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RESEARCH

The dik-diks of Guli Waabayo: Late Pleistocene net-hunting and forager sociality in eastern Africa

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Abstract
Net-hunting is closely linked to organized labor and hunter-gatherer cooperation in many world regions. At the Rifle Range Site (RRS) in southern Somalia, scholars have argued that Later Stone Age (LSA) foragers developed specialized dwarf antelope hunting strategies—possibly using communal net-drives—to facilitate developing concepts of territoriality around resource-rich inselberg environments during a wet period in the early and middle Holocene. Unfortunately, a lack of radiocarbon dates and faunal data limited detailed zooarchaeological perspectives on changing hunting patterns at the site. The large and well-dated dwarf antelope bone assemblage (1263 specimens) from nearby Guli Waabayo (GW) rock shelter, on the other hand, provides an opportunity to explore proposed relationships between net-hunting and LSA social and economic reorganization in southern Somalia ~ 26–6 thousand years ago (ka). Consistently high dik-dik frequencies (55.2–71.9%) and mortality profiles comprised of individuals from all age groups throughout the sequence do not support previous arguments associating specialized dwarf antelope hunting with territoriality and Holocene climatic amelioration at RRS. Instead, they suggest that LSA foraging groups regularly hunted dik-dik (genus *Madoqua*) using nets over a ~ 20,000-year period beginning as far back as the arid Marine Isotope Stage 2, 29–14.5 ka. Findings from this study complement recent arguments for greater economic variability in Late Pleistocene eastern Africa and push discussions of forager social change further back in time than previously considered.

Keywords East Africa · Horn of Africa · Later Stone Age · Paleolithic · Hunter-gatherers · Cooperation

Introduction

Scholars associate small mammal net-hunting with changing labor organization and group dynamics among hunter-gatherers, globally. In parts of central Africa (Harako 1981; Ichikawa 1983; Lupo and Schmitt 2002, 2005) and Australia (Satterthwait 1986, 1987), meat surpluses from successful net-hunts have been linked to increasing cooperation and group cohesion via food sharing and political stratification via feasting rituals. The time and energy involved in creating and maintaining delayed-return technologies like nets, pottery, fish weirs, or storage systems has also been tied to emergent territoriality and concepts of ownership in many parts of the world (Dale et al. 2004; Ingold 1983; Tushingham and Bettinger 2019; Woodburn 1982). In some cases, researchers have observed expanding social networks and changing labor dynamics among hunter-gatherer societies as a way of managing seasonally fluctuating or geographically dispersed plant and animal communities (Bird et al. 2019; Wengrow and Graeber 2015). Considering that hunting and gathering was the primary way of life for most of our existence (~ 300,000 years versus ~ 12,000 for farming), connections between specialized hunting methods (e.g., net-hunting) and forager social organization offer important avenues of inquiry for understanding long-term patterns of human societal variability. Eastern Africa's deep archaeological record and recent evidence of economic diversity among Middle (MSA) and Later (LSA) Stone Age hunter-gatherer groups provide a particularly interesting context for investigating these links in the distant past.

Archaeologists have documented hunter-gatherer lifeways beginning with the earliest evidence of *Homo sapiens* through historical periods in eastern Africa (East Africa and the Horn). This long record provides unique opportunities for investigating societal change among non-food

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producing groups in deep time. Most of the regional literature on hunter-gatherer variability in eastern Africa, to date, has emphasized relationships among social and economic variability, environmental changes, and interactions with early food producers in the Lake Victoria Basin during the Holocene (Dale et al. 2004; Jones and Tibesasa 2022; Prendergast and Lane 2010; Prendergast 2010). Less is known about the range and extent of hunter-gatherer lifeways in earlier periods. However, a recent review of the eastern African faunal record by Prendergast et al. (2023) highlights the use of remote capture devices (e.g., snares, traps, nets) to target small mammals in coastal forest habitats versus large game hunting in more open areas during the Late Pleistocene (~ 125–12 thousand years ago [ka]). This suggests that hunter-gatherer economic systems were more diverse before ~ 12 ka than previously considered.

Given these close links among small game hunting technologies and forager societal organization, findings by Prendergast et al. (2023) also raise questions about the ways small-scale forager social systems varied and changed in certain environmental contexts prior to the Pleistocene/Holocene transition. Recent studies at LSA sites in semi-arid southern Somalia have provided preliminary evidence that hunters used nets to intensively hunt dwarf antelope at certain times between ~ 26 and 6 ka (Jones and Brandt 2022; Jones et al. 2018). This study builds on this work by focusing on the dwarf antelope bones from one site in the region—Guli Waabayo (GW) rock shelter at the Buur Heybe inselberg cluster (Fig. 1)—to explore the antiquity and social contexts of net-hunting activities among LSA foragers living among semi-arid inselberg ("buur" in Somali) habitats in eastern Africa.

Previous research at the Rifle Range Site (RRS) at Buur Hakaba inselberg (~ 25 km SW of Buur Heybe) suggested that LSA groups implemented specialized dwarf antelope hunting strategies—likely involving nets—to facilitate sedentism and territoriality among the resource-rich microenvironments of the southern Somali inselbergs during a period of increased rainfall in the early and middle Holocene (Jones et al. 2018, after Brandt 1988). However, a lack of dates and small sample sizes limited detailed zooarchaeological perspectives on net-hunting at the site. The more robust and well-dated faunal record from nearby GW, on the other hand, provides opportunities for testing earlier assumptions at RRS and investigating long-term LSA hunting patterns in the region ~ 26–6 ka. Evidence that forager groups consistently targeted small (< 20 kg) mammals throughout the site's ~ 20,000-year sequence has shown that LSA groups were likely specialized small game hunters well before the onset of the Holocene. However, no explicit attempts have been made to test whether people used nets to hunt dwarf antelope throughout this period (Jones and Brandt 2022).

For this study, I analyzed the extensive dwarf antelope (tribe Neotragini) assemblages from GW to explore long-term relationships among net-hunting and LSA societies in southern Somalia. Jones and Brandt (2022) originally attributed all Neotragini bones from GW to the genus *Madoqua* (dik-dik). However, because some of the bones could belong to other dwarf antelope species native to eastern Africa, I first tested whether the original classifications were accurate before conducting more detailed analyses. Once the bones were identified, I calculated taxonomic frequencies—the relative percentages of individual taxa within an

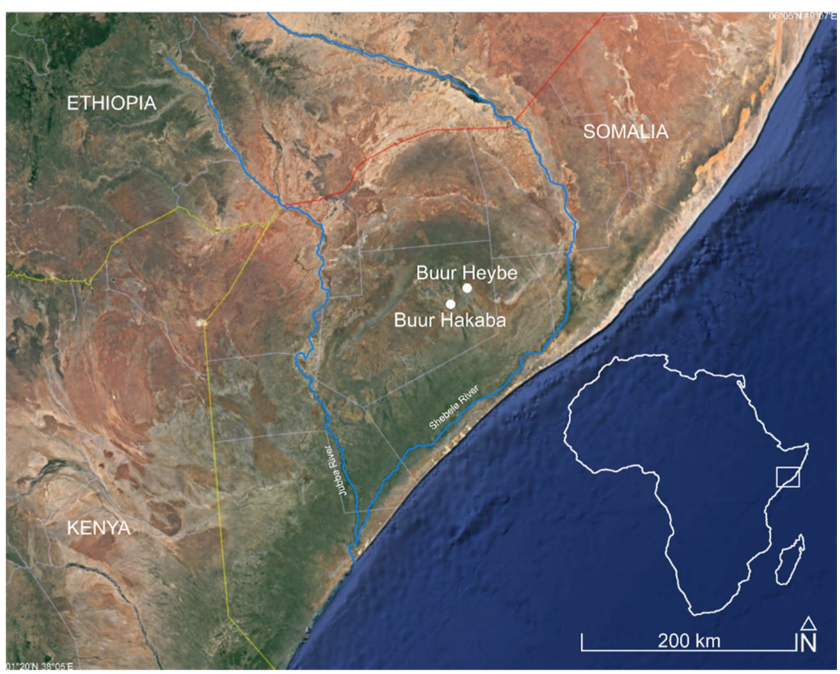

Fig. 1 Map of inter-riverine southern Somalia with locations of the Buur Heybe and Buur Hakaba inselberg clusters (background image © Google Earth)

assemblage—of all bones attributed to mammals weighing < 20 kg to examine changing small game hunting strategies throughout the site's sequence. Mortality profiles—the relative percentage of different age sets of a specific taxon within an assemblage—offered insights into the methods LSA hunters used to capture dwarf antelope over time. Ethnographic observations of dwarf antelope hunting among recent groups in eastern Africa help contextualized the zooarchaeological data. Findings from this study provided new insights into the long-term social legacy of communal net-hunting among hunter-gatherer societies in eastern Africa.

Interpretive frameworks

Archaeologists frequently rely on durable "artifacts" such as lithics (Shea 1998, 2006; Lombard 2022) or landscape features (e.g., cliff jumps; Bamforth 2011; Carlson and Bement 2013; Zedeño et al. 2014) and modifications (e.g., kites; Bar-Oz et al. 2011; Crassard et al. 2022; Groucutt and Carleton 2021) to discuss large game hunting methods in the past. Identifying specialized approaches for capturing small animals is less straightforward. This is because, although smaller game can be hunted with stone projectiles, they are commonly targeted using composite tools (e.g., snares, traps, or nets) crafted from perishable materials like wood, leather, or plant fibers (Adovasio et al. 2001; Hardy et al. 2013). To address this taphonomic bias, zooarchaeologists use taxonomic diversity and mortality data to understand the ways people hunted small game in the past (Holliday 1998; Prendergast et al. 2023; Wadley 2010).

Linking faunal data to past hunting methods is possible because the taxonomic composition of small animals captured—and so deposited at archaeological sites—varies in predictable ways depending on how they were hunted. Based largely on ethnoarchaeological studies in the central African Congo Basin (Hudson 1990, 1991; Lupo and Schmitt 2005; Noss 1995), as well as ethnographic and historical accounts from Australia (Satterthwait 1986, 1987) and the southwest USA (Lowie 1924: 195–200; Steward 1938; Underhill 1941: 23–24), scholars argue that net-drives—in which a line or semi-circle of nets (up to 4 m tall and 90 m wide) are set up and all animals within a specified area are chased into the net wall and dispatched—often produce faunal assemblages characterized by high frequencies of small mammal bones belonging to one or two species. Animals that live in forested, rocky, and/or bushy habitats and maintain small territories are particularly susceptible to this hunting approach. In contrast, individual pursuit or snaring and trapping methods capture one animal at a time and are less restricted in the types of small animals they target, resulting in more diverse and evenly distributed zooarchaeological assemblages.

In addition to taxonomic diversity, different small game hunting methods tend to produce distinctive mortality profiles at archaeological sites. Scholars working in the Congo have argued that snaring and trapping activities capture higher proportions of adults and older individuals than younger animals because juveniles are often too light to trigger snares and also less likely to follow adults into traps (Hudson 1990, 1991; Noss 1995; Lupo and Schmitt 2005). Although net-hunts also favor adult animals, they often result in mortality profiles that closely mirror living communities (i.e., all age groups represented). Individual pursuit using clubs or bow and arrows among San hunters in the Kalahari, on the other hand, have been shown to capture much higher proportions of juveniles (up to 67%) because they are slower and easier to chase down (Wilmsen and Durham 1988; Yellen 1991).

Below, I provide background information about the study area and site to help contextualize my analysis of dwarf antelope hunting methods at GW.

The Inter-riverine Region of southern Somalia

The Inter-riverine Region of southern Somalia is characterized by semi-arid bushland (White 1983) and receives 400–600 mm of rainfall per year today (Hutchinson 1992; Muchiri 2007). Rising abruptly from the surrounding plains, ~ 140 Precambrian granitic inselbergs (or "buur," locally) provide the only significant topographic or ecological diversity in the area. The rocky, irregular surfaces of some of the larger clusters of inselbergs—including Buur Heybe (~ 610 m above sea level and ~ 12 km^2 total) help trap nutrient-rich soils and collect rainwater in pools and ponds, providing favorable habitats for a range of plants and small animals (e.g., hyraxes, dik-diks, monitor lizards) more often found in riverine and coastal regions of southern Somalia (Friis and Vollesen 1989; Kingdon 1977, 1982, 2004; Madgwick et al. 1986). This pattern of relative biological diversity centered on rocky outcrops is observed in other parts of the world as well (Burke 2003; Jürgens and Burke 2000; Müller 2007; Porembski and Barthlott 2000). Archaeological research at rock shelter and open-air sites in southern Somalia suggests that resource clustering around inselbergs extended into the distant past and influenced human settlement patterns and subsistence behaviors as far back as Marine Isotope Stage (MIS) 2, 29–14.7 ka (Brandt 1986, 1988; Clark 1954: 230–250; Graziosi 1940; Jones and Brandt 2022; Jones et al. 2018, 2021).

History of archaeology in inter-riverine Somalia

Since the 1930s, over 100 rock shelter and open-air sites have been identified on and around the inselbergs of inter-riverine Somalia. Intermittent excavations at three sites offered the only available archaeological information from this grossly understudied region. Graziosi's (1940) initial excavations at Gogoshiis Qabe (GQ), followed by Clark's (1954: 230–236) at GW, revealed deep archaeological deposits with distinctive MSA and LSA lithic sequences at Buur Heybe (Fig. 2; for more information see Brandt 1986, 1988; Jones and Brandt 2022; Jones et al. 2018, 2021). A similar sequence recorded by Clark (1954: 236–242) at RRS suggested some degree of cultural continuity in the region. Following these foundational studies, little more than a rough settlement pattern and broad lithic sequence defined the human legacy of inter-riverine Somalia for nearly four decades.

To reignite archaeological interest in the inselbergs of southern Somalia, S. Brandt and the Buur Ecological and Archaeological Project (BEAP) returned to the area between 1985 and 1989 (Brandt 1986, 1988). Their re-excavations at GQ, GW, and RRS recovered large, well-contextualized lithic and faunal assemblages for testing an ecological model of human mobility (after Dyson-Hudson and Smith 1978). Prior to leaving Somalia in 1989, Brandt and the Somali Academy of the Arts and Sciences exported some of these collections to the USA. Due to ongoing civil war and political instability in southern Somalia, these materials have remained in curation at US institutions since. Between 2015 and 2019, I analyzed the faunal remains from RRS and GW in the Zooarchaeology Laboratory at Washington University in St. Louis (Jones and Brandt 2022; Jones et al. 2018, 2021). These materials were later moved to the University of Florida, where the lithics from GQ, GW, and RRS have also been stored. The GQ fauna remains were curated at the University of Wisconsin, Madison.

The GW chronology and faunal record

Brandt and BEAP excavated a total of 11 1 × 1 m squares within GW rock shelter (Fig. 3), revealing a ~ 2.5 m deep stratigraphic sequence characterized by three broad MSA/LSA lithic industries (Fig. 4; see Brandt 1986 and Jones et al. 2021 for more information). Because animal remains were not preserved in the deepest deposits, Jones et al. (2021) were only able to date the upper ~ 1.5 m of the site's sequence. Dates from 23 ostrich eggshell and ungulate enamel apatite samples showed at least intermittent use of the rock shelter between ~ 26 and 6 thousand years ago (ka).

Based on observed depositional and lithic changes, they divided the sequence into two lithostratigraphic units (LSUs). Bayesian modeling of 18 well-contextualized dates indicated two consecutive phases of occupation, which corresponded with distinctive lithic industries, as well as known climatic episodes in northern and eastern Africa:

– LSU 1 (Bardaale) → the wetter African Humid Period, ~ 14.5–6 ka
– LSU 2 (Eibian) → the arid MIS 2, ~ 29–14.5 ka

Using this chronostratigraphic framework, Jones and Brandt (2022) examined changing LSA hunting patterns spanning the Pleistocene/Holocene transition. Their taxonomic analysis of the large GW faunal collections (> 80,000 specimens) showed that hunters targeted a diverse range of game, including large and small mammals, birds, reptiles, and fish throughout the site's use, with a particular emphasis on mammals weighing < 20 kg. Although there was some indication that LSA hunters increased their focus on small mammals during the African Humid Period, Jones

Fig. 2 Aerial view of Buur Heybe with locations of Gogoshiis Qabe and Guli Waabayo rock shelters (background image © Google Earth)

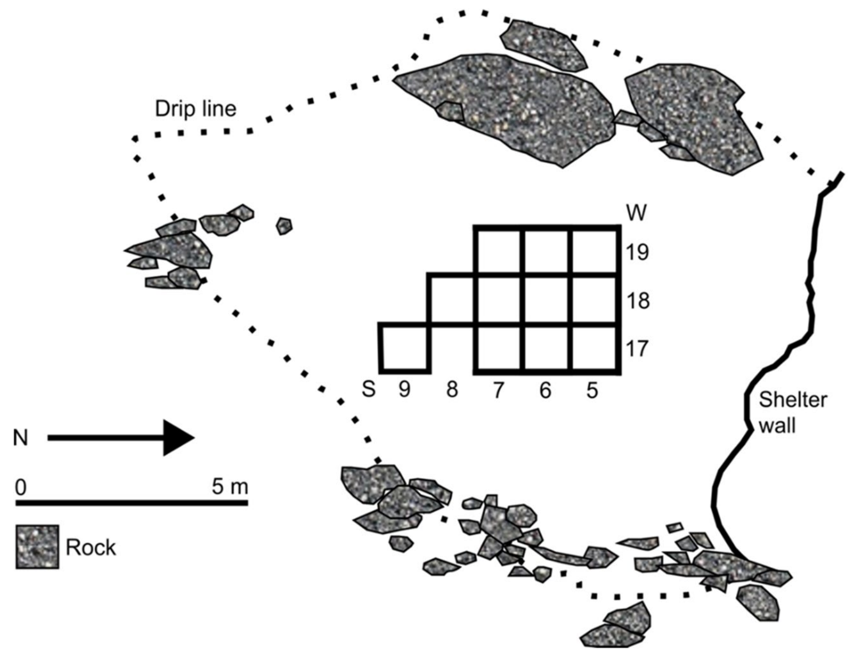

Fig. 3 Site map of Guli Waabayo rock shelter, reproduced from Jones and Brandt (2022), after Jones et al. (2021)

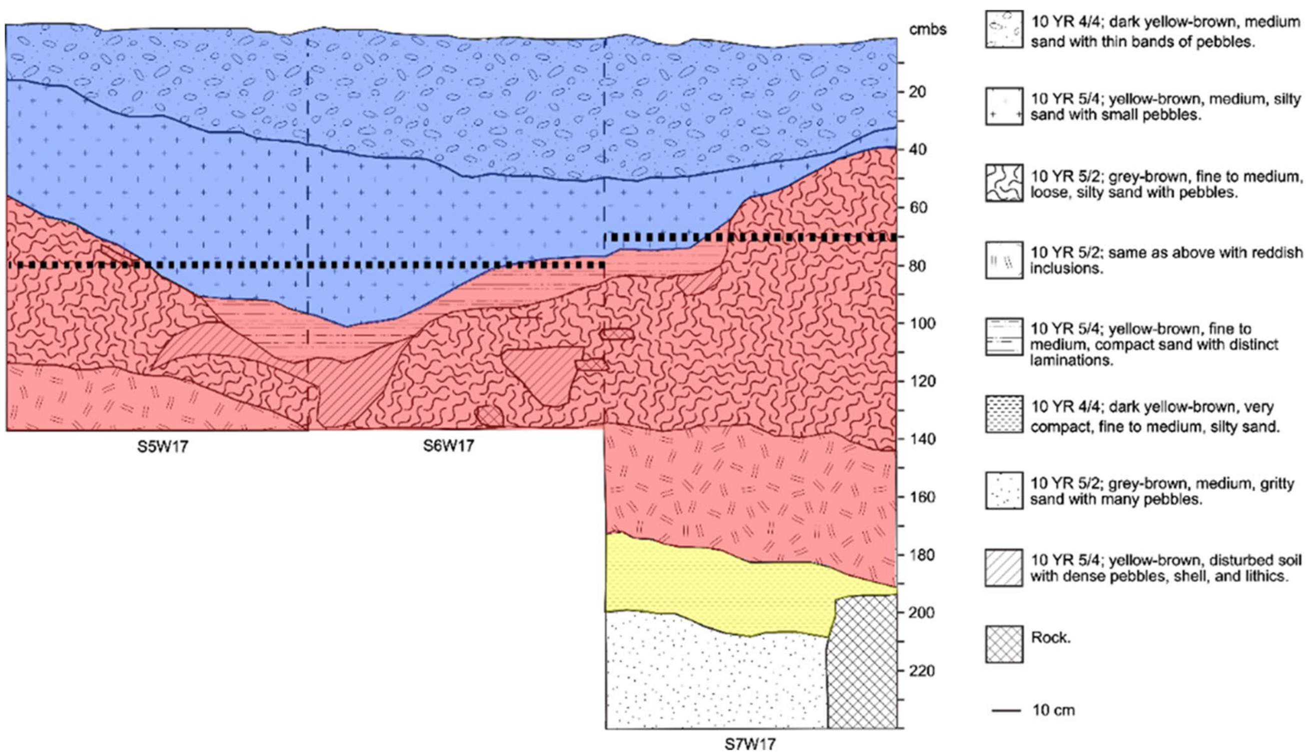

Fig. 4 Example profile from the main trench at Guli Waabayo. Colors represent lithic industries: yellow = "transitional" MSA/LSA; red = Eibian; blue = Bardaale. Dotted lines show the boundaries between lithostratigraphic units (LSUs): LSU 2 ~ 29–14.5 ka below, LSU 1 ~ 14.5–6 ka above. Reproduced from Jones and Brandt (2022), after Reid et al. (2019) and Jones et al. (2021)

and Brandt (2022) found little to no evidence that people fundamentally altered their hunting approaches in response to Holocene rainfall fluctuations. These findings aligned with overall diversity measures showing that the local fauna around Buur Heybe remained mostly the same throughout the site's occupation. Oxygen isotope ratios from archaeological warthog teeth from GW also suggested that rainfall fluctuations associated with the African Humid Period were less pronounced in southern Somalia compared to other parts of eastern Africa (Reid et al. 2019).

Evidence of consistent small game hunting over a 20,000-year period raised interesting questions about the ways MIS 2 and Holocene climatic changes impacted Somalia's inter-riverine environments. These findings also provided new perspectives on the long-term resilience of LSA communities in the semi-arid Horn of Africa. To better understand the social and economic contexts within which LSA groups at GW maintained this unusually stable, long-term approach to small game hunting, this study focuses on the site's extensive dwarf antelope assemblage—the largest ever recorded in Africa.

Dwarf antelope at GW

A total of 3104 identifiable small mammal (< 20 kg) bones were recovered from GW rock shelter, of which 2111 (68.0%) could be attributed to order or lower (Table 1). Although the small mammal assemblage was taxonomically diverse, Jones and Brandt (2022) reported unusually high numbers (59.8%; $n = 1263/2111$) of dwarf antelope (tribe Neotragini) bones throughout the sequence. They originally attributed these remains to the genus *Madoqua* (commonly dik-dik). However, observed overlap in skeletal measurements among dik-dik and another dwarf antelope common to eastern Africa, the suni (*Neotragus moschatus*),

Table 1 Small mammals (< 20 kg) at GW presented as NISP (MNI), modified from Jones and Brandt (2022)

Taxon	Common name	LSU 2	LSU 1	S9W17	Total
Chiroptera	Bats	4 (1)	1 (1)	0 (-)	5 (2)
Primates	Primates < 10 kg	0 (-)	1 (1)	0 (-)	1 (1)
Canis spp.	Jackals	4 (1)	1 (1)	0 (-)	5 (2)
cf. *Otocyon megalotis*	Bat-eared fox	3 (1)	0 (-)	0 (-)	3 (1)
Canidae	Canids < 10 kg	2 (-)	0 (-)	1 (1)	3 (1)
cf. *Proteles cristatus*	Aardwolf	0 (-)	0 (-)	1 (1)	1 (1)
cf. *Ictonyx striatus*	Striped polecat	1 (1)	1 (1)	0 (-)	2 (2)
cf. *Genetta genetta*	Common genet	0 (-)	1 (1)	1 (1)	2 (2)
Viverridae	Civets, genets	3 (1)	1 (-)	0 (-)	4 (1)
cf. *Ichneumia albicauda*	White-tailed mongoose	4 (1)	0 (-)	0 (-)	4 (1)
cf. *Herpstes ichneumon*	Egyptian mongoose	1 (1)	0 (-)	0 (-)	1 (1)
cf. *Herpestes sanguineus*	Slender mongoose	2 (1)	0 (-)	0 (-)	2 (1)
cf. *Mungos mungo*	Banded mongoose	1 (1)	0 (-)	0 (-)	1 (1)
Helogale spp.	Dwarf mongooses	10 (2)	4 (1)	2 (1)	16 (4)
Herpestidae	Mongooses	8 (-)	3 (1)	0 (-)	11 (1)
cf. *Felis sylvestris*	Wildcat	1 (1)	0 (-)	0 (-)	1 (1)
Felidae 1B	Cats 10–20 kg	3 (1)	3 (1)	0 (-)	6 (2)
Carnivora 1A	Carnivores < 10 kg	10 (-)	6 (-)	3 (-)	19 (-)
Carnivora 1B	Carnivores 10–20 kg	10 (-)	5 (-)	2 (-)	17 (-)
cf. *Procavia capensis*	Rock hyrax	199 (18)	36 (5)	18 (5)	253 (28)
cf. *Ourebia ourebi*	Oribi	9 (2)	0 (-)	0 (-)	9 (2)
Neotragini 1A	Dwarf antelope < 10 kg	798 (22)	333 (19)	132 (6)	1263 (47)
cf. *Sylvicapra grimmia*	Bush duiker	2 (1)	0 (-)	2 (1)	4 (1)
Bovidae 1B	Bovids 10–20 kg	75 (1)	18 (2)	11 (-)	104 (3)
cf. *Heterocephalus glaber*	Naked mole-rat	2 (2)	1 (1)	0 (-)	3 (3)
Gerbillinae	Gerbils	12 (2)	2 (1)	1 (1)	15 (4)
Murinae	Rats and mice	0 (-)	1 (1)	1 (1)	2 (2)
Xerus spp.	Ground squirrels	1 (1)	3 (2)	1 (1)	5 (4)
Rodentia	Rodents	105 (-)	20 (-)	10 (-)	135 (-)
Lepus spp.	Hares	169 (9)	21 (3)	19 (2)	209 (14)
cf. *Manis temminckii*	Ground pangolin	1 (1)	0 (-)	0 (-)	1 (1)
cf. *Hystrix cristata*	Crested porcupine	4 (1)	1 (1)	0 (-)	5 (2)
Mammalia 1A	Mammals < 10 kg	405 (-)	366 (-)	90 (-)	861 (-)
Mammalia 1B	Mammals 10–20 kg	92 (-)	29 (-)	11 (-)	132 (-)
Total		1941 (73)	857 (41)	306 (21)	3104 (135)

raised questions about the reliability of their initial determinations (Culley et al. 2021). To address this issue and verify the taxonomic composition of Neotragini bones from GW, I measured all complete archaeological first phalanges belonging to bovids weighing < 10 kg and compared those to modern specimens.

First phalanges were selected for this analysis because they were relatively complete compared to other elements in the assemblage and well represented throughout the site's sequence. Ratios of maximum length (GL) by proximal depth (Dp) followed criteria established by von den Driesch (1976: 96–97). Morphometric analyses of modern first phalanges from eight adult dik-dik and seven adult suni specimens from the Field Museum in Chicago revealed that size ranges of first phalanges did not overlap (Fig. 5), allowing discrimination between taxa. Data from 31 archaeological specimens showed consistent metrics that overlapped with modern dik-diks, supporting the original designation of genus *Madoqua*. Identification beyond genus was not possible based on skeletal measurements.

Madoqua (dik-diks)

Madoqua is a genus of arid-adapted dwarf antelope that first appear in the fossil record during the Miocene (~ 11.6 mya) in eastern Africa (The Paleobiology Database, https://paleobiodb.org). Among the smallest ruminants in Africa, adults stand 30–43 cm tall and weigh between 2 and 7.2 kg (Kingdon 1982, 2004). There are four recognized species of *Madoqua* in Africa today, three of which—*M. guentheri*, *M. saltiana*, and *M. piacentinii*—are endemic to the Horn of Africa (Drake-Brockman 1910, pp. 68–73; Kingdon 1982; Maloiy et al. 1988). The fourth, *M. Kirkii*, is more wide ranging and can be found in southern Somalia, Kenya, Tanzania, and eastern Uganda, as well as western Namibia and Angola today.

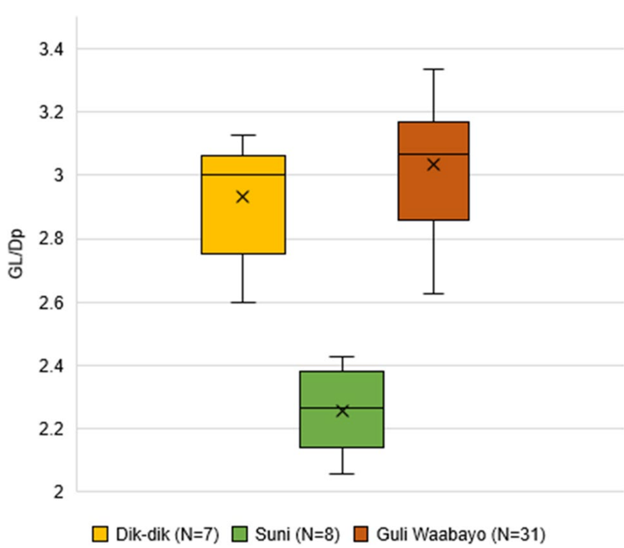

Fig. 5 Morphometric comparison of dwarf antelope (tribe Neotragini) first phalanges: GL (maximum length in mm)/Dp (proximal depth in mm). Measurements follow von den Driesch (1976: 96–97). Modern dik-dik and suni specimens were curated at the Field Museum in Chicago, IL

Dik-dik tend to live in areas with hard, rocky soils and an abundance of low thicket vegetation. Rocky outcrops, such as the inselbergs of southern Somalia, provide sufficient cover from predators and support abundant communities of edible plants for dense dik-dik populations (Kingdon 1982). In such environments, they live in monogamous breeding pairs and maintain well-defined territories (Brotherton and Manser 1997; Drake-Brockman 1910, pp. 68–73; Kranz 1991). Territories are tightly defended and average ~ 1 km^2 but vary widely in size depending on the distribution of food, shelter, and other dik-dik on the landscape (Brotherton and Manser 1997; Kingdon 1982, pp. 253–254; Simonetta 1966).

Dik-dik hunting

Although dik-dik hunting is not well documented anywhere in Africa, a few examples from Somalia and other parts of eastern Africa indicated that recent people hunted dik-dik for food as well as their skins, which are highly prized for making karosses (furred-cloaks) and suede gloves (Kingdon 1982, pp. 261). Marlowe (2010) documented occasional dik-dik hunting among Hadza foragers using bows and arrows. Mutundu (1999) used archaeological and ethnohistorical records to argue that historic Mukogodo hunters targeted dik-dik with snares and by stalking. Recent Somali pastoralist groups were known to sometimes chase down and catch dik-dik by hand (Simonetta 1966). This was possible because—although they can reach speeds of up to 42 km/h—adults are hesitant to leave their territories and will often run in circles around its borders when pursued, allowing hunters to chase animals to exhaustion without losing track of them. In Somalia, Lewis (1955, pp. 75) made brief mention of communal net-hunts to target dik-dik among Hober, Iantar, and Helai agropastoralists. Clark (1953) also documented dik-dik net-hunting among mobile foragers who recently occupied areas on and around the inselbergs of inter-riverine Somalia.

The Eile Giaffei of inter-riverine southern Somalia

In the 1940s, J.D. Clark (1953) identified a group of foragers known as the Eile Giaffei who moved frequently throughout the Buur Heybe area and specialized in hunting dik-dik using communal net-drives. During the day, women and children remained at camp to protect the dik-dik meat and skins left to dry on nearby bushes while the men hunted. The hunters carried large, 5 m-long nets strung between 2 m-long poles.

When they encountered dik-diks, they set up several nets in a wide semi-circle into which the men and their hunting dogs drove the animals before dispatching them with arrows. Clark's brief description of dik-dik net-drives offers an interesting perspective for thinking about the ways people may have interacted with inselberg environments in inter-riverine Somalia during MIS 2 and the African Humid Period.

Faunal methods

Once identification of the dik-dik bones from GW was confirmed, I calculated relative taxonomic frequencies of all small mammal (< 20 kg) bones identified to order or lower (NISP = 1907) and mortality profiles for all ageable dik-dik teeth (MNI = 78) per LSU. Bones from S9W17 could not be attributed to LSU due to possible bioturbation in that part of the site (see Jones et al. 2021 and Jones and Brandt 2022 for more information). Although totals for S9W17 are listed in Table 1 (separate from LSU 1 and LSU 2), they were not included in further analyses because relative ages for the bones could not be determined. Although differential preservation can affect taxonomic frequency and age-at-death patterns at archaeological sites, Jones and Brandt (2022) reported no significant differences in bone weathering or density-related attrition throughout the sequence at GW. This suggests that preservation bias was not a major factor in the accumulation of dik-dik remains at the site.

Taxonomic frequencies were calculated using both number of identifiable specimens (NISP) and minimum number of individuals (MNI) to the abundances of dik-dik bones relative to other small mammals. The following formula was used to calculate taxonomic frequencies at GW (following Reitz and Wing 1999, pp. 200–202): $Xn/Yn = Z_x n$. In this formula: Xn = NISP or MNI of faunal materials attributed to subgroup X by LSU n; Yn = NISP or MNI of ID specimens by LSU n; $Z_x n$ = relative frequency of subgroup X in LSU n.

Mortality profiles were estimated by MNI using dental eruption and wear data following other studies of small ungulate assemblages in Africa (Lupo and Schmitt 2005; Bunn and Pickering 2010; Uchiyama 1999). For this analysis, I focused on complete and partial tooth rows, as well as loose lower 3rd molars and 4th premolars (deciduous and permanent). Because of a general lack of modern dental aging data for *Madoqua* species, teeth and mandibular tooth rows were sorted into four relative age categories (Table 2 and Fig. 6) to calculate mortality profiles. Age estimations were made using tooth eruption data for Kirk's dik-dik (*M. kirkii*; Kellas 1955) and general criteria for tooth eruption and wear patterns observed for bovids (Hilson 1986). Although precise age correlations were not available for dik-dik, Kellas (1955) observed that female Kirk's dik-dik reach sexual maturity at ~ 6 months when old juvenile dentition is present.

Results

Madoqua dominated the small mammal assemblages from GW (Fig. 7). However, differences in taxonomic abundances and frequencies were observed between chronostratigraphic units. LSU 2 (NISP = 798) preserved more than twice as many dik-dik bones as LSU 1 (NISP = 333). These findings mirrored overall faunal counts at the site, which were also higher for earlier occupations (Jones and Brandt 2022). Sample size variability was not surprising considering the lengths of time that each period represented. LSU 2 spans ~ 14,000 years compared to ~ 6,000 years for LSU 1 (see Jones et al. 2021). Although bone counts decreased over time, proportions of dik-diks relative to other small mammals increased from 55.2% in LSU 2 to 71.9% in LSU 1.

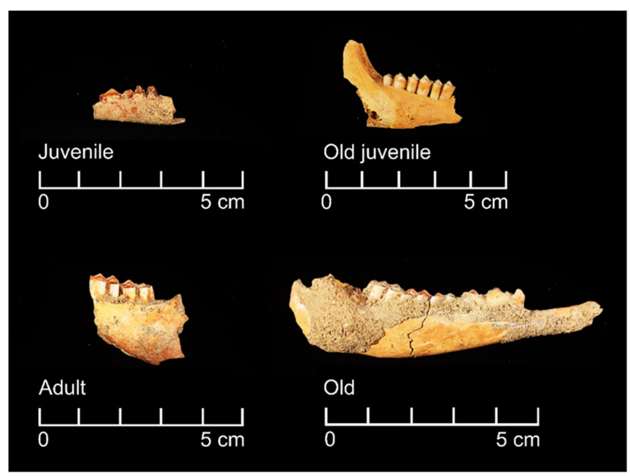

Fig. 6 Madoqua mandibles of different age sets from Guli Waabayo

Table 2 Tooth eruption and wear criteria used for estimating age-at-death of dik-dik mandibular tooth rows and teeth from Guli Waabayo. M3 = third molar; dP = deciduous premolar; P = adult premolar

Age	Tooth eruption	Tooth wear
Juvenile (J)	M3s not present; dPs present	Adult teeth lightly or unworn; dPs lightly or unworn
Old juvenile (OJ)	M3s present; dPs present	M3s lightly or unworn; dPs heavily worn (intra-tooth enamel not present)
Adult (A)	M3s present; adult Ps present	M3s under normal wear (intra-tooth enamel present)
Old (O)	M3s present; adult Ps present	M3s heavily worn (intra-tooth enamel not present)

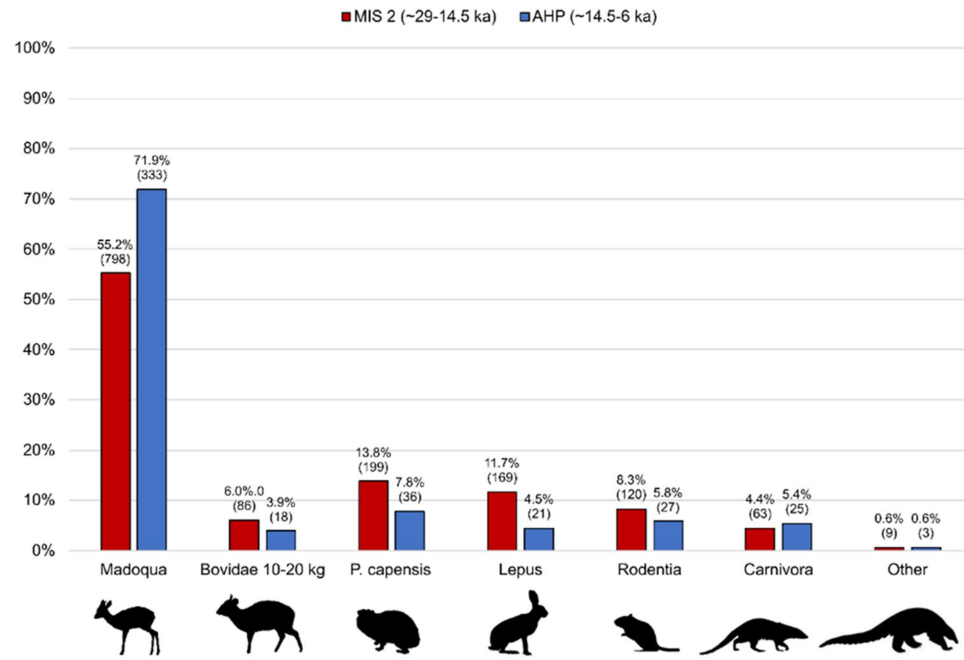

Fig. 7 Small mammal frequencies from Guli Waabayo, presented as % (NISP). MIS 2 = marine isotope stage 2, AHP = African humid period, ka = thousand years ago

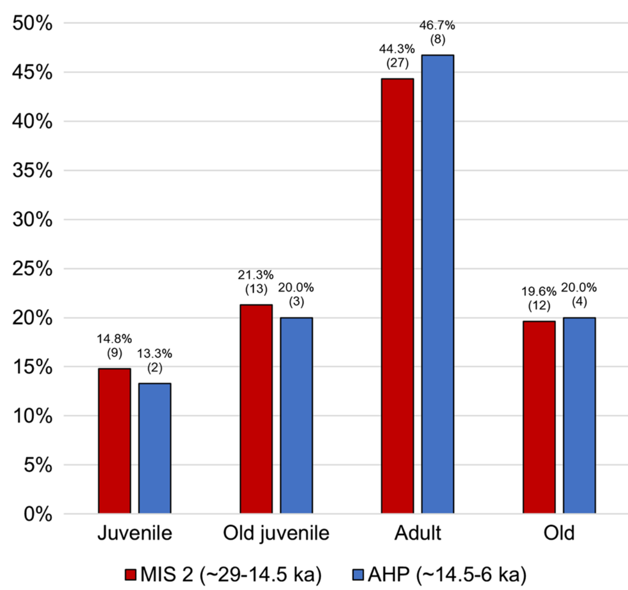

Fig. 8 Dik-dik mortality profiles from Guli Waabayo, presented as % (MNI). MIS 2 = marine isotope stage 2, AHP = African humid period, ka = thousand years ago

Despite a greater emphasis on dik-dik bones in LSU 1, mortality profiles did not change considerably through time. As seen in Fig. 8, nearly half of all ageable teeth were attributed to adults. Juvenile, old juvenile, and old specimens were relatively evenly distributed, comprising between 13.3 and 21.3% of either assemblage. Although these patterns were nearly identical between phases, less than 10 teeth were attributed to each age class for LSU 1. Such small sample sizes could have masked smaller-scale variability in dik-dik capture patterns. However, broad similarities between LSUs suggested general stability in the ways people interacted with dik-dik communities at Buur Heybe during the site's occupation.

Considering the relatively high frequencies of carnivore bones—4.4% (63/1444) in LSU 2 and 5.4% (25/462) in LSU 1—it is possible that some of the dik-dik remains at GW were brought to the rock shelter by non-human predators. Although primarily concerned with large and medium carnivores (e.g., hyenas), zooarchaeologists have argued that juvenile carnivore bones at cave and rock shelter sites can indicate denning (Cruz-Uribe 1991; Pickering 2002; but see Kuhn et al. 2010: 33). Gnaw marks on dik-dik bones could also indicate non-human predation or potential commensal relationships among people and carnivores in the past. Of the 88 small carnivore specimens identified at the site, I found only three with unfused epiphyses—two distal first phalanges (felid 10–20 kg and indeterminate carnivore 10–20 kg) and one proximal tibia (indeterminate carnivore < 10 kg)—as well as one dwarf mongoose (genus *Helogale*) mandible with an erupting third molar. Juvenile large and medium carnivores (hyena, lion, XYA) were not identified at the site (Jones and Brandt 2022) and no neonate carnivore remains (of any size class) were identified. Only one dik-dik bone from LSU 2 (0.1%, 1/798) preserved evidence of rodent gnawing. In LSU 1, three bones (1.0%, 3/333) showed gnawing, two of which were by rodents. No clear evidence of butchery was observed among the GW dik-dik assemblages—which was not surprising given the small size and fragmentary nature of the bones—but 12.3%

(98/798) from LSU 2 and 7.8% (26/333) from LSU 1 were burned. Taken together, these patterns agree with previous findings that humans were the main bone accumulators at the site (see Jones and Brandt 2022).

Discussion

The abundance and ubiquity of dik-dik bones throughout the GW sequence indicate that foraging groups regularly hunted small, territorial bovids during MIS 2 (~29–14.5 ka) and the African Humid Period (~14.5–5 ka). This is consistent with previous findings at the site (see Jones and Brandt 2022). However, whereas prior research emphasized the overall diversity of small game that people hunted (e.g., mammals < 20 kg, reptiles, birds) to investigate broader relationships with the Buur Heybe landscape (Jones and Brandt 2022), this study focuses on the importance of a single genus (*Madoqua*) for understanding changing LSA economic and social systems through time. Evidence that LSA groups developed specialized small mammal hunting strategies during an arid period in the Late Pleistocene contrasts with faunal patterns observed at the only other site where an emphasis on LSA dik-dik hunting has been documented—the nearby Rifle Range Site (RRS) at Burr Hakaba.

At RRS, Jones et al. (2018) argued that specialized dik-dik net-hunting developed as part of a larger socioeconomic strategy to facilitate sedentism and territoriality among inselberg microenvironments as rainfall increased and environments improved in northern and eastern Africa during the African Humid Period. Taxonomic frequencies from GW provide some evidence that people also increased their emphasis on dik-dik after ~ 14.5 ka. However, faunal patterns observed here show that similar hunting strategies also characterized the more arid MIS 2. This indicates that climatic amelioration did not neccessarily coincide with economic reorganization in the broader region. Instead, an observed increase on small game hunting after ~ 12 ka at RRS could relate to poor faunal preservation or ephemeral LSA occupations in the lowest deposits at the site. Mostly consistent bone weathering patterns throughout the RRS sequence and substantially smaller faunal samples from pre-Holocene levels favor the latter scenario, but it remains unclear why people began to use the site more regularly to hunt dik-dik during the Holocene. The robust small mammal bone assemblages from GW, in contrast, emphasize consistency in LSA hunting and site-use patterns.

Taxonomic abundance and mortality data from GW provide insights into the economic approaches that helped facilitate such a long-term commitment to dwarf antelope hunting at Buur Heybe. Dik-dik are, by far, the most common taxon identified at GW. An emphasis on one small mammal over others (e.g., hyraxes and hares) suggests that LSA hunters maintained specialized hunting techniques specifically designed to capture dwarf antelope over a ~ 20,000-year period. Coupled with dik-dik mortality profiles, these faunal patterns provide insights into the technological and practical strategies that helped shape this unique zooarchaeologcal pattern. Dik-dik remains from GW are dominated by adults but include younger and older individuals, suggesting that LSA groups captured dik-diks of all ages. Based on ethnoarchaeological evidence of dwarf antelope hunting in central and southern Africa (Hudson 1990, 1991; Lupo and Schmitt 2002, 2005; Noss 1995; Wilmsen and Durham 1988; Yellen 1991), the most parsimonious explanation for these faunal patterns is that LSA hunters regularly incorporated communal net-drives into their diverse hunting repertoires.

Snaring and individual pursuit were likely practiced at the site as well—for instance, the diversity of small carnivores in Table 1 could indicate snare and/or trap use (following Lupo and Schmitt 2002 and Wadley 2010). However, it is unlikely that these methods played a major role in the accumulation of dik-dik bones at the site. According to the ethnographic literature on small mammal hunting among African foragers (Hudson 1990, 1991; Noss 1995; Lupo and Schmitt 2005), snares tend to capture a wide range of small taxa, including carnivores, hares, and dwarf antelope. Very young small mammals are also less likely to trigger common noose-type snares compared to adult animals. Therefore, if snaring was the primary method for hunting dik-dik at GW, I would expect much more diverse small mammal assemblages with fewer young individuals than observed here. Individual pursuit hunting is also associated with diversified hunting strategies, but this approach tends to favor juvenile small mammals because they are easier to find and chase down than prime-aged adults (Wilmsen and Durham 1988; Yellen 1991). If the GW dik-dik were mostly caught and killed by hand or with bows and arrows, then the assemblages should be more evenly distributed among various small mammal taxa and a greater number of juvenile animals would likely be present. These important distinctions suggest that communal net-hunts—which tend to capture entire small mammal communities at once and emphasize dwarf antelope over other small mammals (Hudson 1990, 1991; Lupo and Schmitt 2002, 2005; Noss 1995)—were practiced regularly enough throughout MIS 2 and the African Humid Period to influence dik-dik abundance and mortality patterns at the site.

Considering that the GW fauna represents thousands of years of hunting activities at Buur Heybe, it is not possible to say that all dik-dik bones from the site resulted from communal net-hunts. However, faunal evidence for MIS 2 net use as part of a broader hunting strategy in southern Somalia offers new opportunities for thinking about the ways delayed-return technologies, communal hunting, and food surpluses influenced LSA hunter-gatherer societies prior to the Holocene in eastern Africa.

Delayed-return technologies and forager societies at GW

Compared to more egalitarian hunter-gatherer groups who generally invest less time and effort in material culture, scholars often associate increasing forager societal complexity with delayed-return technologies and approaches to resource management (Ingold 1983; Tushingham and Bettinger 2019; Woodburn 1982). This is largely because strategies for ensuring the future availability of food—e.g., storage or remote capture devices—often involve stronger ties to certain environmental contexts (e.g., decreased mobility, territoriality, concepts of ownership). In areas where animal and plant resources vary seasonally and/or are spatially isolated across the landscape, researchers have also noted that some foraging groups adopt flexible social and political systems and/or large networks of interaction to help manage fluctuating food availability (Bird et al. 2019; Wengrow and Graeber 2015).

In eastern Africa, delayed-return technologies—such as pottery and fish weirs—designed to exploit seasonal fish stocks in the rivers and lakeshores of the Lake Victoria Basin are linked to resource specialization, long-term site reoccupation, and ideas of resource ownership among Holocene Kansyore fisher-hunter-gatherers (Dale et al. 2004; Prendergast and Lane 2010; Prendergast 2010). Less is known about forager variability along axes of subsistence, land use, and technology in eastern Africa during earlier periods. However, evidence of specialized dik-dik hunting at GW implies considerable material investments in the creation and upkeep of nets and other small mammal hunting implements, as well as commitments to spatially restricted inselberg habitats. These factors suggest that pre-Holocene LSA societies at Buur Heybe may have also organized their labor in ways that helped manage the availability of dik-dik populations and maintain long-term occupations in the area over time. Although more data (i.e., lithic, osteoarchaeological) are needed to understand how dik-dik hunting related to specific LSA economic systems at GW, taxonomic and mortality evidence for specialized MIS 2 hunting strategies that likely involved nets contributes to recent debates about the nature of hunter-gatherer societal variability in Late Pleistocene eastern Africa, more broadly.

Compared to southern Africa (Mitchell 2013; Plug 2017; Wadley 2010), traditional zooarchaeological models of pre-Holocene hunter-gatherers in eastern Africa emphasize relatively homogenous, large game hunters living in small, mobile foraging groups (Collins and Willoughby 2010; Eren et al. 2014; Masele 2020; Masele and Willoughby 2021; Mehlman 1989). Prendergast et al. (2023), however, recently argued that small game was more important to some hunter-gatherer groups during the Late Pleistocene than previously thought. By contrasting the use of delayed-return hunting technologies (e.g., snares, traps, nets) to target small mammals in coastal and island forest habitats with mobile big game hunting in more open environments, their findings highlight economic diversity among eastern African MSA and LSA societies. Evidence of specialized dik-dik hunting at GW during MIS 2 builds on these arguments and provides contextual detail for interpreting the ways small game hunting influenced LSA economic systems in semi-arid inselberg settings. In doing so, findings from this study open the door for further discussion of the relationships between economic variability and hunter-gatherer sociality prior to the Holocene.

Net-hunting, food surpluses, and forager sociality

Whereas trapping, snaring, and bow hunting mostly target one animal at a time, large-scale net-drives—like those argued for GW—provide opportunities for obtaining numerous prey animals in a single go. Among some recent foraging groups, temporary meat surpluses from successful hunts have facilitated group cohesion. For example, net-hunts often include men, women, and children, involve food sharing, and provide opportunities for increased father-child and male-male bonding among Mbuti, Aka, and Bofi communities in the Congo Basin of central Africa, thereby encouraging stronger social bonds among members of hunter-gatherer groups (Bailey and Aunger 1989; Grove 2023: 28–34; Harako 1981; Hewlett 1991: 139; Ichikawa 1983; Lupo and Schmitt 2002, 2005; Wilkie and Curran 1991). In other cases, net-hunts are linked to political reorganization among forager and small-scale horticultural societies. In Australia, excess food from large-scale net-hunts is linked to the rise of "big men" and the establishment of hierarchical political structures among Aboriginal groups (Satterthwait 1986, 1987). Seasonal rabbit drives in the southwestern USA are also associated with inter-group cooperation, feasting, and labor reorganization that involved the establishment of temporary leaders ("rabbit bosses") among Hopi, Paiute, and Shoshone farming communities (Lowie 1924; Shaffer and Gardner 1995; Steward 1938; Underhill 1941).

Although no direct evidence of netting was recovered from GW, faunal patterns suggest that LSA foragers used communal net-drives to capture entire dik-dik communities in single mass-killing events in southern Somalia at points in the past. It is unclear exactly how much meat an average adult dik-dik yields, but these activities could have resulted in shareable amounts of meat from time to time. Another small bovid species commonly hunted in eastern Africa—the bush/common duiker (*S. grimmia*;

11–25 kg)—contributes ~ 52% of its live weight as meat (Hoffman and Ferreira 2001; Topps 1975). Assuming a similar percentage for dik-diks, it is estimated that an adult (2.7–7.2 kg) would yield roughly 1.4–3.7 kg meat. This may not seem like much food on its own, but researchers have suggested that dwarf antelope can provide enough meat to facilitate food surpluses and sharing when caught in large numbers (Ichikawa 1983; Kent 1993; Lupo and Schmitt 2005).

If dik-dik hunting periodically enabled food sharing among LSA groups at GW, then it is possible that people's long-term relationships with dik-diks also encouraged communal gatherings and cooperation through feasting and food sharing at certain times in the past. However, to better understand relationships among dik-dik hunting, nets, and LSA societies over time, more contextual information from associated archaeological datasets is needed. Ongoing analyses of human burials recovered from GW and GQ will provide insights into the lived experiences and ritual systems of the people who occupied Buur Heybe in the past. Detailed lithic studies at GW, GQ, and RRS will also provide new information about changing LSA forager mobility patterns, exchange networks, and food processing strategies in southern Somalia during the Late Pleistocene and Holocene. Together these diverse lines of evidence will help build a clearer picture of this unusual case of Late Pleistocene net-hunting in the semi-arid African tropics.

Conclusions

GW preserves the largest assemblage of archaeological dik-dik bones in Africa. This unique dataset offers an unprecedented ~ 20,000-year perspective on specialized small mammal hunting in southern Somalia. Faunal evidence for dik-dik net-hunting at the site suggests LSA groups developed delayed-return hunting strategies to maintain long-term occupations on and around the spatially restricted Buur Heybe inselberg cluster as far back as MIS 2. Well-documented ethnographic links among net-hunting and forager sociality in central Africa and Australia suggest that specialized dik-dik net-hunting at GW could have also facilitated inter- and intra-group cooperation via food sharing and feasting at points in the past. By attempting to link hunting technologies and resource specialization to societal variability between ~ 26 and 6 ka, this study provides conceptual frameworks for thinking about the ways regional hunting patterns related to economic and social diversity in the Late Pleistocene and Holocene southern Horn of Africa. In doing so, this work builds on recent debates about small game hunting and LSA societal variability in eastern Africa more broadly. Further analyses of the human remains and lithics from GW, as well as materials from GQ and RRS, will help clarify relationships among nets, dik-dik, and people in southern Somalia. Eastern Africa preserves one of the longest unbroken records of hunter-gather occupation in the world. Therefore, future studies of forager societal variability in the region could have global implications for understanding humanity's long history of hunting and gathering as a way of life.

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Author contributions M.J. conducted all analyses, created all figures and tables, and wrote and reviewed the manuscript.

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Data Availability The data that support the findings of this study are available from the corresponding author, MJ, upon reasonable request.

Declarations

Competing interests The author declares no competing interests.

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