating (see Table S1, Table 1 and Figure 1).

Bulgaria

Chicken bones, dated to *c*. 5500-3550 BC by context and artefact association, have been reported for multiple Neolithic to Bronze Age sites (Boev 1993; 1995; 1996; 2004; 2006; 2009a; 2009b). Because so many sites appeared to have early chickens, these key specimens have been used to underpin models of the route/s by which chickens entered eastern, central and western

Europe (e.g. Kyselý 2010; Poole 2010). To test the validity of these models, four specimens were selected from the sites of Hotnitsa, Galabovo and Yabalkovo (see Table S1, Table 1 and Figure 1).

Greece

Historical, iconographic and zooarchaeological records are in accord that chickens were present in Greece by the fifth century BC but there is less evidence that they were established before the ninth century BC (Homer, for instance, does not mention them but Theognis writing in the sixth century BC does (Johansson 2012; Richter 1968). A few excavations, such as that of Late Bronze Age Tiryns, have reported specimens dated by ceramic association to *c.* 1250-1100 BC (von den Driesch and Boessneck 1990) and whist the authors exercised caution in interpreting these, others (e.g. Halstead 2012, 23) cited them as confirmed specimens which have entered general narratives. Therefore, two of the 16 specimens noted for this site were selected for dating (see Table S1, Table 1 and Figure 1).

Italy

Roman expansion is known to have encouraged the spread and uptake of chickens in western and northern Europe (e.g. Maltby 1997; 2016; Maltby *et al*. 2018), by which point, they were already established in Italy itself. The earliest chicken bones in Italy have been identified in a tenth/ninth-century BC cremation tomb (De Grossi Mazzorin 2005; De Grossi Mazzorin and Minniti 2019,10; date following the high Latial chronology, see van der Plicht *et al*. 2009; Guidi 2018) at Monte Cucco, Castel Gandolfo, and were recently re-examined by Albarella and Corbino to confirm their species ID (Corbino *et al*. in press). Unfortunately, although these appear to have secure stratigraphy, they were not available for direct dating. A small number have been reported at eighth century BC sites in Bologna and other sites in the Po Valley (De Grossi Mazzorin 2005; Trentacoste 2020). None of these early specimens could be accessed, but samples were acquired from two Etruscan sites: Forcello (Bagnolo San Vito) which produced (among other finds) a partial skeleton dated stratigraphically to the late sixth century BC, and Orvieto which yielded numerous specimens (at least 32) assigned the fifth century BC (George *et al*. 2017; Corbino and Trentacoste pers. comm.) (see Table S1, Table 1 and Figure 1).

From the mid-first millennium BC chicken remains become increasingly common in the Italian zooarchaeological record, including non-funerary contexts, and as such specimens from this period were not chosen for dating in the first instance (De Grossi Mazzorin 2005; Trentacoste 2014; 2020).

France

The presence of chickens from *c.* 600BC (and particularly 500-400 BC) in France is widely accepted but the security of their date of introduction is unclear (Garcia-Petit 2002; Lignereux and Obermaier 2012; Peters *et al*. In Prep; Seigle 2016). Whilst there are several specimens identified as sixth century BC in France, at present none have been directly dated (Seigle n.d.). Chickens have been claimed in Late Bronze Age contexts at Boulancourt (Bãlãsescu *et al*. 2008.) and their occurrence in sixth century BC assemblages from Marseille has also been noted (Seigle 2016; n.d). As representatives of the most northerly and southerly reaches of France, specimens from both of these sites have been selected (see Table S1, Table 1 and Figure 1).

England

Contrary to popular belief, chickens were not a Roman introduction but rather appear to have been present in low numbers from the Early/Middle Iron Age (Kitch 2006; Hambleton 2008; Maltby 1997; Strid 2015). It has been argued that the earliest populations had special status and were not eaten, as their remains were often deposited as un-butchered articulated skeletons (Poole 2010; Sykes 2012). Three of these apparently early articulated specimens (Winklebury, Weston Down, and Houghton Down) were dated to assess their status. On re-examination during sample extraction, the metrics and morphology indicated that the Winklebury ABGs (Associated Bone Groups) may be less discrete than initially thought and instead represent more than one individual. A further isolated specimen, from the Stonehenge Road improvement Scheme, was also selected (see Table S1, Table 1 and Figure 1).

Scotland (including mainland and the Scottish Islands)

The northward dispersal of chickens to Scotland is known to have been delayed relative to their spread in southern Britain (Best 2014; Best and Mulville 2014; Serjeantson 2013). It has generally been accepted that they arrived in small numbers during the last few centuries of the

Iron Age which spans *c.* 800 BC to AD 800. However, these early chickens come from stratigraphically complex sites. For mainland Scotland, a proposed Iron Age specimen was selected from Covesea Cave 2. In the Scottish Islands, the earliest possible chicken bones come from Orkney in the later Middle Scottish Iron Age (AD 200-400), with a small number reported at Late Scottish Iron Age sites (AD 400-800). A Middle and a Late Iron Age specimen were selected from the site of Howe (see Table S1, Table 1 and Figure 1). Several of the proposed chicken finds from the Iron Age levels of this site were reidentified as red grouse.

2. Analytical Methodologies

This section details the analytical methodologies employed in the study.

2.1 Radiocarbon dating

20 samples were submitted for analysis at the Oxford Radiocarbon Accelerator Unit, two were dated at Kiel AMS, and one at Beta Analytic. All samples produced results, which have been calibrated using OxCal 4.4.2 (Bronk Ramsey 2009). The IntCal20 calibration (Reimer *et al.* 2020) curve was used for all samples except: 4, 18 and 19. These three, being post-bomb, were calibrated using the Bomb13NH1 curve (Hua *et al.* 2013). A 14C age was not available for recalibration of sample 22, and as such lab dates are quoted. The samples dated at ORAU were processed using the gelatinisation and ultrafiltration protocols described by Brock *et al.* (2010) and Bronk Ramsey *et al.* (2004a). They were then combusted, graphitised and dated by Accelerator Mass Spectrometry (AMS) as described by Brock *et al.,* (2010), Dee and Bronk Ramsey (2000), and Bronk Ramsey *et al*. (2004b). ORAU maintains a continual programme of quality assurance procedures, in addition to participation in international inter-comparisons (Scott *et al.*, 2010), which indicate no laboratory offsets and demonstrate the validity of the precision quoted.

2.2 Zooarchaeological analysis

Samples 1-15 were identified to species using the Bournemouth University reference collection and recorded following the protocols outlined by Cohen and Serjeantson (1996). The methods outlined in MacDonald (1992) and Tomek and Bochenski (2009) were used to aid species level identification, and to exclude other galliform species. Where possible bones were measured to an accuracy of 0.01mm. Ageing was assigned following Thomas *et al*. (2014) and all evidence of butchery type and location, rodent and carnivore gnawing, burning, root etching, weathering, and other modifications was recorded. Where possible ABGs (associated bone groups) were targeted since these are less likely to have become stratigraphically displaced than isolated remains and provide more data on the individual bird. Where selected specimens were part of an ABG all other remains were also recorded following these conventions. Medullary bone, an endosteal layer of bone which serves as a rapidly mobile calcium reservoir during egg laying, is a reliable indicator of female sex and was recorded by macroscopic analysis. Spurs, spur scars, and spur shields were recorded and considered a probable, but not definite, indicator of male sex.

2.3 Genetic analysis

A programme of genetic analyses was also run, both for sample specific data, but to also confirm species identification of one specimen that was very large and could not be identified morphologically (4: Hotnitsa). Consequently, prior to dating, DNA analysis was conducted to confirm that this specimen was not a large wild galliform. The surface of each sample was removed via surface sanding and bone powder was obtained using a mikrodismembrator (Sartorius). 0.05 g of bone powder was then incubated overnight at 50°C with 1 mL of extraction buffer (0.5 M EDTA at pH 8.0, 0.5% SDS and 0.5 mg/mL proteinase K) in a 1.5 mL tube. DNA was extracted using a QIAquick purification kit™ according to manufacturer's instructions. Precautions to avoid contamination were taken during every stage of aDNA extraction and PCR set up, which took place in a separate laboratory dedicated to ancient DNA research free from contemporary DNA or PCR product. No laboratory materials or clothing were transferred from the post amplification rooms to the ancient laboratory. All work surfaces and equipment were thoroughly cleaned with 10% bleach (sodium hypochlorite) followed by 70% ethanol. Surfaces, equipment, and solutions were also routinely exposed to UV light for at least 10 minutes. All extractions and PCR setup was carried out in class II PCR hoods. Negative extraction and PCR controls (1 sample in every 5) were included to detect potential contamination in reagents and cross contamination between samples. 50% of samples were replicated by extracting twice from independent samples of the same bone followed by PCR amplification and DNA sequencing.

2.4 Isotope analysis

The $^{12}C/^{13}C$ ($\delta^{13}C$) and $^{14}N/^{15}N$ ($\delta^{15}N$) isotope values presented in this paper were analysed alongside the ^{14}C analysis, in the laboratories detailed in Table 2 following their collagen extraction protocols. In general, two $\delta^{13}C$ values are measured for ^{14}C analysis: the Accelerator Mass Spectrometer (AMS) value, used to correct for isotopic fractionation of the ^{14}C value, and the Isotope Ratio Mass Spectrometer (IRMS) value which is representative of the $\delta^{13}C$ of the sample, and the point at which $\delta^{15}N$ values are also reported. It is the IRMS values that are investigated as dietary indicators in this paper. Carbon and nitrogen isotope values ($\delta^{13}C$, $\delta^{15}N$) are reported per mil. (‰) relative to VPDB and AIR, respectively. Samples CKN1 to CKN21 produced C:N ratios between 3.2-3.4, indicative of well-preserved collagen (DeNiro 1985; Ambrose 1990; van Klinken 1999). C:N ratios were not generated for samples CKN22 and CKN23 due to the graphitisation process during AMS analysis at the Leibniz Lab for Radiometric Dating (KIA). Due to the isotopic fractionation resulting from this process, these samples were omitted from the stable isotope analysis (see Figure 4).

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Supplementary Table 1: Specimens selected presented by country and proposed date, with publication, context and zooarchaeological information where available

SNO	Archaeological site	Country	Proposed date	Refs (if any)	Context information	Zooarchaeological Info
CKN1	Yabalkovo	Bulgaria	4500 BC	Boev 2009b	Settlement site	Isolated adult humerus
CKN2	Galabovo	Bulgaria	3550 BC	Boev 2004	Settlement site	Isolated adult femur
CKN3	Galabovo	Bulgaria	3550 BC	Boev 2004	Settlement site	Isolated adult femur. Female (medullary bone). Slightly greasy appearance.
CKN4	Hotnitsa	Bulgaria	5500 BC	Boev 2009a	Settlement site	Isolated adult tibiotarsus. Very large. Cuts and carnivore gnawing on distal end.
CKN5	Forcello (Bagnolo San Vito)	Italy	530-520 BC	Trentacoste 2014	Use level of outdoor artisan working area (Context 1118: Phase H3)	Femur from a juvenile articulated skeleton.
CKN6	Orvieto	Italy	500-400 BC	George *et al.* 2017	Fill of disused quarry	Isolated adult femur. Female (medullary bone)
CKN7	WA50157: A303 Stonehenge	England	800-100 BC	Grimm 2008	Pit deposit (Context: 530)	Isolated adult tarsometatarsus. Pathological & eroded.
CKN8	Weston Down	England	400-100 BC	Gibson and Knight 2007	Pit deposit (5360)	Femur from articulated skeleton. Female (medullary bone). Pathological.
CKN9	Houghton Down	England	470–360 BC	Hamilton 2000	Pit deposit (340). Layer 6	Tibiotarsus from articulated skeleton. Spur (probably male)
CKN10	Winklebury	England	800-100 BC	Jones 1997	Hillfort. Context: 987. Feature: 986.	Tibiotarsus from supposedly articulated skeleton. Female (medullary bone). Large.
CKN11	Howe, Orkney, Scotland	Scotland	AD 0-400	Bramwell 1994	Rubble layer in settlement: 3337	Isolated adult femur. Large. Cut. Insect modification?
CKN12	Howe, Orkney, Scotland	Scotland	AD 400-800	Bramwell 1994	Rubble layer in settlement	Isolated adult tibiotarsus. Greasy surface appearance.
CKN13	Boulancourt Le Chatelet	France	920-800 BC	Bălăsescu *et al.* 2008.	Internal ditch of fortified hill settlement	Isolated adult femur. Female (medullary bone). Root etched and abraded.
CKN14	Marseille	France	580-560 BC	Seigle, Pers. Comm.	House of the Greek colony of Massalia	Isolated adult ulna with mild root etching.
CKN15	Covesea Cave 2, Moray	Scotland	800 BC–AD 800	Büster & Armit 2016	Cave layer (Context 248)	Isolated adult tarsometatarsus. Spur (probably male)
CKN16	Korucutepe/Elazig	Turkey	1400-1200 BC	Boessneck & von den Driesch 1975	Settlement mound	N/A
CKN 17	Korucutepe/Elazig	Turkey	1800-1600 BC	Boessneck & von den Driesch 1975	Settlement mound	N/A
CKN18	Mogador	Morocco	650 BC	Becker *et al.* 2013	Settlement refuse	Isolated carpometacarpus. (RB586 in Loog *et al.* 2017)
CKN19	Mogador	Morocco	AD 0-300	Becker *et al.* 2013	Settlement refuse	Isolated carpometacarpus. (RB579 in Loog *et al.* 2017)
CKN20	Mogador	Morocco	700-400 BC	Becker *et al.* 2013	Settlement refuse	Isolated adult coracoid
CKN21	Mogador	Morocco	700-400 BC	Becker *et al.* 2013	Settlement refuse	Isolated adult tibiotarsus (RB582 in Loog *et al.* 2017?)
CKN22	Tiryns	Greece	1250-1100 BC	N/A	Settlement mound	N/A
CKN23	Tiryns	Greece	1250-1100 BC	N/A	Settlement mound	N/A

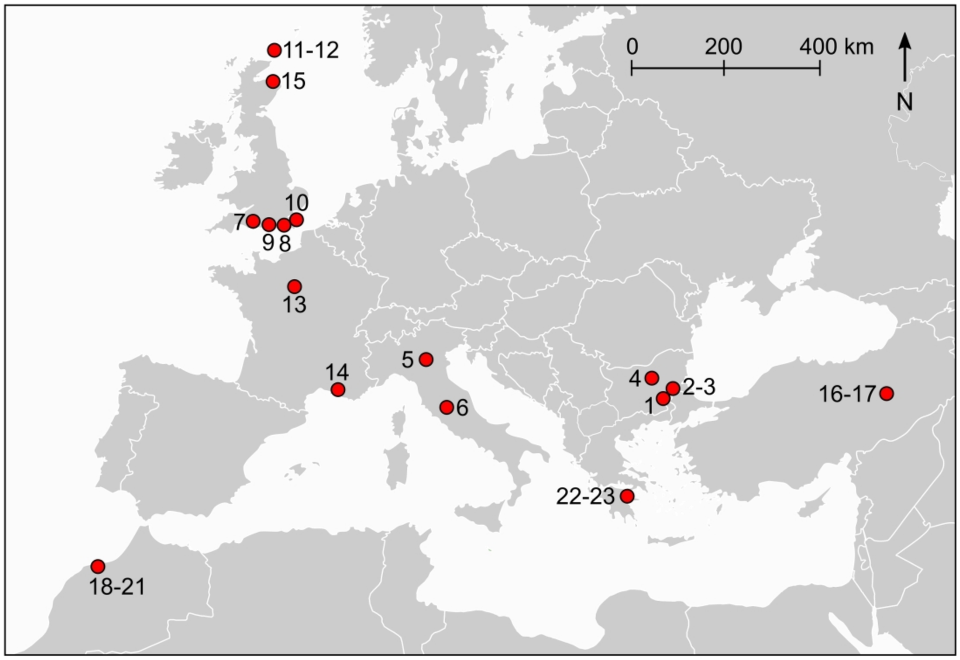

Figure 1: Map of sample locations by sample numbers CKN1-23 (see Table 1, Table S1 and OSM).

702x489mm (96 x 96 DPI)

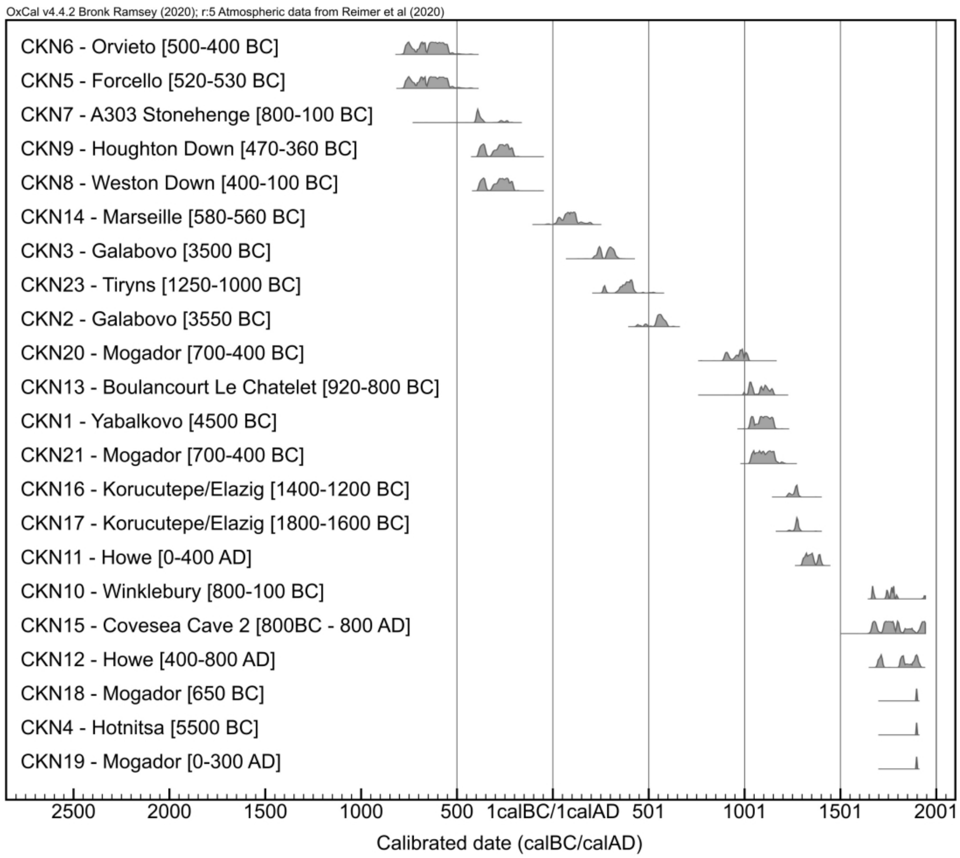

Figure 2: Calibrated radiocarbon results for each specimen with stratigraphically proposed dates in brackets (see Tables 1, 2 and S1, and OSM for further information). CKN22 (thought to date to 1250-1100 BC) was determined to be 'post-1954' and is not included.

702x624mm (96 x 96 DPI)

Figure 3: Comparison of chicken tarsometatarsi from A) Mogador (Becker 2013), B) modern broiler, C) Iron Age Weston Down, showing healthy bone on the left and injured bone on the right (CKN8)

338x278mm (96 x 96 DPI)

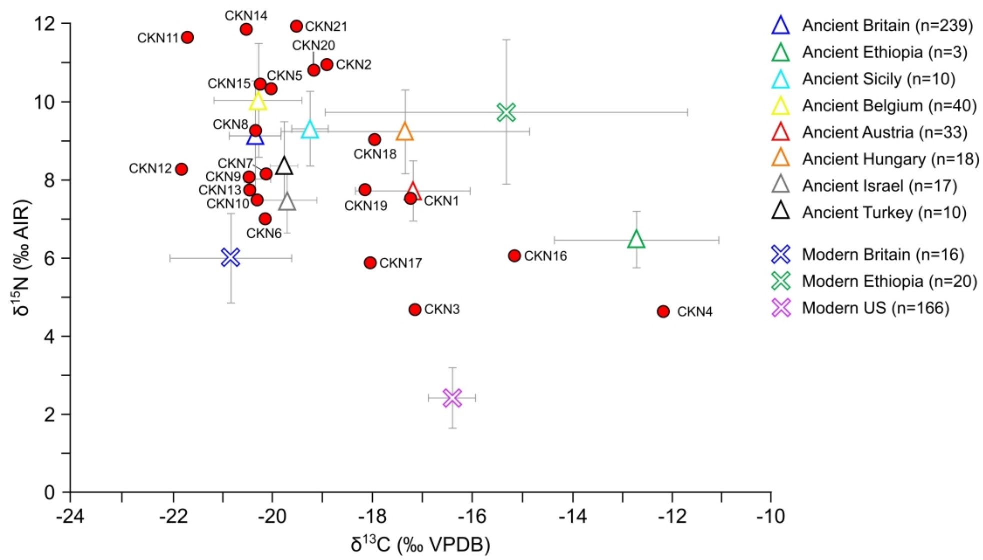

Figure 4: Isotope values for the dated specimens (Table 2) against broader isotope dataset for ancient and modern chickens.

843x493mm (96 x 96 DPI)

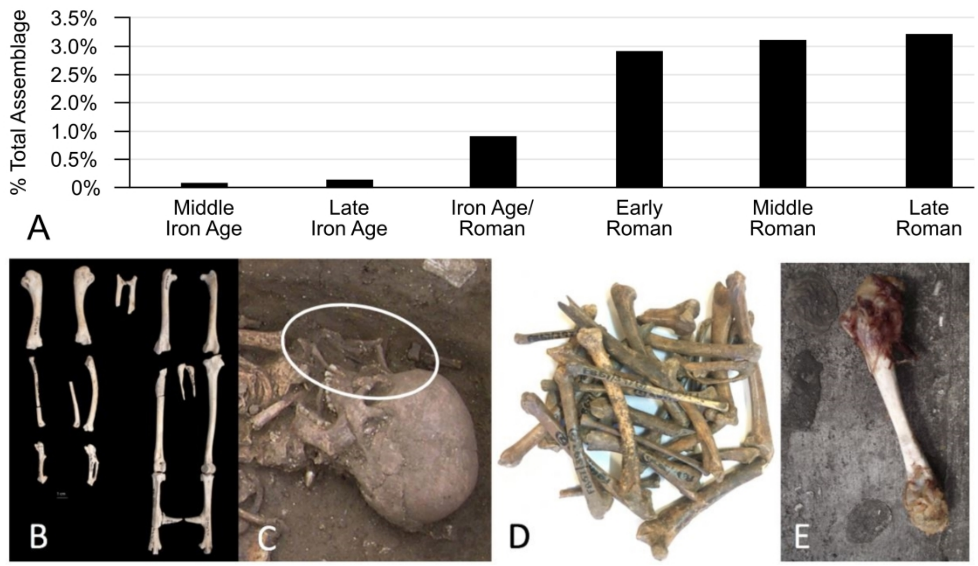

Figure 5: The association between A) zooarchaeological representation (Skelton 2019) and depositional context. From individual burial as at B) Middle Iron Age Houghton Down (CKN9), to gendered human-chicken co-burial as at C) Roman Broughton (Yorkshire) to foodstuff as at D) Fishbourne Roman Palace; and finally E) litter on modern streets.

843x500mm (96 x 96 DPI)