Zooarchaeology for Conservation Biology:
Introducing *A.RE. TI*

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Zoo-archaeology

Exploring human-animal interactions in the past

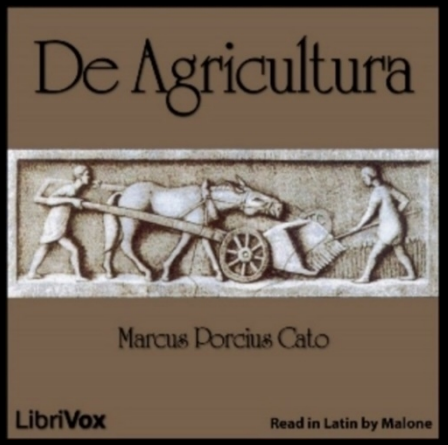
Main themes in Zooarchaeology

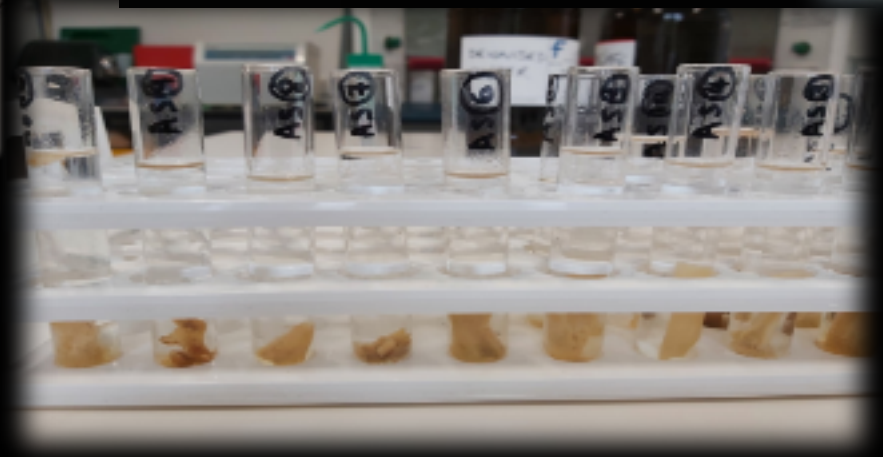
- Prehistoric diets
- Environmental reconstruction
- Mega-faunal extinctions
- Domestication
- Animal management
- Animal mobility
- Phylogeography
- The social role of animals
- **and many others**

The archaeological study of animal bones can inform about the multiple ways human societies have been interacting with animals and shed some light on our ancestors' everyday life!

A.RE.TI
Zooarchaeology
for Conservation Biology

Beyond the remains of animals.....



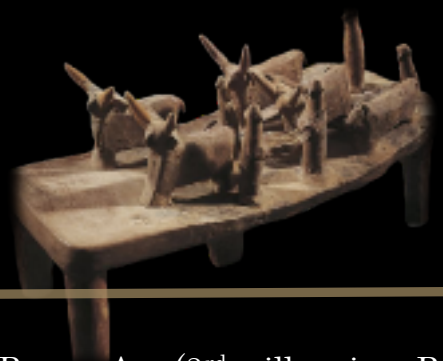


Zooarchaeology for Conservation Biology

Why cattle?

PPNB (8th millennium BC)
First wave of domestic cattle introduction via the sea

Neolithic (6th millennium BC)
Cattle disappear from the island (complete absence of cattle skeletal remains)



Bronze Age (3rd millennium BC)
Cattle re-introduction coincides with human migrations from Anatolia

Cypro Geometric-Classical periods (1st millennium BC)
cattle are invested with high symbolic significance

Until the 1950s the indigenous cattle have been the backbone of the island's rural economy

1970s- today

The Cyprus local cattle breed is at high risk of extinction

Important milestones in the history of human-cattle interactions on the island of Cyprus (8th millennium BC-today)

The status of the Cyprus local cattle breed

ΔΙΑΤΙ
ΟΙ ΓΕΩΡΓΟΙ ΑΓΟΡΑΣΑΝ
820.000 ΤΡΑΚΤΟΡΣ
ΦΕΡΓΚΥΣΟΝ !

"Οταν έφτασε τὸ ΣΥΣΤΗΜΑ ΦΕΡΓΚΥΣΟΝ οἱ γεωργοὶ τὸ ὠνόμασαν «Ἐπανάστασιν στὴν γεωργίαν!». Αὐτὸ συμβαίνει καὶ σήμερα. Ἀπόδειξις δὲ τῆς ἐπιτυχίας αὐτῆς εἶναι τὸ γεγονὸς ὅτι περισσότερα ἀπὸ 820.000 Τράκτορες ΦΕΡΓΚΥΣΟΝ καὶ περισσότερα ἀπὸ 2.500.000 ἐργαλεῖα χρησιμοποιοῦνται τώρα ἀπὸ τοὺς γεωργούς. Οἱ γεωργοὶ σ' ὁλόκληρο τὸν κόσμο καλλιεργοῦν τὴν γῆ τους μὲ ΦΕΡΓΚΥΣΟΝ — καὶ βρίσκουν τὸ σύστημα αὐτὸ πολὺ ἐπικερδές.

Οἱ γεωργοὶ ἀντελήφθησαν ἐπίσης ὅτι μόνον τὸ ΣΥΣΤΗΜΑ ΦΕΡΓΚΥΣΟΝ συνδυάζει ὅλα τὰ χαρακτηριστικὰ ποὺ οἱ ἄλλοι προσπάθησαν νὰ μιμηθοῦν. Μόνον τὸ ΦΕΡΓΚΥΣΟΝ δὲν σκαταλᾶ καύσιμον ὕλην, διαθέτει σταθερότητα τοῦ ἐμπροσθίου μέρους καὶ εἶναι κατασκευασμένον κατὰ τοιοῦτον τρόπον ὥστε νὰ ἐμποδίζονται οἱ ὀλισθες. Μόνον στὸ ΦΕΡΓΚΥΣΟΝ ἡ διατήρησις εἶναι ἁπλῆ, ἀλλάζονται τὰ ἐργαλεῖα μὲ εὐκολίαν, καὶ δὲν χρειάζονται περισσότεροι ἀπὸ ἕνα γιὰ τὴν ἐκτέλεσι τῶν διαφόρων ἐργασιῶν.

Αὐτὰ δὲν εἶναι ἁπλῶς ἀξιώσεις. Αὐτὰ εἶναι γεγονότα τῆς ἐργασίας τοῦ τράκτορ... τῆς ἐργασίας του ποὺ δοκιμάστηκε στὸ χωράφι, σ' ὅλες τὶς ἐδαφικὲς συνθῆκες καὶ σὲ κτήματα διαφόρων μεγεθῶν. Ρωτῆστε τὸν ἄνθρωπον ποὺ γνωρίζει — τὸν γεωργὸ ΦΕΡΓΚΥΣΟΝ!

Γενικοὶ Διανομεῖς ἐν Κύπρῳ :
Α. ΟΥΖΟΥΝΙΑΝ, Μ. ΣΟΥΛΤΑΝΙΑΝ & ΣΙΑ.
(Δ Ο Μ Σ. & ΣΙΑ ΛΤΔ.)
Τηλ. 2220 ΛΕΥΚΩΣΙΑ Τ.Κ. 775

FERGUSON SYSTEM

Ἔκδοσις τοῦ Τμήματος Γεωργίας Κύπρου. Τύποις ΚΟΣΜΟΣ ΛΤΔ., Λευκωσία.

Year	1960	1965	1970	1973	1974	1975	2008	2010	2012	2014	2016	2018	2020	2022
No. of animals	27500	26000	16000	14500	7000	5000	746	807	1102	1392	1384	1324	1244	1202

Population census of the Cyprus local cattle breed for the years 1960-1975; 2008-2022 (Cyprus Ministry of Agriculture, Rural Development and the Environment)

Zooarchaeology
for Conservation Biology

How can zooarchaeology contribute to the conservation of the Cyprus local cattle breed?

Zooarchaeology for Conservation Biology

ARETI's logo was kindly created by Nicolas Loucas

- Both disciplines focus on the utilization and management of animal resources by human societies and study the impact of anthropogenic and non anthropogenic factors on biodiversity
- Zooarchaeology focuses on the **past**
- Conservation biology focuses on the **present** and seeks to identify solutions to conserve biodiversity for the **future**
- Conservation biology is based on short term observations and has a limited perspective of ecosystem flow
- Zooarchaeology stands in a unique position because it can provide **long-term records about human-animal interactions** (e.g. animal translocations, management, genetic admixtures) and inform current conservation efforts

Animals Resilient in Time (*A.RE.TI*): Unravelling the genetic, economic and cultural history of the Cyprus local cattle breed from prehistoric times to the present

A.RE. TI **is an interdisciplinary project that aims to explore the past, present and future of the Cyprus' local cattle breed by weaving together evidence from Archaeology, Ancient and Contemporary cattle genomics, Conservation Biology, History and the Folklore.**

ARETI's core research team

Georgia Hadjipavlou
Animal Geneticist
Agricultural Research Officer A
Cyprus Agricultural Research Institute

Anna Spyrou (PI)
Postdoctoral Researcher
Zooarchaeologist
STARC, CYI

Daniel Bradley
Professor in Population Genetics
The Smurfit Institute of Genetics
Trinity College Dublin

THE A.G. LEVENTIS FOUNDATION

A.RE.TI's main areas of focus

- *Zooarchaeological study of cattle bone collections*
- *Ancient cattle genomics*
- *Contemporary cattle genomics*
- ***Historical documentation*** *(journals, newspaper, travelers' books, photographs etc)*
- ***Collection of oral histories*** *(questionnaires and interviews with farmers of the old generation and cattle breeders involved in the conservation of the breed)*

Human-cattle interactions in prehistoric Cyprus

Evidence from the bones

A non pathological (left) and a pathological (right) *Bos sp.* first phalanx from the Bronze Age Site Kition *Kathari. Distal articulation (development of osteophytes).*

A pair of oxen pulling the cart (Reno Wideson; Cyprus Remembered 2010)

Zooarchaeology
for Conservation Biology

Taurine and Zebu cattle:
Potential trails

Taurine

Cyprus

Zebu

Zooarchaeology for Conservation Biology

Contemporary genetics meet history

The indigenous cattle breed of Cyprus possesses a high indicine ancestry

Alexander the Great, a bull belonging to the indigenous cattle breed of Cyprusroaming freely in the Akrotiri meadow

Flori *et al.* 2019. A genomic map of climate adaptation in Mediterranean cattle breeds. *Molecular Ecology* 28: 1009-1029 (analysis of 9 individuals)

Papachristou *et al.* 2020. Genomic diversity and population structure of the indigenous Greek and Cypriot cattle populations. *Genetics, Selection, Evolution* 52 : 1-23 (analysis of 12 individuals)

Zebu cattle in the iconographic corpus of LBA Cyprus

Terracotta figurine of a zebu from Ayia Irini, LCII-III, Cyprus Museum, Nicosia (Inv. No. 1984/1-21/2).

Terracotta figurine of a zebu from Ayia Irini, LCII-III, Cyprus Museum, Nicosia (Inv. No. 1984/1-21/1).

Drawing of a terracotta figurine of a zebu with Cypro-Minoan inscriptions, from Psilatos *Moutti* (LCII-III), Cyprus Museum,.

Terracotta figurine of a zebu from Enkomi, LBA II-III (Cyprus Museum, Nicosia. Inv. No. 386).

A zebu-shaped balance weight from Enkomi, Cyprus Museum, Nicosia (Inv. No. 386).

Spyrou, A. 2021. From South Asia to the Eastern Mediterranean: Zebu cattle in nature and iconography of Late Bronze Age Cyprus. In: Amadio, M. and Bombardieri, L. (Eds), *Archaeology in the smaller realm: Micro-analyses and methods for reconstruction of Cyprus early societies.* Archaeology Series: Artemide: Roma; pp. 154-166.

Zooarchaeology for Conservation Biology

The appearance of zebu figurines in the light of the Late Bronze Age "Crisis"

Regional Environmental Change
https://doi.org/10.1007/s10113-018-01460-w

ORIGINAL ARTICLE

300-year drought frames Late Bronze Age to Early Iron Age transition in the Near East: new palaeoecological data from Cyprus and Syria

David Kaniewski[1,2,3] · Nick Marriner[4] · Joachim Bretschneider[5] · Greta Jans[6] · Christophe Morhange[7,8] · Rachid Cheddadi[9] · Thierry Otto[1,2] · Frédéric Luce[1,2] · Elise Van Campo[1,2]

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Abstract
In Eastern Mediterranean history, 1200 BCE is a symbolic date. Its significance is tied to the important upheavals that destabilised regional-scale economic systems, leading to the dislocation of mighty Empires and, finally, to the "demise" of a societal model (termed "the Crisis Years"). Recent studies have suggested that a centuries-long drought, of regional scale, termed the 3.2 ka BP event, could be one of the motors behind this spiral of decline. Here, we focus on this pivotal period, coupling new palaeoenvironmental data and radiocarbon dates from Syria (the site of Tell Tweini) and Cyprus (the site of Pyla-*Kokkinokremnos*), to probe whether climate change accelerated changes in the Eastern Mediterranean's Old World, by inducing crop failures/low harvests, possibly engendering severe food shortages and even famine. We show that the Late Bronze Age crisis and the following Dark Ages were framed by an ~300-year drought episode that significantly impacted crop yields and may have led to famine. Our data underline the agro-productive sensitivity of ancient Mediterranean societies to environmental changes, as well as the potential link between adverse climate pressures and harvest/famine.

Keywords Late Bronze Age crisis · Climate change · Drought · 3.2 ka BP event · Food shortages · Famine · Eastern Mediterranean

OPEN ACCESS Freely available online

Environmental Roots of the Late Bronze Age Crisis

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Abstract

The Late Bronze Age world of the Eastern Mediterranean, a rich linkage of Aegean, Egyptian, Syro-Palestinian, and Hittite civilizations, collapsed famously 3200 years ago and has remained one of the mysteries of the ancient world since the event's retrieval began in the late 19th century AD/CE. Iconic Egyptian bas-reliefs and graphic hieroglyphic and cuneiform texts portray the proximate cause of the collapse as the invasions of the "Peoples-of-the-Sea" at the Nile Delta, the Turkish coast, and down into the heartlands of Syria and Palestine where armies clashed, famine-ravaged cities abandoned, and countrysides depopulated. Here we report palaeoclimate data from Cyprus for the Late Bronze Age crisis, alongside a radiocarbon-based chronology integrating both archaeological and palaeoclimate proxies, which reveal the effects of abrupt climate change-driven famine and causal linkage with the Sea People invasions in Cyprus and Syria. The statistical analysis of proximate and ultimate features of the sequential collapse reveals the relationships of climate-driven famine, sea-borne-invasion, region-wide warfare, and politico-economic collapse, in whose wake new societies and new ideologies were created.

Citation: Kaniewski D, Van Campo E, Guiot J, Le Burel S, Otto T, et al. (2013) Environmental Roots of the Late Bronze Age Crisis. PLoS ONE 8(8): e71004. doi:10.1371/journal.pone.0071004

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Competing Interests: The authors have declared that no competing interests exist.

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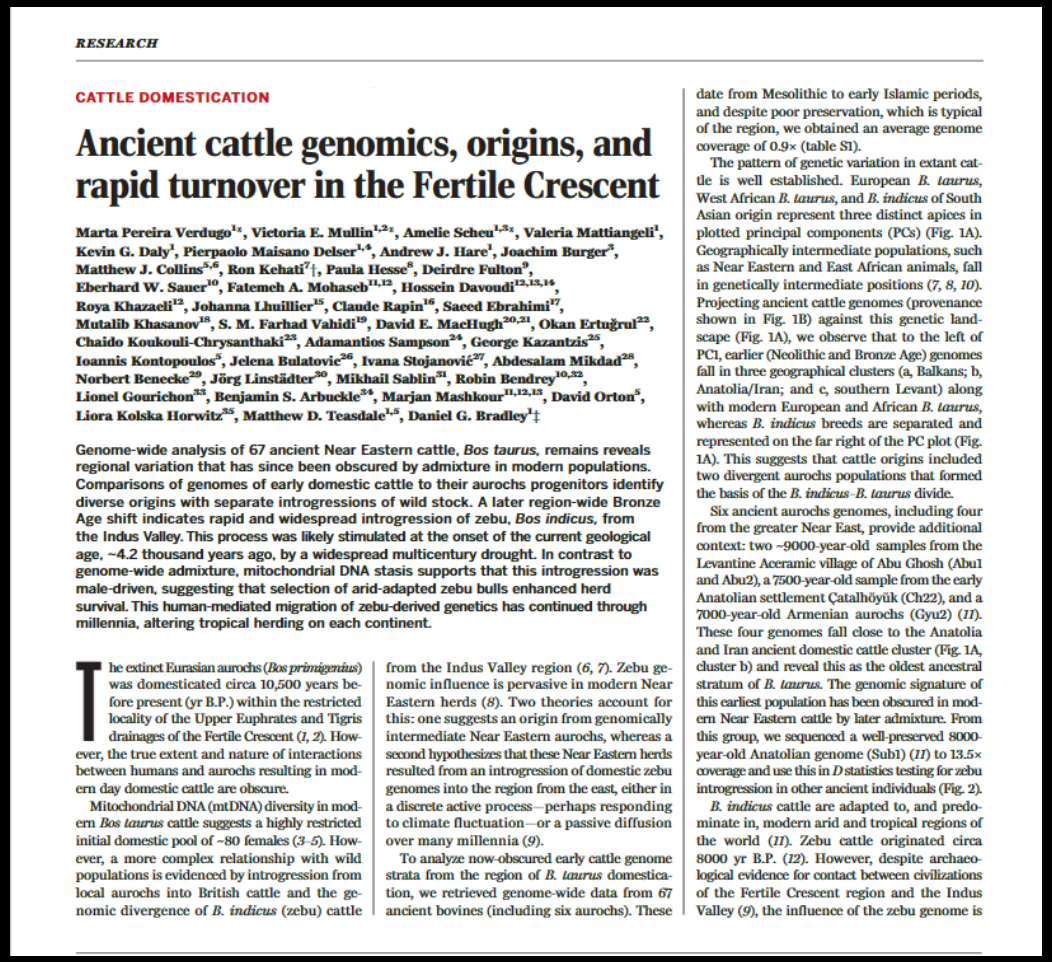
Cattle crossbreeding during prehistoric times

A mitigation strategy to a multi-century drought event



RESEARCH

CATTLE DOMESTICATION

Ancient cattle genomics, origins, and rapid turnover in the Fertile Crescent

Marta Pereira Verdugo[1*], Victoria E. Mullin[1,2*], Amelie Scheu[1,3*], Valeria Mattiangeli[1], Kevin G. Daly[1], Pierpaolo Maisano Delser[1,4], Andrew J. Hare[1], Joachim Burger[3], Matthew J. Collins[5,6], Ron Kehati[7]†, Paula Hesse[8], Deirdre Fulton[9], Eberhard W. Sauer[10], Fatemeh A. Mohaseb[11,12], Hossein Davoudi[12,13,14], Roya Khazaeli[12], Johanna Lhuillier[15], Claude Rapin[16], Saeed Ebrahimi[17], Mutalib Khasanov[18], S. M. Farhad Vahidi[19], David E. MacHugh[20,21], Okan Ertuğrul[22], Chaido Koukouli-Chrysanthaki[23], Adamantios Sampson[24], George Kazantzis[25], Ioannis Kontopoulos[5], Jelena Bulatovic[26], Ivana Stojanović[27], Abdesalam Mikdad[28], Norbert Benecke[29], Jörg Linstädter[30], Mikhail Sablin[31], Robin Bendrey[10,32], Lionel Gourichon[33], Benjamin S. Arbuckle[34], Marjan Mashkour[11,12,13], David Orton[5], Liora Kolska Horwitz[35], Matthew D. Teasdale[1,5], Daniel G. Bradley[1]‡

Genome-wide analysis of 67 ancient Near Eastern cattle, *Bos taurus*, remains reveals regional variation that has since been obscured by admixture in modern populations. Comparisons of genomes of early domestic cattle to their aurochs progenitors identify diverse origins with separate introgressions of wild stock. A later region-wide Bronze Age shift indicates rapid and widespread introgression of zebu, *Bos indicus*, from the Indus Valley. This process was likely stimulated at the onset of the current geological age, ~4.2 thousand years ago, by a widespread multicentury drought. In contrast to genome-wide admixture, mitochondrial DNA stasis supports that this introgression was male-driven, suggesting that selection of arid-adapted zebu bulls enhanced herd survival. This human-mediated migration of zebu-derived genetics has continued through millennia, altering tropical herding on each continent.

The extinct Eurasian aurochs (*Bos primigenius*) was domesticated circa 10,500 years before present (yr B.P.) within the restricted locality of the Upper Euphrates and Tigris drainages of the Fertile Crescent (*1*, *2*). However, the true extent and nature of interactions between humans and aurochs resulting in modern day domestic cattle are obscure.

Mitochondrial DNA (mtDNA) diversity in modern *Bos taurus* cattle suggests a highly restricted initial domestic pool of ~80 females (*3*–*5*). However, a more complex relationship with wild populations is evidenced by introgression from local aurochs into British cattle and the genomic divergence of *B. indicus* (zebu) cattle from the Indus Valley region (*6*, *7*). Zebu genomic influence is pervasive in modern Near Eastern herds (*8*). Two theories account for this: one suggests an origin from genomically intermediate Near Eastern aurochs, whereas a second hypothesizes that these Near Eastern herds resulted from an introgression of domestic zebu genomes into the region from the east, either in a discrete active process—perhaps responding to climate fluctuation—or a passive diffusion over many millennia (*9*).

To analyze now-obscured early cattle genome strata from the region of *B. taurus* domestication, we retrieved genome-wide data from 67 ancient bovines (including six aurochs). These date from Mesolithic to early Islamic periods, and despite poor preservation, which is typical of the region, we obtained an average genome coverage of 0.9× (table S1).

The pattern of genetic variation in extant cattle is well established. European *B. taurus*, West African *B. taurus*, and *B. indicus* of South Asian origin represent three distinct apices in plotted principal components (PCs) (Fig. 1A). Geographically intermediate populations, such as Near Eastern and East African animals, fall in genetically intermediate positions (*7*, *8*, *10*). Projecting ancient cattle genomes (provenance shown in Fig. 1B) against this genetic landscape (Fig. 1A), we observe that to the left of PC1, earlier (Neolithic and Bronze Age) genomes fall in three geographical clusters (a, Balkans; b, Anatolia/Iran; and c, southern Levant) along with modern European and African *B. taurus*, whereas *B. indicus* breeds are separated and represented on the far right of the PC plot (Fig. 1A). This suggests that cattle origins included two divergent aurochs populations that formed the basis of the *B. indicus*–*B. taurus* divide.

Six ancient aurochs genomes, including four from the greater Near East, provide additional context: two ~9000-year-old samples from the Levantine Aceramic village of Abu Ghosh (Abu1 and Abu2), a 7500-year-old sample from the early Anatolian settlement Çatalhöyük (Ch22), and a 7000-year-old Armenian aurochs (Gyu2) (*11*). These four genomes fall close to the Anatolia and Iran ancient domestic cattle cluster (Fig. 1A, cluster b) and reveal this as the oldest ancestral stratum of *B. taurus*. The genomic signature of this earliest population has been obscured in modern Near Eastern cattle by later admixture. From this group, we sequenced a well-preserved 8000-year-old Anatolian genome (Sub1) (*11*) to 13.5× coverage and use this in *D* statistics testing for zebu introgression in other ancient individuals (Fig. 2).

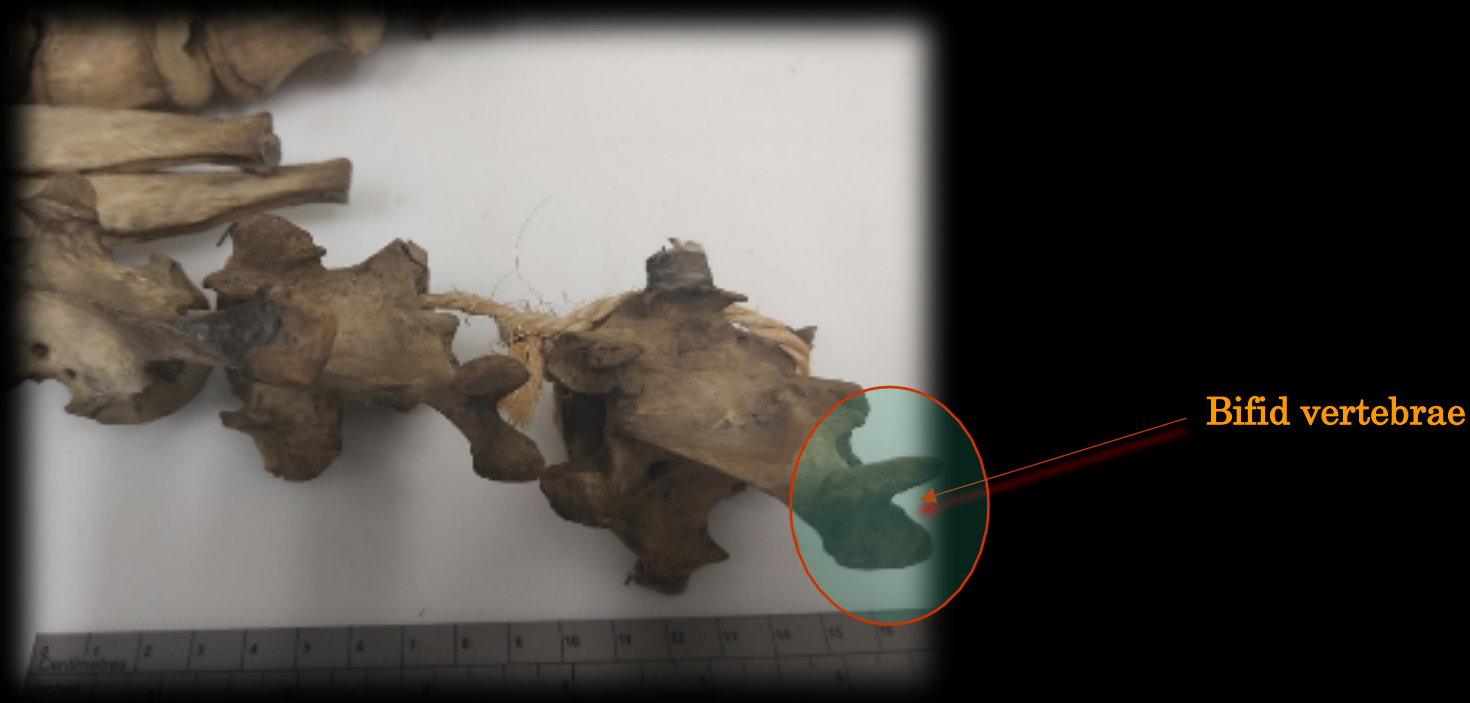
B. indicus cattle are adapted to, and predominate in, modern arid and tropical regions of the world (*11*). Zebu cattle originated circa 8000 yr B.P. (*12*). However, despite archaeological evidence for contact between civilizations of the Fertile Crescent region and the Indus Valley (*9*), the influence of the zebu genome is

Palaegenomic analysis of 67 ancient Near Eastern cattle genomes suggests that the influx of *B. indicus* ancestry into B. taurus populations was particularly pronounced during the end of the LBA.

Adaptive introgression was human-mediated

- It has occurred within a restricted time interval
- mtDNA stasis suggest that the introgression was male-driven
- **Hybrid taurus-indicus herds may have enabled the survival of communities under stress and perhaps facilitated expansion of herding into more peripheral regions**

Osteological evidence for the physical presence of *Bos indicus* in prehistoric Cyprus



Bos indicus bifid vertebrae (with the kind permission of the University Museum of Zoology, Cambridge)

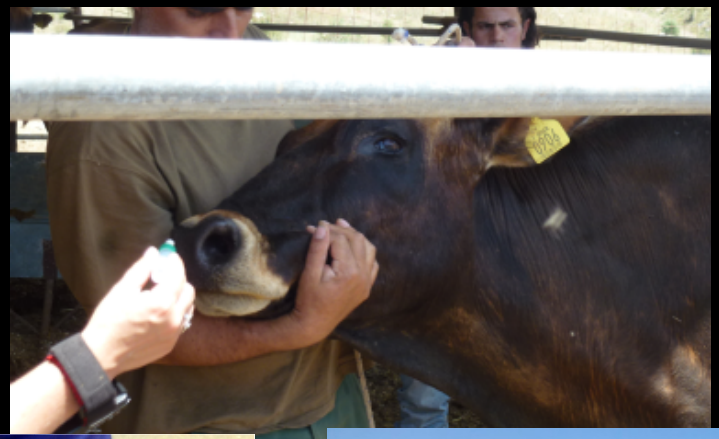
Cattle palaeogenomics

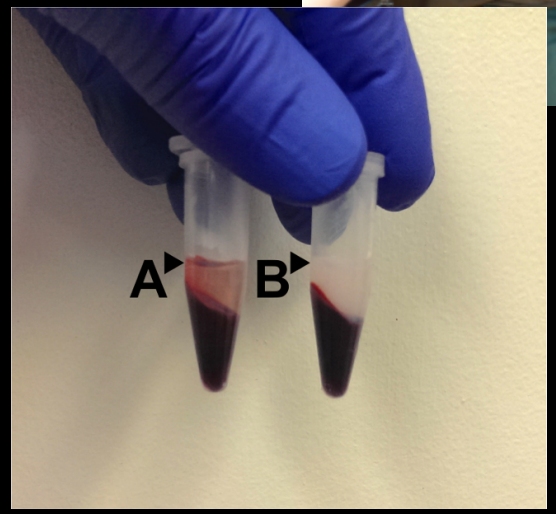
Targeting the densest skeletal elements

Pars petrosa: A small bone with high structural density and high endogenous DNA content (Pinhasi *et al.* 2015)

Cementum layer in teeth roots : A promising substrate for ancient DNA preservation

Characterising the Cyprus local cattle breed
Contemporary genomics



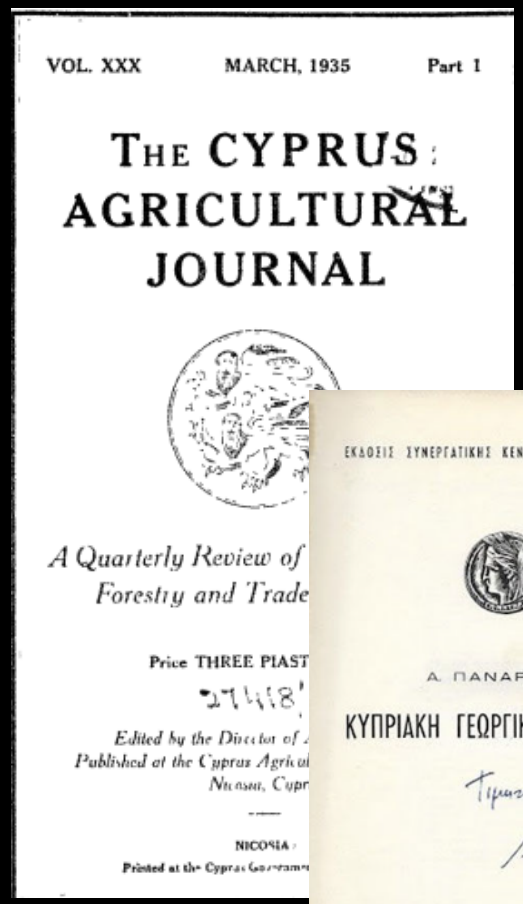


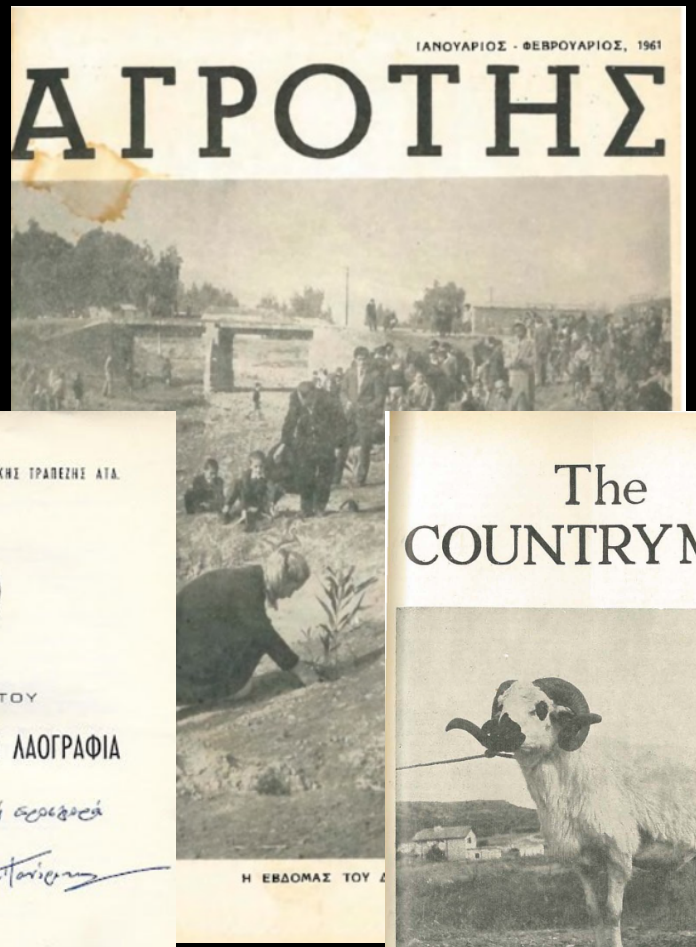
Collection of blood and nasal swab samples from 100 unrelated individuals belonging to the Cyprus local cattle breed

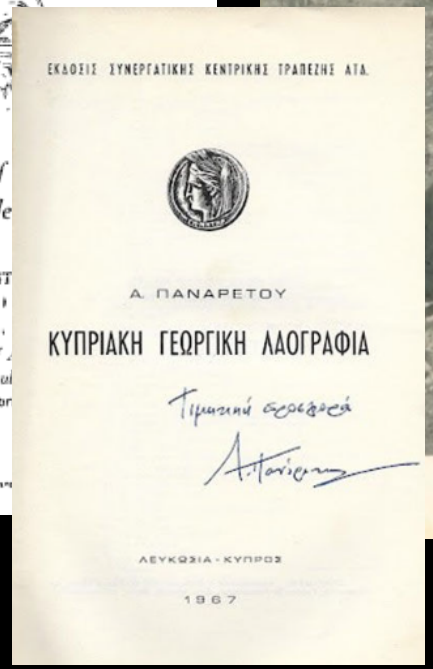
Aiming to:

- Characterise genetically the indigenous cattle breed of Cyprus (High Density bovine 800K bead chip microarray)
- Identify signatures of selection related to adaptation (thermotelerance, feeding efficiency, resistance to disease)
- Compare with archaeological data in order to identify ancestral genes for selection that are still preserved in the indigenous cattle breed of Cyprus
- Create a better place for the Cyprus local cattle breed in research, education and culture

Complementary sources
(Agricultural journals & magazines, photographs, proverbs, folktales, artwork)







Engaging the local community

Educational activities for kids

Collaboration with
local craftspeople

Collection of oral histories

Thank you

- Cyprus Department of Antiquities for providing permits to sample cattle bone assemblages and conduct ancient DNA analysis
- Popi Chrysostomou (DoA) for her valuable help during the selection of samples
- Prof. Dan Bradley and his team of palaeogeneticists at the Smurfit Institute of Genetics (TCD)
- Nicolas Loucas (STARC, CyI) for creating *ARETI's* logo and for his valuable help with the project's artwork
- Rahaf Orabi (STARC, CyI) for helping with the 3D documentation of cattle bones
- Dr. Giorgos Papageorgiou, veterinarian, for introducing me to the various farmers and for always supporting the ARETI team
- Prof. E. Egoumenidou for sharing interesting information about cattle and oxe in pre-industrial Cyprus
- All farmers for their willingness to share their stories and participate in the project as volunteers
- The Larnaca Historical Archives
- Phoivos Stavridis Archives

Most importantly

- My colleagues, Dr. Georgia Hadjipavlou& Dr. Andreas Dimitriou (Cyprus Agricultural Research Institute) for a great collaboration
- My grandfather and my father for passing me their love about cattle and oxen through their stories….