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RESEARCH PAPER

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Reconstructing the climatic niche breadth of land use for animal production during the African Holocene

Leanne N. Phelps[1] | Olivier Broennimann[1,2] | Katie Manning[3] | Adrian Timpson[4] | Hélène Jousse[5,6] | Gregoire Mariethoz[1] | Damien A. Fordham[7,8] | Timothy M. Shanahan[9] | Basil A. S. Davis[1] | Antoine Guisan[1,2]

[1]Faculty of Geosciences and Environment, Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland

[2]Department of Ecology and Evolution, University of Lausanne, Lausanne, Switzerland

[3]Geography Department, King's College London, London, United Kingdom

[4]Research Department of Genetics, Environment and Evolution, University College London, London, United Kingdom

[5]INRAP, CS 2007, Paris, France

[6]UMR 7209 - AASPE, CNRS/Museum National d'Histoire Naturelle, Paris, France

[7]The Environment Institute and School of Biological Sciences, The University of Adelaide, Adelaide, Australia

[8]Center for Macroecology, Evolution, and Climate, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

[9]Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, USA

Correspondence
Leanne N. Phelps, Faculty of Geosciences and Environment, Institute of Earth Surface Dynamics, University of Lausanne, Bâtiment Géopolis, 1015 Lausanne, Switzerland.
Email: LeanneNPhelps@gmail.com

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Université de Lausanne, Institute of Earth Surface Dynamics

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Abstract

Aim: Domestic animals first appeared in the archaeological record in northern Africa *c.* 9000 years before present and subsequently spread southwards throughout the continent. This geographic expansion is well studied and can broadly be explained in terms of the movement of pastoralist populations due to climate change. However, no studies have explicitly evaluated changes in the climatic niche of these domesticates. A priori, one cannot assume a relationship between the geographic spread of animal production and changes in climatic niche breadth because their relationship is highly variable. Therefore, we investigated Holocene changes in the climatic niche of domestic animals (animal production) and compared these to changes in the climatic niche of hunted terrestrial ungulates.

Location: The African continent.

Time period: 9000–500 BP.

Major taxa studied: Domestic animals, hunted (wild) terrestrial ungulates.

Methods: For the first time, we applied methods from environmental niche dynamics to archaeological data to reconstruct and quantify changes in the climatic niche breadth of animal production during the African Holocene. We used faunal remains from archaeological assemblages and associated radiocarbon dates to estimate the proportion of the African climate space used for animal production and hunting at 500-year intervals.

Results: We found that the climatic niche of domestic species broadened significantly with the geographic spread, most notably during the termination of the African Humid Period, whilst no such broadening occurred for the climatic niche of hunted species.

Main conclusions: Our results provide a quantitative measure of the extent to which humans have constructed and adapted the climatic niche of animal production to manage their domestic animals across increasingly diverse ecological conditions. By incorporating ecological analysis into estimations of past land use, our methods have the potential to improve reconstructions of land use change, and to provide a foundation on which further niche construction hypotheses may be tested.

KEYWORDS
animal production, anthropogenic land use change, climate change, global change, Holocene, human–environment interaction, niche breadth, niche construction, niche dynamics, pastoralism

1 | INTRODUCTION

The expansion of pasture and the effects of animal husbandry on Earth have received increased recognition over recent decades (Phelps & Kaplan, 2017: e.g. Asner, Elmore, Olander, Martin, & Harris, 2004, Foley et al., 2005, Vitousek, Mooney, Lubchenco, & Melillo, 1997). However, little attention has been given to the representation of prehistoric animal production in land use and land cover reconstructions, despite archaeological evidence that pastoralism was important and expansive throughout the Holocene (Figure 1, Supporting Information Figure S1). Relatively few anthropogenic land cover change datasets account for pasture or rangeland (e.g. Erb et al., 2007; Klein Goldewijk, Beusen, & Janssen, 2010), and those that do are often based on extrapolations of modern conditions or problematic assumptions about human land use (Phelps & Kaplan, 2017). As a result, existing estimates of prehistoric pasture (e.g. Klein Goldewijk et al., 2010) do not correspond well with animal production evidence, especially for the African continent (Figure 1, Supporting Information Figure S1). In recent years, studies have put more emphasis on land use (e.g. LandUse6k: Morrison, Gaillard, Madella, Whitehouse, & Hammer, 2016), and use of niche-based species distribution modelling (Guisan, Thuiller, & Zimmermann, 2017) in the archaeological context (e.g. Banks, 2017; Conolly, Manning, Colledge, Dobney, & Shennan, 2012; Lorenzen et al., 2011) has increased. Yet even in these efforts, analyses of land use ecology are rarely incorporated into spatial estimates of land use change, albeit see Manning and Timpson (2014) for demographic distributions.

Since the introduction of domestic animals on the African continent around 9000 years before present (BP), land use for animal production has changed dramatically in time and space (Figure 1, Supporting Information Figure S1). From *c*. 9000–7000 BP, during the African Humid Period (AHP), domestic animals spread throughout northern Africa (e.g. Kröpelin et al., 2008; Shanahan et al., 2015). By *c*. 5000 BP, the end of the AHP and aridification of the Sahara prompted a further southward spread. Over the following millennia the expansion of animal husbandry was patchy, occurring in mosaics (Crowther, Prendergast, Fuller, & Boivin, 2018) or multiple events (Fuller et al., 2011; Gifford-Gonzalez, 2000; Hanotte et al., 2002; Sadr, 2015) that often preceded the arrival of cultivation (Dunne et al., 2012; Lane, 2013; Marshall & Hildebrand, 2002; Prendergast, 2011). This latitudinal trend is well established, and thought to be driven by climatic changes or adaptation to disease (Kuper & Kröpelin, 2006; Manning & Timpson, 2014; Marshall, 2000), including trypanosomiasis (e.g. through dwarfing, tick resistance, and the development of grassy corridors; Chritz, Marshall, Esperanza Zagal, Kirera, & Cerling, 2015; Gifford-Gonzalez, 2000, 2017; Gifford-Gonzalez & Hanotte, 2013; Robinson & Rowan, 2017). Yet few publications have explicitly investigated the spatially extensive, underlying ecology of domestic animal expansion (di Lernia, 2013; Manning & Timpson, 2014).

In this paper we investigate prehistoric changes in the climatic niche of domestic animals as a means of advancing understanding of the relationship between changing land use strategies and the development of animal production in Africa. We used faunal remains to reconstruct changes in climatic niche breadth of animal production during the African Holocene. Faunal remains provide direct evidence of past animal production, and despite a number of potential taphonomic biases (e.g. Chang & Koster, 1986; Fauvelle-Aymar, Sadr, Bon, & Gronenborn, 2006), the basic presence and absence of species through time provides a powerful means of assessing changes in the exploitation of animals at archaeological sites. By comparing the climatic niche of domestic animals with that of hunted terrestrial ungulates (wild animals), differences in their development may be empirically investigated. Furthermore, we accounted for taphonomic and sampling biases in the archaeological record by utilizing both the proportion of domestic and wild animal remains at all sites as our primary data. We applied identical analysis methods to both data types, and assessed overall statistical significance with permutation tests. This aspect of our methods ensured that both data types were subject to the same archaeological biases and uncertainties, allowing us to draw confident inferences about the differences between wild and domestic climatic niches.

The relationship between climate and the spread of domestic animals on the African continent has been widely discussed (e.g. Kuper & Kröpelin, 2006; Marshall & Hildebrand, 2002; Smith, 1992). However, no studies have explicitly or quantitatively investigated temporal changes in the climatic space used for Holocene animal production. Whilst it is well established that domestic animals expanded geographically on the African continent, it cannot be assumed that the range of climatic conditions used for animal production, that is, climatic niche breadth, expanded proportionally. Climatic niche expansion has rarely been found for non-native invasive plant species (Petitpierre et al., 2012), even when species have expanded into a new geographic area. The relationship between geographic range and climatic niche breadth is highly variable, with studies showing that both positive and negative correlations are possible (Gregory

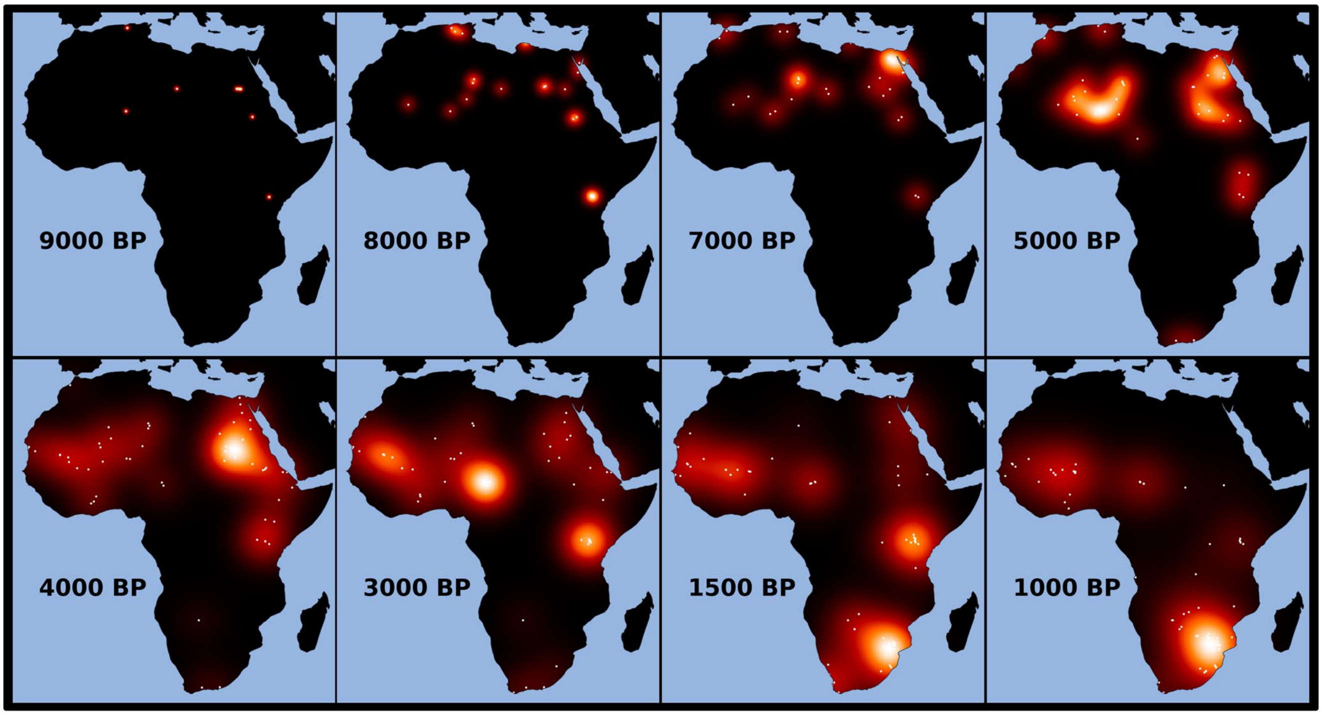

FIGURE 1 Faunal assemblages utilized in this study, generated with kernel density estimation of the number of identified specimens and chronological uncertainties. Individual sites are indicated by a small white dot. Outliers were not excluded. These illustrations are not intended to depict the distribution of land use in space and time (also see Supporting Information Figure S1 and Movies S1, S2)

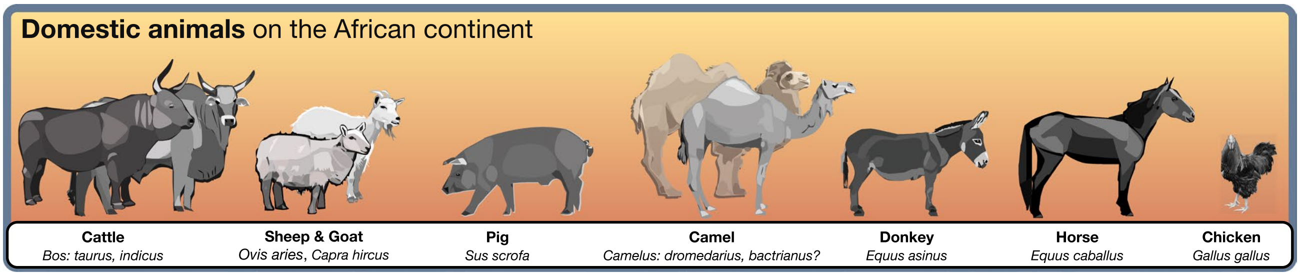

FIGURE 2 Domestic animals on the African continent (illustrations are not intended to represent animal breeds). For more detail, see Supporting Information (section: "Domestic animals in Africa")

& Gaston, 2000; Reif et al., 2006; Slatyer, Hirst, & Sexton, 2013). It is thus crucial to consider geographic and climatic space separately (Colwell & Rangel, 2009). Furthermore, quantitative estimates of climatic niche change require consistent comparison between time periods. For the first time, we therefore apply climatic niche modelling methods to archaeological data to reconstruct and statistically test whether the climatic niches of domestic and wild animals changed during the African Holocene (Figure 2).

1.1 | Applying climatic niche modelling methods to land use

The climatic niche is a term commonly used in ecology and biogeography, referring to the set of climatic conditions where a species can occur. Here we refer specifically to the realized climatic niche, which is traditionally inferred from field observations (Holt, 2009) and represents the portion of the climatic fundamental niche that is occupied at a given time (e.g. Maiorano et al., 2013). Whilst the fundamental niche is defined by the set of theoretical environmental conditions where a species can occur, the realized climatic niche implicitly incorporates further restrictions by including biotic (e.g. competition, carrying capacity) and dispersal limitations in the real world (Soberón, 2007). In addition, changing ecological conditions or evolutionary processes can modify the realized climatic niche through time. The fact that the ecological and evolutionary causes of climatic niche change cannot be discerned from field observations (Maiorano et al., 2013; Pearman, Guisan, Broennimann, & Randin, 2008) has been widely acknowledged and addressed (e.g. Espíndola et al., 2012; Maiorano et al., 2013; Veloz, Williams, Blois, Otto-Bliesner, & Liu, 2012).

We adapt methods from niche dynamics (see Broennimann et al., 2012; Guisan, 2014; Petitpierre et al., 2012) to quantify changes in the climatic niche breadth of domestic animals (the climatic niche of animal production: Figure 2). Such niche dynamic metrics provide tools for estimating climatic niche change in space (e.g. of non-native invasive species) and time (e.g. species' response to climate change: Broennimann et al., 2012; Guisan et al., 2014; Nogues-Bravo, 2009; Petitpierre et al., 2012; Tingley, Vallinoto, Sequeira, & Kearney, 2014). Traditional species distribution models (SDMs), which are typically calibrated with modern data and projected into space or time (Guisan et al., 2017: chapters 1 & 5), can lead to significant inaccuracies when applied to a species with a labile realized niche (Broennimann et al., 2007; Holt, 2009). This bias has been consistently observed for hindcasted mammalian niches, for example (Davis, McGuire, & Orcutt, 2014). Because one expects the human–environment relationship to change through time, standard methods are unsuitable for the land use context. For this reason, we chose to apply a suite of methods from niche dynamics, and to reconstruct the climatic land use niche at 500-year intervals.

Changes in the climatic niche of domestic animals shed light on niche construction processes in prehistory. Niche construction (sometimes referred to as ecosystem engineering) is the process whereby organisms modify their own and each other's niches, and although niche constructors include any species with the capacity to make these modifications, humans are the most prominent (Laland & O'Brien, 2011; Odling-Smee, Laland, & Feldman, 2003; Smith, 2007). Niche construction theory connects evolutionary processes to environmental and social factors (Kendal, Tehrani, & Odling-Smee, 2011; Laland, Odling-Smee, Feldman, & Kendal, 2009; Odling-Smee, 1988). It is often used to explain domestication processes (O'Brien & Laland, 2012; Rowley-Conwy & Layton, 2011; Smith, 2011) and even the onset of the Anthropocene (Smith & Zeder, 2013). A number of studies have used archaeological and palaeoecological data to demonstrate anthropogenic niche construction processes (Boivin et al., 2016). For example, extensive research documents genetic and genomic variations associated with the spread of domestic species on the African continent (e.g. Hanotte et al., 2002; MacHugh, Shriver, Loftus, Cunningham, & Bradley, 1997; Pereira et al., 2009; Pérez-Pardal et al., 2010), including the development of lactase persistence (e.g. Gerbault et al., 2011; Ranciaro et al., 2014).

The effects of these niche construction processes on the climatic niche of domestic animals have yet to be explicitly investigated, however. Here we reconstruct temporal changes in the climatic breadth occupied by domestic and wild animals. We do not aim to provide a dynamic model of land use change that addresses every component of niche construction theory, but we reconstruct temporal changes in the climatic extent of animal production, which broadened as a result of niche construction processes.

2 | METHODS

We derived domestic and wild animal occurrence records from dated faunal remains in the archaeological record from 9000 to 500 BP (Phelps et al., 2019: https://doi.pangaea.de/10.1594/PANGAEA.904942; Supporting Information Figure S2; data sources are listed in the Appendix), and sorted them into three animal groups: domestic species (see Figure 2); hunted species from the families Bovidae, Equidae, Suidae, Cervidae and Giraffidae (wild terrestrial ungulates); and the triad of cattle, sheep and goats. We included only wild terrestrial ungulates in the hunted group because these provide the closest comparison with domestic ungulates (as in Rowan, Kamilar, Beaudrot, & Reed, 2016). Aquatic species and cane rats would also have provided valuable contributions to livelihood strategies, but we do not include these animals. We used the group of cattle, sheep and goats as a control, to test whether the introduction of new domestic animal species had a significant impact on climatic niche development, as these three animals were present throughout the entire study period. We excluded remains that could not be identified as wild or domestic, for example, where the species of *Bos* and *Equus* and the genera of Caprinae and Suidae were not indicated.

Assigning a date range to each archaeological assemblage required the incorporation of substantial chronological uncertainty. We first constructed a date probability distribution for each archaeological assemblage: where radiocarbon dates were available we generated a summed probability distribution (SPD: Rick, 1987, Shennan et al., 2013). Calibrations were performed with the 'Bchron' package in R using either intcal13 or shcal13 depending on the hemispheric location of each site (Haslett & Parnell, 2008; R Core Team, 2018). For assemblages associated with a clear date range but devoid of radiocarbon data, we generated a uniform probability date distribution between the specified typological or cultural start and end dates. In either case we used these probabilistic date distributions to update an empirical prior date distribution, which was an SPD constructed from all radiocarbon dates from all sites. This prior had a deliberately conservative effect of widening each assemblage's date distribution, particularly where typological date ranges were narrow, or only a few radiocarbon dates were available for a particular assemblage. Finally, for each assemblage we summarized start and end dates using the 99.9% range of the date distribution. Therefore, an assemblage date range (start and end) typically spans several of our 500-year time slices, and can be assigned to either a single (mean date) time slice, or to several time slices by weighting accordingly.

We took an inclusive approach to the available radiocarbon and faunal data in order to investigate the most probable changes in the climatic niche of animal production; therefore, we have not attempted to exclude outliers or radiocarbon dates with large uncertainties. This means that some occurrence records are likely to appear earlier than they would have actually arrived, for example, the few domestic records appearing in east Africa before 5000 BP (Figure 1, Supporting Information Figure S1), as a result of errors in dating, sampling, or species identification. Although our reconstructions do not precisely reflect the first securely dated geographic arrivals of domestic animals, the goal of this study is to predict broad-scale changes in the climatic niche of domestic animals. Therefore, these methods are most suitable because they maximize the use of all available data, and are unlikely to be strongly affected by outliers because they are density-based. In this sense, we also avoid interpretation bias and can challenge existing notions about arrival times of domesticates where there is substantial evidence. Nonetheless, we consider the effects of potentially intrusive faunal remains in Supporting Information Table S4, and acknowledge that analyses could be refined in the future with improved radiocarbon dating.

We tested three versions of occurrence records. Version one, '1occ', is unweighted and includes only one occurrence record per assemblage for each time interval. Version two, 'date', is weighted by the probability of occurrence in each time interval. We repeated each occurrence record 100 times, and distributed replications on the basis of the probability that they occurred within each time interval. For example, if an assemblage had a .3 probability of occurrence between 5500 and 5000 BP and a .7 probability of occurrence between 5000 and 4500 BP, we repeated it 30 and 70 times, respectively, and zero times for all other time slices. Version three, 'taxa', is weighted by the number of taxa present at a given site and time interval, effectively weighting occurrence records on the basis of taxonomic diversity. Our analysis of the three animal groups and versions of occurrence records described above is a form of sensitivity testing.

Our data requires analysis in time bins. Initial exploratory tests to assess the influence of bin width on the noise to signal trade-off established that the exact bin width had a negligible effect on our results and did not change the overall inferences. Bin widths in the order of a few centuries provided stable and consistent results, and we arbitrarily settled on 500-year bins as a sensible balance between the number of bins and the sample sizes in each bin. We therefore generated palaeoclimate variables from 9000 to 500 BP to match these bins, with 500-year averages centred on the turn of each half-millennia, e.g. 500 BP ± 250, at 2.5 × 2.5 spatial resolution.

We obtained nine annual climate variables (Supporting Information Figure S3a) from the TraCE-21ka simulation of the Community Climate System Model (version 3: Liu et al., 2009) with PaleoView (Fordham et al., 2017). Although these variables are correlated (Supporting Information Table S1), our methods are based on principal component analysis and therefore are not sensitive to multicollinearity. However, the TraCE-21ka simulation and the latest PMIP3 (The Palaeoclimate Modelling Intercomparison Project) / CMIP5 (Coupled Model Intercomparison Project) models are unable to simulate all of the observed precipitation anomalies during the AHP, typically underestimating the northward extent of the African monsoon during the mid-Holocene (Harrison et al., 2015; Perez-Sanz, Li, González-Sampériz, & Harrison, 2014; Shanahan et al., 2015).

For supplementary analysis, we tested whether similar trends could be obtained after assuming a stable climate gradient through time, using climate data with a higher spatial resolution, and including more climatic variables in the analysis. To do this, we obtained 19 present-day WorldClim variables at 10-min resolution (Fick & Hijmans, 2017: see Supporting Information Table S2). Absolute *D* values cannot be compared when climate data have different spatial resolution. To ensure that climate gradients were comparable between WorldClim data and TraCE21-ka information, we calculated the correlation between the nine corresponding present-day WorldClim variables (upscaled to 2.5 × 2.5) and TraCE-21ka variables at AD 1970 (bias corrected). To validate our results, we also obtained palaeoclimate information at 10-min resolution for nine additional general circulation models at 6000 BP [upscaled to 2.5 × 2.5, Supporting Information Figure S4a (Hijmans, Cameron, Parra, Jones, & Jarvis, 2005)].

2.1 | Quantifying trends in the climatic land use niche

To quantify temporal changes in our climatic land use niches, we adapted methods from niche dynamics (Broennimann, Mráz, Petitpierre, Guisan, & Müller-Schärer, 2014; Di Cola et al., 2017). This approach accounts for niche fluctuations (i.e. shifts, contractions, or expansions), and can be used to track changes in the realized climatic niche through time. Additionally, niche dynamic methods can accommodate incomplete spatial coverage, which is a significant limitation of the archaeological record, especially on the African continent.

First, we defined a reduced climate space with a principal components analysis (PCA), calibrated with the climate space of the entire study area (background climate: Broennimann et al., 2012), pooled across all 18 time periods. Second, for each time interval, we calculated the scores of the corresponding faunal occurrences and their density of occurrence, weighted by the climate availability in PCA space (modified from PCA-env in Broennimann et al., 2012). Third, we used niche dynamics metrics (*Db* and *Dd*, which are based on Schoener's *D*) to measure the overlap between climatic land use niches at each 500-year interval and their corresponding background climates (i.e. the portion of the African climate in which the animals occurred), and the overlap between the domestic and hunted (wild) animal niches (e.g. see Broennimann et al., 2012).

The *Dd* metric—the classic *D* metric (Broennimann et al., 2012; Warren, Glor, & Turelli, 2008)—is based on the ratio of occurrence density to the density of available environmental conditions. Therefore, *Dd* is highly dependent on how the background climate is defined, or the extent of the background climate. Conversely, *Db*, a modified *D* metric, is based on binary representation of niches [i.e. pixels take value of 0 if the density of occurrence is 0, or the value of 1 if the density is higher; see 'niche stability' calculations (Di Cola et al., 2017; Guisan et al., 2014)] and is independent of the background extent, meaning that information about occurrence densities is lost, and all parts of the niche have equal weight. For this reason, *Db* measurements may be more likely to reflect errors in the archaeological record. In the majority of our analyses, *Dd* and *Db* niche metrics provide two ways of measuring the portion of the African climate that is occupied by domestic or wild animals at each time interval (Figure 3a). This aspect of our methods differs from typical applications of niche dynamic metrics, where two niches are compared. We also compared the domestic and wild climatic niches directly (Figure 3b).

After calculating *Dd* and *Db* values, we tested whether the observed broadening of the climatic niche of domestic animals was statistically significant through time (Figure 3), and whether it could

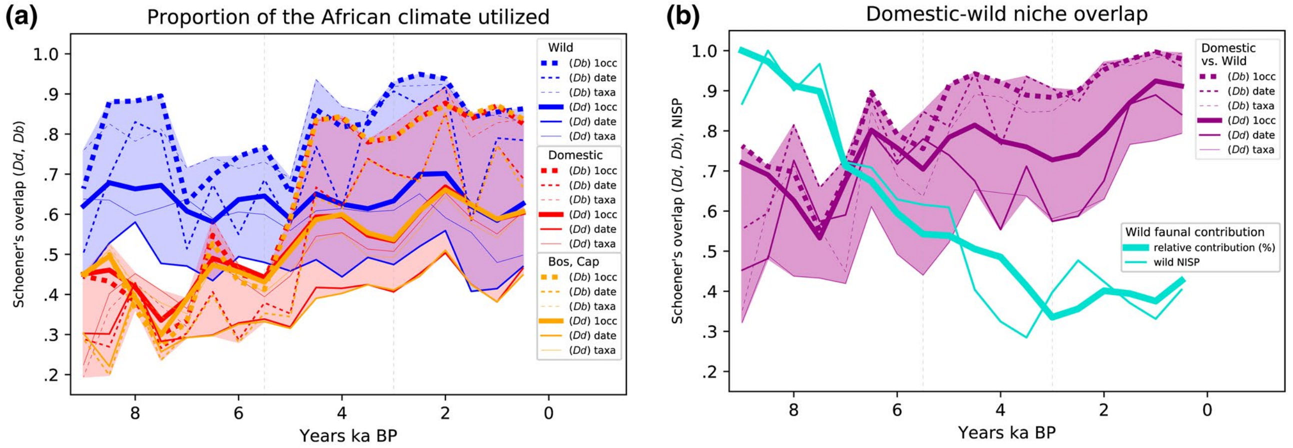

FIGURE 3 Quantification of climatic niche breadth for domestic (animal production), domestic *Bos* and Caprinae only (Bos, Cap), and wild (hunted terrestrial ungulates) animals during the African Holocene. For each niche, three versions of occurrence records were analysed: one occurrence record per assemblage for each time interval (1occ), the number of taxa present at a given site and time interval (taxa), and the probability of occurrence in each interval (date). *D* values (*Dd: density-based niche metric*, *Db: binary niche metric*) quantify the degree of overlap between the animal niche and the African background climate. (a) Degree of overlap among three groups: domestic (red), wild (blue), and cattle, sheep and goats (orange). (b) Overlap between climatic niches of domestic and wild animals (purple), relative contribution of wild and domestic remains, and total number of wild remains (rescaled 0–1), based on assemblage-averaged number of individual specimens present (NISP) where available (turquoise). Vertical, dashed lines indicate the termination of the African Humid Period [*c.* 5500–3000 years before present (BP)]. See Supporting Information for *D* values (Table S3), further comparison against other climate models at 6000 BP (Figure S4), and principle components analysis of pooled occurrence records (PCA-occ) with TraCE-21ka and repeated WorldClim data (Figure S5)

be explained by other factors such as sampling, taphonomic or methodological artefacts. We used a permutation test to randomly shuffle (5,000 times) the climatic niche metrics calculated for domestic animals at each of the 18 time slices, while retaining all other structure in the data. For each shuffle, we calculated the correlation between time and *D* values with Pearson's *R*, which formed a null distribution of test statistics (histograms: Supporting Information Figure S6). We calculated the same test statistic once for the observed data (unshuffled), and calculated a two-tailed *p*-value as the proportion of the null distribution that is greater or equal to the observed test statistic. We then performed the same permutation test on the wild species group.

We performed niche dynamic analyses with the 'ecospat' package in R (Di Cola et al., 2017; R Core Team, 2018), and plotted metrics with Python (Python Software Foundation, 2018). To test the robustness of our results, we performed supplementary analyses using principal components analysis of occurrence records (PCA-occ; see Broennimann et al., 2012), where *D* values were calculated as the proportion of the pooled animal niche rather than the proportion of the background climate information (PCA-env). We also performed supplementary analyses with a stable climate gradient (modern-day WorldClim data: Supporting Information Figure S4). To independently test whether the relative importance of hunting and animal husbandry changed through time, we separately calculated the relative mean contribution of wild and domestic faunal remains for each time interval on the basis of the number of individual specimens (Figure 3b, turquoise line), and the mean absolute number of wild remains. Additionally, we tested the effects of excluding assemblages with potentially intrusive faunal remains (Supporting Information Table S4).

We projected the climatic land use niches of domestic and wild animals into geographic space on the basis of the relative density of occurrence records, providing maps of climate suitability for both animal husbandry and hunting at 500-year intervals (Figure 4). We do not intend these maps to represent past domestic animal densities, although they are likely correlated.

3 | RESULTS

D values increased from past to present for the climatic niche of domestic animals, unlike that of wild animals (Figure 3a, Supporting Information Table S3), indicating that the climatic space used for animal production widened significantly through time with a concomitant increase in domestic–wild climatic niche overlap (Figure 3b, Supporting Information Figure S3). Around 4500 BP, *D* values of the domestic climatic niche increased most obviously (> 7%) across all versions of occurrence records (Supporting Information Table S3). The niche for wild animals, meanwhile, increased much less, and was accompanied by a significant decrease (–20.5%) in the number of individual specimens of wild animals. Trends in the climatic niche of cattle, sheep and goats were nearly identical to that of domestic animals.

Permutation tests (Supporting Information Figure S6) indicated that the widening of the climatic niche of domestic animals was strongly and significantly time dependent (*R* values = .744 to .903, *p* values < .001), whereas that of wild animals did not have a consistent trend (*R* values = −.624 to .56, *p* values = .021 to .802). Sensitivity tests were also included in our analyses, contributing to methodological development and showing that our results were robust: first, we demonstrated that similar trends were produced by two different PCA analyses (PCA-env: Figure 3, PCA-occ: Supporting Information

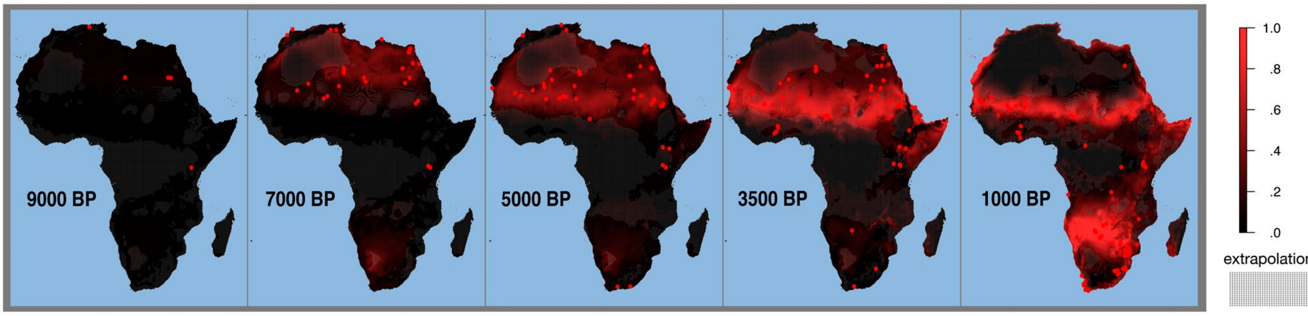

FIGURE 4 Climatic land use niches for domestic animals projected into geographic space with present-day WorldClim data. Reconstructions are based on the relative density of occurrence records in climate space (rescaled from 0 to 1, relative to the maximum density of all time periods), weighted by the probability of radiocarbon date occurrence. Values near zero indicate that the niche is not well established, whereas values near one indicate that the niche is well established, although the niche may not be realized in geographic space for ecological, social or cultural reasons. Domestic occurrence records are plotted (red circles), and grey cross-hatching indicates niche extrapolation (calculated with multivariate environment similarity surface, MESS), that is, the climatic space outside of the sampled area in this study. See Supporting Information for 500-year intervals of domestic and hunted niches using present-day WorldClim data (Figure S7.1, Movie S3) and TraCE-21ka climate information (Figure S7.2, Movie S4)

Figure S4), three types of occurrence records (Figure 3a) and a stable climate gradient through time (Supporting Information Figure S4; although PCA-env and *Dd* values are less reliable because of their sensitivity to changes in the climate gradient). In comparisons of our results with nine additional climate models at 6000 BP, the wild climatic niche always produced higher *D* values than that of domestic animals (Supporting Information Figure S4a). Analysis of the control group of cattle, sheep and goats suggested that the introduction of new domestic species was not responsible for the temporal expansion of the domestic niche. Our empirical and quantitative results imply that continental-scale climatic niche construction was prominent throughout the Holocene, and that extensive land use change is not a recent phenomenon. Our work yielded spatially continuous maps of the suitable climatic space for both animal husbandry and hunting on the basis of the density of occurrence records in climatic space (Figure 4, Supporting Information Figures S7.1, S7.2). Results derived from PCA-occ, repeated modern-day WorldClim data, and other climate models are in Supporting Information Figure S4.

3.1 | Background climate space

In analyses performed with TraCE-21ka climate information, 83.4% of variance in the PCA of pooled background climate was explained by the first two principal component axes (PC1 = 62.1%, PC2 = 21.3%: Supporting Information Figure S3). These two axes provided the climatic space within which niches were plotted, measured and compared. Temperature seasonality and isothermality explain the vast majority of both pooled and individual time period variance, although these variables are highly correlated with each other (Supporting Information Tables S1, S2) and with precipitation variables, which are underrepresented in the TraCE-21ka simulation. For analyses performed with WorldClim data, 69.5% of the background climate variance was explained (PC1 = 46.1%, PC2 = 23.4%), and the nine TraCE-21ka variables (bias corrected) agreed well with corresponding WorldClim data for 1970 AD (Supporting Information Figure S5).

4 | DISCUSSION

4.1 | The expanding climatic niche and niche construction processes

We distinguish the broadening of the climatic niche of animal production, which has never been explicitly analysed, from the time transgressive geographic spread of domestic animals in Africa, which is already well established (e.g. Crowther et al., 2018; Fuller et al., 2011; Gifford-Gonzalez, 2000; Hanotte et al., 2002). For the first time, we quantitatively demonstrate that the climatic niche of African animal production (domestic animals) expanded significantly during the Holocene, whereas that of hunted (wild) terrestrial ungulates did not. This broadening of the domestic animal climatic niche co-occurred with the geographic spread of domestic animals, a relationship that could not be assumed a priori, indicating continental-scale climatic niche construction as a result of land use change. Our findings indicate that novel environments were increasingly incorporated into animal husbandry practices, likely through inceptive relocation or exposure to novel selective environments. Other forms of climatic niche construction likely occurred, for example, counteractive relocation or inceptive perturbation, but we do not explicitly address these (Laland & O'Brien, 2010; O'Brien & Laland, 2012). For further discussion of our methods, see Supporting Information (section: "Methodological contributions to the land use niche").

It seems clear that climatic niche expansion did not result from the addition of new domestic species (e.g. horse, camel, pig, chicken), given that trends in the climatic niche of cattle, sheep and goats were similar to trends observed in the climatic niche of domestic animals. In the case of African animal production, this climatic niche construction likely occurred by two means: first, the physical expansion of animal husbandry into novel climatic environments, and second, in situ adaptation of animal production strategies to novel climates as a result of climate change. The extent to which climate directly (e.g. through thermoregulatory constraints) or indirectly (e.g. through food and water availability) affected niche change is unclear, however. The observed changes in the climatic niche of animal production reflect the development of different production systems (see Phelps & Kaplan, 2017) and their environmental interactions over the past 9000 years.

Our results indicate that climate change was a key driver in broadening the climatic niche of domestic animals, particularly during periods of increasing aridification. For example, the most obvious increase in the domestic animal climatic niche (*c*. 4500 BP) occurred during the end of the AHP (e.g. Shanahan et al., 2015), when both a strong reduction in the cover of tropical trees and Sahelian grassland cover and spatially extensive dust mobilization occurred (Kröpelin et al., 2008). At this point, animal production began to spread substantially into sub-Saharan Africa. This inference is consistent with observations that mobile pastoralism is resilient to variable contemporary rainfall, especially in arid and semi-arid ecosystems (e.g. Ellis & Swift, 1988; Homewood, 2008; Niamir-Fuller, 1999; Vetter, 2005). However, our findings suggest that pastoralism was advantageous during this long period of increasing aridification, with implications for land use planning today. The precise causal relationships between these past land use and land cover changes remain unclear, however.

The evolutionary processes leading to the expansion of the animal production climatic niche are suggested by declines in wild cattle (*Bos primigenius*) around the end of the AHP, whereas domestic cattle (*Bos taurus*), which either bred with or were domesticated from wild African cattle (Pérez-Pardal et al., 2010), expanded southwards into sub-Saharan Africa. Similarly, a hunted and potentially managed wild caprine [Barbary sheep (*Ammotragus lervia*)] remained confined to northern Africa throughout the entire study period, while both domestic sheep and goats expanded southward (i.e. divergence of close relatives: see Supporting Information Figure S8). Regardless of whether domesticates appeared on the African continent through indigenous development or importation, domestication is acknowledged as part of a continuous, coevolutionary process (e.g. Gifford-Gonzalez & Hanotte, 2011). For example, several studies demonstrated the correlated spread of cattle and lactase persistence in humans (Gerbault et al., 2011; Macholdt et al., 2014; Ranciaro et al., 2014; Tishkoff et al., 2007); Pérez-Pardal et al. (2010) demonstrated that sub-Saharan cattle are genetically distinct from other domestic populations; and there is a possible but unproven relationship between dwarfism and trypanotolerance (e.g. Gifford-Gonzalez & Hanotte, 2011; Linseele, 2013). In addition, breed diversification has been a major factor in the zoogeography of African livestock, enabling domesticates to live in a wide variety of modern ecological zones (Bahbahani et al., 2018; Murray & Trail, 1984; Mwai, Hanotte, Kwon, & Cho, 2015; Wang, Dzama, Rees, & Muchadeyi, 2015). Thus, the broadening of the animal production climatic niche is associated with evolutionary trends, and it is highly likely that these were the mechanism for expansion of the climatic land use niche for domestic animals that we observed. We therefore suggest that ecological and evolutionary factors drove the observed geographic expansion of animal husbandry.

In contrast to the animal production climatic niche, and despite a proportional increase in the number of domestic and hunted assemblages through time (Supporting Information Figure S9), we did not find a consistent temporal trend in the climatic niche of hunted animals (Figure 3). This suggests that expansion of the climatic niche of domestic animals is not an artefact of sampling or taphonomic bias in the archaeological record (Supporting Information Figure S6). Our results indicate that spatially, animal production did not replace hunting, but rather moved into the same climatic areas. The apparent spread of domestic animals is associated with a decline in human reliance on absolute numbers of wild taxa [based on average number of individual specimens present (NISP): see Supporting Information Table S5], which was most pronounced around 4500 BP, when the domestic climatic niche expanded substantially and population declined substantially as a result of the end of the AHP. Again, this demonstrates the adaptive advantage that domestic animals likely provided during the end of the AHP, and that expansion of the climatic niche of domestic animals was closely associated with changes in other forms of human subsistence.

Trends in the taxa version of occurrence records for hunted animals suggest that people hunted an increasing variety of terrestrial ungulates in novel climates (Supporting Information Figure S6: *Db R* value = .56, p = .021), but that people also became less reliant on these diversified hunting assemblages through time (*Dd R* value = −.624, p = .035). Increasing *Db* values suggest that a greater diversity in terrestrial ungulates became available in novel climate spaces, or that the hunting of diverse terrestrial ungulates was an adaptive strategy that spread into novel climates. Conversely, decreasing *Dd* values and the overall decline in the wild NISP suggest a gradual transition from hunting to animal production at a continental scale. Further insight on subsistence change could be gained through the inclusion of genetic data that address changes in effective population sizes and admixture of some pygmy hunter-gatherer populations (Verdu et al., 2009) associated with the expansion of Bantu-speaking agriculturalists during the end of the AHP (Batini et al., 2011; Gignoux, Henn, & Mountain, 2011; Patin et al., 2013). Higher resolution analyses with spatial and temporal continuity could also help to clarify land use change during specific time periods, especially via regional and local investigation of changes in livelihood strategies (Phelps & Kaplan, 2017).

The fact that terrestrial ungulates occupied a relatively large portion of the African climate space across our study period (Figure 3a) is consistent with the conclusions of Rowan et al. (2016) that ungulates are ecologically resilient due to their large body sizes and the wide distribution of their food sources, and are strongly influenced by palaeoclimatic adaptations that began during the Last Glacial Maximum, prior to our study period. In this sense, terrestrial ungulates may be ideal species for domestication, but we find it remarkable that anthropogenic niche construction processes facilitated the expansion of the climatic niches of cattle, sheep and goats to the same extent as those of all hunted African ungulates (>90 species). We did not address the fact that the climatic niches of wild terrestrial taxa or hunting strategies may respond to climate change individually. In addition, our analyses were not intended to reflect the distribution of all wild terrestrial ungulates in Africa, but only those that were hunted and appeared in archaeological records.

4.2 | Assumptions, limitations and future work

One limitation of our approach is its reliance on climate models. For example, our results could be altered if the representation of precipitation variables was improved (see Shanahan et al., 2015 for discussion of TraCE-21ka). For this reason, and given errors and patchy spatial coverage of faunal remains, we focused on 500-year continental-scale intervals, performed several sensitivity analyses, and focused on niche changes >7% of the entire African climate space and where similar results were produced across analyses. Further interpretation of regional or local trends requires data that are of higher resolution and more complete. Additionally, although temperature seasonality and isothermality are highly correlated with mean precipitation, precipitation likely contributed more to the past distribution of domestic animals than is reflected in our analyses.

We assumed that the presence of domestic or wild animal remains equates with the location of land use. However, grazing, browsing and foraging are likely to have extended well beyond the archaeological site, or may not have occurred where remains were found. For this reason, we directly compared the climatic niches of domestic and wild ungulates. Because our analyses focused on faunal remains, we did not address the presence of animal production systems that did not yield this kind of data. Examples of pastoralist evidence that we do not consider here include rock art, which has indicated the presence of herding in the central Sahara during past periods of desertification (e.g. Guagnin, 2015), animal daybeds, trampled areas, tracks, and trails (Zerboni & Nicoll, 2019). Furthermore, where pastoralists are highly mobile and rely more on drought adapted species, such as *Camelus dromedarius*, remains may be less likely to appear in faunal assemblages. Therefore, the absence of evidence in our study is not evidence of pastoralist absence.

Investigative power can always be increased by analysing a more complete fossil record at higher temporal resolution, incorporating a wider variety of land use evidence, and making continental comparisons. This type of data-driven approach only recently became possible with the collation of continental databases like that of Jousse (2017) for Africa, or those for Europe (Manning, 2016; Manning, Colledge, Crema, Shennan, & Timpson, 2016). Our methods could be enhanced through the generation of temporally continuous niches rather than discrete time intervals. Radiocarbon date distributions and finer resolution land use changes could be better represented, and comparison with other types of evidence would be simpler. Additionally, land use representation may be enhanced by integrating process-based models (Tingley et al., 2014; Zurell et al., 2016) and geospatial approaches, and by including more types of evidence, such as archaeobotanical and fossil pollen remains; species-specific morphometric, genotypic and genomic faunal data (e.g. Hanotte et al., 2002; Pérez-Pardal et al., 2010), especially for highly mobile species with few faunal remains (Almathen et al., 2016); evidence of aquatic resource exploitation; rock art (e.g. Gallinaro, 2013; Guagnin, 2015); and geomorphic and ethnoarchaeological evidence of herding (e.g. Biagetti, 2014; Zerboni & Nicoll, 2019). The expansion of pastoralist systems likely was associated with cultural adaptations that relate to mobility, territory size, and social networks; further investigation into material culture from associated archaeological records may provide relevant insight. With these types of improvements, understanding of land use extent and intensity can be enhanced, and further niche construction hypotheses may be tested.

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DATA AVAILABILITY STATEMENT

The archaeological data utilized in this study are available at https://doi.pangaea.de/10.1594/PANGAEA.904942 (Phelps et al., 2019). Data sources are listed in the Appendix.

ORCID

Leanne N. Phelps https://orcid.org/0000-0002-7385-3907

Damien A. Fordham https://orcid.org/0000-0003-2137-5592

Antoine Guisan https://orcid.org/0000-0002-3998-4815

REFERENCES

Almathen, F., Charruau, P., Mohandesan, E., Mwacharo, J. M., Orozco-terWengel, P., Pitt, D., … Burger, P. A. (2016). Ancient and modern DNA reveal dynamics of domestication and cross-continental dispersal of the dromedary. *Proceedings of the National Academy of Sciences USA*, *113*(24), 6707–6712.

Asner, G. P., Elmore, A. J., Olander, L. P., Martin, R. E., & Harris, A. T. (2004). Grazing systems, ecosystem responses, and global change. *Annual Review of Environmental Resources*, *29*, 261–299.

Bahbahani, H., Salim, B., Almathen, F., Al Enezi, F., Mwacharo, J. M., & Hanotte, O. (2018). Signatures of positive selection in African butana and kenana dairy zebu cattle. *PLoS ONE*, *13*(1), e0190446.

Banks, W. E. (2017). The application of ecological niche modeling methods to archaeological data in order to examine culture-environment relationships and cultural trajectories. *Quaternaire*, *28*(2), 271–276.

Batini, C., Lopes, J., Behar, D. M., Calafell, F., Jorde, L. B., van der Veen, L., … Comas, D. (2011). Insights into the demographic history of African pygmies from complete mitochondrial genomes. *Molecular Biology and Evolution*, *28*(2), 1099–1110.

Biagetti, S. (2014). *Ethnoarchaeology of the Kel Tadrart Tuareg: Pastoralism and resilience in Central Sahara*. Heidelberg, Germany: Springer.

Bibi, F. (2013). A multi-calibrated mitochondrial phylogeny of extant Bovidae (Artiodactyla, Ruminantia) and the importance of the fossil record to systematics. *BMC Evolutionary Biology*, *13*(166), 1–15.

Boivin, N. L., Zeder, M. A., Fuller, D. Q., Crowther, A., Larson, G., Erlandson, J. M., … Petraglia, M. D. (2016). Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions. *Proceedings of the National Academy of Sciences USA*, *113*(23), 6388–6396.

Broennimann, O., Fitzpatrick, M. C., Pearman, P. B., Petitpierre, B., Pellissier, L., Yoccoz, N. G., … Guisan, A. (2012). Measuring ecological niche overlap from occurrence and spatial environmental data. *Global Ecology and Biogeography*, *21*, 481–497.

Broennimann, O., Mráz, P., Petitpierre, B., Guisan, A., & Müller-Schärer, H. (2014). Contrasting spatio-temporal climatic niche dynamics during the eastern and western invasions of spotted knapweed in North America. *Journal of Biogeography*, *41*(6), 1126–1136.

Broennimann, O., Treier, U. A., Muller-Scharer, H., Thuiller, W., Peterson, A. T., & Guisan, A. (2007). Evidence of climatic niche shift during biological invasion. *Ecology Letters*, *10*(8), 701–709.

Chang, C., & Koster, H. A. (1986). Beyond bones: Toward an archaeology of pastoralism. *Advances in Archaeological Method and Theory*, *9*, 97–148.

Chritz, K. L., Marshall, F. B., Esperanza Zagal, M., Kirera, F., & Cerling, T. E. (2015). Environments and trypanosomiasis risks for early herders in the later Holocene of Lake Victoria basin, Kenya. *Proceedings of the National Academy of Sciences USA*, *112*(12), 3674–3679.

Colwell, R. K., & Rangel, T. F. (2009). Hutchinson's duality: the once and future niche. *Proceedings of the National Academy of Sciences USA*, *106*, 19651–19658.

Conolly, J., Manning, K., Colledge, S., Dobney, K., & Shennan, S. (2012). Species distribution modelling of ancient cattle form early Neolithic sites in SW Asia and Europe. *The Holocene*, *22*(9), 997–1010.

Crowther, A., Prendergast, M. E., Fuller, D. Q., & Boivin, N. (2018). Subsistence mosaics, forager-farmer interactions, and the transition to food production in eastern Africa. *Quaternary International*, *489*, 101–120.

Davis, E. B., McGuire, J. L., & Orcutt, J. D. (2014). Ecological niche models of mammalian glacial refugia show consistent bias. *Ecography*, *37*, 1133–1138.

Di Cola, V., Broennimann, O., Petitpierre, B., Breiner, F. T., D'Amen, M., Randin, C., … Guisan, A. (2017). ecospat: An R package to support spatial analyses and modeling of species niches and distributions. *Ecography*, *40*, 774–787.

Dunne, J., Evershed, R. P., Salque, M., Cramp, L., Bruni, S., Ryan, K., & Biagetti, S. (2012). First dairying in green Saharan Africa in the fifth millennium BC. *Nature*, *486*, 390–394. https://doi.org/10.1038/nature11186

Ellis, J. E., & Swift, D. M. (1988). Stability of African pastoral ecosystems: Alternate paradigms and implications for development. *Journal of Rangeland Management*, *41*, 450–459.

Erb, K.-H., Gaube, V., Krausmann, F., Plutzar, C., Bondeau, A., & Haberl, H. (2007). A comprehensive global 5 min resolution land-use data set for the year 2000 consistent with national census data. *Journal of Land Use Science*, *2*(3), 191–224.

Espíndola, A., Pellissier, L., Maiorano, L., Hordijk, W., Guisan, A., & Alvarez, N. (2012). Predicting present and future intra-specific genetic structure through niche hindcasting across 24 millennia. *Ecology Letters*, *15*(7), 649–657.

Fauvelle-Aymar, F.-X., Sadr, K., Bon, F., & Gronenborn, D. (2006). The visibility and invisibility of herders' kraals in southern Africa, with reference to a possible early contact period khoekhoe kraal at KFS5, western cape. *Journal of African Archaeology*, *4*(2), 253–271.

Fick, S., & Hijmans, R. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, *37*, 4302–4315.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., … Snyder, P. K. (2005). Global consequences of land use. *Science*, *309*(5734), 570–574.

Fordham, D. A., Saltré, F., Haythorne, S., Wigley, T. M., Otto-Bliesner, B. L., Chan, K. C., & Brook, B. W. (2017). Paleoview: A tool for generating continuous climate projections spanning the last 21 000 years at regional and global scales. *Ecography*, *40*, 1348–1358.

Fuller, D. Q., van Etten, J., Manning, K., Castillo, C., Kingwell-Banham, E., Weisskopf, A., … Hijmans, R. J. (2011). The contribution of rice agriculture and livestock pastoralism to prehistoric methane levels: An archaeological assessment. *The Holocene*, *21*(5), 743–759.

Gallinaro, M. (2013). Saharan rock art: Local dynamics and wider perspectives. *Arts*, *2*(4), 350–382.

Gerbault, P., Liebert, A., Itan, Y., Powell, A., Currat, M., Burger, J., … Thomas, M. G. (2011). Evolution of lactase persistence: An example of human niche construction. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*, 863–877.

Gifford-Gonzalez, D. (2000). Animal disease challenges to the emergence of pastoralism in sub-Saharan Africa. *African Archaeological Review*, *17*(3), 95–139.

Gifford-Gonzalez, D. (2017). "Animal disease challenges" fifteen years later: The hypothesis in light of new data. *Quaternary International*, *436*, 283–293.

Gifford-Gonzalez, D., & Hanotte, O. (2011). Domesticating animals in Africa: Implications of genetic and archaeological findings. *Journal of World Prehistory*, *24*(1), 1–23.

Gifford-Gonzalez, D., & Hanotte, O. (2013). Domesticating animals in Africa, Chapter 34. In P. Mitchell & P. Lane (Eds.), *The Oxford handbook of African archaeology* (pp. 491–505). Oxford, UK: Oxford University Press.

Gignoux, C. R., Henn, B. M., & Mountain, J. L. (2011). Rapid, global demographic expansions after the origins of agriculture. *Proceedings of the National Academy of Sciences USA*, *108*(15), 6044–6049.

Gregory, R. D., & Gaston, K. J. (2000). Explanations of commonness and rarity in British breeding birds: Separating resource use and resource availability. *OIKOS*, *88*(3), 515–526.

Guagnin, M. (2015). Animal engravings in the central Sahara: A proxy of a proxy. *Environmental Archaeology*, *20*(1):52–65.

Guisan, A., Petitpierre, B., Broennimann, O., Daehler, C., & Kueffer, C. (2014). Unifying niche shift studies: Insights from biological invasions. *Trends in Ecology and Evolution*, *29*(5), 260–269.

Guisan, A., Thuiller, W., & Zimmermann, N. E. (2017). *Habitat suitability and distribution models, with applications in R*. Cambridge, UK: Cambridge University Press.

Hanotte, O., Bradley, D. G., Ochieng, J. W., Verjee, Y., Hill, E. W., & Rege, J. E. O. (2002). African pastoralism: Genetic imprints and origins and migrations. *Science*, *296*, 336–339.

Harrison, S. P., Bartlein, P., Izumi, K., Li, G., Annan, J., Hargreaves, J., … Kageyama, M. (2015). Evaluation of cmip5 palaeo-simulations to improve climate projections. *Nature Climate Change*, *5*, 735–743.

Haslett, J., & Parnell, A. C. (2008). A simple monotone process with application to radiocarbon-dated depth chronologies. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, *57*(4), 399–418.

Hijmans, R., Cameron, S., Parra, J., Jones, P., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, *25*, 1965–1978.

Holt, R. D. (2009). Bringing the Hutchinsonian niche into the 21st century: Ecological and evolutionary perspectives. *Proceedings of the National Academy of Sciences USA*, *106*(2), 19659–19665.

Homewood, K. (2008). *Ecology of African pastoralist societies*. Athens, OH: Ohio University Press.

Jousse, H. (2017). *Atlas of mammal distribution through Africa from the LGM (18 KA) to modern times: The zoological record*. Oxford, UK: Archaeopress.

Kendal, J., Tehrani, J. J., & Odling-Smee, J. (2011). Human niche construction in interdisciplinary focus. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*, 785–792.

Kingdon, J., Happold, D. C. D., Butynski, T. M., Hoffmann, M., Happold, M., & Kalina, J. (2013). *Mammals of Africa*. London, UK: Bloomsbury.

Klein Goldewijk, K., Beusen, A., & Janssen, P. (2010). Long term dynamic modeling of global population and built-up area in a spatially explicit way: HYDE 3.1. *The Holocene*, *20*, 565–573.

Kröpelin, S., Verschuren, D., Lézine, A., Eggermont, H., Cocquyt, C., Francus, P., … Engstrom, D. (2008). Climate-driven ecosystem succession in the Sahara: The past 6000 years. *Science*, *320*(5877), 765–768.

Kuper, R., & Kröpelin, S. (2006). Climate-controlled Holocene occupation in the Sahara: Motor of Africa's evolution. *Science*, *313*(5788), 803–807.

Laland, K. N., & O'Brien, M. J. (2010). Niche construction theory and archaeology. *Journal of Archaeological Method and Theory*, *17*(4), 303–322.

Laland, K. N., & O'Brien, M. J. (2011). Cultural niche construction: An introduction. *Biological Theory*, *6*(3), 191–202.

Laland, K. N., Odling-Smee, J., Feldman, M. W., & Kendal, J. (2009). Conceptual barriers to progress within evolutionary biology. *Foundations of Science*, *14*(3), 195–216.

Lane, P. (2013). The archaeology of pastoralism and stock-keeping in East Africa, Chapter 40. In P. Mitchell & P. Lane (Eds.),*The Oxford handbook of African archaeology* (pp. 585–601). Oxford, UK: Oxford University Press.

di Lernia, S. (2013). The emergence and spread of herding in northern Africa, Chapter 36. In P. Mitchell, & P. Lane (Eds.), *The Oxford handbook of African archaeology* (pp. 527–540). Oxford, UK: Oxford University Press.

Linseele, V. (2013). From the first stock keepers to specialised pastoralists in the west African savannah, Chapter 4. In M. Bollig, M. Schnegg, & H. -P. Wotzka (Eds.), *Pastoralism in Africa: Past, present and future* (pp. 145–170). New York & Oxford, UK: Berghahn Books.

Liu, Z., Otto-Bliesner, B. L., He, F., Brady, E., Thomas, R., Clark, P. U., … Cheng, J. (2009). Transient simulation of last deglaciation with a new mechanism for Bølling-Allerød warming. *Science*, *325*, 310–314.

Lorenzen, E. D., Nogués-Bravo, D., Orlando, L., Weinstock, J., Binladen, J., Marske, K. A., … Willerslev, E. (2011). Species-specific responses of late quaternary megafauna to climate and humans. *Nature*, *479*(7373), 359–364.

Macholdt, E., Lede, V., Barbieri, C., Mpoloka, S. W., Chen, H., Slatkin, M., … Stoneking, M. (2014). Tracing pastoralist migrations to southern Africa with lactase persistence alleles. *Current Biology*, *24*, 875–879.

MacHugh, D. E., Shriver, M. D., Loftus, R. T., Cunningham, P., & Bradley, D. G. (1997). Microsatellite DNA variation and the evolution, domestication and phylogeography of taurine and zebu cattle (*Bos taurus* and *Bos indicus*). *Genetics*, *146*, 1071–1086.

Maiorano, L., Cheddadi, R., Zimmermann, N. E., Pellissier, L., Petitpierre, B., Pottier, J., … Guisan, A. (2013). Building the niche through time: Using 13000 years of data to predict the effects of climate change on three tree species in Europe. *Global Ecology and Biogeography*, *22*(3), 302–317.

Manning, K. (2016). The cultural evolution of neolithic Europe. euroevol dataset 2: Zooarchaeological data. *Journal of Open Archaeology Data*, *5*, e3.

Manning, K., Colledge, S., Crema, E., Shennan, S., & Timpson, A. (2016). The cultural evolution of neolithic Europe. euroevol dataset 1: Sites, phases and radiocarbon data. *Journal of Open Archaeology Data*, *5*, e2.

Manning, K., & Timpson, A. (2014). The demographic response to Holocene climate change in the Sahara. *Quaternary Science Reviews*, *101*, 28–35.

Marshall. (2000). The origins and spread of domestic animals in East Africa, Chapter 10. In R. M. Blench & K. C. MacDonald (Eds.), *The origins and development of African livestock: archaeology, genetics, linguistics and ethnography* (pp. 191–221). London, UK: UCL Press.

Marshall, F., & Hildebrand, E. (2002). Cattle before crops: The beginnings of food production in Africa. *Journal of World Prehistory*, *16*(2), 99–143.

Morrison, K. D., Gaillard, M.-J., Madella, M., Whitehouse, N., & Hammer, E. (2016). Land use classification workshop: LandCover6k workshop, Paris, France, 22–23 October 2015. *PAGES Magazine*, 24, 40.

Murray, M., & Trail, J. (1984). Genetic resistance to animal trypanosomiasis in Africa. *Preventative Veterinary Medicine*, *2*(1–4), 541–551.

Mwai, O., Hanotte, O., Kwon, Y.-J., & Cho, S. (2015). African indigenous cattle: Unique genetic resources in a rapidly changing world. *Asian-Australian Journal of Animal Sciences*, *28*(7), 911–921.

Niamir-Fuller, M. (1999). Managing mobility in African rangelands, Chapter 4. In N. McCarthy, B. Swallow, M. Kirk, & P. Hazell (Eds.), *Property rights, risk and livestock development in Africa* (pp. 102–131). Washington, DC: International Food Policy Research Institute.

Nogues-Bravo, D. (2009). Predicting the past distribution of species climatic niches. *Global Ecology and Biogeography*, *18*(5), 521–531.

O'Brien, M. J., & Laland, K. N. (2012). Genes, culture, and agriculture. *Current Anthropology*, *53*(4), 434–470.

Odling-Smee, F. J. (1988). *Niche-constructing phenotypes* (pp. 73–132). Cambridge, MA: The MIT Press.

Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche construction: The neglected process in evolution, volume 37 of Monographs in population biology*. Princeton, NJ: Princeton University Press.

Patin, E., Siddle, K. J., Laval, G., Quach, H., Harmant, C., Becker, N., … Quintana-Murci, L. (2013). The impact of agricultural emergence on the genetic history of African rainforest hunter-gatherers and agriculturalists. *Nature Communications*, *5*, 3163. https://doi.org/10.1038/ncomms4163

Pearman, P. B., Guisan, A., Broennimann, O., & Randin, C. F. (2008). Niche dynamics in space and time. *Trends in Ecology and Evolution*, *23*(3), 149–158.

Pereira, F., Queirós, S., Gusmão, L., Nijman, I. J., Cuppen, E., Lenstra, J. A., … Amorim, A. (2009). Tracing the history of goat pastoralism: New clues from mitochondrial and Y chromosome DNA in North Africa. *Molecular Biology and Evolution*, *26*(12), 2765–2773.

Pérez-Pardal, L., Royo, L., Beja-Pereira, A., Curik, I., Traoré, A., Fernández, I., … Goyache, F. (2010). Y-specific microsatellites reveal an African subfamily in taurine (*Bos taurus*) cattle. *Animal Genetics*, *41*(3), 232–241.

Perez-Sanz, A., Li, G., González-Sampériz, P., & Harrison, S. P. (2014). Evaluation of modern and mid-Holocene seasonal precipitation of the Mediterranean and northern Africa in the cmip5 simulations. *Climate of the Past*, *10*(2), 551–568.

Petitpierre, B., Kueffer, C., Broennimann, O., Randin, C., Daehler, C., & Guisan, A. (2012). Climatic niche shifts are rare among terrestrial plant invaders. *Science*, *335*(6074), 1344–1348.

Phelps, L. N., Jousse, H., Manning, K., Broennimann, O., Timpson, A., Mariethoz, G., … Guisan, A. (2019). Faunal dataset: Reconstructing climatic niche breadth of land use for animal production during the African Holocene. *PANGAEA*, https://doi.org/10.1594/PANGAEA.904942.

Phelps, L. N., & Kaplan, J. O. (2017). Land use for animal production in global change studies: Defining and characterizing a framework. *Global Change Biology*, *23*(11), 4457–4471. https://doi.org/10.1111/gcb.13732

Prendergast, M. E. (2011). *Hunters and herders at the periphery: The spread of herding in eastern Africa* (pp. 43–58). Frankfurt am Main, Germany: Africa Magna Verlag.

Python Software Foundation. (2018). *Python language reference* (Version 2.7.15). Retrieved from http://www.python.org

R Core Team. (2018). *R: A language and environment for statistical computing*. Vienna, Austria: Author.

Ranciaro, A., Campbell, M. C., Hirbo, J. B., Ko, W.-Y., Froment, A., Anagnostou, P., … Tishkoff, S. A. (2014). Genetic origins of lactase

persistence and the spread of pastoralism in Africa. *The American Journal of Human Genetics*, *94*, 496–510.
Reif, J., Hořák, D., Sedláček, O., Riegert, J., Pešata, M., Hrázský, Z., … Storch, D. (2006). Unusual abundance—range size relationship in an Afromontane bird community: The effect of geographical isolation? *Journal of Biogeography*, *33*(11), 1959–1968.
Rick, J. W. (1987). Dates as data: An examination of the Peruvian preceramic radiocarbon record. *American Antiquity*, *52*(1), 55–73.
Robinson, J. R., & Rowan, J. (2017). Holocene paleoenvironmental change in southeastern Africa (Makwe Rockshelter, Zambia): Implications for the spread of pastoralism. *Quaternary Science Reviews*, *156*, 57–68. https://doi.org/10.1016/j.quascirev.2016.11.030
Rowan, J., Kamilar, J. M., Beaudrot, L., & Reed, K. E. (2016). Strong influence of palaeoclimate on the structure of modern African mammal communities. *Proceedings of the Royal Society B: Biological Sciences*, *283*, 20161207. https://doi.org/10.1098/rspb.2016.1207
Rowley-Conwy, P., & Layton, R. (2011). Foraging and farming as niche construction: Stable and unstable adaptations. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*, 849–862.
Sadr, K. (2015). Livestock first reached southern Africa in two separate events. *PLoS ONE*, *10*(8), 1–22.
Shanahan, T. M., McKay, N. P., Hughen, K. A., Overpeck, J. T., Otto-Bliesner, B., Heil, C. W., … Peck, J. (2015). The time-transgressive termination of the African humid period. *Nature Geoscience*, *8*, 140–144.
Shennan, S., Downey, S. S., Timpson, A., Edinborough, K., Colledge, S., Kerig, T., … Thomas, M. G. (2013). Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature Communications*, *4*(2486), 1–8.
Slatyer, R. A., Hirst, M., & Sexton, J. P. (2013). Niche breadth predicts geographical range size: A general ecological pattern. *Ecology Letters*, *16*(8), 1104–1114.
Smith, A. (1992). Origins and spread of pastoralism in Africa. *Annual Review of Anthropology*, *21*, 125–141. https://doi.org/10.1146/annurev.an.21.100192.001013
Smith, B. D. (2007). The ultimate ecosystem engineers. *Science*, *315*, 1797–1798.
Smith, B. D. (2011). A cultural niche construction theory of initial domestication. *Biological Theory*, *6*(3), 260–271.
Smith, B. D., & Zeder, M. A. (2013). The onset of the Anthropocene. *Anthropocene*, *4*, 8–13.
Soberón, J. (2007). Grinnellian and Eltonian niches and geographic distributions of species. *Ecology Letters*, *10*, 1115–1123.
Tingley, R., Vallinoto, M., Sequeira, F., & Kearney, M. R. (2014). Realized niche shift during a global biological invasion. *Proceedings of the National Academy of Sciences*, *111*(28), 10233–10238.
Tishkoff, S. A., Reed, F. A., Ranciaro, A., Voight, B. F., Babbitt, C. C., Silverman, J. S., … Deloukas, P. (2007). Convergent adaptation of human lactase persistence in Africa and Europe. *Nature Genetics*, *39*(1), 31–40.
Veloz, S. D., Williams, J. W., Blois, J. L., Otto-Bliesner, B., & Liu, Z. (2012). No-analog climates and shifting realized niches during the late quaternary: Implications for 21st-century predictions by species distribution models. *Global Change Biology*, *18*, 1698–1713.
Verdu, P., Austerlitz, F., Estoup, A., Vitalis, R., Georges, M., Théry, S., … Heyer, E. (2009). Origins and genetic diversity of Pygmy hunter-gatherers from western Central Africa. *Current Biology*, *19*, 312–318 https://doi.org/10.1016/j.cub.2008.12.049
Vetter, S. (2005). Rangelands at equilibrium and non-equilibrium: Recent developments in the debate. *Journal of Arid Environments*, *62*, 321–341.
Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*, 494–499.
Wang, M., Dzama, K., Rees, D., & Muchadeyi, F. (2015). Tropically adapted cattle of Africa: Perspectives on potential role of copy number variations. *Animal Genetics*, *47*(2), 154–164.
Warren, D. L., Glor, R. E., & Turelli, M. (2008). Environmental niche equivalency versus conservatism: Quantitative approaches to niche evolution. *Evolution*, *62*(11), 2868–2883.
Zerboni, A., & Nicoll, K. (2019). Enhanced zoogeomorphological processes in north Africa in the human-impacted landscapes of the Anthropocene. *Geomorphology*, *331*, 22–35.
Zurell, D., Thuiller, W., Pagel, J., Cabral, J. S., Münkemüller, T., Gravel, D., … Zimmermann, N. E. (2016). Benchmarking novel approaches for modelling species range dynamics. *Global Change Biology*, *22*, 2651–2664.

BIOSKETCH

The research of the lead author, **Leanne Phelps**, focuses on the ecological intersection between land use and land cover change, across broad spatial and temporal scales. Her primary research interests lie in improving our understanding of human–environment relationships, in order to inform sustainable conservation and land use planning.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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APPENDIX: DATA SOURCES 1

The archaeological data analysed in this study were modified from Jousse, 2017 and associated datasets (see Phelps et al., 2019: https://doi.pangaea.de/10.1594/PANGAEA.904942). Taxonomy updates were made with reference to Kingdon et al. (2013) and Bibi (2013).

Alhaique, F. (2002). Archaeozoology of the funerary structures. In S. di Lernia & G. Manzi (Eds.), *Sand, stones and bones. The archaeology of death in the Wadi Tannezzuft Valley (5000–2000 BP). The Archaeology of Libyan Sahara Vol. I* (pp. 181–196). Università degli Studi di Roma “La Sapienza”/Edizioni All'insegna del Giglio,Firenze, Italy: Arid Zone Archaeology Monographs 3.
Alimen, H., Beucher, F., Mateu, J., & Roubet, C. (1980). Zmeilet el-Barka, halte saisonnière de chasseurs au VIème millénaire B.C. (Sahara algérien nord-occidental). *L'Anthropologie*, *84*, 198–242.
Amblard-Pison, S. (1999) Communautés villageoises néolithiques des Dhars Tichitt et Oualata (Mauritanie) (Thèse de doctorat d'état). Université Paris I, Paris.
Aouraghe, H. (2000). Les carnivores fossiles d'El Harhoura 1, Temara, Maroc. *L'Anthropologie*, *104*, 147–171.
Arambourg, C. (1948). Observations sur le Quaternaire de la région du Hoggar. *Travaux de l'Institut de Recherches Sahariennes*, *V*, 7–18.
Avery, D. M. (1992). Micromammals and the environment of early pastoralists at Spoeg River, western Cape Province, South Africa. *South African Archaeological Bulletin*, *47*, 116–121.

Avery, D. M. (1999). Holocene coastal environments in the Western Cape Province, South Africa: Micromammalian evidence from Steenbokfontein. *Archaeozoology*, *10*, 163–180).

Avery, G. (1992). Appendix 1: Faunal remains from Klein Kliphuis Shelter, Clamwilliam District, South Africa. *South African Archaeological Bulletin*, *47*(155), 40–43.

Ba, M., Descamps, C., & Thilmans, G. (1997). Fouille d'un tumulus ä Ndiamon-Badat (Iles du Saloum, Sénégal). *Saint-Louis – Lille – Liège*, *3*, 1–14.

Barker, G. (1978). Economic models for the Manekweni, Zimbabwe, Mozambique. *Azania*, *13*, 71–100.

Barton, R. N. E., Bouzouggar, A., Collcutt, S. N., Gale, R., Higham, T. F. G, Humphrey, L. T., … Malek, F. (2005). The Late Upper Palaeolithic occupation of the Moroccan Northwest Maghreb during the last glacial maximum. *African Archaeological Review*, *22*(2), 77–100.

Bathily, M. S., Khattar, M. O., Vernet, R., Cluzel, C., & Ott, J. M. (1998). Les sites néolithiques de Khatt Lemaiteg (Amatlich) en Mauritanie occidentale. In Baumhauer, R. & Runge, J. (Eds.), *CMA*, *UPR 311*, *Meudon* (pp. 179–186). Leiden, Netherlands: CRC Press/Balkema.

Beaumont, P., & Boshier, A. (1974). Report on test excavations in a prehistoric pigment mine near Postmasburg, Northern Cape. *South African Archaeological Bulletin*, *29*, 41–59.

Bedaux, R., Macdonald, K., Person, A., Polet, J., Kléna, S., Schmidt, A., & Sidlibé, S. (2001). The Dia archaeological project: rescuing cultural heritage in the Inland Niger Delta (Mali). *Antiquity*, *75*(290), 837–848.

Boessneck, J. (1986). Vogelknochenfunde aus dem alten Ägypten. *Annalen des Naturhistorisches Museum Wien*, *88/89*, 323–344.

Boessneck, J. (1988). Tierknochenfunde aus der Spätzeit (6.-4. Jh. v. Chr.) aus Minshat Abu Omar (Ägypten). *Fontes Archaeologici Posnanienses*, *36*, 217–220.

Boessneck, J., & von den Driesch, A. (1993). Eine außerwöhnliche Tierknochendeponie in einem Gebäude der 25./26. Dynastie im Stadtgebiet nordwestlich des späten Chnumtemples auf Elephantine. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, *49*, 189–201.

Boessneck, in: Van den Brink, E. C. M. (1989). A transitional Late Predynastic—Early Dynastic settlement site in the Northeastern Nile Delta, Egypt. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, *45*, 55–108.

Boessneck, J. (1976). Tell el Dab'a III. Die Tierknochenfunde 1966–69. Österreischische Akademie der Wissenschaften, Denkschriften der Gesamt-Akademie 5.

Boessneck, J., & von den Driesch, A. (1987). *Tuna el-Gebel I. Die Tiergalerien*. Hildesheimer Ägyptologische Beiträge.

Boessneck, J., & von den Driesch, A., in van den Brink, E. C. M. (1989). A transitional Late Predynastic—Early Dynastic settlement site in the northeastern Nile Delta, Egypt. *Mitteilungen des deutschen Archäologischen Instituts Abteilung Kairo*, *45*, 55–108.

Boessneck, J., & von den Driesch, A. (1982). Studien an subfossilen Tierknochen aus Ägypten. *Münchner Ägyptologische Beiträge*, *40*.

Boessneck, J., von den Driesch, A., & Eissa, A. (1992). Eine Eselbestattung der 1. Dynastie in Abusir. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, *48*, 1–10.

Bouchud, J. (1969). Etude des mammifères er des oiseaux d'Amekni. In G. Camps (Ed.), *Amekni. Néolithique ancien du Hoggar* (pp. 173–177). Paris, France: Mémoires du Centre de recherches anthropologiques préhistoriques et ethnographiques.

Bouchud, J. (1975). La faune de Medjez II. In H. Camps-Fabrer (Ed.), *Un gisement capsien de faciès sétifien: Medjez II, el-Eulma (Algérie)* (pp. 377–391). Paris, France: CNRS.

Bouchud, J. (1983). Paléofaune de Tegdaoust. In A. D. Babacar, T. H. Bah, J. Bouchud, G. S. Colin, J. Devisse, N. Ghali, … (Eds.), *Tegdaoust III—Recherches sur Aoudaghost. Campagnes 1960–1965* (pp. 355–363). Paris: Enquêtes Générales "Mémoires".

Bouchud, J., Brebion, P., & Saban, R. (1981). Etude des faunes holocènes provenant de la zone aride du Sahara atlantique: les mammifères de la Mauritanie occidentale. In C. Roubet, H. J. Hugot, & G. Souville (Eds.), *Préhistoire africaine—Mélanges offerts au doyen L. Balout. Recherches sur les grandes civilisations* (pp. 237–250, 6). Paris, France: A.D.P.F.

Breunig, P., Neumann, K., & Van Neer, W. (1996). New research on the Holocene Settlement and Environment of the Chad Basin in Nigeria. *African Archaeological Review*, *13*, 111–145.

Brewer, D. J. (1989). *Fishermen, Hunters and herders. Zooarchaeology in the Fayum, Egypt (ca. 8200–5000 BP)*. British Archaeological Reports, International Series.

Brink, J., & Holt, S. (1992). A small goat, Capra hircus, from a Late Iron Age site in the Eastern Orange Free State. *South African Field Archaeology*, *1*, 88–91.

Cain, C. R. (2000). *Animals at Axum: Initial zooarchaeological research in the later prehistory of the northern Ethiopian Highlands* (PhD thesis). Dept. of Anthropology, Washington University, St. Louis, Missouri.

Camps, G. (1969). *Amekni. Néolithique ancien du Hoggar*. Paris: Mémoires du Centre de recherches anthropologiques préhistoriques et ethnographiques.

Camps-Fabrer, H. (1989). Capsien du Maghreb et Natoufien du Proche-Orient. *Travaux du Laboratoire d'Anthropologie et de Préhistoire des pays de la Méditerranée Occidentale*, 71–104.

Caneva, I., & Gautier, A. (1994). The desert and the Nile: sixth millennium pastoral adaptions at Wadi el Kenger (Khartoum). *Archéologie du Nil Moyen*, *6*, 65–92.

Caneva, I., Garcea, E. A., Gautier, A., & Van Neer, W. (1993). Pre-pastoral cultures along the Central Sudanese Nile. *Quaternaria Nova*, *3*, 177–252.

Carbonnel, J. P., & Barbey, C. (1972). Découverte de sépultures néolithiques dans le complexe dunaire du Draa Malichigdane (Mauritanie). *Notes Africaines*, *136*, 108–111.

Carter, P. L., & Flight, C. (1972). A report on the fauna from the sites of Ntereso and Kintampo rock shelter six in Ghana: With evidence for the practice of animal husbandry during the second millennium B.C. *Man*, *7*, 277–282.

Carter, P. L., & Clark, J. D. (1976). Adrar Bous and African cattle. In B. Abebe, J. Chavaillon, & J. E. Sutton (Eds.), *Actes du VIIème Congrès Panafricain de Préhistoire et d'Etude du Quaternaire* (pp. 487–493, 1). Addis-Abeba, Ethiopia.

Cassoli, F., & Durante, S. (1974). La fauna del Ti-n-Thora (Acacus, Libia). *Origini*, 8, 159–161.

Chaïd-Saoudi, Y. (1987). *Les mammifères holocènes des gisements préhistoriques de Gueldaman-Akbou (Bédjaia), Columnata (Tiaret) et Ti-n-Hanakaten (Djanet) en Algérie* (PhD thesis). Université Claude-Bernard Lyon1, Villeurbanne.

Chaïd-Saoudi, Y. (2007). Les Bovidés du Site Holocène de Mankhor (Sahara Central). Observations Paléontologiques Archéozoologiques et taphonomiques. *ATHAR*, *6*, 1–17.

Chaix, L. (1987). Rapport préliminaire sur la faune du site de Kadruka I, Soudan Nord (Néolithique et Protohistorique). In J. Reinold (Ed.), *Les fouilles pre- et proto-historiques de la section francaise de la direction des antiquités du Soudan: Les campagnes 1984–85 et 1985–86* (pp. 61–62). Archéologie du Nil Moyen.

Chaix, L. (1993). The archaeozoology of Kerma (Sudan). In W. V. Davies & R. Walker (Eds.), *Biological anthropology and the study of ancient Egypt* (pp. 175–185). London, UK: British Museum Press.

Chaix, L. (1998). Nouvelles données sur l'exploitation du monde animal au Soudan central et septentrional. *Cahiers de Recherche de l'Institut de Papyrologie et d'Egyptologie de Lille*, *17*(3), 79–84.

Chaix, L. (1998). The fauna. In D. A. Welsby (Ed.), *Soba II. Renewed excavations within the metropolis of the Kingdom of Alwa in Central Sudan* (pp. 233–255, pl. 70–75). London, UK: Memoirs of the British Institute in Eastern Africa, British Museum Press.

Chaix, L. (2000). An Hyksos horse from Tell Heboua (Sinaï, Egypt). In A. M. C. M. Mashkour, H. Buitenhuis, & F. Poplin (Eds.), *Archaeozoology of the Near East* (pp. 177–186). Groningen, Netherlands: 3 + append.

Chaix, L. (2000). La faune des peintures murales du temple K XI. In C. Bonnet (Ed.), *Edifices et rites funéraires à Kerma* (pp. 163–199). Paris, France: Errance.

Chaix, L. (2003). La faune des sites mésolithiques et néolithiques de la zone du Nil Bleu (Soudan Central). *Complutum*, *14*, 373–396.

Chaix, L. (2006). New data about rural economy in the Kerma culture: the site of Gism el-Arba (Sudan). In *Archaeology of Early Northeastern Africa* (pp. 25–37). Studies in African Archaeology.

Chaix, L., & Gratien, B. (2002). Un cheval du Nouvel empire a Sai (Soudan). *Archéologie du Nil Moyen*, *9*, 53–61.

Chaix, L., & Olive, C. (1986). Annexe II: La faune du Mastaba V (2200 BC) à Balat (République Arabe d'Egypte). In M. Valloggia, (Ed.), *Balat I. Le Mastaba de Medou-Nefer* (pp. 201–213). Cairo, Egypt: Institut Français d'Archéologie Orentale.

Chavane, B. (1980). Extrait: Recherches archéologiques sur la moyenne vallée du fleuve Sénégal (MS thesis). Univ Aix en Provence, Aix en Provence, France.

Chavane, B. (1985). *Villages de l'ancien Tekrour*. Paris: Karthala/CRA.

Chenal-Vélardé, I. (1996). Etude taphonomique, observations ethnologiques et interprétations archéozoologiques: essai sur les techniques de boucherie a Hamdallahi (Mali, XIXe siècle). *Anthropozoologica*, 85–95.

Churcher, C. S. (1999). Holocene faunas of the Dakhleh Oasis. In C. S. Churcher & A. J. Mills (Eds.), Reports from the survey of the Dakleh Oasis, Western Desert of Egypt, 1977–1987 (pp. 133–170). Oxford, UK: Oxford Monograph.

Churcher, C. S., & Smith, P. E. L. (1972). Kom Ombo: Preliminary report on the fauna of Late Paleolithic sites in Upper Egypt. *Science*, *177*, 259–261.

Clark, J. D. (1973). (no title). *Nyame Akuma*, *3*, 56–64.

Close, A. E. (2002). Sinai, Sahara, Sahel: The introduction of domestic caprines to Africa. In Jennerstrasse 8 (Eds.), *Tides of the Desert—Gezeiten der Wüste* (pp. 459–469). Köln, Germany: Heinrich-Barth-Institut, Africa Praehistorica 14, Monographs on African Archaeology and Environment.

Clutton-Brock, J. (1974). The Buhen horse. *Journal of Archaeological Science*, *1*, 89–100.

Collett, B. P. (1982). Excavations of stone-walled ruin types in the Badfontein Valley, Eastern Transvaal, South Africa. *South African Archaeological Bulletin*, *37*, 34–43.

Corridi, C. (1998). Faunal remains from Holocene archaeological sites of the Tadrart Acacus and surroundings (Libyan Sahara). In M. Cremaschi & S. di Lernia (Eds.), *Wadi Teshuinat Palaeoenvironment and Prehistory in south-western Fezzan (Libyan Sahara)* (pp. 89–94). Firenze, Italy: All'Insegna del Giglio.

Cruz-Uribe, K. (1983). The mammalian fauna from Redcliff Cave, Zimbabwe. *South African Archaeological Bulletin*, *38*, 7–16.

Cruz-Uribe, K., & Schrire, C. (1991). Analysis of faunal remains from Oudepost 1, an early outpost of the Dutch East India Company, Cape Province. *South African Archaeological Bulletin*, *46*, 92–106.

de Maret, P., Clist, B., & Van Neer, W. (1987). Résultats des premières fouilles dans les abris de Shum Laka et Abeke au nord-ouest du Cameroun. *L'Anthropologie*, *Paris*, *91*(2), 559–584.

Deacon, H. J., Deacon, J., Brooker, M., & Wilson, M. L. (1978). The evidence for herding at Boomplaas Cave in the southern Cape, South Africa. *South African Archaeological Bulletin*, *33*, 39–65.

Deacon, J. (1972). Wilton: An assessment after fifty years. *South African Archaeological Bulletin*, *27*(105/106), 10–48.

Deme, A., & McIntosh, S. (2006). Excavations at Walaldé: New light on the settlement of the Middle Senegal Valley by Iron-Using people. *Journal of African Archaeology*, *4*(2), 317–347.

Denbow, J. (1981). Broadhurst—A fourteenth century A.D. expression of the Early Iron Age in Southeastern Botswana. *South African Archaeological Bulletin*, *36*, 66–74.

Denbow, J. (1990). Congo to Kalahari: Data and hypothesis about the political economy of the western stream of the Early Iron Age. *African Archaeological Review*, *8*, 139–176.

Dreyer, G., von den Driesch, A., Engel, E.-M., Hartmann, R., Hartung, U., Hikade, T., … Peters, J. (2000). Umm el-Qaab, Nachuntersuchungen im frühzeitlichen Känigsfriedhof. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, *56*, 43–129.

Durand, A., Paris, F., & Saliège, J.-F. (1999). Vallée de l'Azawagh (Sahara du Niger). I. Peuplements et environnements holocènes du bassin oriental de l'Azawagh (Niger). *Etudes Nigériennes*, *57*, 1–193.

ElMahi, A. T. (1988). *Zooarchaeology in the Middle Nile Valley*. Oxford, UK: British Archaeological Reports, International Series.

Esterhuysen, A. B., Behrens, J., & Harper, P. T. (1994). Leliehoek Shelter: A Holocene sequence from the eastern Orange free State. *South African Archaeological Bulletin*, 49, 73–78.

Evers, T. M. (1980). Klingbell Early Iron Age sites, Lydenburg, Eastern Transvaal, South Africa. *South African Archaeological Bulletin*, *35*, 46–57.

Evers, T. M. (1982). Excavations at the Lydenburg Heads Site, Eastern Transvall, South Africa. *South African Archaeological Bulletin*, *37*, 16–33.

Fagan, B. M. (1960). The Glentyre Shelter and Oakhurst re-examined. *South African Archaeological Bulletin*, *15*, 80–94.

Faye, B. (1988). Le site archéologique de Chin-Tafidet au Niger. *Bulletin mensuel de la Société linnéenne de Lyon*, *57*, 212–213.

Finucane, B., Manning, K., & Touré, M. (2008). Late Stone Age subsistence in the Tilemsi Valley, Mali: Stable isotope analysis of human and animal remains from the site of Karkarichinkat Nord (KN05) abd Karkarichinkat Sud (KS05). *Journal of Anthropological Archaeology*, *27*, 82–92.

Frank T., Breunig P., Müller-Haude P., Van Neer W., Neumann K., Vogelsang R., & Wotzka H. P. (2001). The Chaîne de Gobnangou, SE Burkina Faso: Archaeological, archaeobotanical, archaeozoological and geomorphological studies. *Beiträge zur Allgemeinen und Vergleichenden Archäologie*, *21*, 127–190.

Gaillard, C. (1934). Contribution ä l'étude de la faune préhistorique de l'Egypte. *Archives du Muséum d'Histoire Naturelle de Lyon*, XIV, 1–143.

Garcea, E. (2003). Animal exploitation and pottery technology during Pastoral times: The evidence from Uan Telocat, Libyan Sahara. *Journal of African Archaeology*, *1*, 111–126.

Garlake, P. S. (1973). Excavations at the Nhunguza and Ruanga ruins in Northern Mashonaland. *South African Archaeological Bulletin*, *27*, 107–143.

Gasc, J. P. (1969). Etude des reptiles de la faune d'Amekni. In G. Camps (Ed.), *Amekni. Néolithique ancien du Hoggar* (pp. 171–172). Paris, France: Mémoires du Centre de recherches anthropologiques préhistoriques et ethnographiques.

Gautier, A. (1974). Some mammalian remains from a fossil wadi near the base of the Gademotta formation, VI. In F. Wendorf & R. Schild (Eds.), *A Middle Stone Age sequence from the Central Rift Valley, Ethiopia*. Wroclaw, Poland: Polska Akademia Nauk Instytut Historii Kultury Materialnej, 160–165.

Gautier, A. (1976). Animal remains from archaeological sites of Terminal Paleolithic to Old Kingdom age in the Fayum, Appendix I. In F. Wendorf & R. Schild (Eds.), *Prehistory of the Nile Valley* (pp. 369–380). New York, San Francisco, London: Academic Press.

Gautier, A. (1978). La faune de vertébrés des sites épipaléolithiques d'Elkab, Chapter IV. In P. M. Vermeersch (Ed.), Elkab II. L'Elkabien, Epipaléolithique de la vallée du Nil égyptien. Bruxelles: Comité des fouilles belges en Afrique, 103–114.

Gautier, A. (1980). Contributions to the Archaeozoology of Egypt. In F. Wendorf & R. Schild (Eds.), *Prehistory of the Eastern Sahara* (pp. 317–343). New York: Academic Press.

Gautier, A. (1983). Animal life along the prehistoric Nile: The evidence from Saggai 1 and Geili (Sudan). *Origini*, *12*, 50–115.

Gautier, A. (1984). The fauna of the Neolithic site of Kadero (Central Sudan). In L. Kryzaniak & M. Kobusiewicz (Eds.), *Origin and early* *development of food-producing cultures in North-Eastern Africa* (pp. 317–319). Poznan, Poland: Polish Academy of Sciences and Poznan Archaeological Museum.

Gautier, A. (1984). Archaeozoology of the Bir Kiseiba region, eastern Sahara. In F. Wendorf, R. Schild, & A. E. Close (Eds.), *Cattle keepers of the Sahara. The Neolithic of Bir Kiseiba* (pp. 49–72, 6). Dallas, Texas: Department of Anthropology, Institute for the Study of Earth and Man, Southern Methodist University.

Gautier, A. (1984). New data concerning the prehistoric fauna and domestic cattle from Ti-n-Torha (Acacus, Libya). In J. A. Coetzee & E. M. S. Van Zinderen Bakker (Eds.), *Palaeoecology of Africa and the surrounding islands* (pp. 305–309). Rotterdam, Netherlands: A.A. Balkema.

Gautier, A. (1984). *Quaternary mammals and archaeozoology of Egypt and the Sudan: A survey*. Origin and early development of food-producing cultures in north-eastern Africa. L. K. M. Kobusiewicz (pp. 43–56). Poznan: Polish Academy of Sciences.

Gautier, A. (1986). La faune de l'occupation néolithique d'el Kadada (secteurs 12–22–32) au Soudan central. *Archéologie du Nil Moyen*, *1*, 59–111.

Gautier, A. (1987). Prehistoric men and cattle in North Africa: A dearth of data and a surfeit of models. In A. E. Close (Ed.), *Prehistory of arid North Africa: essays in honour of Fred Wendorf* (pp. 163–187). Dallas, TX: Southern Methodist University Press.

Gautier, A. (1988). Notes on the animal bone assemblage from the early Neolithic at Geili (Sudan). El Geili. The history of a middle Nile environment 7000 B.C.- A.D. 1500. I. *Caneva*, *BAR International Series*, *424*, 57–63.

Gautier, A. (2002). The evidence for the earliest livestock in North Africa: or adventures with large bovids, ovicaprids, dogs and pigs, Chapter 12. In F. A Hassan (Ed.), *Droughts, Food and Culture. Ecological change and food security in Africa's later Prehistory* (pp. 195–207). New York: Kluwer Academic/Plenum.

Gautier, A., & Hendrickx, S. (1999). Vultures and other animal remains from a tomb in the Elkab necropolis, Upper Egypt: An exercise in salvage archaeozoology. Historia Animalium ex Ossibus, Festschrift für Angela von den Driesch. *Rahden*, *Internationale Archäologie*, *Studia honoraria*, *8*, 161–179.

Gautier, A., & Van Neer, W. (1982). Prehistoric fauna from Ti-n-Torha (Tadrart Acacus, Libya). *Origini*, *11*, 87–127.

Gautier, A., & Van Neer, W. (1989). The animal remains from the Late Paleolithic sequence in Wadi Kubbaniya, Chapter 6. In F. Wendorf, R. Schild, & A. E. Close (Eds.), *The Prehistory of Wadi Kubbaniya, Vol. 2, Stratigraphy, paleoeconomy and environment* (pp. 119–161). Dallas, TX: Southern Methodist University Press.

Gautier, A., & Van Neer, W. (1997). Animal remains from Debbat El Eheima and Debbat Bangdit (1600–1000 B.C./400-1000 A.D., southern Sudan). *Archaeozoologia*, *9*, 49–72.

Gautier, A., & Van Neer, W. (2005). The continuous exploitation of wild animal resources in the archaeozoological record of Ghana. *Journal of African Archaeology*, *3*(2), 195–212.

Gautier, A., & Van Neer, W. (2006). Animal remains from Tahal Teglinos (Kassala, Sudan) and the arrival of cattle pastoralism in the Southern Atbai. *Journal of African Archaeology*, *4*(2), 223–233.

Gautier, A., Ballmann, P., & Van Neer, W. (1980). Molluscs, fish, birds and mammals from the Late Palaeolithic sites in Wadi Kubbaniya. In F. Wendorf, R. Schild, & A. E. Close (Eds.), *Loaves and fishes: The Prehistory of Wadi Kubbaniya* (pp. 281–294). New Dehli, India: Pauls Press.

Gautier, A., Linseele, V., & Van Neer, W. (2002). The fauna of the Early Khartoum occupation on Jebel Umm Marrahi (Khartoum Province, Sudan). In Jennerstrasse 8 (Ed.), *Tides of the desert—Gezeiten der Wüste. Contributions to the archaeology and environmental history of Africa in honour of Rudolph Kuper*. Köln, Germany: Heinrich-Barth-Institut, Africa Praehistorica 14, Monographs on African Archaeology and Environment.

Gehlen, B., Kindermann, K., Linstädter, J., & Riemer, H. (2002). The Holocene occupation of the Eastern Sahara: Regional chronologies and supra-regional developments in four areas of the absolute desert. In Jennerstrasse 8 (Ed.), *Tides of the Desert—Gezeiten der Wüste* (pp. 85–116). Köln, Germany: Heinrich-Barth-Institut, Africa Praehistorica 14, Monographs on AfricanArchaeology and Environment.

Geraads, D. (1983). Faunal remains from the Gash Delta, Sudan. *Nyame Akuma*, *23*, 22–23.

Gifford, D. P. (1981). The faunal remains. In D. W. Philipson (Ed.), *Kulchurdo Rock Shelter and the Stone Age of Mount Marsabit* (Vol. 16, pp. 167–180). Azania.

Gifford-Gonzalez, D. (2003). The fauna from Ele Bor: Evidence for the persistence of foragers into the Later Holocene of arid north Kenya. *African Archaeological Review*, 20(2), 81–119.

Gifford-Gonzalez, D., & Parham, J. (2008). Fauna from Adrar Bous and surrounding areas, Chapter 11. In J. D. Clark & D. Gifford-Gonzalez (Eds.), *Adrar Bous: Archaeology of a central Saharan granitic ring complex in Niger* (pp. 313–353). Tervuren, Belgium: Royal Museum for Central Africa.

Gifford-Gonzalez, D. P. (1984). Implications of a faunal assemblage from a Pastoral Neolithic site in Kenya: Findings and a perspective on research, Chapter 22. In J. D. Clark & S. Brandt (Eds.), *From Hunters to Farmers: The causes and consequences of food production in Africa* (pp. 213–251). Berkeley, CA: University of California Press.

Gifford-Gonzalez, D. P. (1998). Early pastoralists in East Africa: ecological and social dimensions. *Journal of Anthropological Archaeology, 17*, 166–200.

Gifford-Gonzalez, D. P., & Kimengich, J. (1984). Faunal evidence for early stock keeping in the central rift of Kenya: Preliminary findings. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Origin and early development of food-producing cultures in north-eastern Africa* (pp. 457–471). Poznan, Poland: Polish Academy of Science.

Green, H. S. (1975). Sudanese Radiocarbon chronology: A provisional date list. *Nyame Akuma*, *6*, 10–24.

Gronenborn, D., Van Neer, W., & Skorupinsky, T. (1995). Kleiner Vorbericht zur archäologischen Feldarbeit südlich des Tschad-Sees. *Berichte des Sonderforschungsbereichs*, *268*(5), 27–39.

Guérin, C., & Faure, M. (1996). Chasse au chacal et domestication du boeuf dans le site néolithique d'Asa Koma (République de Djibouti). *Journal des Africanistes*, *66*, 299–311.

Gutherz, X., Joussaume, R., Amblard, S., & Mohamed, G. (1996). Le site d'Asa Koma (République de Djibouti) et les premiers producteurs dans la corne de l'Afrique. *Journal des Africanistes*, *66*, 255–297.

Hartung, U., el-Gelil, M. A., von den Driesch, A., Fares, G., Hartmann, R., Hikade, T., & Ihde, C. (2003). Vorbericht über neue Untersuchungen in der prädynastischen Siedlung von Maadi. *Mitteilungen des deutschen Archäologischen Instituts Abteilung Kairo*, *59*, 149–198.

Hendricks, S., Midant-Reynes, B., & Van Neer, W. (2001). Mahgar Dendera 2 (Haute Egypte), un site d'occupation badarien. Leuven, Belgium: Leuven University Press.

Henshilwood, C. (1996). A revised chronology for pastoralism in Southermost Africa: new evidence for sheep at c. 2000 BP from Blombos Cave, South Africa. *Antiquity*, *70*, 945–949.

Henshilwood, C. (1997). Identifying the collector: evidence for human processing of the Cape Dune Mole-Rat, Bathyergus suillus, from Blombos Cave, Southern Cape, South Africa. *Journal of Archaeological Science*, 35, 659–662.

Hipondoka, M. H. T., Jousse, H., Kempf, J., & Busche, D. (2006). Fossil evidence for perennial lake conditions during the Holocene at Etosha Pan, Namibia. *South African Journal of Science*, 102, 93–95.

Holl, A. (1985). Subsistence patterns of the Dhar Tichitt Neolithic, Mauritania. *African Archaeological Review*, *3*, 151–162.

Holl, A. (1986). Economie et société néolithique du Dhar Tichitt (Mauritanie). In *Recherches sur les Civilisations* (p. 197). Mémoire 69, Paris, France:Recherches sur les Civilisations.

Huffman, T. N. (1975). Cattle from Mabveni. *South African Archaeological Bulletin*, *30*, 23–24.

Huffman, T. N. (1979). Test excavations at Chamabvefva, Southern Mashonaland. *South African Archaeological Bulletin*, *34*, 57–70.

Huffman, T. N. (2008). Zhizo and Leopard's Kopje: Test excavations at Simamwe and Mtanye, Zimbabwe. In S. Badenhorst, P. Mitchell, & J. C. Driver (Eds.), *Animals and people: Archaeozoological papers in honour of ina plug*. Oxford, Archaeopress, British Archaeological Reports, series 1849, 200–214.

Jackes, M., & Lubell, D. (2008). Early and Middle Holocene environments and Capsian cultural change: Evidence from the Télidjène Basin, Eastern Algeria. *African Archaeological Review*, *25*, 41–55.

Jerardino, A. (1998). Excavations at Pancho's kitchen middens, Western Cpae coast, south Africa: Further observations into the megamidden. *South African Archaeological Bulletin*, *53*, 16–25.

Jerardino, A., & Yates, R. (1996). Preliminary results from excavations at Steenbokfontein Cave: Implications for past and future research. *South African Archaeological Bulletin*, *51*, 7–16.

Jesse, F., Kräpelin, S., Lange, M., Pällath, N., & Berke, H. (2004). On the periphery of Kerma—The Handessi Horizon in Wadi Hariq, Northwestern Sudan. *Journal of African Archaeology*, *2*(2), 123–164.

Jousse, H. (2004). Impact des variations environnementales sur la structure des communautés mammaliennes et l'anthropisation des milieux: exemple des faunes holocènes du Sahara occidental. *Documents des laboratoires de Géologie de Lyon*, 160, pp. 273.

Jousse, H., & Chenal-Vélardé, I. (2001–2002). Nouvelles données sur la faune mammalienne de Kobadi (Mali) au Néolithique: implications paléoéconomiques et paléoenvironnementales. *Préhistoire, Anthropologie méditerranéennes*, *10–11*, 145–158.

Jousse, H., Obermaier, H., Raimbault, M., & Peters, J. (2008). Late Holocene economic specialisation through aquatic resource exploitation at Kobadi in the Méma, Mali. *International Journal of Osteoarchaeology*, *18*, 549–572.

Jousse, H., Ould Mohamed Kaber, N., & Raimbault, M. (2003). Aperäu archéozoologique d'un site de chasseurs au Néolithique ancien ä Berouâga (Mauritanie nord-occidentale). *Sahara*, *14*, 81–88.

Juwayeyi, Y. M. (2008). Human and animal interaction on the Shire Highlands, Malawi: The evidence from Malowa rockshelter. In S. Badenhorst, P. Mitchell, & J. C. Driver (Eds.), *Animals and People: Archaeozoological Papers in Honour of Ina Plug* (pp. 83–93). Oxford, UK: Archaeopress, British Archaeological Reports, International Series 1849.

Karega-Munene. (2002). Holocene foragers, fishers and herders of Western Kenya. Oxford, UK: British Archaeological Reports, International Series.

Klatzow, S. (1994). Roosfontein, a contact site in the Eastern Orange Free State. *South African Archaeological Bulletin*, *49*, 9–15.

Klein, R. G. (1972). The Late Quaternary mammalian fauna of Nelson Bay Cave. *Quaternary Research*, *2*, 135–142.

Klein, R. G. (1976). The mammalian fauna of the Klasies River Mouth sites, Southern Cape Province, South Africa. *South African Archaeolical Bulletin*, *31*, 75–98.

Klein, R. G. (1977). The mammalian fauna from the middle and later Stone Age (Late Pleistocene) levels of Border Cave, Natal Province, South Africa. *South African Archaeological Bulletin*, *32*, 14–27.

Klein, R. G. (1978). A preliminary report on the larger mammals from the Boomplaas Stone Age cave site, Cango Valley, Oudtshoorn District, South Africa. *South African Archaeological Bulletin*, *33*, 66–75.

Klein, R. G. (1978). The vertebrate fauna from the Buffelskloof Rock Shelter. *South African Archaeological Bulletin*, *33*, 35–38.

Klein, R. G. (1979). Palaeoenvironmental and cultural implications of Late Holocene archaeological faunas from the Orange Free State and North-Central Cape Province, South Africa. *South African Archaeological Bulletin*, *34*, 34–49.

Klein, R. G. (1981). Later Stone Age subsistence at Byeneskranskop Cave, South Africa. In R. S. O. Harding & G. Teleki (Eds.), *Omnivorous primates: Gathering and hunting in human evolution* (pp. 166–190). New York: Columbia University Press.

Klein, R. G. (1984). Later Stone Age faunal samples from Heuningneskrans Shelter (Transvaal) and Leopard's Hill Cave (Zambia). *South African Archaeological Bulletin*, *39*, 109–116.

Klein, R. G. (1986). The Prehistory of Stone Age herders in the Cape Province of South Africa. *South African Archaeological Society Goodwin Series*, *5*, 5–12.

Klein, R. G., & Cruz-Uribe, K. (1987). Large mammal and tortoise bones from Eland's Bay Cave and nearby sites, Western Cape Province, South Africa. In J. Parkington & M. Hall (Eds.), *Papers in the prehistory of the Western Cape*, *South Africa* (pp. 350–372). Cambridge, UK: British Archaeological Reports, International Series.

Klein, R. G., & Cruz-Uribe, K. (1989). Faunal evidence for prehistoric herder-forager activities at Kasteelberg, western Cape Province, South Africa. *South African Archaeological Bulletin*, *44*, 82–97.

Klein, R. G., Cruz-Uribe, K., & Beaumont, P. B. (1991). Environmental, ecological and paleoanthropological implications of the late Pleistocene mammalian fauna from Equus Cave, Northern Cape province, South Africa. *Quaternary Research*, *36*, 94–119.

Klein, R. G., & Scott, K. (1986). Re-analysis of faunal assemblages from the Haua Fteah and other Late Quaternary archaeological sites in Cyrenaican Libya. *Journal of Archaeological Science*, *13*(6), 515–542.

Korsman, S., & Plug, I (1994). Two Later Stone Age sites on the farm Honingklip in the Eastern Transvaal. *South African Archaeological Bulletin*, *49*, 24–32.

Lesur, J., & Langlois, O. (2002). Une communauté d'"Agro-chasseurs" au XIXe siècle dans la Haute Bénoué. Analyse du matériel archéozoologique du site de Djaba-Hosséré. Actes du XIe colloque Megatchad, Ressources vivrières et choix alimentaires dans le Bassin du lac Tchad. Paris: IRD, pp. 113–129.

Lesur, J., Vigne, J.-D., & Gutherz, X. (2007). Exploitation of wild mammals in South-west Ethiopia during the Holocene (4000 BC-500 AD): the finds from Moche Borago shelter (Wolayta). *Environmental Archaeology*, *12*(2), 139–159.

Linseele, V. (2004). Size and change of the African Aurochs during the Pleistocene and Holocene. *Journal of African Archaeology*, *2*(2), 165–185.

Linseele, V. (2005). *Domestic livestock, subsistence strategies and environmental changes in the Sahelian West Africa during the past 4000 years: Evidence from archaeofaunal remains* (Unpublished PhD thesis). Katholieke Universiteit Leuven, Leuven, Belgium.

Loubser, J. H. N. (1985). Buffelshoek: an ethnoarchaeological consideration of a Late Iron Age settlement in the southern Transvaal. *South African Archaeological Bulletin*, *40*, 81–87.

Lubell, D. (2001). Late Pleistocene-Early Holocene Maghreb. In P. N. Peregrine & M. Ember (Eds.), *Encyclopedia of Prehistory* (pp. 129–149). New York: Kluwer Academic/Plenum Publishers. Vol. 1, Africa.

Lubell, D., & Gautier, A. (1975–77). Holocene environment and capsian subsistence in Algeria. In E. M. V. Z. Bakker & J. A. Coetzee (Eds.), *Palaeoecology of Africa and the surrounding islands* (pp. 171–178, 1), Rotterdam, Netherlands.

Lubell, D., Hassan, F. A., Gautier, A., & Ballais, J. -L. (1976). The Capsian Escargotières. An interdisciplinary study elucidates Holocene ecology and subsistence in North Africa. *Science*, *191*, 910–920.

Luff, R. M. (2001). New light on Ancient Egyptian fishing and fowling. In Animals and Man in the Past. In H. Buitenhuis & W. Prummel (Eds.), *Essays in honour of Dr. A.T. Clason* pp. 357–363. 2. Groningen, Netherlands: ARC-Publicatie.

MacDonald, K. C. (1993). Chickens in Africa: the importance of Qasr Ibrim. *Antiquity*, *67*(256), 584–590.

MacDonald, K. C. (1994). *Socio-economic diversity and the origins of cultural complexity along the Middle Niger (2000 BC to AD 300)* (Unpublished PhD thesis). University of Cambridge, Cambridge.

MacDonald, K. C. (1995). Analysis of the mammalian, avian and reptilian remains. In S. K. McIntosh (Ed.), *Excavations at Jenné-Jeno, Hambarketolo, and Kaniana (Inland Delta, Mali), the 1981 season* (pp. 291–318, 9). Berkeley, CA: University of California Press Publications in Anthropology.

MacDonald, K. C. (1996). The Windé Koroji complex: Evidence for the peopling of the eastern Inland Niger Delta (2100–500 BC). *Préhistoire Anthropologie Méditerranéennes*, *5*, 147–165.

MacDonald, K. C. (1997). Korounkorokalé revisited: The Pays Mande and the west African microlithic technocomplex. *African Archaeological Review*, *14*, 161–200.

MacDonald, K. C. (1997). The avifauna of the Haua Fteah (Libya). *Archaeozoologia*, *IX*, 83–102.

MacDonald, K. C., & Van Neer, W. (1993). An initial report on the fauna of Akumbu (Mali), Appendix 1. In T. Togola (Ed.), *Archaeological investigations of Iron Age sites in the Méma region (Mali)* (pp. 215–232, unpublished Ph.D. thesis). Houston, TX: Rice University.

MacDonald, K. C., & MacDonald, R. H. Report on the mammalian, avian and reptilian remains from the 1990 season at the sites of Culabel and Siouré (Sénégal). Unpublished manuscript, n.d.

MacDonald, K. C., & MacDonald, R. H. (2000). The origins and development of domesticated animals in arid West Africa. In R. Blench & K. MacDonald (Eds.), *The origins and development of African livestock. Archaeology, genetics, linguistics and ethnography* (pp. 127–162). London, UK: UCL Press.

MacDonald, K. C., & Van Neer, W. (1994). Specialised fishing peoples in the Later Holocene of the Méma (Mali). In W. Van Neer (Ed.), *Proceedings of the 7th meeting of the ICAZ, Fish remains working group*. Tervuren, Belgium: Annales du Musée royal de l'Afrique Centrale, Sciences zoologiques, 243-251. Annales du Musèe Royal de l'Afrique Centrale, Sciences Zoologiques 274.

MacDonald, R. H., & MacDonald, K. C. (1996). A preliminary report on the faunal remains recovered from Gao Ancien and Gao Saney (1993 season). In T. Insoll (Ed.), *Islam, Archaeology and History, Gao Region (Mali) ca AD900-1250* (pp. 124–126). Cambridge, UK: British Archaeological Reports, International series.

MacEachern, S., Bourges, C., & Reeves, M. (2001). Early horse remains from Northern Cameroon. *Antiquity*, *75*, 62–67.

Marean, C. W. (1985). The faunal remains from Smitswinkelbaai Cave, Cape Peninsula. *South African Archaeological Bulletin*, *40*, 100–102.

Marean, C. W. (1992). Hunter to herder: large mammal remains from the hunter-gatherer occupation at Enkapune Ya Muto rock-shelter, Central Rift, Kenya. *African Archaeological Review*, *10*, 65–127.

Marean, C. W. (1992). Implications of the Late Quaternary mammalian fauna from Lukenya Hill (south central Kenya) for paleoenvironmental change and faunal extinctions. *Quaternary Research*, *37*, 239–255.

Marean, C. W., Mudida, N., & Reed, K. E. (1994). Holocene palaeoenvironmental change in the Kenyan Central Rift as indicated by micromammals from Enkapune Ya Muto Rockshelter. *Quaternary Research*, *41*, 376–389.

Marinova, E., Linseele, V., & Vermeersch, P. (2008). Holocene environment and subsistence patterns near the Tree Shelter, Red Sea Mountains, Egypt. *Quaternary Research*, *70*, 392–397.

Marks, A. E., Peters, J., & Van Neer, W. (1987). Late Pleistocene and Early Holocene Occupations in the Upper Atbara River Valley, Sudan. In A. E. Close (Ed.), *Prehistory of arid North Africa, essays in honor of Fred Wendorf*. Dallas, TX: S.M.U. Press: (pp. 137–161).

Marshall, F. (2000). The origins and spread of domestic animals in East Africa, Chapter 10. In R. Blench & K. MacDonald (Eds.), *The origins and development of African livestock. Archaeology, genetics, linguistics and ethnography* (pp. 191–221). London, UK: UCL Press.

Marshall, F. B. (1986). *Aspects of the advent of pastoral economies in East Africa* (PhD thesis). University of California, Berkeley.

Marshall, F., & Stewart, K. (1994). Hunting, fishing and herding pastoralists of western Kenya: the fauna from Gogo Falls. *Archaeozoologia*, *7*, 7–27.

Mbida, C. M., Van Neer, W., Doutrelepont, H., & Vrydaghs, L. (2000). Evidence for banana cultivation and animal husbandry during the first millennium BC in the forest of Southern Cameroon. *Journal of Archaeological Science*, *27*, 151–162.

Mehlman, M. J. (1979). Mumba-Hühle revisited: The relevance of a forgotten excavation to some current issue in East African prehistory. *World Archaeology*, *11*, 80–94.

Merzoug, S., & Sari, L. (2008). Re-examination of the Zone I material from Tamar Hat (Algeria): Zooarchaeological and technofunctional analyses. *African Archaeological Review*, *25*, 57–73.

Midant-Reynes, B., Crubezy, E., Janin, T., & Van Neer, W. (1993). Le site prédynastique d'Adaïma. Rapport préliminaire de la quatrième campagne de fouille. *Bulletin de l'Institut Franäais d'Archéologie Orientale*, *93*, 349–370.

Monod, T. (1970). A propos d'un Aulacode (Thryonomys) du gisement néolithique d'Amekni (Ahaggar). *Bulletin de l'Institut fondamental d'Afrique noire*, *32*, 531–550.

Munson, P. (1974). Late Holocene climatic chronology of the southwestern Sahara. *Presented at the 3rd Biennal Meeting of the American Quaternary Association* (pp. 1–14). Madison, Wisconsin.

Munson, P. J. (1971). *The Tichitt Tradition: A late prehistoric occupation of the Southwestern Sahara* (PhD thesis). Champaign, IL: University of Urbana-Champaign.

Nespoulet, R., El Hajraoui, M. A., Amani, F., Ncer, A. B., Debénath, A., El Idrissi, A., … Stoetzel, E. (2008). Palaeolithic and Neolithic occupations in the Témara Region (Rabat, Morocco): Recent data on hominin contexts and behavior. *African Archaeological Review*, *25*. 21–39.

Opperman, H. (1978). Excavations in the Buffelskloof Rock Shelter near Calitzdorp, Southern Cape. *South African Archaeological Bulletin*, *33*, 18–38.

Ouchaou, B. (2000). *Les faunes mammalogiques holocènes des gisements du nord du Maroc: étude paléontologique et observations archéozoologiques* (PhD Thesis). University Moulay Ismail, Meknes, Morocco.

Pachur, H. J., & Hoelzmann, P. (1991). Paleoclimatic implications of late Quaternary lacustrine sediments in Western Nubia, Sudan. *Quaternary Research*, *36*, 257–276.

Pachur, H. J., & Kräpelin, S. (1987). Wadi Howar. Paleoclimatic evidence from an extinct river system in the Southeastern Sahara. *Science*, *237*, 298–300.

Pachur, H.-J., & Peters, J. (2001). The position of the Murzuq Sand Sea in the palaeodrainage system of the Eastern Sahara. *Palaeoecology of Africa*, *27*, 259–290.

Pällath, N. (2007). History hidden in bones: Holocene environmental change in northwestern Sudan. In M. Bollig, O. Bubenzer, R. Vogelsang, & H. P. Wotzka (Eds.), *Aridity, change and conflict in Africa* (pp. 91–104). Köln, Germany: Colloquium Africanum 2, Heinrich-Barth-Institut.

Paris, F. (1992). Chin Tafidet, village néolithique. *Journal des Africanistes*, *62*, 33–54.

Person, A., Ibrahim, T., Jousse, H., Finck, A., Alabret, C., Garenne-Marot, L., … Ould M'Heimam, S. (2004). Environnement et marqueurs culturels en Mauritanie sud-orientale: le site de Boä Khzâmâ (DN4), premiers résultats et approche biogéochimique. In A. Bazzana & A. Boccoum (Eds.), *Du nord au sud du Sahara: cinquante ans d'archéologie franäaise en Afrique de l'ouest et au Magreb, bilan et perspectives* (pp. 195–213). Paris, France: Sepia.

Peters, J. (1986). A revision of the faunal remains from two Central Sudanese sites: Khartoum Hospital and Esh Shaheinab. In P. Ducos (Ed.), *Archaeozoologia Mélanges, publiés à l'occasion du 5^e Congrès international d'archéozoologie Bordeaux, France, August*, 11–33.

Peters, J. (1987). The faunal remains collected by the Bagnold-Mond expedition in the Gilf Kebir and Jebel Uweinat in 1938. *Archéologie du Nil moyen*, *2*, 251–264.

Peters, J. (1989). Faunal remains and environmental change in central and eastern Sudan from terminal Pleistocene to middle Holocene times. *Mededelingen van de koninklijke Academie voor Wetenschappen Letteren en Schone Kunsten van België*, *4*, 123–147.

Peters, J. (1990). Late Palaeolithic ungulate fauna and landscape in the plain of Kom Ombo. *Sahara*, *3*, 45–52.

Peters, J. (1990). Late Pleistocene hunter-gatherers at Ishango (eastern Zaire): the faunal evidence. *Revue de Paléobiologie*, *9*(1), 73–112.

Peters, J. (1991). The faunal remains from Shaqadud, Chapter 10. In A. E. Marks & A. Mohammed-Ali (Eds.), *The late Prehistory of the Eastern Sahel: The Mesolithic and Neolithic of Shaqadud, Sudan* (pp, 197–235). Dallas, TX: Southern Methodist University Press.

Peters, J. (1993). Animal exploitation between the 5th and 6th Cataract: A preliminary report on the faunas from El Damer, Abu Darhein and Aneibis. In L. Krzyzaniak, M. Kobusiewicz, & J. Alexander (Eds.), *Environmental change and human culture in the Nile Basin and northern Africa until the second millennium BC* (pp. 413–419). Poznan, Poland: Poznam Archaeological Museum.

Peters, J., & von den Driesch, A. (1993). Mesolithic fishing at the confluence of the Nile and the Atbara, Central Sudan. In A. Clason, S. Payne, & H.-P. Uerpmann (Eds.), *Skeletons in her Cupboard: Festschrift for Juliet Clutton-Brock* (34, pp. 75–83). Oxford, UK: Oxbow Books.

Peters, J., & von den Driesch, A. (2002). Archäozoologisch-kulturhistorische Auswertung frühgeschichtlicher Krokodilknochen aus Al-Ma'abda (Mittelägypten). *Bonner Zoologische Beiträge*, *50*(3), 211–219.

Peters, J., Pöllath, N., & von den Driesch, A. (2002). Ichthyological diversity in the Holocene palaeodrainage systems of Western Nubia. *Africa Praehistorica*, 14, 325–335.

Petit-Maire, N. (1979). Le Sahara Atlantique ä l'Holocène. Peuplement et écologie. Alger: Mémoires du CRAPE.

Petit-Maire, N., & Riser J. (1983). Sahara ou Sahel? Quaternaire récent du bassin de Taoudenni (Mali) (pp.473). Marseille: Laboratoire de géologie du Quaternaire du Centre national de la recherche scientifique.

Plug, I. (1979). Namakala and Nanga: faunal report on two early Iron Age sites, Zambia. *South African Archaeological Bulletin*, *34*, 123–126.

Plug, I. (1981). Some research results on the Late Pleistocene and Early Holocene deposits of Bushman Rock Shelter, eastern Transvaal. *South African Archaeological Bulletin*, 36, 14–21.

Plug, I. (1989). Aspects of life in the Kruger National Park during the early Iron Age. *Goodwin Series*, *6*, 62–68.

Plug, I. (1989). Notes on distribution and relative abundances of some animal species, and on climate in the Kruger National Park during prehistoric times. *Koedoe*, *32*, 101–119.

Plug, I. (1996). Seven centuries of Iron Age traditions at Bosutswe, Botswana: a faunal perspective. *South African Journal of Science*, *92*, 91–97.

Plug, I. (1997). Cattle remains in some pre- and protohistoric societies of the central cattle pattern in Southern Africa. *Anthropozoologica*, *25*, 747–752.

Plug, I. (1997). Late Pleistocene and Holocene Hunter-Gatherers in the Eastern Highlands of South Africa and Lesotho: A faunal interpretation. *Journal of Archaeological Science*, *24*, 715–727.

Plug, I. (1999). Some Early Iron Age communities of the Eastern escarpment and lowveld, South Africa: A faunal perspective. In I. Plug & R. Klein (Eds.), *Archaeozoology in Africa* (pp. 189–200, 2). ArchaeoZoologia.

Plug, I. (2000). The faunal remains from Westbury, Ladybrabdt District, Free State, Appendix C. In C. R. Thorp (Ed.), *Hunter-gatherers and farmers: An enduring frontier in the Caledon Valley, South Africa*. Oxford, UK:British Archaeological Reports, International Series, 860, 87–88.

Plug, I., & Brown, A. (1982). Mgoduyanuka: Faunal remains. *Annals of the Natal Museum*, *25*, 115–121.

Plug, I., & Dippenaar, N. J. (1979). Evidence of Rattus rattus (House Rat) from Pont Drift, an Iron Age Site in Northern Transvaal. *South African Journal of Science*, *75*, 82.

Plug, I., Mitchell, P. J., & Bailey, G. (2003). Animal remains from Likoaeng, an open-air river site, and its place in the post-classic Wilton of Lesotho and the Eastern Free State, South Africa. *South African Journal of Science*, *99*, 143–151.

Plug, I., & Pistorius, J. C. (1999). Animal remains from industrial Iron Age communities in Phalaborwa, South Africa. *Archaeological Review*, *16*(3), 155–184.

Plug, I., & Roodt, F. (1990). The faunal remains from recent excavations at uMgungundlovu. *South African Archaeological Bulletin*, *45*, 47–52.

Plug, I., & Skelton, P. (1991). Fish and other faunal remains from a Late Iron Age site on the Letaba River, Kruger National Park. *Koedoe*, *34*, 1–6.

Plug, I., Soper, R., & Cirawu, S. (1997). Pits, tunnels and cattle in Nyanga, Zimbabwe: new light on an old problem. *South African Archaeological Bulletin*, *52*, 89–94.

Plug, I., & Voigt, E. A. (1985). Archaeozoological studies of Iron Age communities in southern Africa. *Advances in World Archaeology*, *4*, 189–238.

Raimbault, M., Guérin, C., & Faure, M. (1987). Les Vertébrés du gisement néolithique de Kobadi (Mali). *Archaeozoologia*, *I*, 219–238.

Reinold, J. (1987). Les fouilles pre- et proto-historiques de la section francaise de la direction des antiquités du Soudan: Les campagnes 1984–85 et 1985–86. *Archéologie du Nil Moyen*, *2*, 17–67.

Rivallain, J., & Van Neer, W. (1983). Les fouilles de Koyom (sud du Tchad): étude du matériel archéologique et faunique. *L'Anthropologie*, *87*, 221–239.

Rivallain J., & Van Neer W. (1984). Inventaire du matériel archéologique et faunique de Koyom, sud du Tchad. *L'Anthropologie*, *Paris*, *88*(3), 441–448.

Robbins, L. H., Campbell, A. C., Murphy, M. L., Brook, G. A., Liang, F., Skaggs, S. A., … Badenhorst, S. (2008). Recent archaeological research at Toteng, Botswana: early domesticated livestock in the Kalahari. *Journal of African Archaeology*, *6*(1), 131–149.

Robbins, L. H., Murphy, M. L., Stevens, N. J., Brook, G. A., Ivester, A. H., Haberyan, K. A., … Winkler, A. J. (1996). Paleoenvironment and archaeology of Drotsky's Cave, Western Kalahari Desert, Botswana. *Journal of Archaeological Science*, *23*, 7–22.

Robbins, L. H., Murphy, M. L., Brook, G. A., Ivester, A. H., Campbell, A. C., Klein, R. G., … Stevens, N. J. (2000). Archaeology, palaeoenvironment and chronology of the Tsodilo Hills White Paintings Rock Shelter, Northwest Kalahari Desert, Botswana. *Journal of Archaeological Science*, *27*, 1085–1113.

Robbins, L. H., Whitty, A.. Excavations at Harleigh farm near Rusape, Rhodesia, 1958–1962. *South African Archaeological Bulletin*, *21*, 61–80.

Robertshaw, P. T. (1977). Excavations at Paternoster, South Western Cape. *South African Archaeological Bulletin*, *32*, 63–73.

Roset, J.-P. (1987). Néolithisation, Néolithique et Post-Néolithique au Niger nord-oriental. *Bulletin de l'Association franäaise pour l'Etude du Quaternaire*, *4*, 203–214.

Roset, J.-P., de Broin, F., Faure, M., Gayet, M., Guérin, C., & Mouchet, F. (1990). La faune de Tin Ouaffadene et d'Adrar Bous 10, deux gisements archéologiques de l'Holocène ancien au Niger nord-oriental. *Géodynamique*, *5*, 67–89.

Scott, K., & Brink, J. S. (1992). Quaternary palaeoenvironments of pans in central South Africa: Palynological and palaeontological evidence. *Suid-Afrikaanse Geograaf*, *19*, 22–34.

Sereno, P. C., Garcea, E. A. A., Jousse, H., Stojanowski, C. M., Saliège, J-F., Maga, A., … Stivers, J. P. (2008). Lakeside cemeteries in the Sahara: 5000 years of Holocene population and environmental change. *PLoS ONE*, *3*, e2995.

Smith, A. B. (1974). Preliminary report of excavations at Karkarichinkat Nord and Karkarichinkat Sud, Tilemsi Valley, Republic of Mali. *West African Journal of Archaeology*, *4*, 33–55 + 7 pl.

Smith, A. B. (1975). A note on the flora and fauna from the post-paleolithic sites of Karkarichinkat Nord and Sud. *West African Journal of Archaeology*, *5*, 201–204.

Smith, A. B. (1980). The neolithic tradition in the Sahara. In M. A. J. Williams & H. Faure (Eds.), *The Sahara and the Nile* (pp. 451–465). Rotterdam, Netherlands: A.A. Balkema.

Smith, A. B. (1981). An archaeological investigation of Holocene deposits at Rooeils Cave, South-western Cape. *South African Archaeological Bulletin*, *36*, 75–83.

Smith, A. B. (2008). The Kiffian. In J. D. Clark & Gifford-Gonzalez, D. (Eds.), Adrar Bous, Archaeology of a central Saharan granitic ring complex in Niger (pp. 179–199). Tervuren, Belgium: Royal Museum for Central Africa.

Smith, A. B. (2008). The Tenerian. In J. D. Clark & D. Gifford-Gonzalez (Eds.), *Adrar Bous, Archaeology of a central Saharan granitic ring complex in Niger* (pp. 201–243). Tervuren, Belgium: Royal Museum for Central Africa.

Smith, A. B., Sadr, K., Gribble, J., & Yates, R. (1991). Excavations in the south-western Cape, South Africa, and the archaeological identity of prehistoric hunter-gatherers within the last 2000 years. *South African Archaeological Bulletin*, *46*, 71–91.

Smith, A. B., Yates, R., Miller, D., Jacobson, L., & Evans, G. (1995). Excavations at Geduld and the appearance of Early domestic stock in Namibia. *South African Archaeological Bulletin*, *50*, 3–14.

Stewart, K. M. (1989). Fishing site of North and East Africa in the Late Pleistocene and Holocene: Environmental change and human adaptation. Oxford, UK: British Archaeological Reports, International Series, 521.

Stewart, K. M., Stevens, N. J., & Robbins, L. H. (1991). Fish and reptiles from the Tsodilo Hills White Paintings Rock Shelter, Botswana. *Nyame Akuma*, *35*, 11–17.

Tauveron, M., Striedter, K. H., & Ferhat, N. (2009). Neolithic domestication and pastoralism in Central Sahara: the cattle necropolis of Mankhor (Tadrart Algérienne). In R. Baumhauer & J. Runge (Eds.), Holocene Palaeoenvironmental History of the Central Sahara (pp. 179-186). Leiden, Netherlands: CRC Press/Balkema.

Thackeray, A. I. (1979). An analysis of faunal remains from archaeological sites in southern South West Africa (Namibia). *South African Archaeological Bulletin*, *34*, 18–33.

Thilmans, G., & Ravisé, E. (1980). Protohistoire du Sénégal. Recherches archéologiques. T. II. Sintiou-Bara et les sites du fleuve. *Mémoires de l'Institut fondamental d'Afrique Noire*, *91*, 1–215.

Thorp, C. R. (2000). Hunter-gatherers and farmers. An enduring frontier in the Caledon Valley, South Africa. Oxford, UK: British Archaeological Reports, International Series, 860.

Togola, T. (1993). *Archaeological investigations of Iron Age sites in the Mema region, Mali (West Africa)* (PhD thesis). Houston, TX: Rice University.

Turner, G. (1986). Faunal remains from Jubilee Shelter, Transvaal. *South African Archaeological Bulletin*, *41*, 63–68.

Van Neer, W. (1978). Analyse de la faune trouvée dans les tombes de l'âge du Fer dans la dépression de l'Upemba, Zaïre. *Revue de Zoologie africaine*, *92*, 703–710.

Van Neer, W. (1986). Some notes on the fish remains from Wadi Kubbanyia (Upper Egypt, Late Palaeolithic). In D. C. Brinkhuizen & A. T. Clason (Eds.), *Fish and Archaeology. Studies in osteometry, taphonomy, seasonality and fishing methods* (pp. 103–113). Oxford, UK: British Archaeological Reports, International Series 294.

Van Neer, W. (1989). Contribution to the Archaeozoology of central Africa. *Tervuren: Musée royal de l'Afrique central*, *Annales des Sciences zoologiques*, *259*.

Van Neer, W. (1990). Description of Holocene vertebrate remains from archaeological sites in the Algerian Sahara. In L. Fiedler (Ed.), *Weitere Beiträge zur Urgeschichte der Sahara* (31, pp. 211–215). Marburg, Germany: Kleine Schriften aus dem Vorgeschichtlichen Seminar der Phillips-Universität Marburg.

Van Neer, W. (1990). Les faunes de vertébrés quaternaires en Afrique centrale. In R. Lanfranchi & D. Schwartz (Eds.), *Paysages quaternaires de l'Afrique centrale atlantique* (pp. 195–220). Paris, France: ORSTOM, Collection Didactiques.

Van Neer, W. (1994). Fish remains from Late Pleistocene and Holocene archaeological sites near Khasm el Girba, Sudan. *Archaeofauna*, *3*, 115–126.

Van Neer, W. (1995). Analysis of the fish remains. In S. K. McIntosh (Ed.), *Excavations at Jenné-Jeno, Hambarketolo, and Kaniana (Inland Delta, Mali), the 1981 season* (pp. 319–347). Berkeley, CA: University of California Press.

Van Neer, W. (1997). Archaeozoological data on the food provisioning of Roman settlements in the Eastern Desert of Egypt. *Archaeozoologia*, *9*, 137–154.

Van Neer, W. (1997). Etude des ossements animaux de l'amas coquillier de Ndiamon-Badat (Delta du Saloum). In G. Thilmans (Ed.), *Fouille et dégradations dans les Îles du Saloum* (pp. 15–21). Leuven, Belgium: Dakar.

Van Neer, W. (1999). Fish remains from the late Predynastic site of Maadi, Egypt. In C. Becker, H. Manhart, J. Peters, & J. Schibler (Eds.), *Historia Animalium ex Ossibus, Festschrift für Angela von den Driesch* (pp. 463–468). Leidorf, Germany, Rahden/Westfalen: Internationale Archäologie, Studia honoraria.

Van Neer, W. (2000a). Domestic animals from archaeological sites in Central and West-Central Africa, Chapter 9. In R. M. Blench & K. C. MacDonald (Eds.), *The Origins and Development of African Livestock: Archaeology, genetics, linguistics and ethnography* (pp. 163–190). London, UK: UCL Press.

Van Neer, W. (2000b). Faunal remains from Shuwikhat 1. In P. M. Vermeersch (Ed.), *Palaeolithic living sites in Upper and Middle Egypt* (pp. 153–154). Leuven, Belgium: Leuven University Press.

Van Neer, W. (2001). Animal remains from the medieval site of Kizimkazi Dimbani, Zanzibar. In B. S. Scarcia Amoretti (Ed.), *Islam in East Africa: New sources* (pp. 385–410). Roma, Italy: Herder.

Van Neer, W. (2001). Restes fauniques du site Badarien de Mahgar Dendera 2 (Haute Egypte). In S. Hendrickx, B. Midant-Reynes, & W. Van Neer (Eds.), *Mahgar Dendera 2 (Haute Egypte), un site d'occupation Badarien* (pp. 91–109). Leuven, Belgium: Leuven University Press.

Van Neer, W. (2002). Le matériel faunique. In B. Middant-Reynes and N. Buchez (Eds.), Adaïma 1- Economie et habitat. *Institut franäais d'archéologie orientale, Le Caire*, *45*, 521–565.

Van Neer, W. (2008). Fishing in the Senegal river during the Iron Age: The evidence from the habitation mounds of Cubalel and Siouré. In S. Badenhorst, P. Mitchell, & J. C. Driver (Eds.), *Animals and People: Archaeozoological Papers in Honour of Ina Plug* (pp. 117–130). Oxford, UK: Archaeopress, British Archaeological Reports, International Series 1849.

Van Neer, W., & Bocoum, H. (1991). Etude archéozoologique de Tulel-Fobo, site protohistorique (IVe-Xe siècle) de la moyenne vallée du Fleuve Sénégal (République du Sénégal). *Archaeozoologia*, *4*(1), 93–114.

Van Neer, W., & Breunig, P. (1999). Contribution to the archaeozoology of the Brandberg, Namibia. *Cimbebasia*, *15*, 127–140.

Van Neer, W., & Ervynck, A. (1998). The faunal remains. In S. E. Sidebotham & W. Z. Wendrich (Eds.), *Berenike 1996- Report of the 1996 Excavations at Berenike (Egyptian Red Sea Coast) and the survey of the Eastern Desert* (pp. 349–390). Leiden, Netherlands: CNWS Publications, Special Series.

Van Neer, W., & Ervynck, A. (1999). Faunal remains from Shenshef and Kalatlat. In S. E. Sidebotham & W. Z. Wendrich (Eds.), *Berenike 1997- Report of the 1997 Excavations at Berenike and the survey of the Egyptian Eastern Desert, including excavations at Shenshef* (4, pp. 431–445). Leiden, Netherlands: CNWS Publications. Special Series.

Van Neer, W., & Gayet, M. (1988). Etude des poissons en provenance des sites holocènes du Bassin de Taoudenni-Araouane (Mali). *Bulletin du Muséum national d'Histoire naturelle*, *10*, section C (4), 343–383.

Van Neer, W., & Lanfranchi, R. (1985). Etude de la faune découverte dans l'abri Tshitolien de Ntadi Yomba (République Populaire du Congo). *L'Anthropologie*, *89*(3), 351–364.

Van Neer, W., & Lanfranchi, R. (1986). Une association de faune et d'industrie du Tshitolien (Age récent de la pierre, 7000 B.P.) dans l'abri de Ntadi Yomba (Région du Niari) en R.P. du Congo. Elements nouveaux pour un essai de reconstitution du paysage ä cette époque. Comptes Rendus de l'Académie des sciences t. 302, série II, 831–834.

Van Neer, W., & Lentacker, A. (1996). The faunal remains. In S. Sidebotham & W. Wendrich (Eds.0, *Berenike '95. Preliminary report of the excavations at Berenike (Egyptian Red Sea Coast) and the survey of the Eastern Desert* (2, pp. 337–355). Leiden, Netherlands: CNWS Publications. Special Series.

Van Neer, W., & Lesur, J. (2004). The ancient fish fauna from Asa Koma (Djibouti) and modern osteometric data on 3 Tilapiini and 2 Clarias catfish species. *Documenta Archaeobiologiae*, *2*, 141–160.

Van Neer, W., Linseele, V., & Friedman, R. (2004). Animal burials and food offerings at the Elite Cemetry HK6 of Hierakonpolis. In S. Hendrickx, R. F. Friedmann, K. M. Cialowicz, & M. Chlodnicki (Eds.), *Egypt at his origins*, *Studies in Memory of Barbara Adams*, *Orientalia Lovaniensia Analecta* 138 (pp. 67–130). Leuven, Belgium: Peeters.

Van Neer, W., Paulissen, E., & Vermeersch, P. M. (2000). Chronology, subsistence and environment at the late palaeolithic fishing sites of Makhadma 2 and 4. In P. M. Vermeersch (Ed.), *Palaeolithic living sites in Upper and Middle Egypt* (pp. 271–287). Leuven, Belgium: Leuven University Press.

Van Neer, W., & Sidebotham, S. (2002). Animal remains from the fourth-sixth century A.D. military installations near Abu Sha'ar at the Red Sea coast, Egypt. In Jennerstrasse 8 (Ed.), *Tides of the desert—Gezeiten der Wüste. Contributions to the archaeology and environmental history of Africa in honour of Rudolph Kuper* (14, pp. 171–195). Köln, Germany: Heinrich-Barth-Institut, Africa Praehistorica 14, Monographs on African Archaeology and Environment.

Van Neer, W., & Uerpmann, H.-P. (1989). Palaeoecological significance of the Holocene Faunal remains. Forschungen zur Umweltgeschichte der Ostsahara. R. Kuper. *Köln*, *Africa Praehistorica*, *2*, 307–341.

Van Peer, P., Vermeersch, P., Moeyersons, J., & Van Neer, W. (1996). Palaeolithic sequence of Sodmein Cave, Red Sea Mountains, Egypt. In G. Pwiti & R. Soper (Eds.), *Aspects of African Archaeology*. Harare, Zimbabwe: University of Zimbabwe Publications, 149–156.

Van Rijssen, W. J. (1992). The Late Holocene deposits at Klein Kliphuis Shelter, Cedarberg, Western Cape Province. *South African Archaeological Bulletin*, *47*(155), 34–43.

Van Schalkwyk, J. (1994). Wosi: An Early Iron Age village in the lower Thukela Basin, Natal. *Natal Museum Journal of Humanities*, *6*, 65–117.

Van Waarden, C. (1987). Matanga, a Late Zimbabwe cattle post. *South African Archaeological Bulletin*, *42*, 107–124.

Vélardé, I. (1994). *La faune de Hamdallahi (Mali, XIXème S.) et les origines du boeuf en Afrique: Etude archéozoologique et essai de synthèse critique* (Travail de diplôme). Université de Genève—Faculté des Sciences—Département d'Anthropologie et d'Ecologie, Geneva.

Vermeersch, P. M. (2002). The Egyptian Nile Valley during the early Holocene. In Jennerstrasse 8 (Ed.), *Tides of the Desert—Gezeiten der Wüste* (pp. 27–40). Köln, Germany: Heinrich-Barth-Institut, Africa Praehistorica 14, Monographs on African Archaeology and Environment.

Vermeersch, P. M., Paulissen, E., & Van Neer, W. (1989). The Late Paleolithic Makhadma sites (Egypt): Environment and subsistence. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Late Prehistory of the Nile Basin and the Sahara* (pp. 87–114). Poznan, Poland: Poznan Archaeological Museum.

Vermeersch, P. M., Van Peer, P., & Paulissen, E. (2000). El Abadyia, a Shuwikhatian site, Chapter 7. In P. M. Vermeersch (Ed.), *Palaeolithic living sites in Upper and Middle Egypt*. (pp. 159–199). Leuven, Belgium: Leuven University Press.

Vermeersch, P. M., Van Neer, W., & Hendrickx, S. (2004). El Abadiya 2, Naqadq I site near Danfiq, Upper Egypt. In S. Hendrickx, R. F. Friedmann, K. M. Cialowicz, & M. Chlodnicki (Eds.), *Egypt at his origins*, *Studies in Memory of Barbara Adams*, *Orientalia Lovaniensia Analecta* (138, pp. 213–276).

Vermeersch, P. M., Van Peer, P., Moyersons, J., & Van Neer, W. (2002). The Tree Shelter, a Holocene site in the Red Sea Mountains. *Archéo-Nil*, *12*, 123–138.

Vermeersch, P. M., Van Peer, P., Moeyersons, J., & Van Neer, W. (1994). Sodmein Cave site, Red Sea Mountains. *Sahara*, *6*, 31–40.

Vernet, R. (1998). Inventaire des datations 14C, Coopération française.

Vernet, R., Hervé-Gruhier, C., Saliège, J. F., lamarche, B., & Cherif, O. (2004). Le peuplement de l'île Tidra (Banc d'Arguin, Mauritanie) ä l'Holocène récent. In *Actes du XIe Congrès Panafricain de Préhistoire*. Bamako, Mali, thème 6, pp. 8.

Vogel, J., Plug, I., & Webbley, L. (1997). New dates for the introduction of sheep into South Africa: the evidence from Spoegrivier Cave in Namaqualand. *South African Journal of Science*, *93*, 246–248.

Voigt, E. (1979). The faunal remains from Icon. *South African Archaeological Society*, *Goodwin Series*, 3, 80–85.

Voigt, E. A. (1973). Faunal remains from the Iron Age site of Matope Court, Namichimba and Chikumba, southern Malawi. In K. R. Robinson (Ed.), *The Iron Age of the Upper and Lower Shire*, *Malawi* (pp. 135–167). Zomba, Malawi: Government Press.

Voigt, E. A. (1980). Reconstructing Iron Age economy of the northern Transvaal: A preliminary report. *South African Archaeological Bulletin*, *35*, 39–45.

Voigt, E. A. (1984). Faunal remains from Magogo and Mhlopeni: small stock herding in the Early Iron Age of Natal. *Annals of the Natal Museum*, *26*, 141–163.

Voigt, E. A. (1984). Iron Age herders of the northern transvaal, South Africa, in the first millennium A.D. In J. C. Brock & C. Grigson (Eds.), *Animals and Archaeology: 3. Herders and their Flocks* (pp. 371–393, 4). Oxford, UK.

Voigt, E. A., & Peters, J. (1994). The faunal assemblage from the Early Iron Age site of Mamba 1 in the Thukela Valley, Natal. *Natal Museum Journal of Humanities*, *6*, 145–152.

Voigt, E. A., & Peters, J. (1994). The faunal assemblage from Wosi in the Thukela Valley. *Natal Museum Journal of Humanities*, *6*, 105–117.

Voigt, E. A., & Plug, I. (1984). Happy Rest: the earliest Iron Age fauna from the Soutpansberg. *South African Journal of Science*, *80*, 221–227.

Voigt, E. A., & von den Driesch, A. (1984). Preliminary report on the faunal assemblage from Ndondondwane, Natal. *Annals of the Natal Museum*, *25*, 95–104.

von den Driesch, A. (1983). Some archaeozoological remarks on fishes in Ancient Egypt. *Animals and Archaeology*, *British Archaeological Reports 2*.

von den Driesch, A. (1986). Fische im Alten Ägypten. Eine Osteoarchäologische Untersuchung. *Documenta Naturae*, *34*, 1–33.

von den Driesch, A. (1986). Tierknochenfunde aus Qasr el-Sagha, Fayoum (Neolithikum und Mitteles Reich). *Mitteilungen des deutschen Archäologischen Instituts Abteilung Kairo*, *42*, 1–8.

von den Driesch, A. (1997). Tierreste aus Buto im Nildelta. *Archaeofauna*, *6*, 23–39.

von den Driesch, A., & Boessneck, J. (1983). A Roman Cat Skeleton from Quseir on the red Sea Coast. *Journal of Archaeological Science*, *10*, 205–211.

von den Driesch, A., & Boessneck, J. (1985). *Die Tierknochenfunde aus der neolitischen Siedlung von Merimde-Benisalâme am westlichen Delta*. Deutsches Archäologisches Institut Abteilung Kairo.

von den Driesch, A., & Boessneck, J. (1985). Krankhaft veränderte Skelletreste von Pavianen aus altägyptischer Zeit. *Tierärztliche Praxis*, *13*, 367–372.

von den Driesch, A., & Deacon, H. J. (1985). Sheep remains from Boomplaas Cave, South Africa. *The South African Archaeological Bulletin*, *40*, 39–44.

von den Driesch, A., Kessler, D., & Peters, J. (2004). Mummified baboons and other primates from the Saitic-Ptolemaic animal necropolis of Tuna el-Gebel, Middle Egypt. *Documenta Archaeobiologiae*, *2*, 231–278.

von den Driesch, A., & Peters, J. (2001). Frühe Pferde- und Maultierskelette aus Auaris (Tell El-Dab'a), Östlisches Nildelta. In M. Bietak (Ed.), *Ägyptian und die Levante*, *11*, 301–311.

Wadley, L. (1995). Review of dated Stone Age sites recently excavated in the eastern Free State, South Africa. *South African Journal of Science*, *91*, 574–579.

Watson, E. J. and Watson, V. (1990). Of commoners and kings': faunal remains from Ondini. *South African Archaeological Bulletin*, *45*, 33–46.

Wendorf, F., & Schild, R. (1994). Are the early Holocene cattle in the eastern Sahara domestic or wild? *Evolutionary Anthropology*, *3*, 118–128.

Wendorf, F., Schild, R., Close, A. E., Hillman, G. C., Gautier, A., Van Neer, W., … Linick, T. W. (1988). New radiocarbon dates and Late Palaeolithic diet at Wadi Kubbaniya, Egypt. *Antiquity*, *62*, 279–283.

Wendt, E. W., and Reed, C. A. (1966). Two prehistoric archaeological sites of Egyptian Nubia. *Postilla*, *102*, 1–46.

Wilson, M. L. (1988). Forest Hall Shelter: an early excavation on the Southern Cape Coast. *South African Archaeological Bulletin*, *43*, 53–55.