

Birds as indicators of Early Holocene biodiversity and the seasonal nature of human activity at WF16, an early Neolithic site in Faynan, Southern Jordan

Article

Published Version

Creative Commons: Attribution 4.0 (CC-BY)

Open Access

Mithen, S. ORCID: <https://orcid.org/0000-0002-3391-7443>, White, J., Finlayson, B., Greet, B. and Khoury, F. (2022) Birds as indicators of Early Holocene biodiversity and the seasonal nature of human activity at WF16, an early Neolithic site in Faynan, Southern Jordan. *Journal of Quaternary Science*, 37 (6). pp. 1148-1163. ISSN 0267-8179 doi: 10.1002/jqs.3429 Available at <https://centaur.reading.ac.uk/104671/>

It is advisable to refer to the publisher's version if you intend to cite from the work. See [Guidance on citing](#).

To link to this article DOI: <http://dx.doi.org/10.1002/jqs.3429>

Publisher: Wiley

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the [End User Agreement](#).

www.reading.ac.uk/centaur

CentAUR

Central Archive at the University of Reading

Reading's research outputs online

Birds as indicators of early Holocene biodiversity and the seasonal nature of human activity at WF16, an early Neolithic site in Faynan, Southern Jordan

STEVEN MITHEN,^{1*} JUDITH WHITE,² BILL FINLAYSON,³ BEN GREET⁴ and FARES KHOURY⁵

¹Department of Archaeology, School of Archaeology, Geography and Environmental Science (SAGES), University of Reading, Reading, UK

²Department of Life Sciences, Natural History Museum, Tring, UK

³School of Archaeology, Oxford, UK

⁴Religionwissenschaftliches Seminar, Universität Zurich, Zurich, Switzerland

⁵Department of Biology and Biotechnology, Faculty of Science, American University of Madaba, Amman, Jordan

Received 16 December 2021; Revised 24 March 2022; Accepted 28 March 2022

ABSTRACT: Birds are useful indicators of biodiversity. Their bones have been used for reconstructing the local environments and seasonality of human activity at Epipalaeolithic and early Neolithic sites in south-west Asia. We consider the bird bones from WF16, an early Neolithic settlement in southern Jordan, currently located in an arid environment. The settlement has elaborate pisé-built architecture and material culture. The species represented in the WF16 avian assemblage suggest the environment was considerably wetter and more wooded than today, supporting the idea that early Holocene communities targeted locations with abundant and diverse resources. However, while the range of species at WF16 is equivalent to that found at other Epipalaeolithic and early Neolithic sites in the region, the diversity of the assemblage is strikingly limited, with a heavy dominance of raptors, notably buzzards. We suggest an annual pattern of seasonally based activities, with a relatively small resident population drawing on supplies of water during the winter months for constructing and maintaining site architecture and spring/autumn gatherings of people from across the region to hunt migratory raptors and undertake performance and ceremony at the settlement.

© 2022 The Authors. *Journal of Quaternary Science* Published by John Wiley & Sons Ltd.

KEYWORDS: bird bones; Faynan; Jordan; Neolithic; seasonality

INTRODUCTION

Understanding the role of climatic and environmental change in the transition from mobile hunting and gathering to sedentary farming communities in south-west Asia requires studies at both regional and local scales of analysis. The use of multiproxy approaches for the former has provided compelling evidence that in certain regions of south-west Asia there was a human response to climate change, notably in the abrupt warming periods at c. 14.5 and 11.7 ka BP for which summed probability distributions (SPDs) of calibrated radiocarbon dates and site numbers suggest population growth (Roberts *et al.*, 2018; Palmisano *et al.*, 2021). These analyses indicate a marked population rise in the southern Levant associated with the earlier warming period, and hence related to the Natufian culture, while that in the northern Levant was associated with the later warming period and related to the Pre-Pottery Neolithic. Such studies need to be evaluated and complemented by reconstructing the local environments around archaeological sites: we need to consider how people made day-to-day decisions in response to ecological conditions, seasonal change, and short-term events, such as periods of winter rainfall or prolonged drought. The 'human responses to climate change' as detected by the long-term, regional, multiproxy models arose from the accumulated decisions made by multiple generations of geographically dispersed communities.

Making inferences about local environments can be challenging within the often arid and eroding landscapes of south-west Asia. Fine-grained sedimentary deposits that contain pollen and/or other microfossils for palaeoenvironmental reconstruction are rarely found in the immediate vicinity of archaeological sites. The large mammals represented among faunal remains, such as gazelle, ibex and bezoar, may have been hunted at some distance, while the on-site preservation of plant remains is frequently poor and often biased by a range of cultural and taphonomic factors.

These constraints are relevant for WF16, an early Neolithic settlement in southern Jordan, dating to between 11.84 and 10.24 ka BP (Figs. 1 and 2; Mithen *et al.*, 2018). Located in an arid environment today, this site has relatively elaborate architecture and material culture when compared with contemporary sites in the region. Might this reflect a local response to diverse and abundant resources that were once available in the now arid landscape surrounding WF16? In this contribution we consider whether the bird bones from WF16 can provide insights into that local environment, what the bird bones indicate about the seasonality and nature of human activity, and how these compare with those at Epipalaeolithic and Neolithic sites elsewhere in the Levant.

Birds as indicators of biodiversity and environmental change

Birds are recognised as good indicators for overall biodiversity and environmental change, especially in terrestrial habitats

*Correspondence: S. Mithen, as above.
E-mail: S.J.Mithen@reading.ac.uk

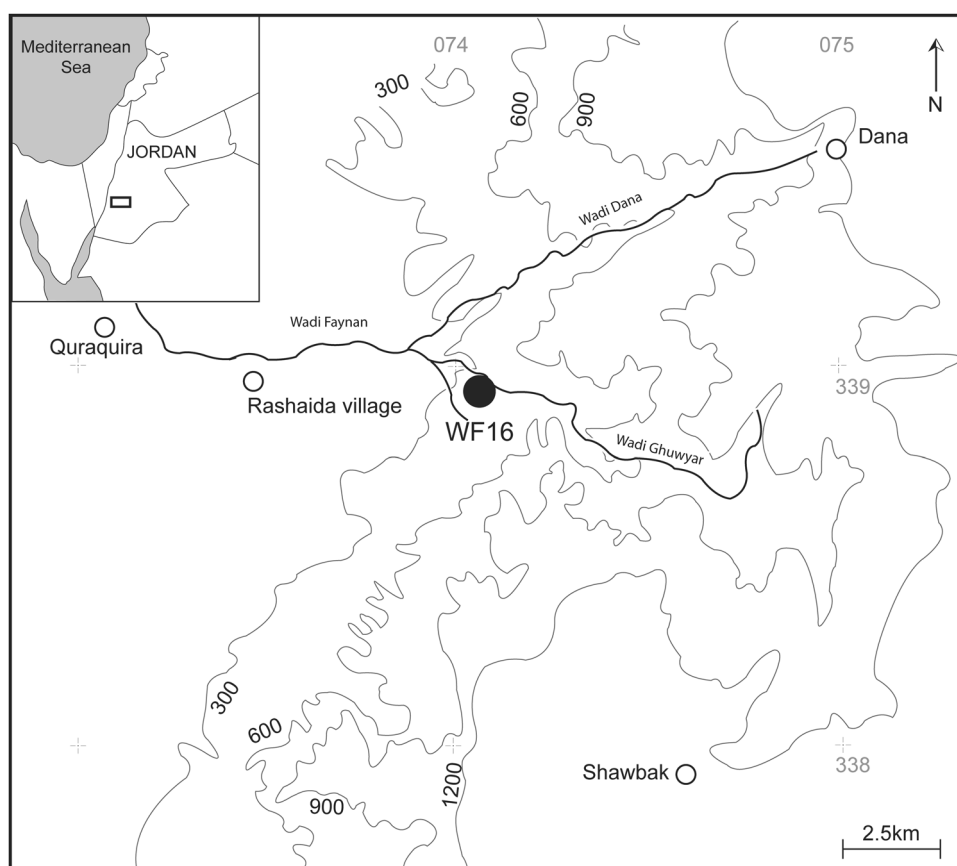


Figure 1. The location of WF16 in southern Jordan, at the confluence of Wadis Dana, Faynan and Ghuwyar.



Figure 2. The knoll of WF16, viewed from the south (image: Richard Tipping). [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)].

where their range and diversity can capture those of plants and mammals (Brooks *et al.*, 2001; Donald *et al.*, 2001; Gregory *et al.*, 2003; BirdLife International, 2013; Fraixedas *et al.*, 2020). The Levant has considerable potential for using birds in this manner. This arises from the number of excavated archaeological sites with bird bones, its geographical context and its diverse environments that provide an opportunity for high levels of avian diversity. The region is positioned at the interface between Africa, Asia and Europe, encompassing sandy desert, rocky slopes, mountains, woodland, rivers and wetlands. Many bird species are resident today, while others either visit or pass through the region as migrants into Jordan and Israel or as passage migrants to/from Europe and Africa (Andrews, 1995). Most notable are large flocks of raptors and storks making use of thermals along the corridor of the Wadi

Araba and Jordan Valley, with seasonally restricted periods of migration. Many of the migratory and resident species are adapted to specific types of habitat, such as woodland, wetlands, marshes and rocky slopes. Although recent agricultural intensification and urban development has reduced biodiversity, the present-day avian fauna can provide a baseline against which to compare that from the more distant past as derived from archaeological assemblages.

When dealing with archaeological samples there are numerous factors that will bias the range and diversity of bird taxa present. Primary among these is human selection – only a fraction of the bird taxa in the local environment are likely to have been captured/killed and then discarded in a manner that would lead to their representation in the archaeological assemblage. People might choose to trap just one species

from a wide array, selecting this for its food value or exotic feathers. Some bones might derive from birds killed far from the settlement, perhaps brought to the site by visitors as exotic gifts or simply because of long-distance hunting expeditions. Conversely, some birds might be present in the archaeological assemblage that had died at the archaeological site after it was abandoned by people. They may have scavenged on rubbish or used deserted structures for roosting and nesting.

A further set of challenges arises from differential preservation and identification. Small birds and those with fragile bones are less likely to be preserved than larger and more robust types, while fragmentation may result in a relatively small proportion of bird bones being identified to taxa. Taxonomic identification can also depend on the availability of reference material; for this study we used the reference collection of the Natural History Museum, Tring. Translating the number of identified specimens (NISP) for a taxon into the minimum number of individuals (MNI) can be problematic, causing archaeologists to often use NISP when measuring the abundance of taxa and diversity within an assemblage.

When using archaeological evidence as environmental indicators, we must assume the ecological preferences of the birds represented were similar to those of the present day. Likewise, if we are to make inferences about the seasonality of their presence, and hence of the people exploiting them, we must assume that past patterns of migration remain unchanged. These are not unreasonable assumptions, with ecological preferences being determined by body size and physiology and simulation studies indicating a stability in global patterns of bird migration for 50 000 years (Somveille *et al.*, 2020). When variations in migratory patterns have been detected, these relate to short and medium distances within continental areas, rather than long-distance migration, such as along the Wadi Araba routeway (e.g. Miller-Rushing *et al.*, 2008; Martin *et al.*, 2014). A major influence on local patterns of migration in the southern Levant has been a decline in the overall presence and distribution of water resources, including the replacement of natural pools with artificial reservoirs and ponds. Topography, however, dictates that Wadi Faynan will have always provided a route from the Wadi Araba to the Jordanian plateau.

The opportunity provided by the geography and environmental diversity of the Levant has enabled archaeologists to make effective use of bird bones to reconstruct local habitats and seasonal patterns of human activity during the Epipalaeolithic and early Neolithic (e.g. Tchernov, 1994; Simmons and Nadel, 1998; Gourichon, 2002; Martin *et al.*, 2013; Simmons, 2004; Zeder and Spitzer, 2016; Yeomans and Richter, 2018). Although drawing trends from a relatively small number of assemblages is problematic, these studies suggest a shift from a predominant exploitation of migratory waterfowl in the winter seasons during the Epipalaeolithic, as represented at Ohalo II (Simmons and Nadel, 1998) and Shubayqa (Yeomans and Richter, 2018), to a more balanced exploitation of taxa from diverse habitats during the early Neolithic, such as at Hallan Çemi (Zeder and Spitzer, 2016), Netiv Hagdud (Tchernov, 1994) and Jerf el Ahmar (Gourichon, 2002). Simmons (2004) initially proposed this trend based on sites in the Jordan Valley, while Zeder and Spitzer (2016) concluded their study of the Hallan Çemi avifauna by supporting long held views reaching back to Flannery (1969) that that, 'people across the Fertile Crescent seemed to capitalize on new opportunities afforded by Early Holocene climatic amelioration. They targeted specific locations where abundant and diverse resources could be found within well-defined catchments ... the constructed subsistence strategies that yielded a secure, year-round resource base, allowing

these small communities to remain together for longer periods of time.' (Zeder and Spitzer, 2016: 156).

One of the challenges with making such interpretations is the range of potentially biasing factors and the often small size of the avian assemblages. The 68 species present at Ohalo II, for instance, are represented by only 488 specimens, with 48 of the taxa each represented by a single bone; Simmons (2004) drew on the Neolithic sites of Gilgal, Ain Darat, Fazael Vi and Salabiya IX, but each has fewer than 100 specimens. This makes WF16 a particularly important assemblage. With 7808 specimens identified to taxa, this is twice as large as the next largest, that coming from Shubayqa I (NISP = 3080; Yeomans and Richter, 2018) and more than five times larger than the Neolithic assemblages from Netiv Hagdud (1214), Hallan Çemi (1154) and Jerf el Ahmar (1554). What inferences can be drawn from the WF16 assemblage about the early Holocene environment of Faynan? Does this assemblage confirm or challenge Zeder and Spitzer's claim that Neolithic communities targeted specific locations where abundant and diverse resources could be found? What does it indicate about the seasonality and nature of human activity?

WF16: Present-day and past environments

WF16 is located at the confluence of Wadi Ghuwayr and Wadi Dana, which merge into Wadi Faynan that drains into the Wadi Araba (Fig. 1). To its immediate east the land climbs steeply to the Jordanian plateau (Fig. 2), while to the west it opens onto a broad flat desert landscape (Fig. 3). The climate is arid with hot summers and mild winters, with a mean annual temperature of 24°C and mean annual precipitation of 60 mm. Rain falls occasionally in the winter months, when temperatures are 15° lower than in the summer. Rainfall in the mountains can lead to unpredictable and sometimes destructive flash floods. Springs in the lower reaches of Wadi Ghuwayr supply a stream in Wadi Faynan that flows close to the WF16 site, although this can disappear when the water table falls.

Habitats in the immediate vicinity of WF16 include sand plains and dunes; acacia, tamarisk and oleander-dominated scrub; rocky slopes and mountainsides. The springs in the lower reaches of Wadi Ghuwayr support dense woodland comprising *Salix acmophylla*, *Populus euphratica*, *Nerium oleander*, *Tamarix amplexicaulis*, *Ficus carica*, *Phoenix dactylifera*, *Smilax aspera*, *Phragmites australis* and *Arundo donax* (Palmer *et al.*, 2007). These local habitats and Faynan's position on the migratory flyway support a diverse bird fauna, with 187 species having been identified in Faynan, 42 of which are resident and the remainder migratory species (Mithen *et al.*, 2019).

Palaeoenvironmental, historical and archaeological evidence suggests that Faynan was previously wetter and supported higher levels of vegetation. Computer modelling indicates that precipitation was higher in the early Holocene, falling to its present-day levels between 10.0 and 6.0 ka BP (Brayshaw *et al.*, 2011). During the Nabataean and Roman periods, aqueducts carried water from Wadi Ghuwayr to support extensive farming and copper production along the course of Wadi Faynan (Barker *et al.*, 2007), reducing that available to support riparian woodland. The introduction of irrigation pipes and small reservoirs since the 1990s to irrigate fields growing tomatoes and melons now leaves Wadi Faynan entirely dry for most, sometimes all, of the year.



Figure 3. WF16 under excavation in April 2010, viewed from the east looking along the Wadi Faynan (image: Steven Mithen). [Color figure can be viewed at wileyonlinelibrary.com].

The known history of settlement suggests that vegetation, and especially woodland, would have been reduced, if not devastated, by human activity. This would have begun in the later Neolithic with grazing from domesticated goats and land clearance for fields. The copper industry from the early Bronze Age to the classical periods would have aggravated vegetation loss, as this requires huge quantities of timber for fuel and pit props. In more recent times and continuing to the present day, the construction of roads, houses and dams has further reduced the extent of woodland and biodiversity in general (Barker *et al.*, 2007; Mithen and Black, 2011; Khoury and Korner, 2018).

The reduction of vegetation is likely to have had a substantial impact on the hydrological regime because vegetation enhances the infiltration of rainfall into the soil. Simulation models for the hydrology of Faynan have shown that with increased infiltration, especially in the upland catchments, water accumulates in the groundwater store to produce a higher perennial flow while reducing the frequency and magnitude of floods, downcutting and erosion (Wade *et al.*, 2011). As such, one might expect that the Wadi Ghuwayr springs and the Wadi Faynan stream would have been more substantial during the early Holocene, possibly leading to large pools of standing water.

Direct evidence for early Holocene vegetation comes from wood charcoal and plant macros from the excavations at WF16 and pollen records from nearby sediments. These indicate that early Holocene vegetation had the same range of species as today, with *Juniperus*, *Pinus*, *Ulmus*, *Olea* and *Quercus* (Hunt *et al.*, 2004; Mithen *et al.*, 2007). Phytoliths from WF16 indicate extensive use of reeds (Jenkins and Rosen, 2007) of the type that are now found in Wadi Ghuwayr. While it is tempting to suggest that this vegetation was more abundant and growing as riparian woodland in the immediate vicinity of WF16, there is no direct evidence that was the case: all these trees and plants can still be found within a day's walking distance of WF16 and

hence cannot be used as strong indicators of local environmental change.

WF16: the Neolithic settlement and economy

WF16 was discovered in 1996, evaluated between 1997 and 2001 (Finlayson and Mithen, 2007) and subject to area excavation between 2008 and 2010 (Mithen *et al.*, 2018). This revealed a dense cluster of pisé-constructed semi-subterranean structures, interpreted as a mix of dwellings, store-rooms and workshops, representing considerable investment in this place (Figs. 4 and 5). An amphitheatre-like structure (Structure O75 on Figs. 4, 6 and 7) suggests communal activity was required for its construction and implies gatherings of people for performance and ceremony. The overall scale of the settlement, however, does not suggest that large numbers of people were permanently resident. At c. 10.8 ka BP there was a shift to free-standing circular structures, often with burials placed below their floors that cut into the earlier semi-subterranean structures. The amphitheatre-like structure was reused as a centralised midden for the settlement. These developments suggest an increased degree of sedentism.

The pisé-based architecture implies that water is likely to have been readily available. Experimental reconstruction of a small semi-subterranean structure from WF16 required 3000 l of water to make c. 5.5 m³ of mud for its pisé walls and floors (Flohr *et al.*, 2015). The number and size of structures at WF16, notably the 20 m × 18 m amphitheatre-like structure, suggests that large quantities of water must have been readily available for their construction.

Excavations at WF16 recovered abundant material culture: chipped and coarse stone, worked bone artefacts, stone and shell beads, decorated stone and bone objects, anthropomorphic and zoomorphic figures (Mithen *et al.*, 2018). Although only coming from a small sample, perhaps 10%, of the archaeological deposits, the quantity and diversity of this material culture exceeds that from broadly contemporary

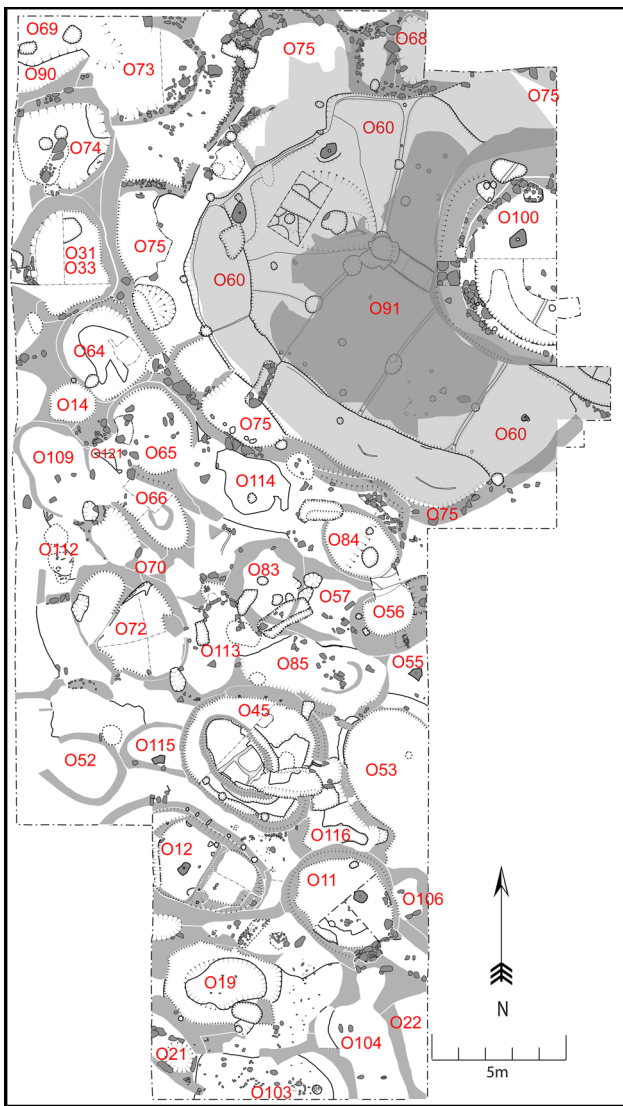


Figure 4. Excavation plan of WF16 showing dense cluster of semi-subterranean pisé-built structures. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)].

settlements in the region such as ZAD 2 (Edwards *et al.*, 2002), El-Hemmeh (Makarewicz *et al.*, 2006), Dhra' (Finlayson *et al.*, 2003), and further afield including Netiv Hagdud (Bar-Yosef and Gopher, 1997) and Gilgal (Bar-Yosef *et al.*, 2010). The quantity of stone beads may indicate the significance of the settlement. Approximately 500 stone beads were recovered, some of particularly elaborate design (e.g. Mithen *et al.* 2018: Figs 27.6, 35.16, 38.8). When constructing Neolithic stone bead typology for the Levant, Bar-Yosef Mayer (2013) had to rely on 453 beads coming from 22 sites, with the PPNA sites of Netiv Hagdud, Gilgal and Ain Darat providing 13, 16 and 1, respectively.

This flourishing of early Neolithic architecture and culture at WF16 was based on an economy of hunting and gathering. Plant material from the 2008–2010 excavation remains under study but initial indications confirm that a wide range of seeds from legumes and grasses, including barley, were utilised, as recognised from the 1997–2003 site evaluation (Kennedy, 2007). The current samples are insufficiently preserved to identify whether these are entirely wild or partially domesticated. The latter would not be surprising considering the archaeobotanical evidence from Dhra', 50 km north (Colledge *et al.*, 2018), and evidence for the types of raised floors at WF16 that have been interpreted as granaries

at Dhra' (Mithen *et al.*, 2018: Fig. 8.4 and 14.41; Kuijt and Finlayson, 2009).

The analysis of the mammalian remains is ongoing, but a clear pattern has emerged of a heavy focus on the exploitation of goats, probably ibex, with some exploitation of gazelle and aurochs, and a limited presence of other taxa (Carruthers and Dennis 2007). The fauna appear considerably less diverse than at the contemporary sites of El-Hemmeh and Dhra' which have higher proportions and a greater range of small game (Makarewicz and Finlayson, 2021). Whether this reflects the immediate environment around the site or economic decisions about what to hunt remains unclear, and might be tested by considering the bird bones from WF16.

Bird bones from WF16

The 2008–2010 excavations recovered 17 700 bird bones, of which 7808 were identified to at least family level or the order of Passeriformes (Fig. 8; White *et al.*, 2021a). At least 63 bird taxa are represented. As evident from Fig. 8, Accipitridae dominate the assemblage, constituting c. 90% of identified specimens, and within that family, *Buteo* cf. *buteo* are most frequent, providing c. 63% of the Accipitridae specimens, Fig. 9.

An analysis of body parts and cut marks indicated that steppe buzzards had been brought to the settlement as whole carcasses. Some of these were skinned, as may have also been the case for honey buzzards and kites, and some were processed for consumption (White *et al.*, 2021b). Other large birds, including the lappet-faced vulture, eastern Imperial, Bonelli's and Verreaux's eagles, were probably utilised for their plumage, as only their wing bones were present at the site, several with indicative cut marks. The white stork, northern bald ibis, and little egret also provide strong evidence for removal of wings and feathers. A wide range of taxa were primarily used as a source of food although these are found in low numbers in the assemblage: Anatidae, Phasianidae, Columbidae, Pteroclididae, Rallidae and Otidae. Although only eight specimens from MacQueen's bustard were recovered, this may have been a resident of Faynan and hunted primarily for food. Skeletal part frequencies also indicate that buzzards, kites and honey buzzards are likely to have been consumed (White *et al.*, 2021b). The bird bones were heavily concentrated in three structures, O45, O11 and O56 (Fig. 4), suggesting that these were locations for processing the carcasses or elements of carcasses returned to the site. Structure O11 is especially notable for the number of buzzard bones with 25 sets of articulating toe bones (White *et al.*, 2021a).

It seems unlikely that birds formed a significant component of the WF16 diet considering the large quantities of bones recovered from large mammals (c. 600 kg; Mithen *et al.*, 2018: Table 45.1). If the buzzards had been consumed, they would not have provided much fat due to the limited amounts stored on birds during their migrations (Berthold *et al.*, 2001). The primary motivation for their capture may have been to secure feathers, talons and skins, although the buzzards, along with Anatidae and Pteroclididae, may have been a valuable dietary supplement perhaps during ceremonial occasions. Whatever the motivation for capturing birds, the taxa represented at WF16 may indicate aspects of the local environment that are not apparent from other sources of data.

Birds as indicators of Faynan's early Holocene environment

Based on present-day ecology, the 63 species represented in the WF16 assemblage fall into three categories, residents,



Figure 5. Excavation at WF16 in 2009, looking from the north over partially excavated semi-subterranean pisé-built structures including the amphitheatre-like structure with a section through the midden deposits it contained (O75) (Image: Steven Mithen). [Color figure can be viewed at wileyonlinelibrary.com].



Figure 6. The amphitheatre-like structure (O75) at WF16, under excavation in 2010, with a later free-standing structure constructed within it (image: Steven Mithen). [Color figure can be viewed at wileyonlinelibrary.com].

passage migrants and seasonal visitors, although certain taxa show a degree of flexibility between categories (Tables 1 and 2, with further information in Supplementary Table S1). While there are more resident than passage migrant taxa

represented, the latter are dominant in terms of NISP because of the focus on *Buteo buteo* and to a lesser extent *Pernis apivorus*.

The WF16 bird taxa reflect a variety of present-day habitats suggesting that the same were accessible and exploited



Figure 7. The 'benches' on the south side of the amphitheatre-like structure (O75) during excavation in 2010 (image: Steven Mithen).

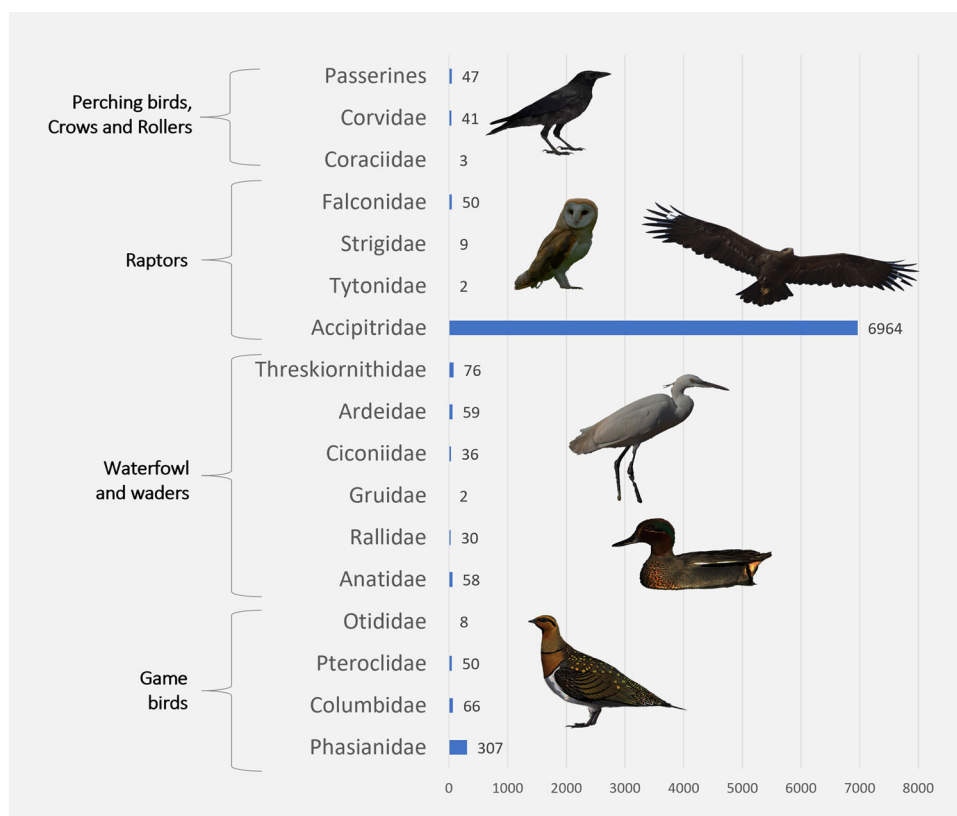


Figure 8. Bird families represented at WF16 (NISF). Data from White *et al.*, 2021a. [Color figure can be viewed at wileyonlinelibrary.com].

by the Neolithic inhabitants of WF16 including watery areas (mallard, white stork, little egret), steppe (e.g. buzzard, eagles), rocky slopes (partridge), cliffs and mountains (raven, eagles). We must, however, be cautious because many of the birds in the WF16 assemblage are migrants and can be forced to stop and overnight in what would have been unsuitable habitats for them. As such, their known habitat preferences may not be significant for environmental reconstruction in Faynan.

Indications of environmental change come from 23 (35%) of the WF16 bird taxa that are not currently recorded in Faynan today (Table 3). These fall into three groups.

Water-related birds

First are water-related birds: the osprey, coot, little bittern and several members of Anatidae: greylag goose, pochard,

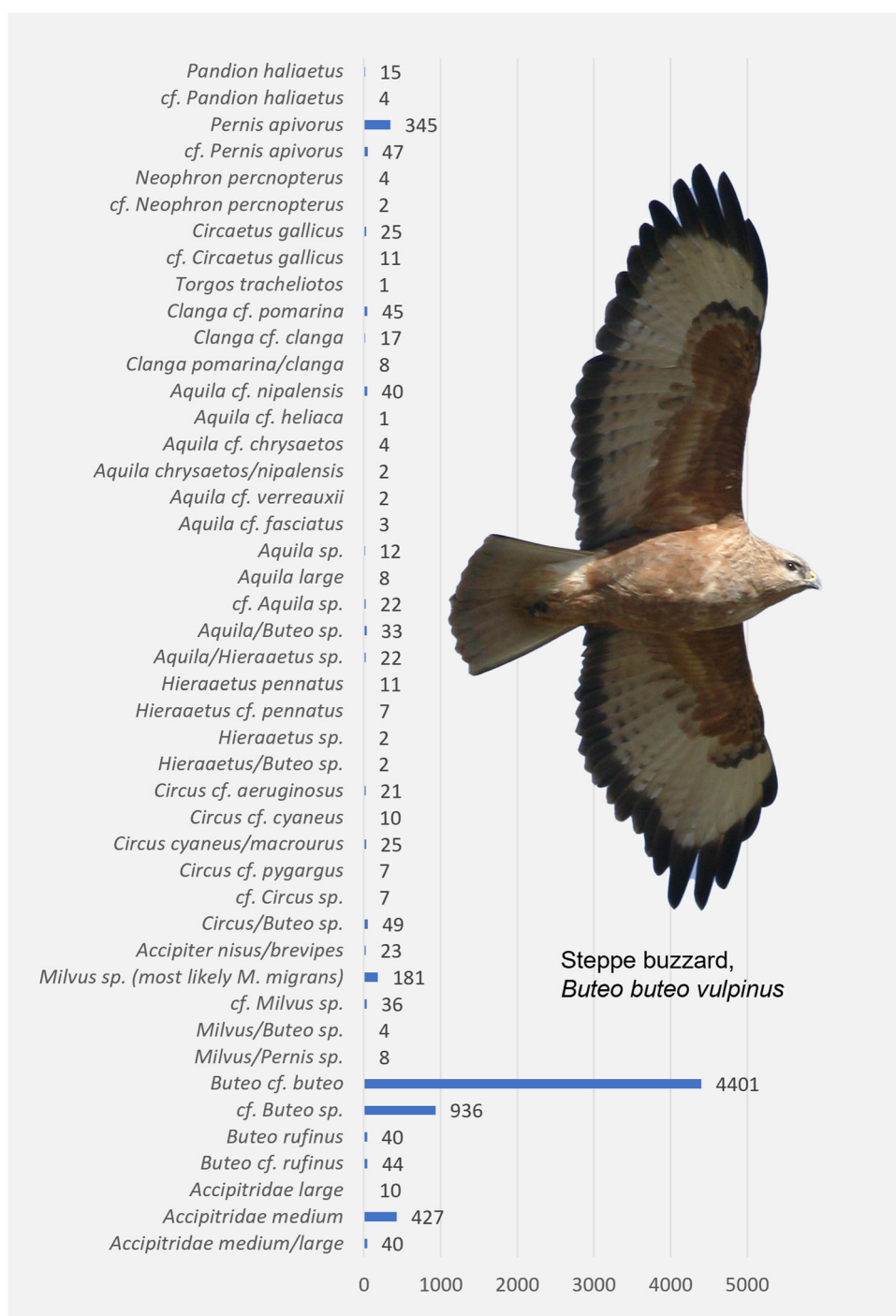


Figure 9. Members of Accipitridae represented at WF16 (NISP), and the steppe buzzard (photo: Fares Khoury). Data from White *et al.*, 2021a. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)].

tufted duck, gadwall, wigeon and pintail. Today, these species are winter visitors to Jordan, most common in the Azraq wetlands and flooded Qas of eastern Jordan, and artificial reservoirs and wastewater ponds in the Rift Valley. The osprey requires large areas of open, shallow water and would currently pass over the arid landscape of Faynan without stopping. The coot also requires open, shallow water, while the little bittern prefers marshes and overgrown riverbanks. The short-eared owl is also known to nest in marshes, with a record from 1995 of a short-eared owl wintering near Faynan.

Each of the Anatidae are represented at WF16 by a small number of bones, often a single element, suggesting they were not heavily exploited (although, as noted above,

representation of species by a single bone is not unusual in assemblages from this period). Their number and the small size of these birds suggest they were locally available rather than brought to the settlement from some distance. These water-related birds support the inferences from the pisé-structures of WF16, sedimentary deposits and hydrological modelling, that Faynan was significantly wetter in the early Holocene than today, most likely with a permanent marsh at the confluence of Wadis Dana, Ghuwyar and Faynan, that at times became an extensive shallow lake. The 'Faynan wetland' would have provided an attractive environment for several of the other birds in the WF16 assemblage, such as the spotted eagle, marsh and hen harrier, white stork and little egret.

Table 1. Passage migrants, residents and seasonal visitors represented at WF16. Faunal data from White *et al.* (2021a); ecological data from Andrews (1995) and Khoury (personal observations)

Passage migrants (NISP = 6193)

Crex crex (18); cf. *Crex crex* (5); *Ciconia* cf. *Ciconia* (21); *Ciconia* sp. (15); *Ardea purpurea* (2); *Pandion haliaetus* (15); cf. *Pandion haliaetus* (4); *Pernis apivorus* (345); cf. *Pernis apivorus* (47); *Clanga* cf. *pomarine* (45); *Clanga* cf. *clanga* (17); *Clanga pomarina/clanga* (8); *Hieraaetus pennatus* (11); *Hieraaetus* cf. *pennatus* (7); *Hieraaetus* sp. (2); *Hieraaetus/Buteo* sp. (2); *Circus* cf. *pygargus* (7); cf. *Circus* sp. (7); *Circus/Buteo* sp. (49); *Milvus* sp. (most likely *M. migrans*) (181); cf. *Milvus* sp. (36); *Milvus/Buteo* sp. (4); *Milvus/Pernis* sp. (8); *Buteo* cf. *buteo* (4401); cf. *Buteo* sp. (936).

Passage migrant/Summer breeder (NISP = 4)

Otus scops (1); *Coracias garrulus* (2); cf. *Coracias garrulus* (1).

Passage migrant/Summer visitor (NISP = 42)

cf. *Neophron percnopterus* (2); *Neophron percnopterus* (4); *Circaetus gallicus* (25); cf. *Circaetus gallicus* (11).

Passage migrant/Winter visitor (NISP = 184)

Gallinula chloropus (1); *Grus grus* (1); *Grus/Ciconia* sp. (1); *Aquila* cf. *nipalensis* (40); *Aquila* cf. *heliacal* (1); *Circus* cf. *aeruginosus* (21); *Circus* cf. *cyaneus* (10); *Circus cyaneus/macrourus* (25); *Accipiter nisus/brevipes* (23); *Falco* cf. *peregrinus* (6); Falconidae small (3); Falconidae small/medium (1); Falconidae large (4); *Aythya* cf. *farina* (1); *Aythya* cf. *fuligula* (1); cf. *Aythya* sp. (1); *Mareca* cf. *strepera* (2); *Mareca* cf. *Penelope* (4); *Anas* cf. *acuta* (1); *Anas* cf. *crecca* (5); *Anas crecca/querquedula* (9); *Anas* sp. (18); cf. *Anas* sp. (2); *Anas/Aythya* sp. (3).

Passage migrant/Winter visitor/Summer breeder (NISP = 6)

Fulica atra (6).

Resident (NISP = 1202)

Aquilac. verreauxii (2); *Coturnix coturnix* (29); *Alectoris chukar* (254); cf. *Alectoris chukar* (3); *Francolinus/Alectoris* sp. (5); *Ammoperdix heyi* (14); cf. *Ammoperdix heyi* (1); Phasianidae medium (1); *Columba* cf. *livia* (8); *Streptopelia decaocto* (7); cf. *Streptopelia decaocto* (1); *Streptopelia/Columba* sp. (2); *Pterocles* cf. *senegallus* (8); *Pterocles* sp. (42).

Egretta garzetta (56); *Aquila* cf. *fasciatus* (3); *Aquila* sp. (12); *Aquila* large (8); cf. *Aquila* sp. (22); *Aquila/Buteo* sp. (33); *Aquila/Hieraaetus* sp. (22); *Buteo rufinus* (40); *Buteo* cf. *rufinus* (44); Accipitridae large (10); Accipitridae medium (427); Accipitridae medium/large (40); *Tyto alba* (2); *Strix* sp. (3); *Strix/Asio* sp. (1); *Bubo ascalaphus* (3); *Falco* cf. *tinnunculus* (7); *Falco* cf. *biarmicus* (29); *Corvus* cf. *ruficollis* (5); *Corvus* cf. *rhypidurus* (1); *Corvus rhypidurus/ruficollis* (11); *Corvus* cf. *corone cornix* (7); *Corvus* sp. (12); *Lanius* cf. *excubitor* (1); cf. *Lanius* sp. (5); cf. *Motacilla* sp. (2); cf. *Sylvia* sp. (1); cf. *Oenanthe* sp. (1); Passerine small (1); Passerine medium (6).

Resident/Passage migrant (NISP = 1)

Ixobrychus minutus (1).

Resident/Winter visitor (NISP = 24)

Chlamydotis sp. (8); *Turdus* cf. *merula* (1); *Turdus* sp. (8); cf. *Turdus* sp. (7).

Visitor (NISP = 1)

Corvus cf. *frugilegus* (1).

Winter visitor (NISP = 55)

Anser cf. *anser* (1); cf. *Anser* sp. (1); *Columba* cf. *oenas* (2); *Columba oenas/livia* (42); *Columba palumbus* (1); *Columba* sp. (3); *Asio flammeus* (1); *Turdus* cf. *viscivorus* (4).

Winter visitor/Passage migrant/Rare breeder (NISP = 9)

Anas cf. *platyrhynchos* (3); *Mareca penelope/Anas platyrhynchos* (6).

Extremely rare (NISP = 6)

Aquila chrysaetos/nipalensis (2); *Aquila* cf. *chrysaetos* (4).

Not present in Jordan (NISP = 81)

Geronticus eremita (70); cf. *Geronticus eremita* (5); *Platalea leucorodia/Geronticus eremita* (1); *Torgos tracheliotus* (1); cf. *Pyrhocorax pyrrhocorax* (4).

Woodland-related birds

A second group of birds present at WF16 but absent from Faynan today are those that prefer a wooded environment, suggesting Faynan had significantly greater tree cover in the

early Holocene than today. Most significant is the wood pigeon, represented by a single coracoid. This is an occasional visitor to northern Jordan today but may have been resident in the past. The presence of the stock dove, barn owl, hooded crow and mistle thrush at WF16, each represented by a single or a few bones with an MNI of one, also suggests a higher density of woodland and/or more humid environment in the early Holocene than today, although these birds can inhabit open country. Stock doves and mistle thrush may have been winter visitors, as they are occasionally recorded in the highlands to the east and north, and in open steppe and desert but close to trees (e.g. in Wadi Butum, Khoury, personal observation).

Raptors and cliff-related birds

The present-day absence of this small group of birds reflects an overall decline in their population numbers relating to regional and/or continent-wide factors. The lappet-faced vulture, golden eagle, and Verreaux's eagle are present in the WF16 assemblage but are no longer visitors to Faynan. Most notable is the northern bald ibis. Today, this is a critically endangered species and is probably extinct in the Levant, last being spotted in Syria in 2015. With an NISP of 76 this has a significant presence at WF16, with all body parts represented. As White *et al.* (2021b) described, these distinctive birds had been carefully butchered at WF16 to detach wings and feathers, and most likely for consumption. With a preference for semi-arid environments and rocky escarpments, the northern bald ibis nests on cliffs close to watercourses (Serra *et al.*, 2011, 2015). Such locations would have been readily available in early Holocene Faynan, although it is unclear whether the birds would have been early Holocene residents or migrants.

The northern bald ibis survives as a semi-wild population of c. 600 individuals in Morocco (dependent on captive breeding), about 200 individuals in southern Turkey, and perhaps a few individuals in East Africa. Its population decline can be attributed to a combination of habitat loss, pesticides and hunting, with the same factors accounting for the decline of the lappet-faced vulture, golden eagle and Verreaux's eagle in the southern Levant.

Seasonality at WF16 and hunting methods

The most significant bird-related activity at WF16 was the catching of buzzards. Based on present-day ecology, buzzards would have passed through Faynan during their northward spring migration from Africa to their breeding grounds in Europe and western Asia (Table 2). More than 300 000 birds have been recorded in a single season passing the Gulf of Aqaba (Porter and Beaman, 1985), with a median arrival time for adults of 9 April, and juveniles of 26 April (Yosef *et al.*, 2002). Buzzards would have returned in the autumn, passing through Faynan between September and October. Travelling in large flocks, they are likely to have rested in Faynan. This provided opportunities for killing/capturing birds, with the largest concentrations in the spring (Andrews, 1995). It is not known whether buzzards would have been attracted to baited carcasses, although this has been observed for eagles, black kites and vultures. We must assume that the buzzards were shot with arrows, snared, or captured in nets and traps (e.g. Barber and Bildstein, 2011). A proportion of the El-Khiam stone points from WF16 have impact fractures and were evidently arrowheads (Smith, 2007), numerous grooved stones were likely used as shaft-straighteners (e.g. Mithen *et al.*, 2018: Figs 5.7 and 6.9) and feathers from eagles and other larger raptors may have been used to fletch the arrows

Table 2. Present day seasonal distribution in Jordan of birds represented at WF16 (derived from Andrews 1995), see also updated list at <http://www.jordanbirdwatch.com/birds-in-jordan/jordan-bird-list/>

Taxon	Ja n	Fe b	Ma r	Ap r	Ma y	Jun e	Jul y	Aug	Sep	Oct	Nov	Dec
<i>Anser</i> cf. <i>anser</i>												
<i>Aythya</i> cf. <i>ferina</i>												
<i>Aythya</i> cf. <i>fuligula</i>												
<i>Mareca</i> cf. <i>strepera</i>												
<i>Mareca</i> cf. <i>penelope</i>												
<i>Anas</i> cf. <i>platyrhynchos</i>												
<i>Anas</i> cf. <i>acuta</i>												
<i>Anas</i> cf. <i>crecca</i>												
<i>Coturnix</i> <i>coturnix</i>												
<i>Alectoris</i> <i>chukar</i>												
<i>Ammoperdix</i> <i>heyi</i>												
<i>Columba</i> cf. <i>livia</i>												
<i>Columba</i> cf. <i>oenas</i>												
<i>Columba</i> <i>palumbus</i>												
<i>Streptopelia</i> <i>decaocto</i>												
<i>Pterocles</i> cf. <i>senegallus</i>												
<i>Crex</i> <i>crex</i>												
<i>Gallinula</i> <i>chloropus</i>												
<i>Fulica</i> <i>atra</i>												
<i>Grus</i> <i>grus</i>												
<i>Chlamydotis</i> sp. (<i>macqueenii</i>)												
<i>Ciconia</i> cf. <i>ciconia</i>												
<i>Ixobrychus</i> <i>minutus</i>												
<i>Ardea</i> <i>purpurea</i>												
<i>Egretta</i> <i>garzetta</i>												
<i>Geronticus</i> <i>eremita</i>												
<i>Pandion</i> <i>haliaetus</i>												
<i>Pernis</i> <i>apivorus</i>												
<i>Neophron</i> <i>percnopterus</i>												

(Continued)

[illegible]

less frequently recorded

Table 3. Bird taxa represented at WF16 but not found in Faynan today**Water- and marsh-related (NISP = 35)**

Anser cf. *anser* (1); *Aythya* cf. *farina* (1); *Aythya* cf. *fuligula* (1); *Mareca* cf. *strepera* (2); *Mareca* cf. *Penelope* (4); *Anas* cf. *acuta* (1); *Fulica* *atra* (6); *Ixobrychus minutus* (1); *Ardea purpurea* (2); *Pandion haliaetus* (15); *Asio flammeus* (1).

Woodland-related birds (NISP = 17)

Columba cf. *oenas* (2); *Columba palumbus* (1); *Tyto alba* (2); *Corvus* cf. *corone cornix* (7); *Corvus* cf. *frugilegus* (1); *Turdus* cf. *viscivorus* (4).

Cliff-related (NISP = 74)

Geronticus eremita (70); cf. *Pyrrhocorax pyrrhocorax* (4).

Raptors (NISP = 7)

Torgos tracheliotus (1); *Aquila* cf. *chrysaetos* (4); *Aquila* cf. *verreauxii* (2).

(White *et al.*, 2021b). Impressions of textiles on gypsum plaster, most likely made from twisted vegetable fibres, indicate that nets could have been made (Mithen *et al.*, 2018: Fig. 21.20), with evidence that these had been in use since the Natufian period (13th millennium BP; Bar-El and Tchernov 2000).

The majority of the other Accipitridae from WF16 were also passage migrants, with similar seasons for passing through Faynan and some migrating in large numbers: over 200 000 honey buzzards, 25 000 black kites and 19 000 steppe eagles having been recorded in single spring seasons at the Gulf of Aqaba (Porter and Beaman, 1985). These are also more common over the Rift highlands in the spring than the autumn (Andrews, 1995). Quite why there was such a focus on the steppe buzzard at WF16 remains unclear: this might reflect their early Holocene ecology, migrating in larger flocks and more frequently resting in Faynan than any other species, thereby providing a greater opportunity for capturing them as a source of food and feathers. Alternatively, there might have been a particular preference for the steppe buzzard based on an unidentified utilitarian value or related to a symbolic meaning attached to this species. Buzzards do not have especially colourful plumage, but this is the case for all medium and large birds in the region. Buzzard plumage does vary, with some individuals having a rufous coloration and others having feathers that vary from dark brown to whitish, and with sharp contrasts in their flight feathers (Fig. 9).

The larger eagles and vultures are likely to have been trapped as individuals and appear to have been butchered in the field, or scavenged, with selected body parts, notably wings, returned to WF16 (White *et al.*, 2021b). Whereas buzzard capture is likely to have been a carefully planned activity to secure multiple birds, the hunting of larger raptors and birds such as storks and cranes may have been more opportunistic, responding to the sight of such birds at Faynan. The smaller raptors such as sparrowhawks and falcons might have been captured by using hides and nets, possibly with the use of decoy birds, in a manner similar to that in historic times (e.g. Musil, 1928: 32; Dickson, 1949: 368–370).

While we cannot determine whether the buzzards and other passage migrants were hunted/captured in the spring, autumn, or both, we can be confident that some bird exploitation was occurring in the spring and possibly summer because of medullary bone in five specimens of chukar partridge (three femur fragments and two coracoid), the presence of seven immature bones and a further two bones from a very young bird tentatively identified as chukar. Medullary bone forms prior to and during egg-laying to provide calcium for eggshell. It cannot provide a precise month for when the chukar

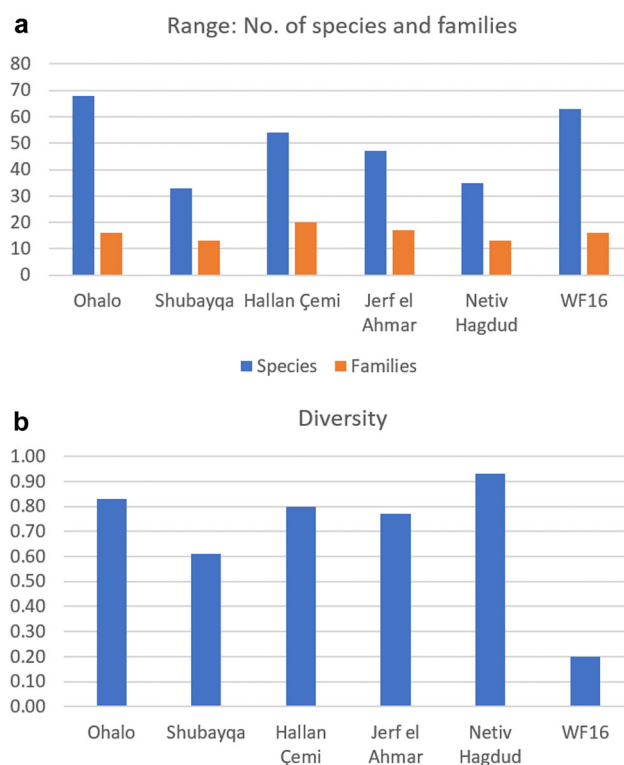


Figure 10. Comparison of the avian assemblages from selected Epipalaeolithic and early Neolithic sites in south-west Asia. (a) The minimum number of families and species represented. For this graph, all passerines families have been grouped together. (b) The diversity of the assemblage, as measured by Simpson's diversity index. Data from: Ohalo (NISP = 488): Simmons and Nadel, 1998; Shubayqa (NISP = 3080): Yeomans and Richter, 2018; Hallan Çemi (NISP = 1154): Zeder and Spitzer, 2016; Jerf el Ahmar (NISP = 1554): Gourichon, 2002; Netiv Hagdud (NISP 1214): Tchernov, 1994; WF16 (NISP = 7808): White *et al.*, 2021a). [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)].

partridges were killed because of the long duration of the egg-laying period, from early March to mid-August (Mackie and Buechner, 1963). One carpometacarpus of a kestrel also contained medullary bone. Kestrel egg-laying is more restricted, indicating spring occupation at WF16. This is also represented in the mammalian remains from the 1997–2002 site evaluation which identified neonatal and natal *Capra* sp., indicative of hunting in the spring (Carruthers and Dennis, 2007). Three corvid bones also appear to be from immature birds, as is the case for a distal wing phalanx of MacQueen's bustard and the tarsometatarsus of a dove.

Most Anatidae were winter visitors and passage migrants to Jordan today, arriving between November and February. It is reasonable to assume this was also their predominant time in Faynan during the early Holocene, although cooler climates may have expanded their range. Anatidae are not found in large numbers at WF16, but their presence suggests fowling in wetlands close to the settlement, most likely using snares and traps during the winter months. Winter visitors represented at WF16 might also include the wood pigeon, coot and rook, although other seasons cannot be entirely ruled for these species.

Discussion: intersite comparisons, sedentism and seasonal activity at WF16

The bird bones from WF16 indicate that a range of habitat types were accessible to its Neolithic occupants between 11.8 and 10.24 ka BP. Other than extensive wetlands and pools of standing water, these habitats remain in the landscape today,

although the extent of woodland is severely diminished. The confluence of Wadis Ghuwayr, Dana and Faynan is likely to have consisted of marsh with seasonal flooding that created an expanse of open water. This would have enhanced the position of WF16 at the juncture between various habitats: mountains, rocky slopes, woodland, steppe and wetlands – a classic location for hunter-gatherer groups trying to minimise their residential mobility while maximising the resources available to them.

This environmental reconstruction supports Zeder and Spitzer's (2016: 156) proposal that avian assemblages indicate that early Holocene Neolithic communities targeted specific locations where abundant and diverse resources could be found. We must note, however, the dramatic contrasts between the WF16 avian assemblage and those from both contemporary and the earliest settlements in the region.

Fig. 10a compares the minimum number of families and species represented at Epipalaeolithic and Neolithic sites with relatively large avian assemblages for south-west Asia. This shows the WF16 assemblage to be quite typical, having the second highest minimum number of species and midway for the minimum number of families. In this regard, an equivalent level of environmental biodiversity can be inferred, recognising the efficacy of birds as a generic measure of biodiversity, one encompassing plants and animals.

Fig. 10b compares the diversity of bird families within these assemblages, using Simpson's index which considers both the number of families present and the relative abundance of each family. WF16 now appears atypical, having a significantly lower diversity index than all other sites, including that of Shubayqa where bird exploitation was heavily focussed on waterfowl.

This highly specialised focus on raptors at WF16 appears to have occurred within a local environment of mixed habitats that supported a range of bird taxa equivalent to that found at other Neolithic localities. When the seasonality evidence for hunting is combined with that from the site architecture and burials, some degree of year-round occupation seems likely, although the dominance of raptors suggests activity was heavily focussed during the spring and/or autumn migrations.

This evidence from WF16 indicates that the notion of residential and sedentary communities in early Neolithic south-west Asia needs to be considered with greater nuance than that expressed by Zeder and Spitzer (2016: 156). While abundant and diverse resources could allow communities to remain together for long periods of time, this may not have always been desirable for hunter-gatherers because of the challenges arising from sedentism of increased social tension, poor health, and increased mortality (Page *et al.* 2016, 2018). Reduced mobility also decreases access to non-local resources, environmental knowledge, and social information from other communities (Kelly 2013: 104–113). As Kelly (2013: 107) explained, 'The decision to become sedentary is based on regional, not just local, resource conditions. It is not enough for resources to be abundant in one place because if they are equally abundant elsewhere, then we expect movement, even if infrequent, simply as a product of foraging-related depletion. Stated in the vernacular, sedentism is a product of local abundance in a context of regional scarcity.'

Following Kelly, we suggest that the contrast between the highly diverse avian fauna from Ohalo, Hallan Çemi, Jerf el Amar, Netiv Hagdud and Subayqar, and the highly specialised pattern from WF16 may reflect contrasting patterns of mobility relating to resource availability within their surrounding regions. We suspect that resources were relatively abundant throughout the northern Levant during the early Holocene arising from increased rainfall, driving the population growth

detected by Roberts *et al.* (2018) and Palmisano *et al.* (2021). Within that region, however, there were locations with particularly high resource diversity and abundance that were targeted in the manner described by Zeder and Spitzer (2016). High population levels may have provided a further 'push factor' towards greater sedentism (Kelly 1992: 53) while the storage of cultivated grain would have enhanced the contrast between these locations and the wider region, which was one of *relative* scarcity.

Whatever the impact of Holocene climate change, the region surrounding Faynan would always have been one of relatively low rainfall, with its resources both less abundant and more evenly distributed than in the northern Levant. Seasonal wetlands, such as Faynan, would have been restricted in size and of short duration. While Faynan's annual biodiversity might have been high, this would have been seasonally limited, with its resident bird taxa boosted by waterfowl in the winter and passage migrants in the spring and autumn. The absolute numbers of birds are likely to have been relatively low compared with sites in the northern Levant and those adjacent to more extensive wetlands, such as Netiv Hagdud and Subayqar.

While early Neolithic sites in the northern Levant are likely to have had a resident human population that remained consistent in size throughout the year, that at WF16 is likely to have been seasonally variable – relatively low in the winter months and high during the spring/autumn coinciding with the migrations. The winter would have been an ideal time for constructing and maintaining the pisé architecture, using the water from the seasonal wetland that also attracted the waterfowl. During spring, as the open water turned to marsh, which may have dried up in years of low rain and high temperatures, people gathered from across the region to hunt the migratory birds, especially buzzards. While these provided a source of food, they were also taken for their feathers, talons and skins. We suspect these were combined with stone and shell beads for body decoration and costumes used during performance and ceremony in the amphitheatre-like structure at the settlement. Such seasonally focussed activity might also explain the relatively low diversity in mammalian fauna, this being dominated by the short-term killing of *Capra* herds to feed social gatherings. Feasting on the occasion of social gatherings might be represented by the hearths and mortars in the floor of the amphitheatre-like structure O75 (Mithen *et al.* 2018: Fig. 38.22).

WF16 appears ideally located for periodic or seasonal gatherings, positioned on the migratory pathway from Africa to Europe, and with access from the highlands to its east via Wadis Dana and Ghuwayr, and from the west along Wadi Faynan that opens into the north–south corridor of Wadi Araba. Such gatherings play a key role in hunter-gatherer social networks which function to maintain food security (Whallon 2006), resolve social tensions and mitigate conflict (Johnson 1982), facilitate cooperation (Apicella *et al.* 2012) and achieve reproductive success (Page *et al.* 2017). Periodic and seasonal gatherings may have become of greater rather than lesser importance during the transition to farming with the uncertainty of harvests from partially domesticated cereals, when the technology of storage remained in development, and before communities experienced the population growth associated with farming (Belfer-Cohen and Goring Morris, 2010). Social gatherings may have played a critical role in sharing knowledge, new ideas and technology about plant cultivation and herd management.

The annual appearance of migratory birds would have been seen throughout the southern Levant, perhaps providing a sign for travel to WF16. Such birds were no doubt attributed

symbolic significance considering the role of birds, and especially those that migrate, in the ideology of hunter-gatherers throughout the world (see e.g. Pritchard (2013) for birds in the ideology of Native Americans, Balzer (1996) for birds in Siberian shamanism, and Cocker and Tipling (2013) for a comprehensive study of the relationships between birds and people).

CONCLUSION

By using the SPDs of calibrated radiocarbon dates as a proxy for human population, long-term studies have inferred population increase associated with warming periods at c. 14.5 and 11.7 ka BP (Roberts *et al.*, 2018; Palmisano *et al.*, 2021). While these analyses inferred such population growth in the southern Levant at c. 14.5 ka BP, there was no indication of it occurring during the time span of WF16, 11.84–10.25 ka BP. If correct, this indicates that the development and cultural flourishing of WF16 relates to local environmental conditions and the redistribution and/or changing mobility patterns of an existing population rather than population increase in the southern Levant.

Zeder and Spitzer (2016) used evidence from avian remains to support the idea that people had capitalised on the climatic amelioration by targeting specific locations where abundant and diverse resources could be found within well-defined catchments, allowing communities to remain together for long periods. The bird bones from WF16 provide partial support for that proposal by showing that Faynan had been significantly wetter and more wooded during the early Holocene, while also maintaining the range of habitats found within the arid landscape today – a localised wetland within a challenging environment. Its wide range of bird taxa indicates a high level of overall biodiversity, birds being recognised as an indicator of this for plants and animals in general. In this regard, WF16 appears similar to Netiv Hagdud, Jerf el Ahmar and Hallan Çemi which appear to have been positioned in diverse environmental settings. In those cases, however, bird bones suggest a relatively even exploitation of the habitats on a year-round basis whereas activity at Faynan was seasonally focussed in the spring/autumn to exploit the migratory flocks of buzzards and other raptors.

We propose that this reflects marked seasonal variation in the size of the population at WF16: a relatively small population during the winter months, exploiting waterfowl in what became a Faynan wetland, while maintaining/building the pisé architecture; a larger population in the spring, attracted by the flocks of buzzards that rested in Faynan during their migrations. These provided an opportunity for social gatherings during which costumes were made from the skins, wings and feathers of buzzards and other birds for performance in the amphitheatre-like structure at WF16. Such gatherings are likely to have played a critical role in managing risk and transmitting information during the formative stages of farming economies.

Acknowledgements. The authors thank the AHRC for funding the 'People and Birds in the Southern Levant' project (AH/P007546/1) that enabled this work to take place. Steven Mithen thanks support from the University of Reading and Judith White thanks Joanne Cooper and Julian Hume from the Natural History Museum, Tring, for their help and advice. They are grateful to three referees for their helpful comments on a previous version of this manuscript. The authors have no conflicts of interest.

Data Availability Statement

Mithen, Steven and White, Judith (2022): WF16 bird bone data from 2008–2010 excavation. University of Reading. Dataset. <https://researchdata.reading.ac.uk/id/eprint/357>.

Supporting information

Additional supporting information can be found in the online version of this article.

REFERENCES

- Andrews IJ. 1995. *The Birds of the Hashemite Kingdom of Jordan*. I. J. Andrews: Scotland.
- Apicella C, Marlowe F, Fowler JH *et al.* 2012. Social networks and cooperation in hunter-gatherers. *Nature* **481**: 497–501.
- Balzer MM. 1996. Flights of the sacred: symbolism and theory in Siberian shamanism. *American Anthropologist* **98**: 305–318.
- Bar-El T, Tchernov E. 2000. Lagomorph remains at prehistoric sites in Israel and the southern Sinai. *Paléorient* **26**: 93–109.
- Barber DR, Bildstein KL. 2011. A lightweight portable, walk-in trap for catching vultures. *Vulture News* **60**: 22–25.
- Barker G, Gilbertson D, Mattingley D. 2007. *Archaeology and Desertification. The Wadi Faynan Landscape Survey, Southern Jordan. Council for British Research in the Levant*. Oxbow Books: Oxford.
- Bar-Yosef O, Gopher A (eds). 1997. *An Early Neolithic Village in the Jordan valley. Part I: The Archaeology of Netiv Hagdud*. American School of Prehistoric Research Bulletin 44. Peabody Museum of Archaeology and Theology, Harvard University: Cambridge, MA.
- Bar-Yosef O, Goring-Morris N, Gopher A. 2010. *Gilgal: Early Neolithic Occupations in the Lower Jordan Valley (The Excavations of Tamar Noy)*. Oxbow Books: Oxford.
- Bar-Yosef Mayer D. 2013. Towards a typology of stone beads in the Neolithic Levant. *Journal of Field Archaeology* **38**: 129–142.
- Belfer-Cohen A, Goring-Morris N. 2010. The initial Neolithic in the Near East: Why is it so difficult to deal with the PPNA. *Journal of the Israel Prehistoric Society (Mitekufat Haeven)* **40**: 149–166.
- Berthold P, Elverfeldt D, Fiedler W *et al.* 2001. Magnetic resonance imaging and spectroscopy (MRI, MRS) of seasonal patterns of body composition: a methodological pilot study in White Storks (*Ciconia ciconia*). *Journal für Ornithologie* **142**(1): 63–72.
- BirdLife International. 2013. *Birds are very useful indicators for other kinds of biodiversity*. [online]. Available from: <http://www.birdlife.org> (accessed 17/11/2021).
- Brayshaw D, Black E, Hoskins B *et al.* 2011. Past climates of the Middle East. In *Water, Life and Civilisation: Climate, Environment and Society in the Jordan Valley*, Mithen S, Black E (eds). Cambridge University Press: Cambridge; 25–50.
- Brooks T, Balmford A, Burgess N *et al.* 2001. Conservation priorities for birds and biodiversity: do East African Important Bird Areas represent species diversity in other terrestrial vertebrate groups? *Ostrich–Journal of African Ornithology Supplement* **15**: 3–12.
- Carruthers DB, Dennis SJ. 2007. The mammalian faunal remains. In *The Early Prehistory of Wadi Faynan, Southern Jordan*, Finlayson B, Mithen SJ (eds). Council for British Research in the Levant/Oxbow Books: Oxford; 372–386.
- Cocker M, Tipling D. 2013. *Birds and People*. Jonathan Cape: London.
- Colledge S, Conolly J, Finlayson B *et al.* 2018. New insights on plant domestication, production intensification, and food storage: the archaeobotanical evidence from PPNA Dhra. *Levant* **50**: 14–31.
- Dickson HRP. 1949. *The Arab of the Desert*. George Allen & Unwin Ltd: London.
- Donald PF, Green RE, Heath MF. 2001 Agricultural intensification and the collapse of Europe's bird populations Proceedings of the Royal Society of London. Series B **268**: 25–29.
- Edwards PC, Meadows J, Sayej G *et al.* 2002. Zahrat Adh-Dhra' 2: A New Pre-Pottery Neolithic A Site on the Dead Sea Plain in Jordan. *Bulletin of the American Schools of Oriental Research* **327**: 1–15.
- Finlayson B, Mithen SJ (eds). 2007. *The Early Prehistory of Wadi Faynan, Southern Jordan*. Oxbow Books: Oxford.
- Finlayson B, Kuijt I, Arpin T *et al.* 2003. Dhra' Excavation project 2002, interim report. *Levant* **35**: 1–38.
- Flannery K. 1969. Origins and Ecological Effects of Early Domestication in Iran and the Near East. In *The Domestication and*

- Exploitation of Plants and Animals*, Uko PJ, Dimbleby GW (eds). Aldine Publishing Co: Chicago; 73–100.
- Flohr P, Finlayson B, al-Najjar M *et al.* 2015. Building WF16: The reconstruction of a Pre-Pottery Neolithic A (PPNA) pisé structure in Southern Jordan. *Levant* **47**: 143–163.
- Fraixedas S, Lindén A, Piha M *et al.* 2020. A state-of-the-art review on birds as indicators of biodiversity: advances, challenges, and future directions. *Ecological Indicators* **118**: 106728.
- Gourichon L. 2002. Bird Remains from Jerf el Ahmar, a PPNA site in Northern Syria, with special reference to the Griffon Vulture. In *Archaeozoology of the Near East V*, Buitenhuis H *et al.* (ed). ARC-Publicatie 62: Groningen; 138–152.
- Gregory RD, Noble D, Field R *et al.* 2003. Using birds as indicators of biodiversity. *Ornis Hungarica* **12**: 11–24.
- Hunt CO, Elrishi HA, Gilbertson DD *et al.* 2004. Early-Holocene environments in the Wadi Faynan, Jordan. *Holocene* **14**: 921–930.
- Jenkins E, Rosen A. 2007. The phytoliths. In *The Early Prehistory of Wadi Faynan, Southern Jordan*, Finlayson B, Mithen SJ (eds). Council for British Research in the Levant/Oxbow Books: Oxford; 429–436.
- Johnson G. 1982. *Organizational structure and scalar stress*. In: Renfrew C., Rowlands M. and Segraves B. (eds). *Theory and Explanation in Archaeology*; 389–421. New York: Academic Press.
- Kelly RL. 1992. Mobility/sedentism: concepts, archaeological measures and effects. *Annual Review of Anthropology* **21**: 43–66.
- Kennedy A. 2007. The plant macrofossils. In *The Early Prehistory of Wadi Faynan, Southern Jordan*, Finlayson B, Mithen SJ (eds). Council for British Research in the Levant/Oxbow Books: Oxford; 420–428.
- Kelly RL. 2013. *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*. Cambridge University Press: New York.
- Khoury F, Korner P. 2018. Grazing in remnant wetland habitats in an arid region: direct and indirect effects on two specialist bird species. *Bird Study* **65**(4): 557–563.
- Kuijt I, Finlayson B. 2009. Evidence for food storage and pre-domestication granaries, 11,000 years ago in the Jordan Valley. *Proceedings of the National Academy of Sciences* **106**(27): 10966–10970.
- Mackie RJ, Buechner HK. 1963. The Reproductive Cycle of the Chukar. *The Journal of Wildlife Management* **27**: 246–260.
- Makarewicz C, Finlayson B. 2021. *Bring us your dead: Mortuary practice and community in the Early Neolithic of southern Jordan* [online]. Available from: <https://www.onlineolitic.com/cheryl-makarewicz-bill-finlayson>
- Makarewicz C, Goodale N, Rassmann P *et al.* 2006. El-Hemmeh: a multi-period Pre-Pottery Neolithic site in the Wadi El Hassa. *Jordan. Eurasian Prehistory* **4**(1–2): 183–220.
- Martín B, Onrubia A, Ferrer MA. 2014. Effects of climate change on the migratory behaviour of the common buzzard *Buteo buteo*. *Climate Research* **60**: 187–197.
- Martin L, Edwards Y, Garrard A. 2013. Broad spectrum or specialised activity? Birds and tortoises at the Epipalaeolithic site of Wadi Jilat 22 in the eastern Jordan steppe. *Antiquity* **87**: 649–665.
- Miller-Rushing A, Lloyd-Evans TL, Primack R, Satzinger P. 2008. Bird migration times, climate change, and changing population sizes. *Global Change Biology* **14**: 1959–1972.
- Mithen SJ, Black E (eds). 2011. *Water, Life & Civilisation: Climate, Environment and Society in the Jordan Valley*. Cambridge University Press/UNESCO International Hydrology Series.
- Mithen SJ, Austin P, Kennedy K *et al.* 2007. Neolithic woodland composition and exploitation in the Southern Levant: A comparison between archaeobotanical remains from WF16 and present-day woodland at Hammam Adethni. *Environmental Archaeology: The Journal of Human Palaeoecology* **12**: 71–92.
- Mithen SJ, Finlayson B, Maricevic D *et al.* 2018. *WF16: Excavations at an Early Neolithic Settlement in Southern Jordan*. Council for British Research in the Levant: London.
- Mithen SJ, Khoury F, Greet B *et al.* 2019. *The Birds of Faynan: Past and Present*. University of Reading: Reading and Jordan Birdwatch: Amman.
- Musil A. 1928. *The Manners and Customs of the Rwala Bedouins*. American Geographical Society. New York.
- Page AE, Viguier S, Dyble M *et al.* 2016. Reproductive trade-offs in extant hunter-gatherers suggest adaptive mechanism for the Neolithic expansion. *Proceedings of the National Academy of Sciences* **113**: 4694–4699.
- Page AE, Chaudhary N, Viguier S *et al.* 2017. Hunter-Gatherer Social Networks and Reproductive Success. *Scientific Reports* **7**: 1153.
- Page AE, Minter T, Viguier S *et al.* 2018. Hunter-gatherer health and development policy: How the promotion of sedentism worsens the Agta's health outcomes. *Social Science and Medicine* **197**: 39–48.
- Palmer C, Gilbertson D, El-Rishi H *et al.* 2007. The Wadi Faynan Today: Landscape, Environment, People. In *Archaeology and Desertification: The Wadi Faynan Landscape Survey*, Barker G, Mattingly DJ (eds). Council for British Research in the Levant/Oxbow Books: Oxford; 25–58.
- Palmisano A, Lawrence D, de Gruchy M *et al.* 2021. Holocene regional population dynamics and climatic trends in the Near East: A first comparison using archaeo-demographic proxies. *Quaternary Science Reviews* **252**: 106739.
- Porter RF, Beaman AS. 1985. A resume of raptor migration in Europe and the Middle East. *ICBP Technical Publication* **5**: 237–242.
- Pritchard ET. 2013. *Bird Medicine: The Sacred Power of Bird Shamanism*. Bear & Company: Vermont.
- Roberts N, Woodbridge J, Bevan A *et al.* 2018. Human responses and non-responses to climatic variations during the last Glacial-Interglacial transition in the eastern Mediterranean. *Quaternary Science Reviews* **184**: 47–67.
- Serra G, Bruschini C, Lindsell JA *et al.* 2011. Breeding range of the last eastern colony of critically endangered Northern Bald Ibis *Geronticus eremita* in the Syrian steppe, a threatened area. *Bird Conservation International* **21**(3): 284–295.
- Serra G, Lindsall A, Peske L *et al.* 2015. Accounting for the low survival of the critically endangered Northern Bald Ibis *Geronticus eremita* on a major migratory flyway. *Oryx* **49**(2): 312–320.
- Simmons T. 2004. 'A feather for each wind that blows' Utilizing avifauna for assessing changing patterns palaeoecology and subsistence at Jordan Valley archaeological sites. In *Human Paleoeecology in the Levantine Corridor*, Goran-Inbar N, Speth JD (eds). Oxbow Books: Oxford; 191–205.
- Simmons T, Nadel D. 1998. The avifauna of the Early Epipalaeolithic site of Ohalo II (19,400 years BP), Israel: species diversity, habitat and seasonality. *International Journal of Osteoarchaeology* **8**: 79–96.
- Smith S. 2007. The use wear analysis of chipped stone points. In *The Early Prehistory of Wadi Faynan, Southern Jordan*, Finlayson B, Mithen SJ (eds). Council for British Archaeology in the Levant: London; 284–318.
- Somveille M, Wikelski M, Beyer RM *et al.* 2020. Simulation-based reconstruction of global bird migration over the past 50,000 years. *Nature Communications* **11**: 801.
- Tchernov E. 1994. *An Early Neolithic Village in the Jordan valley. Part II: The Fauna of Netiv Hagdud*. American School of Prehistoric Research Bulletin 44. Peabody Museum of Archaeology and Theology, Harvard University: Cambridge, MA.
- Wade A, Holmes P, el Bastawes M *et al.* 2011. The hydrology of Wadi Faynan. In *Water, Life & Civilisation: Climate, Environment and Society in the Jordan Valley*, Mithen SJ, Black ECL (eds). Cambridge University Press/UNESCO: Cambridge; 157–173.
- Whallon R. 2006. Social networks and information: Non-“utilitarian” mobility among hunter-gatherers. *Journal of Anthropological Archaeology* **25**: 259–270.
- White J, Finlayson B, Makarewicz C *et al.* 2021a. The bird remains from WF16, an early Neolithic settlement in southern Jordan: assemblage composition, chronology, and spatial distribution. *International Journal of Osteoarchaeology* **31**(6): 1030–1045.
- White J, Khoury F, Greet B *et al.* 2021b. The utilization of birds at Neolithic WF16, southern Jordan: cut marks, body parts and experimental skinning. *International Journal of Osteoarchaeology* **31**(6): 1203–1216.

- Yeomans L, Richter T. 2018. Exploitation of a seasonal resource: bird hunting during the Late Ntufian at Shubayqa 1. *International Journal of Osteoarchaeology* **28**: 95–108.
- Yosef R, Tryjanowski P, Bildstein KL. 2002. Spring migration of adult and immature buzzards (*Buteo buteo*) through Elat, Israel: Timing and body size. *Journal of Raptor Research* (**36**): 115–120.
- Zeder MA, Spitzer MD. 2016. New insights into broad spectrum communities of the Early Holocene Near east: The birds of Hallan Çemi. *Quaternary Science Reviews* **151**: 140–159.