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Human-animal Relationships in the Indus Civilisation: Challenges, Opportunities and Questions

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Abstract: Animals played a vital economic and symbolic role in the settlements of the Indus Civilisation. This paper provides an overview of how zooarchaeological studies help us understand human-animal relationships in the urban period of the Indus Civilisation. It discusses evidence from different regions of the Indus Civilisation that provides information about the feeding and management of domestic ruminants; their role in the agricultural or pastoral economy; and the use of animals in subsistence and foodways. Although there is increased recognition of the value of zooarchaeology in the archaeology of the Indus Civilisation, it is challenging to make nuanced inferences about the role, management and meaning of a variety of animals across its geographic extent. This contribution highlights opportunities and questions that remain crucial for future exploration in Indus zooarchaeology.

Introduction

Spread across a vast geographic region and occupying multiple environmental contexts, which include alluvial plains, foothills, deserts, scrubland and coastal regions (Wright 2010; Petrie et al. 2017), the Indus Civilisation (*c*.3000-1800 BC) provides a unique opportunity to understand an ancient society's relationship with different types of animals. Recognising its importance as one of the early urban civilisations in the world, researchers have documented the rise of pastoralism and the emergence of specialised breeds of domestic livestock in the Indus Civilisation, as well as the role of large bovids (zebu cattle and water buffalo) in the development of its agricultural economies and urbanism (Meadow 1991, 1996, 1999; Patel 1997; Meadow and Patel 2002, 2003; Miller 2003, 2004). Additionally, a number of site-specific zooarchaeological studies and reviews exist that highlight the exploitation of both domestic and wild mammals, as well

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as non-mammalian resources, across a vast range of Indus sites (Thomas and Joglekar 1994; Meadow and Patel 2002, 2003; Joglekar et al. 2013).

This paper is dedicated to Prof. P.P. Joglekar, who has been one of the foremost contributors to research on Indus zooarchaeology. It provides an overview of the state of zooarchaeological research in the Indus Civilisation, specifically in the urban period, and uses this to understand what is known about human-animal relationships. It highlights questions that remain unanswered and examines the potential for other bioarchaeological methods that can supplement zooarchaeological research to help understand the social meaning of animals in the Indus Civilisation.

Zooarchaeology of Sites in the Indus Civilisation

State of the field

Despite the increase in the number of zooarchaeological studies in South Asia since the 1950s (Meadow and Patel 2002), there are still many gaps in our knowledge of human-animal interactions in different sites and regions of the Indus Civilisation. Joglekar et al. (2013) have pointed out that problems include a lack of systematic sampling, gaps in reporting of sample sizes, the absence of detailed contextual or stratigraphic recording or association (and, as a result, poor chronological resolution), as well as the absence of standard zooarchaeological protocols for reporting faunal remains. Problems of identification are acute in South Asia because of the presence in archaeological sites of skeletal parts that are morphologically quite similar between taxa. The most common difficulties of identification relate to distinguishing the bones of different ruminants, for example, differentiating *Ovis* (sheep) from *Capra* (goat) from *Gazella* (chinkara) from *Antilope* (blackbuck) as well as large ruminants such as *Bos* (cattle) from *Bubalus* (water buffalo) from *Boselaphus* (nilgai).

Additionally, the resolution of data collected is not typically nuanced enough to make interpretations about the social meaning of animals. Across the Indus, Gujarat is perhaps the region with the most detailed site-based zooarchaeological studies, with work on the reconstruction of mortality profiles and systematic analyses of butchering practices (Chase 2010, 2012, 2014; Chase et al. 2014a, 2018). In Pakistani Punjab, Harappa has had the most intensive examination of animal bones (Belcher 1991; Meadow 1991; Miller 2003, 2004). Few sites in Sindh and Baluchistan have had limited systematic investigation of faunal material, except for Mehrgarh and Nausharo (Meadow 1989, 1991; Belcher 1991; Chase 2005, 2012). In Haryana, excavators have begun to conduct zooarchaeological analyses on faunal assemblages (e.g., Joglekar et al. 2013, 2017), but many of the reports are either preliminary or unpublished and the interpretations that can be made are limited to a general level (Joglekar et al. 2013).

Animals in the Indus Civilisation

On average, about 80% of the faunal assemblage from various Indus sites belongs to domestic animal species (Thomas and Joglekar 1994; Thomas 2002; Joglekar et al. 2013), which include *Bos indicus* (zebu cattle), *Bubalus bubalis* (water buffalo), *Ovis aries* (sheep), *Capra hircus* (goat), and *Sus* (pig). Of the domestic animals, cattle (and possibly buffalo)

are the most abundant type of animal discovered in faunal assemblages across the Indus Civilisation, averaging between 50 to 60% of the animal bones found across Indus sites (Thomas 2002; Miller 2004; Joglekar et al. 2013; Chase 2014). As it can be difficult to distinguish securely between cows and buffalo, differences in proportions of *Bos* and *Bubalus* at individual sites cannot always be determined. Meadow (1991) has claimed that the ratio of cattle to buffalo at Harappa is 34:1, indicating that buffalo made a very small contribution to Harappa's economy and diet and may have not been fully domesticated. In contrast, water buffalo appear to be present in large proportions at Dholavira (Patel 1997). Despite the arid environment of Khadir Island, it is possible that their survival was assured by their immersion in the water in the large reservoirs around the site (Bisht 1991, 2005; Patel 1997, 2015). Meanwhile, on average, sheep/goat remains account for about 10% of the total faunal assemblage across Indus sites located on alluvial plains (Thomas and Joglekar 1994; Meadow and Patel 2003). Wright (2010: 173) has noted that goats were more likely to be found in arid and semi-arid environments, such as at Nausharo and regions in Gujarat, whereas in better-watered areas, such as Pakistani Punjab, sheep probably outnumbered goats, as seen, for example, at Harappa (Meadow 1991). Pigs make up about 2-3% of total faunal assemblages across Indus sites (Thomas 2002). Faunal assemblages from rural village sites that have been studied appear to be broadly similar to those from urban centres with respect to species ratios (Joglekar et al. 2013, 2017; Chase 2014; Chase et al. 2020).

The overwhelming proportions of cattle bones across Indus sites indicate a cultural preference for beef consumption across Indus populations, supplemented by the consumption of mutton and lamb. It is possible that meat consumption was complemented by the widespread existence of dairy economies (Miller 2004). Wild animal species like deer, antelope, gazelle, hares, birds, and possibly wild pigs are also found in small proportions in the faunal assemblages of both rural and urban Indus sites, suggesting a taste for the game. Riverine resources such as reptiles, fish and molluscs are featured at Harappa, Allahdino, Balakot and Nausharo (Belcher 1991, 1994, 2003), as are marine resources at coastal sites such as Balakot and sites in Gujarat (Belcher 1991; Deshpande-Mukherjee 1996, 1998; Abhayan 2016; Abhayan et al. 2018, 2020), suggesting that these diverse resources had a place in the Indus diet. The presence of a marine catfish species (family *Ariidae)* at Harappa (Belcher 1991) indicates that some fish may have reached this inland site in dried form through long-distance exchange networks running between Harappa and sites located near coastal environments.

While discussions about the diversity and variability of agricultural practices across the Indus Civilisation have increased in scholarship in recent years, our understanding of cultural and regional variations in patterns of animal exploitation has been extremely limited. Crucially, as it stands, reports suggest *uniformity* in the use and cultural preference for certain animals, for example, the importance of cattle across the Indus Civilisation (Possehl 1979; Thomas 1989, 2002; Thomas and Joglekar 1994; Meadow and Patel 2003). This pattern has been highlighted previously by several scholars (e.g., Fairservis 1986; Thomas and Joglekar 1994; Meadow and Patel 2003); but it has not been critically assessed in terms of Indus commensality and the social context of the role of animals in Indus societies.

Indus Faunal Analysis

To gain insight into the relationship between humans and animals beyond species identification, zooarchaeologists use species ratios, animal mortality and sex profiles, and studies of butchery practices (e.g., Payne 1973; Grant 1982; Reitz and Wing 1999; O'Connor 2000; Sykes 2014). Some or a combination of these methods have been used successfully at Indus sites, but poor preservation conditions have introduced problems that limit the extent of detailed analyses. For example, many bones from Indus sites are mineralised, have salt and phosphate inclusions, and/or are encrusted with calcite and organic materials (e.g., Chase et al. 2014a; Joglekar et al. 2017). The taphonomic alteration of bones makes it difficult to conduct detailed studies of cut marks or butchery practices, which would help reconstruct the *chaîne opératoire* of how cuts of meat were produced (e.g., Chase 2005, 2012). The alteration may also obscure the pathology of animal bones that may be informative about the use of animals for traction or dairying in their lifetimes (Miller 2004). Taphonomy aside, the scarcity of ageable and sexable faunal specimens within an assemblage or the small size of assemblages makes slaughter profiles difficult to construct, which in turn makes inferences about the extent of meat-production or secondary-product exploitation challenging. These problems persist within the Indus context (see Chase 2010, 2012, 2014; Joglekar et al. 2013, 2017).

Studies at Harappa (Meadow 1991; Miller 2004), Dholavira (Patel 1997, 2015), and Farmana (Channarayapatna 2014, 2018), as well as smaller sites such as Mehrgarh (Meadow 1989), Balakot (Meadow 1988), Shikarpur (Chase 2014; Chase et al. 2020), Kanmer (Goyal 2021), Bagasra, Jaidak (Chase 2010, 2012; Chase et al. 2014a, 2014b, 2018, 2020) and Kotada Bhadli (Chakraborty et al. 2018; Goyal et al. 2018) have recorded site-specific variations in the exploitation of certain species. For example, changes in species ratios over time have been noted at large and small sites such as Harappa, Dholavira and Nausharo, suggesting the increasing and/or decreasing importance of particular animal species. These patterns are possibly correlated with the demands of increasing urbanism. Research on animal bones from Harappa has also indicated that cattle became more important in the economy over time. Miller's (2004) research on the assessment of the extent of the secondary products' economy at Harappa suggested more intensive cattle husbandry strategies and secondary products' exploitation in the urban period, with a notable decrease in the post-urban period, and a higher proportion of medium or small animals being observed in later contexts (Meadow 1991: 103; Miller 2003, 2004). She suggested this pattern might be consistent with a decline in specialist pastoral producers, and a return to generalised household pastoral production systems. Alternatively, it could also be interpreted as a potential decrease in secondary product exploitation over time, perhaps as a strategy to cope with the stress on resources in the post-urban period. Among the small ruminants, sheep are more numerous than goats at Harappa, suggesting a further emphasis on dairying, and perhaps, on fibre products (Meadow 1991; Meadow and Kenoyer 1997). At both Nausharo and Dholavira, however, sheep and goats are found in relatively equal proportions, although there are slightly more sheep present (Meadow 1989; Patel 1997, 2015). The differences in kill-off patterns suggest that sheep may have been bred principally for wool (Wright 2010).

As faunal analyses at Indus urban sites have mostly used bones from secondary or trash deposits (e.g., Meadow 1991; Miller 2004), making inferences about within-site

variation in the access or consumption of different animals is challenging. For instance, there may be no correlation between the distribution, consumption and disposal patterns that eventually led to the creation of the archaeological assemblage (Meadow 1991; Miller 2004). The presence of elements of cattle on all of Harappa's mounds, however, suggests that residents in all mounds (or neighbourhoods) had access to animals that might be used for traction and as a meat source (Miller 2003). Similar patterns of large bovid bones in street deposits have been found in Dholavira (Patel 1997). In Haryana, Girawad had wild mammal remains concentrated in the central part of the site in the Early Harappan period, but at Farmana, an assessment of the different anatomical parts of different animals, including wild species, revealed that a system of distribution or sharing of high meat-bearing parts may have been in place, as not all the house complexes had all the parts across all time periods (Channarayapatna 2014, 2018). These patterns may be indicative of distributive systems or preferences of particular social groups within these settlements.

Butchery and Carcass-processing/Cooking

Butchery practices have only been systematically studied at a few sites in the Indus Civilisation. Chase (2005: 51) noted that butchery and carcass-preparation/cooking practices reflect cultural preferences and technological choices, and the specific way in which an animal is prepared for consumption encapsulates important economic and social information. These practices also inform us about foodways and food preparation.

There is variation in the methods of butchery and suggestions for differential carcass-preparation/cooking between different sites. Cut-marks have been observed on meat and marrow-rich bones of domestic and wild animals across the Indus Civilisation (Meadow 1979; Belcher 2003; Joglekar et al. 2013; Channarayapatna 2014, 2018). At Farmana and Girawad in northwest India, cut-marks appear to have been made with a sharp metal blade (Channaryapatna 2014). Additionally, completely charred and vitrified bones were dominant among the bone modifications observed at Farmana, Masudpur I and Masudpur VII (Joglekar et al. 2013, 2016, 2017; Channarayapatna 2014). At Farmana, it was also noted that nearly all anatomical elements of cattle/buffalo had charring marks, whereas for sheep/goat only the cranial fragments, ribs, scapula, vertebrae, and phalanges were charred to different degrees (Channarayapatna 2014, 2018). Although charring may have been a result of depositional or post-depositional processes, these differences may hint at different carcass-processing practices for different animals and may indicate preferences for the roasting of meat. Using a different approach, Goyal (2017) suggested that at Kanmer, preparation via roasting was more common in wild animals, particularly deer, than in domestic animals.

There is also variation in the methods of butchery and carcass preparation/cooking within individual sites. In Gujarat, faunal assemblages at Bagasra suggested that relatively more cut-marked pieces of bone were found within the walled precinct of the settlement compared to outside the walls (Chase 2012). Chase (2012) suggested that this pattern indicates that residents within the enclosure prepared meat-based dishes differently from those outside the walls, perhaps signifying a social or cultural variance. Meanwhile, at Shikarpur, bones from all portions of the skeletons of animals were present in all areas of the site (Chase 2012, 2014). However, at Bagasra, the initial stages

of the butchery process were the same for all animals that were eventually consumed as food, and the butchering process was done solely with the use of metal tools (Chase 2012), as seen in northwest India. Chase (2014) suggested that this pattern would arise if both communities were raising and butchering their animals, or if they were receiving meat from an external, common meat market. These observations raise important questions about the provisioning and distribution of foodstuffs in the urban period.

Animal Management

Age and slaughter profiles

The construction of age and slaughter profiles reveals patterns that help reconstruct the strategies used for the creation and management of animal products (meat, milk, or traction). These activities also reflect ontological changes in the relationship between humans and animals (Sykes 2014).

However, the precise origins and extent of secondary product exploitation in ancient South Asia are not well understood. Several scholars have commented on the importance of large bovids like *Bos indicus* and *Bubalus bubalis* for dairy products and draft/traction, suggesting the overwhelming importance of cattle pastoralism for Indus society (e.g., Possehl 1979; Fairservis 1986; Meadow and Patel 2002; Miller 2004). Dairy production provides milk, butter, ghee, cheese, and yoghurt, which are all items that are high in nutritional value, but also storable and replenishable (Miller 2004: 46; Greenfield 2010).

Similarly, it has been argued that the use of traction animals for agricultural purposes and the transport of agricultural products, craft items, and building materials (e.g., wood, clay) would have been vital for the provisioning of urban and rural populations (Miller 2004). The evidence of miniature terracotta bullock cart frames from Indus sites throughout the region, as well as yokes from Indus phase levels at Nausharo, and ploughs from Banawali, suggest that bovines were harnessed for draught (Meadow and Patel 2002). Scholars have also noticed an emphasis on male cattle across the Indus Civilisation. The most common engraving on Indus stamp seals consists of a male bovid (often called a 'unicorn') in a profile that faces the left side of the seal (Rissman 1989), and other bovids usually include male zebu cattle, bison and water buffalo (Ameri 2013: 361). These representations may suggest a requirement for bulls.

Despite being limited in number, slaughter profiles for Indus settlements reveal a general trend of the presence of older adults (for bovine and caprine/ovine species) (Joglekar et al. 2013; Chase 2010, 2012, 2014; Chase et al. 2020). The present state of knowledge regarding species distinctions among the large stock and breed variation within these preclude the morphometric analyses required to distinguish cow, bulls, and castrates among cattle and buffalo (Chase et al. 2014a: 9). Miller (2004) incorporated ethnoarchaeological studies in present-day Pakistan, and artefactual and zooarchaeological analyses of cattle remains to specifically address the extent of secondary product exploitation of cattle at Harappa. She found that out of the bovine animals studied, 90% were kept alive until the age of 3-3.5 years, which indicates that females were used for dairy production, whereas males were used for traction (Miller 2004). An increase in the use of cattle for traction is documented by their increased size

from the late pre-urban to the urban period at Harappa, a change suggestive of an emphasis on males and castrates (Miller 2004: 619; Wright 2010: 204). Miller suggested that there is evidence for the development of special cattle breeds for traction, such as for plough agriculture and harnessing carts (2003: 304; see also Wright 2010: 207). Additionally, there were higher proportions of older adults in the urban period (42% pre-urban vs. 56% urban), which indicates the increasing importance of secondary products in the urban period and the use of animals for longer productive lifetimes (Miller 2004). Based on this evidence, Miller (2004) suggested that dairying and traction activities were vital for the agro-pastoral economy at Harappa, with an intensification of secondary product exploitation and specialisation in pastoral production systems during the urban phase.

Age and slaughter profiles at Bagasra, Shikarpur, Jaidak, Kanmer and Kotada Bhadli in Gujarat indicate that cattle were probably exploited for secondary products (milk and traction), but sheep/goat were likely primarily raised for meat (Chase 2014; Chase et al. 2014a, 2018, 2020; Goyal 2021; Goyal et al. 2018; Chakraborty et al. 2018). For example, at Shikarpur during the urban period, fewer adult sheep/goat were kept in a herd (enough to maintain its long-term viability), but more than half of the cattle were kept to adulthood age prior to consumption (Chase et al. 2014a). These patterns are consistent with subsistence-oriented production and secondary product exploitation (milk and traction), respectively (Chase et al. 2014a). In northwest India, Joglekar and colleagues (2013) suggest that, based on cattle size measurements, a small number of bulls versus a dominance of castrated bulls or females were present in the assemblages studied, a herding strategy likely adopted to practice dairying (Joglekar et al. 2013).

Miller (2004), Chase (2014) and Chase and colleagues (2014a) have all noted that most zooarchaeological studies use the presence of high numbers of young animals (nursing calves) as evidence of dairying production (e.g., Payne 1973), as most milk is available for human consumption if male lambs, kids or calves are slaughtered soon after birth. In contrast, the presence of adult males has been interpreted as a strategy for the maximisation of meat products. However, this interpretative approach has also been widely criticised (e.g., Halstead 1998; Greenfield 2010) and may only be relevant in the case of a focus on a single-product economy. Given the absence of the slaughtered calves at Harappa and some sites in Gujarat, and a predominance of adult animals, it is likely that most Indus settlements adopted complex mixed product-economies, possibly ones that emphasised both meat and secondary-product use. Similar evidence exists at Dholavira (Patel 1997), which has a predominance of adult bovids. However, Patel (1997) noted the presence of higher proportions of young animals slaughtered in the 2.5 to 3.5-year age ranges at Dholavira, hinting at a different production economy. She also observed differences in cattle size distributions, suggesting the presence of different and smaller cattle breeds at the site, as well as a high number of water buffalo bones (Patel 1997). Taken altogether, age, size, and species patterns suggest regional diversity in subsistence strategies, particularly between Harappa and Dholavira in the urban period, but less clear differences between Harappa and smaller settlements in Gujarat such as, Shikarpur, Bagasara, Jaidak and Kotada Bhadli (Chase 2014; Chase et al. 2014a, 2018, 2020; Chakraborty et al. 2018).

An example of clear regional variation in cattle slaughter patterns is evident at the site of Balakot (Meadow 1979). The slaughter profiles of cattle in the urban period were

recorded as 90% juvenile, with a high proportion of sub-adults versus adult cattle (Meadow 1979). The high proportion of young cattle visibly contrasts with patterns observed at sites such as Harappa, Dholavira, Shikarpur, Bagasra, Jaidak and Kotada Bhadli. The pattern at Balakot was interpreted as a strategy employed for optimising meat production (Meadow 1979). When compared to patterns observable from the pre-urban period, however, an increase in the slaughter of adults was observed, possibly suggesting a gradual increase in the importance of secondary products exploitation from the pre-urban to urban period (Meadow 1979). Miller (2004) suggested that this shift might have occurred at a regional or multi-regional level, with a shift towards intensive secondary products exploitation representing larger subsistence and economic trends for civilisation as a whole. Such a claim would need much more evidence from many other Indus settlements.

Animal management: feeding

Carbon isotopic results from domestic and wild ungulate tooth enamel from various Indus sites provide information about animal feeding, which is an essential, everyday aspect of interacting and relating with animals. Bioapatite carbonate values from animal teeth from small, rural Indus settlements demonstrate differential animal management practices and give insight into the diets of different species of domestic animals and wild ruminants (Sarkar et al. 2016; Jones 2017; Lightfoot et al. 2020). In northwest India, the carbon stable isotope results show that the cattle and water buffalo consumed diets that were extremely high in C_4 foodstuffs, with evidence for the mixed consumption of C_4 and C_3 plants for wild ungulates and sheep/goats at most sites. There is little evidence for seasonal variation in the diet in any of the species; the diets were broadly consistent through the time of tooth formation (Lightfoot et al. 2020). The diets were also consistent across different environmental zones represented by the samples, and there was little change over time except for sheep/goats, which demonstrated an increase in consumption of C_4 foodstuffs (Lightfoot et al. 2020).

Results from animal enamel carbonate $\delta^{13}C$ values from sites in Gujarat (Chase et al. 2014a, 2018, 2020) reveal patterns very similar to the data from Haryana, except at Kotada Bhadli (Chakraborty et al. 2018). Evidence from most sites in Gujarat suggests that cattle were consistently feeding on C_4 plants, whereas sheep/goat demonstrated some mixing of C_3 and C_4 plants (but data for wild ruminants is not provided) (Chase et al. 2014a, 2018, 2020; Chakraborty et al. 2018). Chase et al. (2014a; 2020) concluded that the high proportion of C_4 in cattle diets is an indication of cattle being fed millet throughout the year. However, at the Sorath Harappan site of Kotada Bhadli, individual cattle/buffalo demonstrate considerable variation and appear to have consumed a mixed diet of C_4 and C_3 vegetation, whereas sheep possibly consumed more C_4 plants than goats (Chakraborty et al. 2018).

The input of C_4 plants into the diets of wild ruminants and sheep/goats in both northwest India and Gujarat suggests the presence of C_4 plants in the surrounding landscape. Although consistent C_4 diets for cattle/buffalo are suggestive of specific feeding practices for these animals, the possibility that they were feeding on wild C_4 vegetation cannot be excluded (Lightfoot et al. 2020). Human control of these animal diets may have involved letting cows and water buffalo graze in millet fields after

harvest, as well as more direct foddering of wild and/or domesticated C_4 plant species to these animals (Lightfoot et al. 2020). According to Reddy (1994) and Pokharia and colleagues (2017), the soil organics from sites in Gujarat indicate a C_3-dominated environment during the Mature Harappan period, with an increased input of C_4 plants towards the end of the Mature Harappan period due to the increased cultivation of millets (Chakraborty et al. 2018). Thus, in Gujarat, it is possible that the primary source of C_4 for cattle/buffalo was from agricultural millets through specialised foddering (Chase et al. 2020). Not much is known about the diets of non-ruminant animals (for example, pigs), except for limited evidence from northwest India that suggests they had primarily C_3 diets (Lightfoot et al. 2020).

Managing a dairying economy

The use of cattle for secondary-product exploitation like traction and dairying in the Indus Civilisation has been broadly assumed (Fairservis 1967; Gouin 1990; Thomas and Joglekar 1994; Wright 2010; Chase et al. 2014a, 2018). However, few researchers have discussed the complexities involved in managing cattle for maintaining a dairy economy in the Indus River basin. For example, the survival of a high proportion of females and the early slaughter of all but the few males kept for breeding purposes (Chase et al. 2014a) are vital herd management strategies for a dairy economy. In contrast, keeping cattle for draught animals requires that a high proportion of castrated males be allowed to live a good deal longer than would be the case in herds managed for meat and milk. It is likely that multiple cattle management strategies were needed to produce different resources of traction, meat and milk (Zeder 2006: 165). As it is not yet possible to distinguish cows, bulls, and castrates among cattle and buffalo in Indus contexts, making nuanced assessments of different management strategies based on the age and sex profiles of faunal remains alone is difficult (Chase et al. 2014a: 9). At Harappa, Miller suggested that since 90% of the bovine animals were kept alive into adulthood, it was likely that cows were used for dairying and bulls were used for draft/traction, but evidence for dairying at Harappa is ambiguous (2004: 625).

Additionally, cattle have higher water requirements than sheep and goats, and more selective pasturing preferences. They require shade and rest for almost eight hours a day to ruminate food from one stomach to another, limiting their mobility (Bhattacharya and Bhattacharya 2002: 165). Additionally, although nowadays we have come to rely on milk as a staple commodity, without human management, milk is a seasonal product. A cow must give birth every year in order to continue producing milk. The amount of milk cows produce depends on how much fodder they have access to, which changes throughout the year. Producing milk for any animal is demanding and requires suitable nutrition, which requires adding grain to the animal's diet. Ethnographic research conducted by Miller (2004) demonstrated that dairy animals are dependent on fresh green fodder supplies because the lactation process depletes animals of minerals, proteins, and sugars, components vital for their nutritional health. Although animals that consume dry fodder (chaff, grass) will continue to produce milk, the quantity and quality (fat content) of the milk are severely reduced with this diet. Miller (2004) noted that in present-day Punjab, when green fodder is scarce during the summer, cattle and buffalo are milked only once a day, and the volume of milk produced is much lower than

in the winter and spring, when they are milked twice a day. During the driest summer months, many animals cease producing milk entirely and dry up (Miller 2004), but recover later in the year. Thus, extensive foddering may have been needed to maintain cattle within areas under intensive cultivation (Zeder 2006: 166). In northwest India and Gujarat, isotopic evidence suggests that cattle/buffalo were primarily fed C_4 plants (millets and/or wild C_4 plants throughout the year) (Chase et al. 2014a; Sarkar et al. 2016; Jones 2017; Lightfoot et al. 2020). It is possible this feeding regime would have affected the production of cow/buffalo milk in the summertime, making it a seasonal product.

The storage of milk is an additional practical aspect of managing a dairy economy. As milk spoils quickly and may be difficult to digest in its various raw forms, it must be quickly consumed or converted into products like butter, yoghurt, clarified butter (*ghee*) or cheese. DNA studies of modern Indian populations indicate that the lactase persistence -13910*T allele has the highest frequency among observed mutations as well as the widest distribution throughout the Indian subcontinent, but only one out of eighteen individuals in modern-day India can digest lactose (Gallego Romero et al. 2011; Gerbault et al. 2011). This statistic suggests that populations may have developed strategies to convert milk into more easily digestible products (such as yoghurt or ghee) from an early period. Intriguingly, preliminary evidence from organic residue analysis suggests that dairy products were not widely processed in vessels from Indus sites in northwest India (Suryanarayan 2020; Suryanarayan et al. 2021) or from Chalcolithic and Indus-period sites in Gujarat (García-Granero et al. 2022). It is however possible that dairy was mixed with other products in vessels, or that specific vessels were used for processing dairy (Suryanarayan et al. 2021). Alternatively, in Gujarat, at the site of Kotada Bhadli, organic residue analysis suggests the substantial processing of dairy products (Chakraborty 2020). The possibility that dairy products were seasonal, or rare, or considered 'special' at certain settlements, opens up new ways of understanding the relationship between Indus pastoral groups and communities and the ruminant animals they herded.

Animal-human Relationships and 'Continuum of Lifestyles'

Sykes (2014) has argued that methods and approaches in zooarchaeology often make it difficult to conduct 'social zooarchaeology', which is an understanding of how human-animal relations transform both parties, with the two becoming mutually socialised through their exchanges (see also Mullin 1999; Mlekuz 2007; Brittain and Overton 2013). For example, the determination of kill-off patterns and age profiles focuses on the productive and alimentary rather than the social significance of animals (Sykes 2014). The emphasis on the death of animals rather than their life-histories also diminishes the relationships that exist between people and the living animals around them (Sykes 2014). Other issues result from quantitative methods such as NISP, MNI, or MNE, which have come under tremendous scrutiny for what they calculate, but they have not been interrogated for what they might mean or represent socially (Sykes 2014: 9). It is also well-recognised that different parts of an animal carcass will be deemed variously as 'good' or 'poor' depending on cultural attitudes (Crabtree 1990). Additionally, these distinctions may not just be in terms of high or low-value foodstuffs, but they may

represent ontologies that are representative of power relations and extend into ritual and/or political lives (Davis 2008; Choyke 2010).

Direct correlations between the number of bones found in a faunal assemblage and the importance of animals are also found in Indus archaeology (e.g., Meadow and Patel 2003; Joglekar et al. 2013). The frequency of cattle bones is high in Indus faunal assemblages, leading to the assumption that cattle/buffalo were the most important animal(s). However, high levels of archaeological representation need not equate to an animal's social importance, and there may also be taphonomic variables contributing to biases in the archaeological record. The presence of adult cattle in a majority of faunal assemblages at Indus sites (see above) does suggest that bonds would have developed between people and their cattle. Ethnographic parallels exist with modern pastoral communities; the Suri herders of northeast Africa see cattle as extensions of human society (Abbink 2003: 342), while the Sakha of northeastern Siberia see cows as central to society (Crate 2008), even though they do eventually consume them (Wright 2010).

Additionally, while species counts and ratios in Indus zooarchaeology provide some insight into the relative importance of different animals to the food economy, many questions remain concerning who husbanded/managed domestic animals, and how wild animals and riverine/coastal resources were hunted/fished (deFrance 2009). Some scholars have discussed how the relationship between people and their animals framed the lives of various Indus societies. For example, Wright (2010: 173-174) has discussed how a 'continuum of lifestyles' marked by degrees of mobility would have accommodated the keeping of animals in the Indus context, including nomadic pastoralists, semi-sedentary pastoralists and sedentary pastoralists. Wright (2010) has suggested that sedentary pastoralism is reflected by the large numbers of animal bones and cart tracks found in street deposits at Harappa, and water storage tanks in Dholavira. She suggests that settled pastoralists on the alluvial plains most likely took advantage of its varied landscape, seeking out well-watered areas for water buffalo, while sheep and goats could graze on marginal lands on the outskirts of agricultural lands and stubble from harvested fields (Wright 2010: 173-174). Archaeological evidence also suggests that some animals may have been procured from different locations and moved to larger settlements. For example, evidence from Bagasra shows that all the animals were pastured in the region with no seasonal migration. However, unlike sheep/goats, which were raised locally at Bagasra, many of the cattle/buffalo were acquired at a young age from different locations, but probably from within the same broad region (Chase et al. 2014a, 2018; 2020). Semi-sedentary pastoralism was possibly practised at settlements such as Nausharo, where pastoralists moved seasonally between upland and lowland settlements to avoid harsh winters and hot summers when grazing areas were reduced (Wright 2010), and at Oriyo Timbo in Gujarat, which was seasonally occupied (Rissman 1985; Reddy 1994; Wright 2010). Examples of nomadic pastoralism in the pre-urban (Hakra) period are suggested by the presence of surface scatters of small campsites in Cholistan, which were documented by Mughal (1997). It is possible that nomadic pastoralists lived beyond the limits of agricultural zones and returned to the same location on a seasonal basis (Wright 2010). Elsewhere, it has been suggested that hunting and gathering populations possibly engaged in symbiotic relationships with village and town dwellers (Possehl 2002; Wright 2010), but there is limited evidence to support any of these ideas.

Overall, evidence from Indus faunal assemblages has led scholars to focus on questions about the extent of urban pastoralism and/or mobile pastoralism practised across settlements and the relationship between urban dwellers and hunter-gatherer groups across time. As the history of the development of pastoral systems in South Asia remains unclear (Meadow and Patel 2003: 84), archaeologists often rely on ethnographic and historical records to make interpretations about the past (e.g., Guha 1994; Chase et al. 2020). It is likely that the mix of environments and specialisation of husbandry could have provided a rich resource variability and exchange of products that was mutually beneficial. No pastoral system exists or is likely to have existed for very long, without agricultural products being available through one means or another (Meadow and Patel 2003: 75), as agent-based modelling (ABM) has indicated (Balbo et al. 2014). Nomadic pastoralists may have facilitated the movement of trade goods and their own products through their mobility. However, it is possible that these relationships were complex and required negotiation, especially during periods of food stress or crisis.

The different species of wild plants, animals and forest products in archaeological assemblages across the Indus Civilisation suggest that these resources might have been exchanged between hunters and gatherer groups, nomadic populations, and/or permanently-settled people (Wright 2010: 175). It is also possible that rural and urban inhabitants hunted and consumed wild animals and gathered wild plant foods. The consistent presence of the bones of wild species of animals and fish, at both large and small Indus sites, attests to the continued use of wild animal resources by inhabitants. The possible complex systems of animal production and distribution are not easy to untangle with present evidence as they may have involved networks of multiple 'animal specialists': urban, rural, and nomadic; or conversely, they may not have involved 'specialists' at all and may have been seasonal occupations of the same group/groups.

Questions and Challenges for Indus Zooarchaeology

Although the rate of zooarchaeological studies has increased across newly-excavated sites of the Indus Civilisation, a number of challenges still exist for systematic zooarchaeology in the region. The establishment of standard protocols for reporting faunal remains as well as the recording of detailed contextual and chronological information is essential for the future of the discipline. Additionally, several questions remain to be explored, as well as the use of new methods to supplement zooarchaeological analyses. These are highlighted below.

Domestication: chicken and pigs

Various strands of evidence suggest that zebu cattle and water buffalo were domesticated in South Asia, most probably in the Indus region (Loftus et al. 1994; Chen et al. 2009; Nagarajan et al. 2015; Colli et al. 2017), although the timing and mechanism of their spread to Africa and the Middle East is still debated (Colli et al. 2017; Perez-Pardal et al. 2018). However, knowledge about the domestication of chicken (*Gallus gallus domesticus*) and pigs (*Sus domesticus*) in South Asia remains contested.

It is a popular notion that Indus populations domesticated the chicken and that poultry farming was practised in the Mature Harappan period (e.g., Crawford 1990; Al-

Nasser et al. 2007). It has also been suggested that chicken was cooked in *tandoors* during this period (Lawler 2013; Bhattacharya 2016). Although early reports attributed bird bones found at Mohenjo-daro, Harappa and Kalibangan to domesticated chicken (Sewell and Guha 1931; Prasad 1936; Fairservis 1967), it is likely these have been misidentified or are modern intrusions as *Gallus* bones have not been identified at other sites. Rather, blue peafowl (*Pavo cristatus*) and other types of birds such as ducks are more commonly identified at Indus settlements (Joglekar et al. 2013).

The idea of the chicken being a bird unique to the Indus Civilisation also comes from Mesopotamian texts dated to the Ur III period (During-Caspers 1989). Two Sumerian myths refer to a 'Meluhhan bird', described as the '*dar-musen Me-luh-ha*' that wears a 'beard' made of carnelian, and another reference mentions the '*dar-dar*' cries of the *dar* bird (During-Caspers 1989). Meluhha is a toponym for the region of the Indus Civilisation from where Mesopotamia appears to have acquired several raw materials and products, as listed in administrative texts (Potts 1990, 1993; Magee 2014; Laursen and Steinkeller 2017). It is suggested that this description refers to a cock, the red carnelian 'beard' possibly being the red wattles underneath the beak of this bird, and the sound of its cries indicates the crowing of a cock (During-Caspers 1989). While it is possible the bird in question was a cock, it is also possible the texts are referring to another bird, or even a mythical bird.

Genetic studies have revealed that the red junglefowl (*Gallus gallus*) was the primary wild ancestor of the domestic chicken and that there were possibly multiple, independent domestication events in southern China, South Asia and Southeast Asia (Liu et al. 2006; Kanginakudru et al. 2008; Miao et al. 2013). Modern genetics suggests that the Indian subspecies *Gallus gallus murghi* contributed significantly to the domestic gene pool (Kanginakudru et al. 2008; Miao et al. 2013), but the timing of this domestication is debated (West and Zhou 1988; Sykes 2012). It is important to investigate the possible location/timing of the domestication of the South Asian chicken subspecies to understand its role in ancient culture (e.g., Sykes 2012) and subsequent spread from South Asia. A recent paper that reviews all available evidence of ancient chicken remains in the subcontinent suggests that poultry farming in South Asia was a post-Harappan development (Peters et al. 2022).

Similarly, Thomas (2002) and Chase (2014) have noted that the domestic status of the pig in Indus stock-raising is yet to be ascertained. Zeder (1996:298) mentions that pigs have higher reproductive rates and a greater per capita yield of fat-rich meat than any other domestic livestock species. Pigs would thus have likely provided "a low-cost, low-labour intensive, highly reliable and highly productive resource" within household-based sty management, providing a different set of opportunities and obstacles for provisioning in early urban contexts (also Zeder 1991:30-32, 1996, 2003). In Zeder's (1996: 298) opinion, within the Near Eastern urban context, pig-raising likely gave the urban household considerable autonomy in an otherwise highly specialised and interdependent economy. Although pigs only account for about 2-3% of the faunal assemblages at various Indus settlements, their consistent presence suggests they were an important part of the agricultural economy. Organic residue analysis also suggests the presence of non-ruminant fats (possibly pigs) in pottery vessels in both northwest India and Gujarat (Suryanarayan 2020; Suryanarayan et al. 2021; García-Granero et al. 2022). As domestication reflects a profound ontological change in the relationship

between humans and animals (Sykes 2014), an understanding of the domestic status and the role of pigs in Indus stock-raising and the food economy is vital.

Faunal diversity: fish and wild animal exploitation

Apart from domestic animals, numerous Indus sites report a variety of wild ruminants, hares, birds and freshwater fish and molluscs. Riverine resources have been found at numerous sites (Belcher 1991, 1994, 2003), as have marine resources at coastal sites and even at Harappa (Belcher 1991; Deshpande-Mukherjee 1996, 1998). In northwest India, a high rate of faunal diversity across settlements has been observed, and percentages of wild mammal utilisation diversity have been calculated (Joglekar et al. 2013; Channarayapatna 2018). For example, at Farmana, a single trench yielded high proportions of freshwater fish (58.2% NISP) and the site exhibited the highest level of wild mammal utilisation diversity (over fifteen species of wild ruminants and freshwater fish) compared to other sites in the region (61% compared to 20-40%) (Joglekar et al. 2013; Channarayapatna 2014, 2018). Thus, it is likely that a targeted effort at characterising the extent of the role of fish and wild animals in the Indus economy will enable a new understanding of the underestimated importance of these resources.

Use of complementary methods

A variety of biomolecular methods such as stable isotope analysis (Chase et al. 2014a, 2018; Sarkar et al. 2016; Jones 2017; Chakraborty et al. 2018; Lightfoot et al. 2020; Nayak in prep.), organic residue analysis on pottery (Chakraborty et al. 2020; Suryanarayan et al. 2021) and archaeogenetics (Nagarajan et al. 2015) are enhancing our understanding of the feeding, breeding, management and role of animals in the Indus Civilisation. Additional methods in proteomics, or, for example, the use of Zooarchaeology by Mass Spectrometry (ZooMS) in Indus archaeology would enable the distinction between cattle and buffalo, and sheep and goat (e.g., Buckley et al. 2010), even from very small fragments, allowing for more nuanced animal-use patterns to be detected. The scope for such types of biomolecular methods is wide, and will likely increase in the future. Unfortunately, however, poor preservation conditions may limit these analyses. For example, collagen preservation in bones found from Indus sites is poor (Lightfoot et al. 2020), limiting stable isotopic analyses and ZooMS. Additionally, the collection of regional collagen sequences and the building of reference databases are important for the successful discrimination of species via ZooMS (Collins et al. 2010) or organic residue analysis (Suryanarayan et al. 2020). Future research must take these considerations into account. These methods must be complemented with primary zooarchaeological analysis and sound contextual information to be truly meaningful.

Conclusion

This contribution has reviewed the state of zooarchaeological research in the Indus Civilisation, discussing how faunal analysis informs us about the management and maintenance of animals in the urban period. It has also addressed potential questions and opportunities for future research, such as the investigation of the extent of dairying

in the Indus Civilisation, the domestication of chicken and pigs, and the characterisation of faunal diversity. Such approaches, along with the use of complementary biomolecular methods, are likely to revolutionise our understanding of human-animal relationships in the Indus Civilisation.

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