Infection, disease, and biosocial process at the end of the Indus civilization

By: Gwen Robbins Schug, K. Elaine Blevins, Brett Cox, Kelsey Gray, and V. Mushrif-Tripathy

Robbins Schug, G., Blevins, K.E., Cox, B., Grey, K.M., & Mushrif Tripathy, V. (2013). Infection, disease, and biosocial process at the end of the Indus civilization. *PLoS One,* 0084814. https://doi.org/10.1371/journal.pone.0084814

Abstract:

In the third millennium B.C., the Indus Civilization flourished in northwest India and Pakistan. The late mature phase (2200-1900 B.C.) was characterized by long-distance exchange networks, planned urban settlements, sanitation facilities, standardized weights and measures, and a sphere of influence over 1,000,000 square kilometers of territory. Recent paleoclimate reconstructions from the Beas River Valley demonstrate hydro-climatic stress due to a weakened monsoon system may have impacted urban centers like Harappa by the end of the third millennium B.C. the impact of environmental change was compounded by concurrent disruptions to the regional interaction sphere. Climate, economic, and social changes contributed to the disintegration of this civilization after 1900 B.C. We assess evidence for paleopathology to infer the biological consequences of climate change and socio-economic disruption in the post-urban period at Harappa, one of the largest urban centers in the Indus Civilization. Bioarchaeological evidence demonstrates the prevalence of infection and infectious disease increased through time. Furthermore, the risk for infection and disease was uneven among burial communities. Corresponding mortuary differences suggest that socially and economically marginalized communities were most vulnerable in the context of climate uncertainty at Harappa. Combined with prior evidence for increasing levels of interpersonal violence, our data support a growing pathology of power at Harappa after 2000 B.C. Observations of the intersection between climate change and social processes in proto-historic cities offer valuable lessons about vulnerability, insecurity, and the long-term consequences of short-term strategies for coping with climate change.

Keywords: Harappa | leprosy | maxillary sinus infection | tuberculosis | climate change | paleoclimatology

Article:

*****Note: Full text of article below**

Infection, Disease, and Biosocial Processes at the End of the Indus Civilization

Gwen Robbins Schug[1*], K. Elaine Blevins[1], Brett Cox[1], Kelsey Gray[2], V. Mushrif-Tripathy[3]

1 Department of Anthropology, Appalachian State University, Boone, North Carolina, United States of America, **2** Institute of Archaeology, University College, London, United Kingdom, **3** Department of Archaeology, Deccan College Post-Graduate Research Institute, Pune, India

Abstract

In the third millennium B.C., the Indus Civilization flourished in northwest India and Pakistan. The late mature phase (2200-1900 B.C.) was characterized by long-distance exchange networks, planned urban settlements, sanitation facilities, standardized weights and measures, and a sphere of influence over 1,000,000 square kilometers of territory. Recent paleoclimate reconstructions from the Beas River Valley demonstrate hydro-climatic stress due to a weakened monsoon system may have impacted urban centers like Harappa by the end of the third millennium B.C. the impact of environmental change was compounded by concurrent disruptions to the regional interaction sphere. Climate, economic, and social changes contributed to the disintegration of this civilization after 1900 B.C. We assess evidence for paleopathology to infer the biological consequences of climate change and socio-economic disruption in the post-urban period at Harappa, one of the largest urban centers in the Indus Civilization. Bioarchaeological evidence demonstrates the prevalence of infection and infectious disease increased through time. Furthermore, the risk for infection and disease was uneven among burial communities. Corresponding mortuary differences suggest that socially and economically marginalized communities were most vulnerable in the context of climate uncertainty at Harappa. Combined with prior evidence for increasing levels of interpersonal violence, our data support a growing pathology of power at Harappa after 2000 B.C. Observations of the intersection between climate change and social processes in proto-historic cities offer valuable lessons about vulnerability, insecurity, and the long-term consequences of short-term strategies for coping with climate change.

Citation: Robbins Schug G, Blevins KE, Cox B, Gray K, Mushrif-Tripathy V (2013) Infection, Disease, and Biosocial Processes at the End of the Indus Civilization. PLoS ONE 8(12): e84814. doi:10.1371/journal.pone.0084814

Editor: Michael D. Petraglia, University of Oxford, United Kingdom

Received August 22, 2013; **Accepted** November 27, 2013; **Published** December 17, 2013

Funding: This research was funded by a Fulbright-Nehru Senior Research Fellowship. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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

* E-mail: Robbinsgm@appstate.edu

Introduction

We examined the human skeletal remains from Harappa, one of the largest cities in the Indus Civilization (Figure 1), to determine the impact of climate, economic, and social changes that accompanied the disintegration of this proto-historic society. Using an analysis of paleopathology in the human skeletons from three different burial populations that span the decline of this ancient civilization, we assessed the signature of large-scale social processes (urbanization, extensive culture contact, migration, social differentiation, and the economic and social changes that led to the collapse of a relatively weak prehistoric state) in the epidemiological profile. Combined with prior evidence for inter-personal violence [1], we estimate factors that determined the relative risk of social suffering through time and discuss the implications for human security during periods of climate and culture change in this prehistoric complex society.

The Harappan Civilization

The Indus Civilization is best known for its late mature phase (2200-1900 B.C.) when it was characterized by large, well-organized cities, sanitation facilities and sophisticated water management practices, an undeciphered script, standardized system of measurements, craft specialization, and participation in the third millennium B.C. Interaction Sphere [2–8]. The Indus civilization has also gained attention as a rare example of a heterarchical prehistoric state, which developed without strong, centralized social control or structural violence [6,9,10]. But it is perhaps best known for its 'disintegration' in the Late Harappan phase (1900-1300 B.C.)—retraction of the interaction sphere, depopulation of urban centers, re-organization of the human population, and re-emphasis on agrarian village life for most of the second millennium B.C.

The Harappan Civilization developed in the context of a semi-arid climate that was pervasive in South Asia for the latter half of the Holocene [11–18]. Since it was first proposed as a

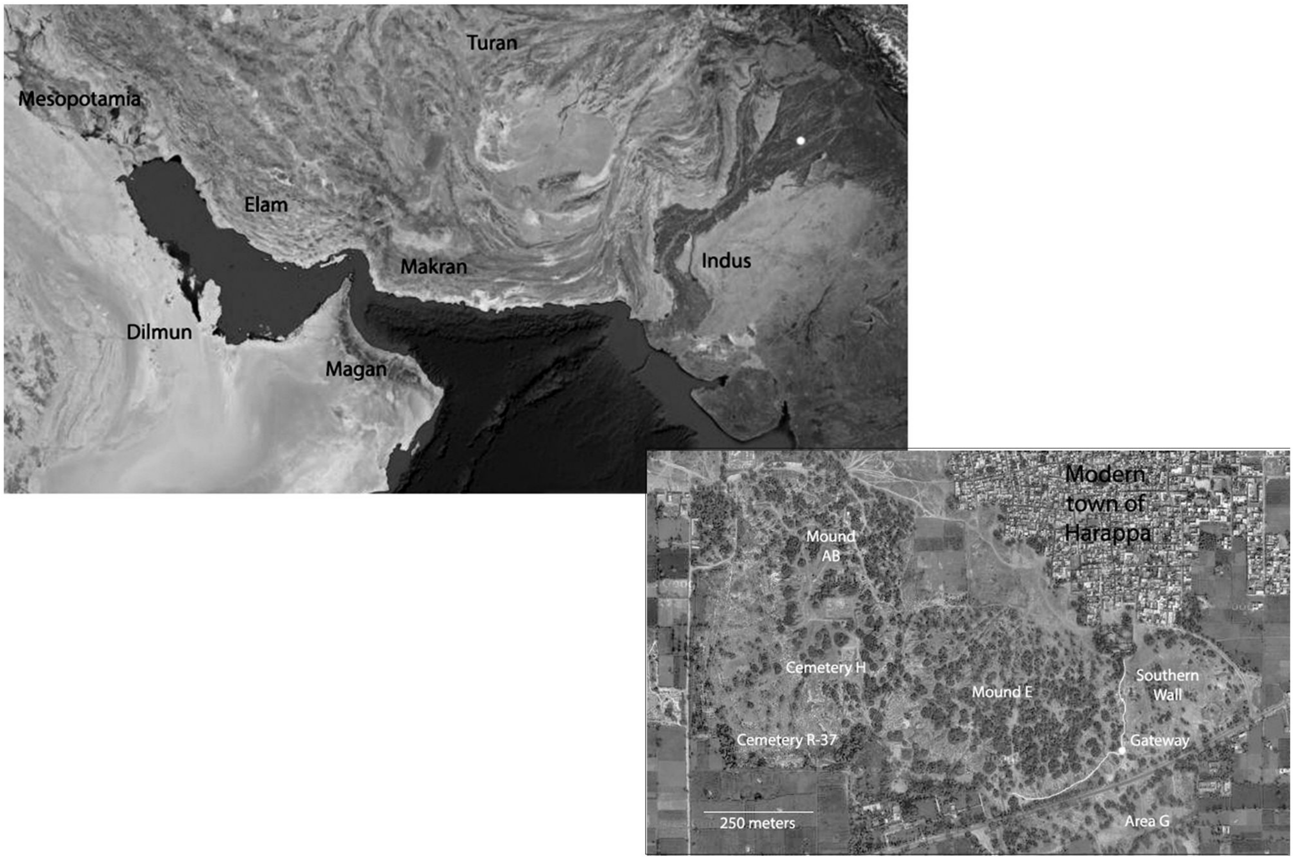

Figure 1. Map of the Third Millennium Interaction Sphere, the Geographic Extent of the Indus Civilization, and the location of the city of Harappa.
doi: 10.1371/journal.pone.0084814.g001

factor in the demise of the Indus Civilization, debates about the role of climate and environmental changes have raged on [19–27] but it has become increasingly clear that by 2800 B.C., aridity levels in the Indus Valley were broadly similar to contemporary levels [28–32] until a period of destabilized environment—fluctuating rainfall, increased seasonality, and accelerate channel migration—began in the Indus Valley after 2000 B.C. [31,32]. From 2200-1700 B.C., a significant rapid climate change event in South Asia saw disruptions in monsoon rainfall and significant changes in fluvial dynamics along the Indus Rivers, including the Beas River [13,14,18,29,30,33–40].

Increasing aridity initially occurred in the context of a flourishing interaction sphere that spanned West and South Asia in the third millennium B.C. [6,41–44]. Historical records from Mesopotamia describe regular trade with 'Meluhha' (the Indus Valley) from 2400-2000 B.C. [43]. Harappans manufactured etched, biconical carnelian beads, shell, faience and steatite ornaments, ivory, copper, and ceramic items, cotton, silk, jute, cloth, barley, oil and other perishables [43,45–51]. Exports focused on raw materials for these products, items which have been recovered from sites around the Persian Gulf region; Harappan seals have also been recovered; and cylindrical seals resembling those from Mesopotamia have been recovered at Indus urban centers as well [3,6,43,44,48].

Participation in the interaction sphere facilitated a period of rapid urbanization at the city of Harappa, creating a dense and heterogeneous population in the ancient city. Cities are political, economic, and ceremonial centers that can offer opportunities unavailable in the hinterlands [44]. Technology, production, and consumption transformed Indus society, particularly in period IIIC, when population growth was at its fastest rate: high levels of immigration disrupted the formerly organized settlement pattern; houses in the core areas of the city spilled over onto the streets and 'suburban' areas sprang up on low mounds to the west and northwest of the city center [41,42].

After 1900 B.C., in the Late Harappan phase, population density was diminished and settlement focused largely in the core areas of the city. Declining sanitation conditions and an increasingly disorganized settlement plan indicate disruptions to authority were systemic [41,44,52]. Disruptions in the exchange network also occurred after 2000 B.C. [35,37,53–55] at a time when West Asian trading partners were responding to their own rapid climate change event. At this point, Magan and Dilmun are mentioned more frequently in Mesopotamian writings while references to Meluhha largely disappear and material evidence of trade interactions declines [44]. Large-scale depopulation of Indus cities in the Late Harappan phase weakened Indus society. Late Harappan settlements flourished in Gujarat and Rajasthan while only a handful of settlements remained occupied in the Beas River Valley [56–62].

Climate change is a significant challenge for human communities but climate alone does not determine the fate of human societies; it exists as one variable intertwined with other political, social, historical, and cultural forces [63–69]. A translation of the social forces at work in the creation of the urban environment thus serves as a context for understanding its collapse. When mortuary treatment and bioarchaeological evidence are considered, three core features of Indus society emerge—Indus cities were heterogeneous, socially differentiated, and hierarchical. As discussed above, heterogeneity in a large city is expected, particularly in the context of rapid population growth and participation in a wide reaching exchange network. A heterogeneous composition at Harappa was recently confirmed by preliminary analysis of isotopic signatures in skeletons from the urban phase cemetery R-37, some of which demonstrated a non-local origin [70]. Although the female skeletons from cemetery R-37 that were studied had isotopic signatures consistent with local origins, the sample size was small and there are probably males and females of local and non-local origins buried here. The isotopic data indicate that individuals buried in Cemetery R-37 shared some aspect of occupational, affinal, or consanguinal identity but 'Harappans' were diverse in regard to their geographic origins.

Archaeologists have suggested Indus cities were governed by an elite class, or by competing elite groups based on features of the settlement organization, construction of high walls around the mounds, water management practices, and presence and patterning of artifact types in Indus cities [6,41,42,44,70–72]. This model is supported by mortuary data. Given the large population size of the city, the majority of Harappans were not interred in the city cemeteries. In addition, hundreds of people were buried in cemetery H during the post-urban period but a small contingent of human crania, 50% of which demonstrated evidence for traumatic injury, were disposed of in an ossuary outside the city [1,7,73]. Evidence for social differentiation and exclusion at Harappa indicate that even if organization on a larger scale was relatively weak, social differentiation and control were exercised locally within the city [1,10].

Urbanization, migration, extensive culture contact, and climate change all present significant social and biological challenges for human populations, particularly the introduction of new pathogens [74]. Both molecular and skeletal evidence suggest that *Mycobacterial tuberculosis* Complex (MTBC) lineages have been circulating in South Asian populations for millennia [75–77]. A high degree of latency in MTBC infections indicates a long-term association with human communities, near the origin of urban life [78]. *M. tuberculosis* has infected human populations in West Asia since at least 7000 B.C. [79]; tuberculosis has been present in Egypt since 3500-2650 B.C. [80]. Molecular biology studies demonstrate that polymorphisms associated with resistance to members of the MTBC lineage have been conserved in South Asian populations for millennia [75]. Thus the molecular evidence lends support to the hypothesis that MTBC lineages have been circulating in South Asia since at least the late Holocene, when maintenance in human populations would have been facilitated by significant increases in population density and culture contact [81]. Bioarchaeological research recently confirmed that leprosy was present in a rural Indus outpost in Rajasthan, India by 2000 B.C. [82] providing additional impetus to look for evidence of the disease in proto-historic, urban populations in South Asia.

In this study, we examine the hypothesis that increased population density and culture contact led to new opportunities for infection and infectious disease in South Asian populations. Based on molecular and bioarchaeological evidence, we predicted that evidence for infection and infectious disease will be present in the skeletal remains from Harappa. Furthermore, based on our previous bioarchaeological research [1], we predicted that the prevalence of infection and disease will not be evenly experienced across all segments of the population. Our previous work on skeletal material from Harappa demonstrated that violence was a part of life in the ancient city and that the prevalence of violent injury increased through time with the strains of ecological and social change in the Late Harappan period [1]. The data indicated strong differences in the risk for violent injury among different burial populations through time, suggesting that aspects of individual and community identity shaped the risk for violent injury. In that paper, we joined scholars who have argued against the long-standing view that the Indus civilization was peaceful [83] but we also hypothesized that these data could be interpreted as evidence that vulnerability in Harappan society was determined through a process of structural violence—unequal power, uneven access to resources, systematic oppression, and exploitation that kills through the denial of basic needs and outright violence. We suggested than an examination of differences among burial areas in the epidemiological profile could provide additional support for that hypothesis.

Our goal here is to assess whether there is evidence for systematic structural differences in the risk for infection and infectious disease, similar to those previously reported for interpersonal violence [1]. In complex societies, political, economic, social, and historical forces leave marginalized citizens more vulnerable to food insecurity, risk of violence, and infectious disease [84–90]. In the context of climate, social, and economic changes, these social forces and structural inequalities often become exacerbated and consequences are most acutely felt by the most vulnerable citizens [91–98]; this vulnerability is inscribed on the human skeleton [99–101].

Materials and Methods

The Human Skeletal Remains from Harappa

This paper presents an analysis of paleopathology across the urban to post-urban transition at Harappa. All necessary permits were obtained for the described study, which complied with all relevant regulations. The Anthropological Survey of India allowed access to the collections and the museum staff

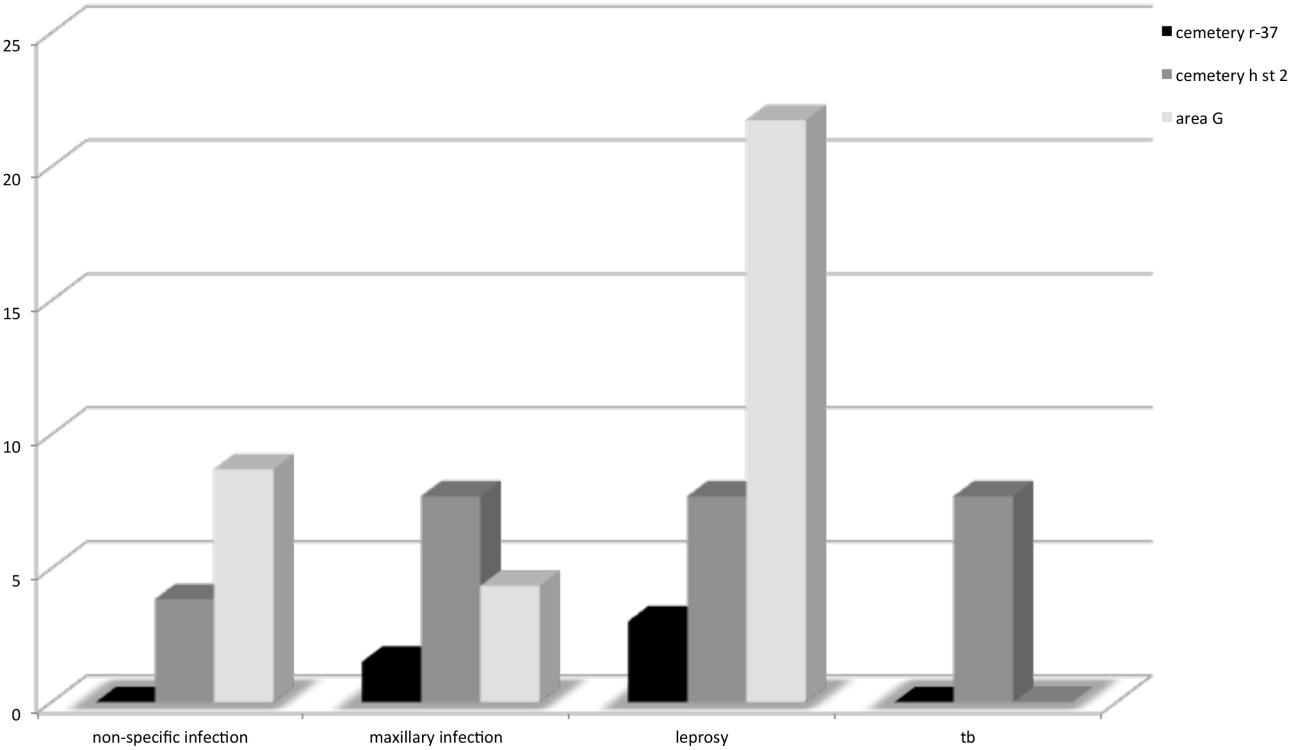

Figure 2. Prevalence of infection and disease in three mortuary assemblages from Harappa.
doi: 10.1371/journal.pone.0084814.g002

provided research support. We examined 160 individuals (67% of the total number excavated) from three main burial areas at Harappa: an urban period cemetery (R-37), a post-urban cemetery (H), and an ossuary (Area G) (Figure 2). This total represents all of the individuals excavated from 1923 to 1967 that have survived to date. Detailed scientific analyses have also been published on 90 additional individuals recovered from Cemetery R-37 by the HARP project and those remains are not included in this analysis [102–107]. Cemetery R-37 came into use in the mature period at Harappa; burials span approximately 500 years (2550-2030 B.C.) [108]. The cemetery is comprised of local and non-local individuals, a group that may represent traders, merchants or craftspeople [70]. Some of these burials were the most elaborate and the richest of any cemetery at the site, although there was considerable variation among individual graves [3,70]. In all, they contained pottery; bangles, necklaces, beads, and amulets of semi-precious stone, gold, and steatite; toilet objects such as mirrors, spoons, and small containers; and other grave goods [3,6,46,103,104,107,109].

Of 209 skeletons excavated from Cemetery R-37, 66 (31.6%) were available at AnSI (Anthropological Survey of India) for the present research. Of these 66, 16 were from complete burials, 29 were from fractional burials, and 21 were from multiple burials. Most of the burials were adults (64/66) but there were two immature individuals present (both children over five years of age). This paper primarily concerns an analysis of the remains that were excavated prior to independence. These remains are stored at Anthropological Survey of India, Kolkata. The preservation, completeness, morphology and metrics are provided in several books, monographs, and articles already published [73,110,111]. These remains are not the same sample described in previous studies of paleopathology; those remains were recovered during the HARP project from 1986-1989 [102–106,112]. That sample was skeletally relatively healthy and mainly suffered from a low prevalence of anemia, enamel defects, and moderate dental caries, suggesting a small amount of developmental stress and a mixed economic system with heavy reliance on agricultural effort for subsistence.

Cemetery H represents a late extension of Cemetery R-37 [113]. This burial ground consisted of two strata—the Late Harappan phase is represented in Stratum II (1900-1700 B.C.) and a Chalcolithic phase is represented in Stratum I (1700-1300 B.C.) . In stratum II, the dead were laid out in an extended posture and occasionally with legs somewhat flexed; they were buried with little ornamentation [8]. Stratum I skeletons were interred in funerary jars. Of the 78 individuals excavated from Cemetery H, 26 individuals from Stratum II are available for study at AnSI; 20 adults and six immature individuals. 45 individuals from Stratum I are available for study at AnSI (31 adults and 14 immature individuals) but in this paper, we are only considering burials from stratum II because our questions concern the transition from the Mature Harappan period IIIC to the Late Harappan, period IV. The Stratum I burials date to period V, a much later time period; the analysis

Table 1. Age and Sex of Skeletons from Harappa included in this analysis.

	N total	n examined	Immature	Young adult (18-34)		Middle adult (35-54)		Old adult (55+)		Indet. Age (adult)
				male	*female*	*male*	*female*	*male*	*female*	
Cemetery R-37	108	66	3	3	9	2	3	7	3	31
Cemetery H										
Stratum II	26	26	6	0	4	0	2	0	1	13
Stratum I[1]	78	45	15	0	5	0	2	3	1	19
Area G	23	23	9	1	2	3	2	1	0	5
Total	**235**	**160**	**33**	**4**	**20**	**5**	**9**	**11**	**5**	**68**

[1] The pathological profile for this cemetery was examined but the results will be reported elsewhere because this cemetery is later (1700-1300 B.C.) and does not address the research question considered here.

doi: 10.1371/journal.pone.0084814.t001

of pathological lesions in that sample is not apropos to the current research questions and will be reported at a later date.

Area G is located in a low-lying field outside the southeastern wall of the city, just beyond a sewage drain built under the southeastern gateway. This locality consisted of poorly preserved architectural remains and an ossuary, which contained a small number of goblets, vases, and offering dishes as well as 20 human crania, three human mandibles, five human long bones, a human scapula, and two partial human vertebral columns. A bovine cranium and a canine vertebral column were also found in the ossuary remains [7]. No absolute dates are available for Area G and the ossuary was relatively dated using the ceramic typology. Vats described the Area G ceramics as closely resembling those of the habitation area, with some resemblance in forms with Cemetery R-37 but little affinity with Cemetery H. “Hence whatever may be the interval in time between the two mounds and Cemetery H, the Area G very likely stands between the two.” (pg. 200) As Cemetery R-37 extends to 2030 B.C. and Cemetery H is dated to 1900-1300 B.C. (strata I and II), this interpretation would suggest dates of roughly 2000-1900 B.C. for Area G. A minimum number of 23 individuals (12 adults and 9 subadults) were interred here and were available for study at AnSI.

Bioarchaeological methods

The available skeletal material from Harappa is fragmentary and many individuals are incomplete, poorly preserved, and some elements are partially covered with a thick layer of vinyl acetate preservative, which sometimes hindered macroscopic evaluations of pathology. The preservative was removed with a soft toothbrush when possible; otherwise observations were limited to observable surfaces, where vinyl acetate had not been applied.

Because this skeletal collection was initially studied for evidence of ‘racial’ affinities [73], metrical analysis has been published previously [73,110] and cranial material was preserved in this collection more frequently than any other element. We estimated age-at-death for immature individuals based on dental development and eruption timing [114,115] and timing of epiphyseal fusion [116]. Sexing of subadults was not attempted. We used Standards for Data Collection to determine demographic characteristics from the adult remains [117]. Cranial elements were the most commonly preserved but yield less accurate sex estimates and less precise age estimates than other elements. Sex was estimated using pelvic indicators when the pelvis was present; otherwise cranial features were used [116]. For individuals only represented by cranial material, age was estimated using cranial suture stenosis and dental attrition [118], the latter was preferred when teeth were available. The specimens were categorized into three age categories: Young adult (18-29), Middle adult (30-54), and Older adult (55+). These categories are consistent with earlier studies of the material from Cemetery R-37 [103–105,112]. Demographic characteristics are provided in Table 1.

Pathological lesions were recorded based on macroscopic observations of the human skeletal remains using standard methods. We noted the presence of proliferative and lytic lesions, as well as alterations to the morphology of the bones. Differential diagnosis was undertaken by comparing the presence and patterning of lesions with expectations from the paleopathology literature [119–128]. Because many individuals are fragmentary or incomplete, it was not always possible to examine the patterning of lesions beyond one or two elements. Thus our analysis is restricted to an evaluation of “periosteal reaction” in postcranial elements because this term does not connote a specific etiology, it refers to a response to inflammation, trauma, infection, or infectious disease in a single element [129]. Its lack of specificity makes it appropriate for use in fragmentary and incomplete remains.

When the cranium was preserved, we evaluated evidence of maxillary infection and leprosy; lesions pathognomic of leprosy are primarily found in the craniofacial skeleton and evidence from the post-cranial elements is not required for a diagnosis. A diagnosis of leprosy was based on diagnostic criteria listed in Table 2. In one case, evidence for inflammation or infection (proliferative and destructive lesions on the external table of the cranial vault) was associated with cranial trauma. In a case like this, it is difficult to determine whether the periosteal reaction is solely related to the injury, or if infectious disease was also present. We erred on the side of caution and attributed these lesions to the category of “periosteal reaction”. Tuberculosis was only evaluated in cases where the individual had vertebrae and other post-crania available for study because vertebral changes are most diagnostic for tuberculosis.

Results

In our examination of the Harappan skeletons, we found evidence for non-specific periosteal reactions, maxillary infections, and individuals that demonstrate a pattern of lesions consistent with leprosy and/or tuberculosis (Table 2). Because the skeletal collection is fragmentary and many individuals are poorly preserved, many individuals were diagnosed with non-specific infections or maxillary infection when they might in fact have had an infectious disease but because the majority of the skeleton is not present a more detailed diagnosis is not possible [130]. Descriptions and images are provided in the following sections.

A summary of the number of individuals affected from each cemetery is provided in Figure 2. Prevalence of pathological conditions was calculated based on the proportion of individuals affected from each cemetery. For Cemetery R-37, 90 additional individuals were excavated from cemetery R-37 during the 1986-89 HARP project [52]. Those remains are stored elsewhere and were not available in the present analysis so they were not included in the proportion of affected individuals reported in the results section, Figure 2, or Table 2. As those individuals were studied previously for evidence of pathology, those prior results were included in the conclusions and discussion.

Non-specific periosteal reactions and infection related to trauma

One individual demonstrated evidence of a non-specific periosteal reaction, an adult (H.698) from stratum 2 of Cemetery H (3.9%). Individual H.698 had periostitis on a fragment of her tibial diaphysis. Because the tibia is fragmentary and the antimere is not present, this was recorded at non-specific periosteal reaction. There is no evidence of trauma, however it also cannot be ruled out as this individual also suffered from four violent injuries to her cranial vault [1].

Evidence for infection related to trauma was found on two individuals from Area G (8.7%), one of which (G.II.32) consisted solely of an isolated metacarpal fragment with a sequestrum and involucrum (~5 mm) on the palmar surface of the head and a cloaca that has formed along the proximal margin (Figure 3). There is extracortical bone formation on the metacarpal head. There are no other remains clearly associated with this bone so the etiology of this lesion is unknown, although it appears to be a localized infection that probably resulted from an injury. Individual I.S.11 suffered from sharp blunt force trauma to the left frontal bone near glabella [1]. There is evidence for proliferative and destructive lesions on the external table of cortical bone of the left frontal and parietal (Figures 4a and 4b). We classified this as non-specific infection given that the cranium is the only skeletal element securely associated with this individual, and given the injury to the left frontal, which also demonstrates reactive bone formation along its margins.

Maxillary Sinus Infection

Evidence for maxillary sinus infection was found in one individual from Cemetery R-37 (H.804), one individual from Area G (G.I.S.15), and two individuals from Cemetery H stratum 2 (H.344 and H.700a). H. 804 had a complete splanchnocranium but most of the neurocranium is missing (except for the right temporal, sphenoid, and the anterior half of the right parietal). The post-crania were missing. This individual is not very well preserved but there are large periapical abscesses at the right and left lateral incisor and canine. The left lateral incisor was lost antemortem and the alveolus is completely resorbed. A severe level of attrition affects the right canine and the pulp chamber was exposed. There is porosity on the right frontal squama above the right eminence (a circular lesion approximately 2 cm in diameter).

Individual G.I.S.15 from Area G demonstrated evidence of a severe maxillary infection. There is a large alveolar abscess on the left maxilla where the canine and third premolar were lost antemortem (Figure 5a). The right lateral incisor was lost antemortem and the alveolus was actively remodeling. The bony palate is porous and an opening behind the left central incisor has reactive bone margins and opens to an abscess in the anterior alveoli (Figure 5b). There is porosity on the alveolar bone of the maxilla, remodeling along the inferior margin of the pyriform aperture, including at the nasal spine, and porosity at the inferior orbital margin above an enlarged infraorbital foramen on the left maxilla (Figure 5c). Individual H. 344 had an alveolar abscess at the left maxillary canine and third premolar. Individual H.700a lost the left maxillary canine antemortem; the ventral wall of the alveolus has been resorbed and the exposed surfaces are actively remodeling (Figure 6). The left sinus is exposed and the surfaces are porous, with reactive bone formation.

Leprosy

There were two individuals from Cemetery R-37 (H.779 and H.820), a minimum number of five individuals from Area G (G.II.S.5, G.S.No.5, G.III.S.3/4, G.III.S.21, and remains labeled G.289), two individuals from Cemetery H stratum 2 (H.488, H. 696) that demonstrated lesions consistent with a diagnosis of leprosy (Table 2). A diagnosis of leprosy was confined to individuals that demonstrated lesions related to severe rhino-maxillary infection: remodeling of the pyriform aperture is demonstrated by G.II.S.5 including resorption of the anterior nasal spine, changes to the anterior nasal margin, remodeling of the nasal septum, and exposure of the neurovascular channel (Figure 7a and b). Other changes associated with leprosy include resorption of the dental alveoli of the anterior dentition up to the level of the naso-palatine nerve, remodeling of the pyriform aperture, porosity on the bony palate, zygoma, nasal and orbital processes of the maxilla in H.306a (Figure 7c).

These individuals also demonstrated reactive bone formation and porosity in the maxillary sinus, as demonstrated by a left maxilla labeled G.289 from Area G (Figure 8a). The floor of the pyriform aperture is covered with porous, reactive bone and there is remodeling along the anterior margin. There is also a perforation at the midline of the palate. New compact bone

Table 2. Specimen table for lesions associated with non-specific periosteal reactions, maxillary infection, leprosy, and tuberculosis.

	Cemetery R-37 (N=66)		Cemetery H (stratum II) (N=26)		Area G (N=23)	
	Affected individuals	*% affected*	*Affected individuals*	*% affected*	*Affected individuals*	*% affected*
Non-specific infection			**1**	**3.9**	**2**	**8.7**
Periostitis			H.698			
Osteomyelitis					II.32; I.S.11	
Maxillary infection	**1**	**1.5**	**2**	**7.7**	**1**	**4.4**
Periapical abscess	H.804		H.344		I.S.15	
AMTL	H.804		H.344; H.700a		I.S.15	
Alveolar resorption	H.804		H.700a		I.S.15	
Sinusitis			H.700a		I.S.15	
Porosity on the maxilla					I.S.15	
Lesions consistent with leprosy	**2**	**3.0**	**2**	**7.7**	**5**	**21.7**
Remodeling, pitting, vascular impressions, and/or new bone formation in the pyriform aperture	H.779		H.488		G.289; II.S.5; III.S.21	
Resorption of anterior nasal spine	H.779; H.820;		H.488		G.289; II.S.5; S#5; III.S.21	
Remodeling of the nasal margin	H.779; H.820		H.488		G.289; II.S.5; S#5; III.S.21	
Pitting and remodeling at the base of the nasal septum	H.779				G.289; II.S.5; III.S.21	
Exposure of the neurovascular channel in the pyriform aperture	H.779; H.820				G.289	
Porosity on the palatal surface and alveolar process of the maxilla	H.779; H.820				G.289; II.S.5; S#5; III.S.21	
Periodontosis	H.779; H.820		H.488		G.289; II.S.5; S#5; III.S.21	
Ante-mortem Tooth Loss (AMTL)	H.779; H.820		H.488		G.289; II.S.5; S#5	
Alveolar resorption to naso-palatine nerve	H.820		H.488			
Porosity on zygoma and orbital process of maxilla			H.488		II.S.5; III.S.21	
Pitting and grooves in the maxillary sinuses			H.488		G.289; S#5	
Periostitis on tibia/fibula					G.289	
Tarsal, metatarsal, and/or phalangeal osteomyelitis or sepsis					G.289; III.S.3/4	
Phalangeal concentric diaphyseal remodeling, palmar groove, cupping deformity, and/or interphalangeal ankylosis			H.696		G.289; III.S.3/4	
Changes to the ventral surface of naviculars and/or cunieforms					G.289; III.S.3/4	
Navicular squeezing					G.289	
Lesions consistent with tuberculosis			**2**	**7.7**		
Penetrating lytic lesions on the cranial vault < 2 cm in diameter			H.488; H.710			
Reactive bone formation on the zygoma and/or maxilla, necrosis of the mastoid process and/or petrous pyramid of the temporal			H.710			
Periosteal reaction or erosion of the occipital condyles, sphenoid body and/or greater wing						
Lupus vulgaris						
Reactive bone formation on ventral surface of vertebral centra			H.710			
Destructive focal lesions (cavitation) on vertebral centra			H.710			
Kyphosis of thoracic vertebrae						
Ankylosis of one or two affected vertebral bodies						
Periostitis or cavitation on ventral surface of ribs at vertebral end			H.722			
Lytic lesions on the manubrium, scapula, clavicle, humeral head, distal humerus, proximal radius or ulna, ilium, femoral head, femoral trochanters, femoral condyles, and/or tibial condyles			H.710; H.722			
Cavitation and/or sequestrum on the long bone shafts			H.710			
Lesions on carpals and/or tarsals			H.710			
Total affected	**3**	**4.5**	**7**	**26.9**	**8**	**34.8**

doi: 10.1371/journal.pone.0084814.t002

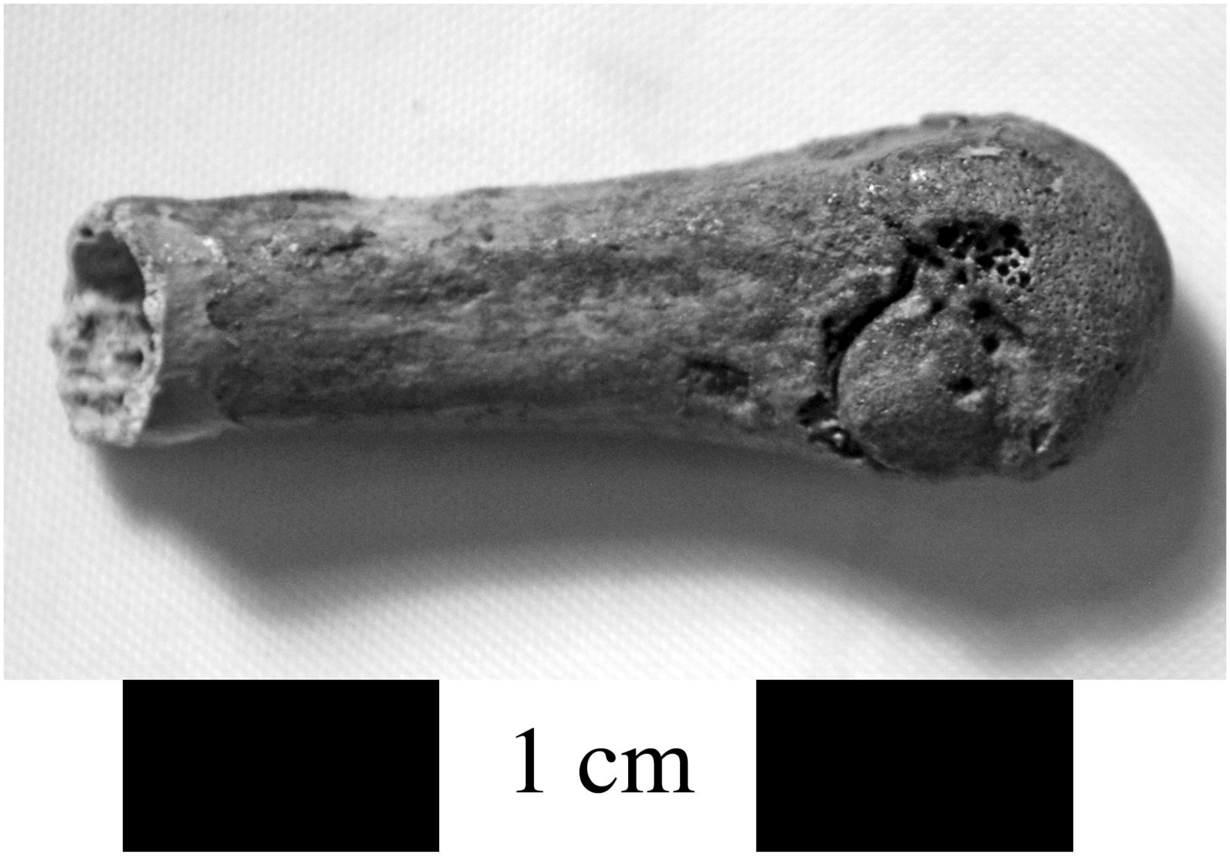

Figure 3. Infection in a metacarpal fragment from individual G.II.32 probably related to a local traumatic injury (lateral view).
doi: 10.1371/journal.pone.0084814.g003

formation with a vascular pattern is present on the lateral margins of the nasal aperture. The anterior nasal spine has been remodeled, the alveolus for the left central incisor is resorbed, there is reactive bone along the alveolar margin, and there is porosity on the inferior margin of the left orbit (Figure 8b). The first and second molar are present but the anterior dentition was lost post-mortem. The alveolus for the third molar was actively remodeling; porosity is present on the interior surfaces of the alveolus and there is reactive bone formation along its alveolar margin.

A first cervical vertebra, four lumbar vertebrae, a fibular shaft fragment, right and left navicular, left intermediate and lateral cuneiform, and left fourth metatarsal were also labeled G.289 but this label refers to the provenience of the remains and their association with the maxilla is not definite but is highly likely. Postcranial changes included evidence of supperative osteomyelitis in the vertebral column (G.289). The vertebral centra were affected by focal lytic lesions on the left side, osteosclerotic reaction, erosion of the anterior rim, and hypertrophic new bone formation (Figure 9a). Postcranial changes consistent with leprosy include periostitis on the fibula, porosity and a palmar groove on an intermediate manual phalanx (Figure 9b), reactive bone formation and osteomyelitis of tarsals, including the naviculars, navicular squeezing, periostosis and septic changes to the joint surfaces on the first metatarsal and associated phalanx (Figure 9c).

Tuberculosis

Evidence for skeletal lesions consistent with a diagnosis of tuberculosis was limited to two individuals (H.710 and H.722) from Cemetery H, stratum 2 (Table 2). The evidence from H. 710 included reactive bone formation on the anterior centrum of the cervical vertebrae; vertebral changes consistent with psoas abscess formation in the thoracic vertebrae (cavitation on the right lateral centrum) associated with reactive bone formation and ankylosis of the adjacent elements (Figure 10a); abscess formation in the distal third of the left ulna (Figure 10b); porotic spongiosa on the femoral head; periostitis and reactive endosteal bone formation on the tibia; hallux valgus; periosteal reaction on the plantar surface near the head of the left first metatarsal; and bloated periosteum on the second metatarsal base. Individual H.722 was more fragmentary but demonstrated evidence for osteomyelitis in the acromial end of the right clavicle (Figure 10c); endosteal bone deposition on a fragment of left distal tibia (Figure 10d); periostitis on both the pleural and the dorsal surface of the ribs at the angle (Figure

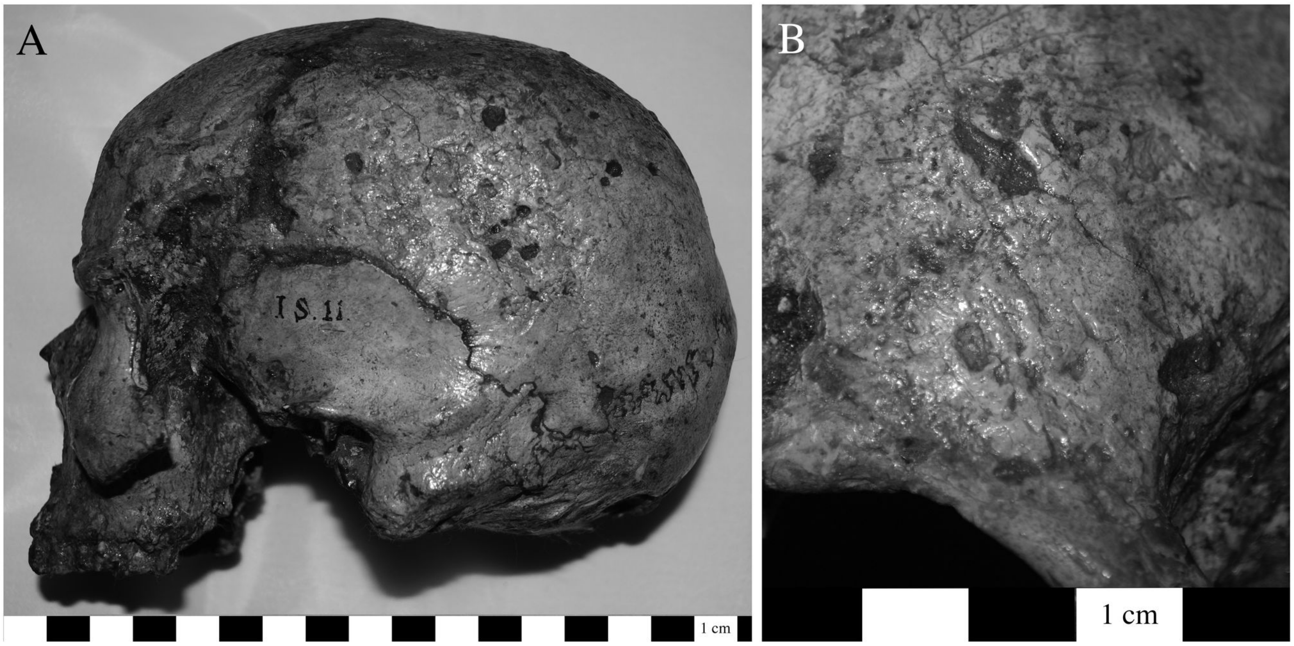

Figure 4. Lesions on the cranial vault of a male skull, I.S.11. This individual also has an injury (sharp blunt force trauma) on the frontal bone. The cranium is isolated and thus the etiology of these lesions is unclear (a: left lateral view). A close-up image demonstrates the destructive and proliferative character of these lesions (b: right frontal bone).
doi: 10.1371/journal.pone.0084814.g004

10e); and reactive bone changes on the cuneiforms and naviculars, including navicular squeezing.

One of these individuals (H.710) also had cranial remains present and demonstrated evidence of abscess formation and destruction of the maxillary alveoli; periosteal reaction in the right maxillary sinus; destruction of the bony palate and initial changes leading to perforation at the midline (Figure 11); and a healing lesion approximately 2 cm in diameter on the frontal squama. Because of the advanced state of healing it is difficult to determine whether this is related to infection or trauma; the latter explanation is preferred [1]. This individual also has a traumatic injury on the occipital bone [1].

Discussion

We are broadly interested in understanding how human health was impacted by environmental and social changes in the past. Theoretically, challenges like urbanization, extensive culture contact, climate and socio-economic changes would exacerbate the risks for the spread of infectious diseases. Based on prior evidence for leprosy in the human population at the peripheral settlement of Balathal circa 2000 B.C. [82], and molecular evidence for long-standing interaction among MTBC lineages and human populations in South Asia [75,128], we hypothesized that there would be evidence for infectious diseases from the MTBC family in the skeletal populations from Harappa. Our results provide support for this hypothesis and from these data we infer that: 1) the presence of leprosy in the urban phase skeletal sample from cemetery R-37 demonstrates the disease was present at Harappa before the end of period IIIC (2030 Cal. B.C.) [108], 2) urbanization and culture contact likely facilitated the spread of MTBC lineages in Indus populations, 3) it is also likely that mycobacterial pathogens migrated between South and West Asia and Africa as part of the Third Millennium interaction sphere [76,81], and finally 4) the low incidence of infection with leprosy (3.0%) in the remains studied from this period suggests the disease was *relatively* uncommon in the urban phase, as was infection in general (4.5%).

Our second prediction was that the prevalence of infection and infectious disease will vary through time at Harappa, correlated with fluctuating levels of environmental, social, and economic stress. The combined evidence from mortuary treatment, traumatic injury, and infection indicate that the stresses of the post-urban period were accompanied by increasing levels of inter-personal violence and disease. Leprosy was present in a relatively small proportion of individuals during the urban period but the post-urban phase saw increasing risks for health and safety. By the Late Harappan phase, leprosy and tuberculosis affected 15.4% of the individuals buried at Cemetery H and leprosy affected 21.7% of the Area G specimens. Combined with our previous work demonstrating that the prevalence of violence also increased through time, affecting men, women, and children from Area G at an unequaled rate of 50% [1], we infer aspects of identity or behavior created greater vulnerability in some Harappan communities.

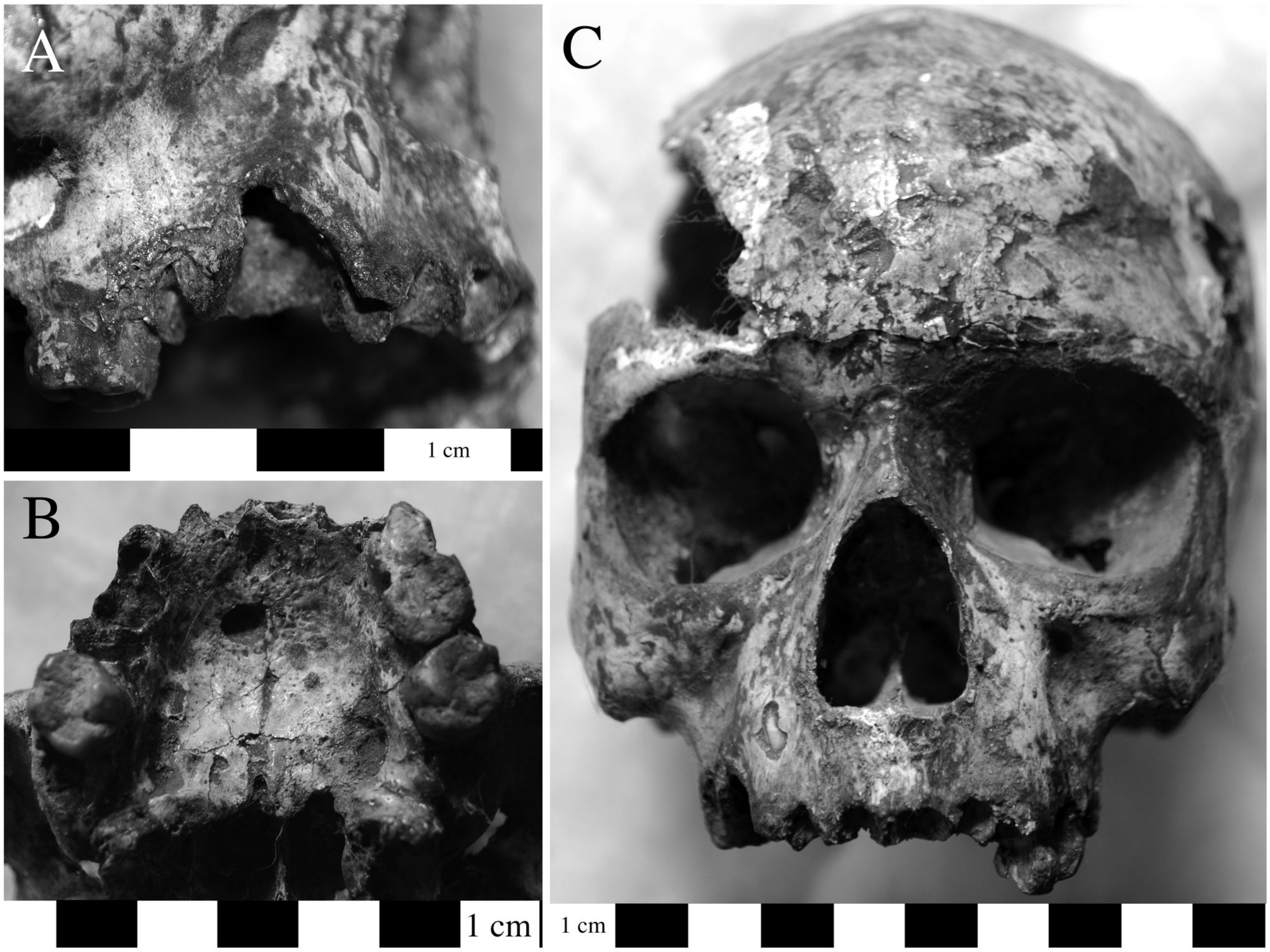

Figure 5. Evidence for maxillary infection in individual G.I.S.15. The lesions included porosity, alveolar resorption, abscessing at the right canine and third premolar, and antemortem tooth loss (a = right ventral view). This individual also had inflammatory changes to the palatine process of the maxilla leading to localized bone destruction and perforation (b = inferior view of palate). There is evidence for porosity and inflammation at the inferior margin of the pyriform aperture, porosity and deformation of the infraorbital foramen caused by infection of the left maxillary sinus (c: ventral view).

doi: 10.1371/journal.pone.0084814.g005

This paper reports the results of an analysis of 115 skeletons from Harappa. The human remains are incomplete; thus if molecular techniques become possible in the future, these individuals would be good candidates for analysis. While our results do support the hypothesis that disease burden increased with climate and social changes in the Late Harappan phase, the present analysis only concerns paleopathological indicators for individuals who were buried, preserved, and excavated at Harappa. The skeletal sample does not reflect the percent individuals affected in the living population. While this is obviously only a small fraction of the living population size, it is also the largest sample of skeletons that has been studied from an Indus city thus far. Our data include individuals from three different burial areas at Harappa, spanning a period of 700 years, making the BHaRaT (Bioarchaeology of Harappa, Research and Training) project the most comprehensive survey of skeletal pathology from an Indus city to date. While the paleoepidemiological profiles are not directly representative of the specific risks of violence and infection should the entire living population be considered, these data are useful for making comparisons of the relative risks among burial communities through time and the human remains do inform us about social processes, as they were inscribed on the skeletons preserved at the site.

An alternative explanation for these data is that burial traditions changed through time and individuals affected by disease were increasingly likely through time to be buried, as opposed to some other means of disposal. However, an examination of differences among the skeletal assemblages demonstrates that the presence of disease alone is insufficient to explain mortuary treatment, including whether an individual would be included or excluded from the cemetery. Evidence for

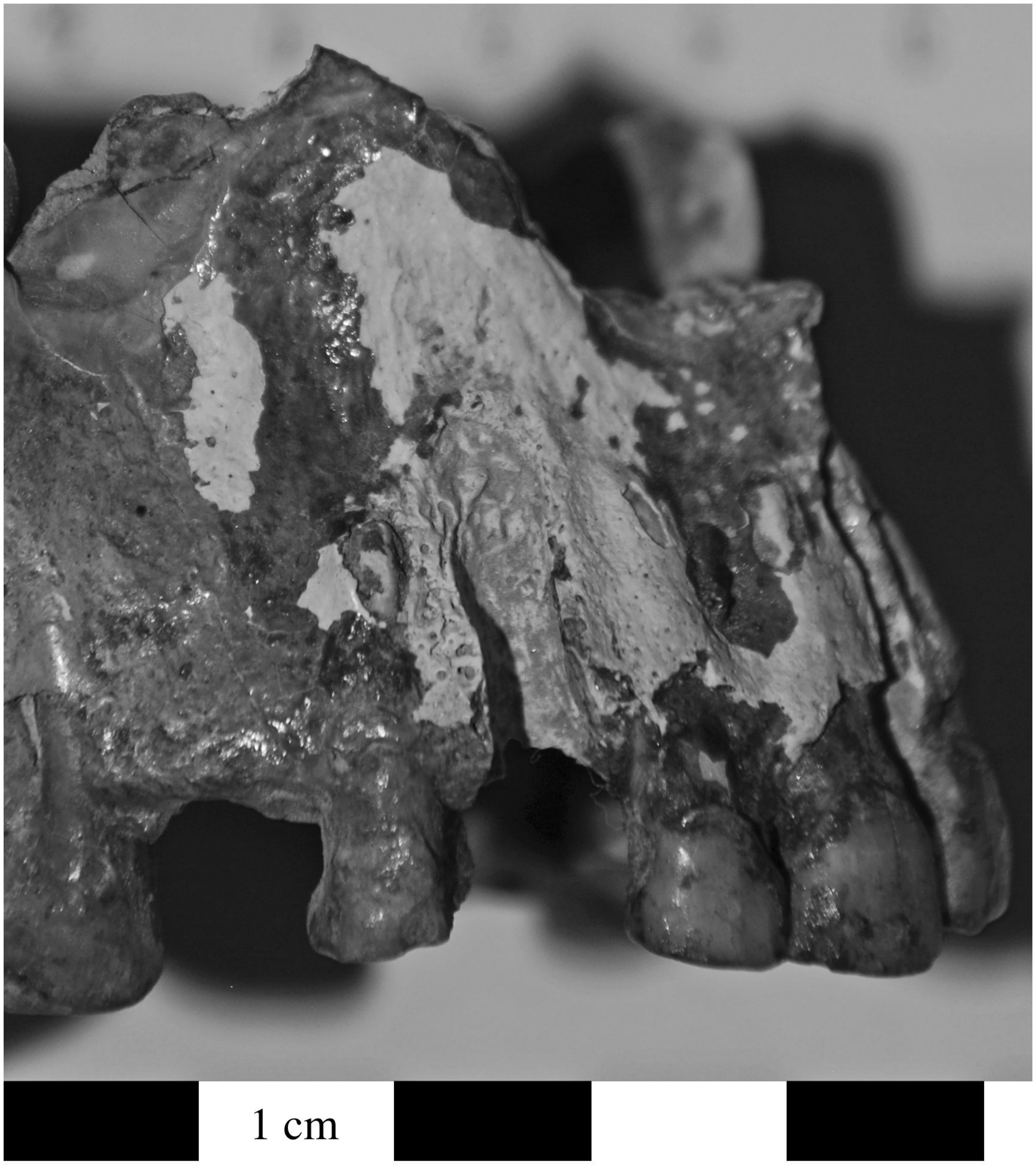

Figure 6. Porosity and alveolar resorption at the maxillary canine of individual H.700a (view of the right maxilla).
doi: 10.1371/journal.pone.0084814.g006

infection was present in small frequency in Cemetery R-37 and in Cemetery H Stratum II. In the latter sample, 26.9% of the skeletons we analyzed demonstrated evidence of pathological lesions consistent with a diagnosis of leprosy. These individuals were accorded the same burial treatment as skeletally unaffected individuals. Thus we argue that disease alone was insufficient to warrant exclusion from or inclusion in the cemetery population.

Twenty-three individuals were accorded very different mortuary treatment at Harappa. They were interred at Area G, southeast of the city. This area consisted of some poorly preserved architectural remains that were interpreted as small dwellings, alongside a pit of 20 male, female and immature crania and isolated postcranial remains [7]. The crania piled in this trench demonstrated the highest prevalence of infection and infectious disease of any skeletal assemblage at Harappa (34.8% of 23 individuals). Our previous research also demonstrated a high risk for violent injury among these individuals [1]. These results demonstrate that individuals who were excluded from the cemetery were also the most vulnerable and at the highest risk for infection, infectious diseases, and interpersonal violence.

Stigma has often accompanied leprosy in the historic period [131], and the presence of lepers outside of city walls is almost

Figure 7. Severe rhinomaxillary infection is consistent with a diagnosis of leprosy. These lesions include resorption of the anterior nasal spine, changes to the inferior nasal margin, and remodeling of the nasal septum in individual H.779 (a: ventral view of cranium; b:superior view of pyriform aperture and maxilla). Among other changes indicative of leprosy, individual H.306a demonstrates recession of the anterior alveolar bone to the level of the naso-palatine nerve, porosity along the margin of and remodeling of the pyriform aperture, porosity on the bony palate, zygoma, nasal and orbital processes of the maxilla (b: ventral view).

doi: 10.1371/journal.pone.0084814.g007

Figure 8. Individual G.289 was relatively complete for individuals in the Area G assemblage. Among other changes, this individual demonstrates porosity and reactive bone formation in the left maxillary sinus, as well as exposure of the neurovascular channel in the pyriform aperture (a: superior view of anterior and inferior surfaces of left sinus and floor of pyriform aperture). The anterior nasal spine has been remodeled; the alveolus for the left central incisor is resorbed; and there is porosity on the inferior margin of the left orbit (b: superior view of left maxilla).

doi: 10.1371/journal.pone.0084814.g008

Figure 9. Individual G.289 also demonstrated postcranial changes, some of which are consistent with a diagnosis of leprosy. There is evidence of supperative osteomyelitis in the vertebral column, with focal lytic lesions on the ventral and left lateral surfaces of a thoracic centrum and osteosclerotic reaction, erosion of the anterior rim, and hypertrophic new bone formation on adjacent vertebral bodies (a: lateral view). Of other postcranial changes consistent with leprosy, there was a palmar groove and a small cloaca on an proximal manual phalanx (indicated by arrows on image b: palmar view); evidence for inflammation and/or infection causing bone overgrowth on the first pedal phalanx and metatarsal (c: top image is of the superior surface; superior and inferior view of the proximal phalanx are on the left and right side on the bottom row).
doi: 10.1371/journal.pone.0084814.g009

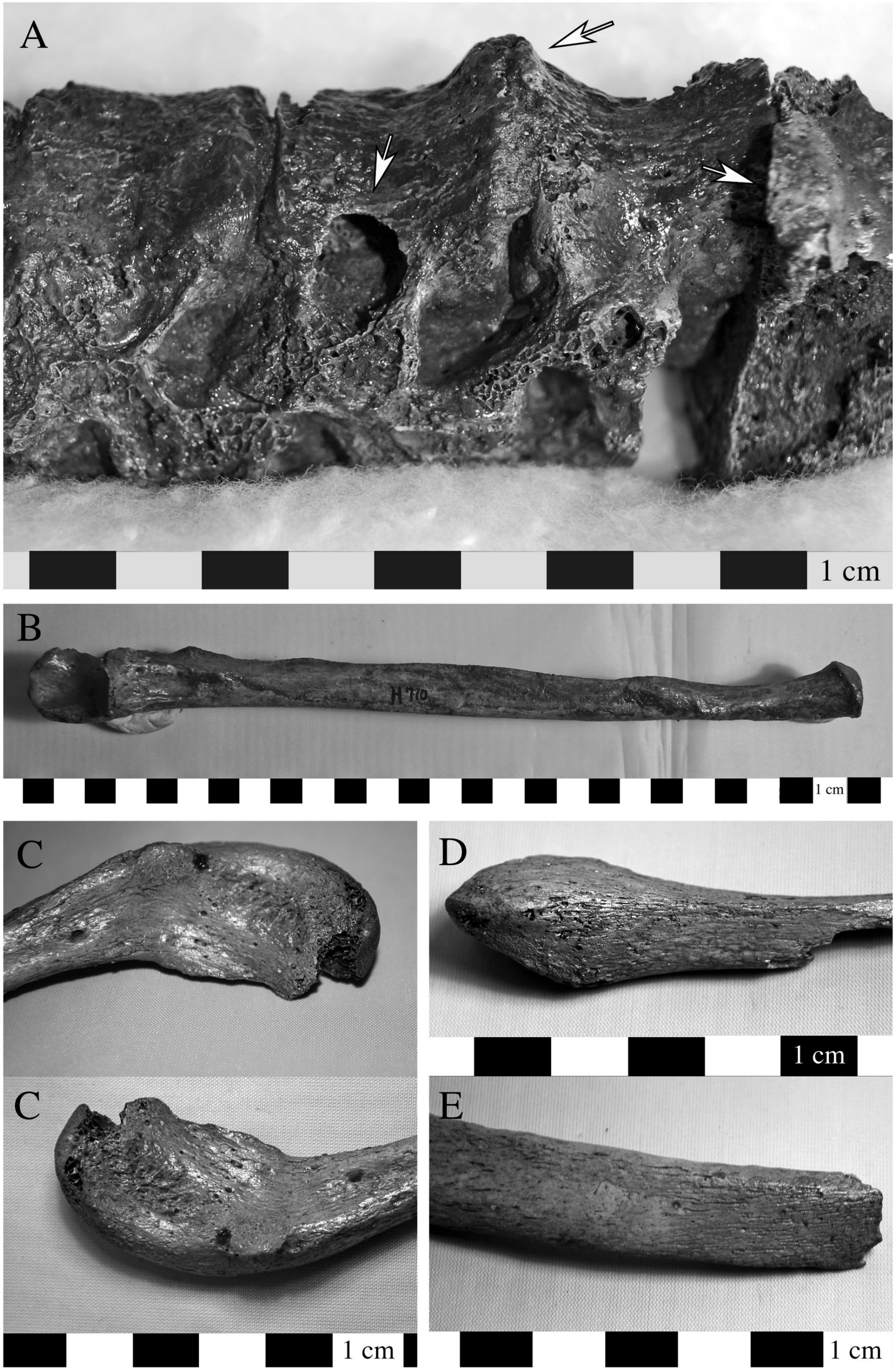

Figure 10. Two individuals from Cemetery H demonstrated cranial and postcranial lesions consistent with a diagnosis of tuberculosis. The postcranial lesions included a smooth walled cavitation consistent with evidence for a psoas abscess formation on the right side of the ninth thoracic vertebral centrum and associated reactive bone formation and ankylosis of the adjacent elements in H. 710 (a: lateral view, with arrows indicated abscess and reactive bone formation or ankylosis); osteomyelitis affected the distal third of the left ulna (b: ventral view). H.722 demonstrated evidence of inflammation and bone swelling in the acromial end of the right clavicle (c: inferior view), periostitis on the left distal fibula (d: lateral view), and inflammatory changes to the surface of a left rib at the angle (e: dorsal view).

doi: 10.1371/journal.pone.0084814.g010

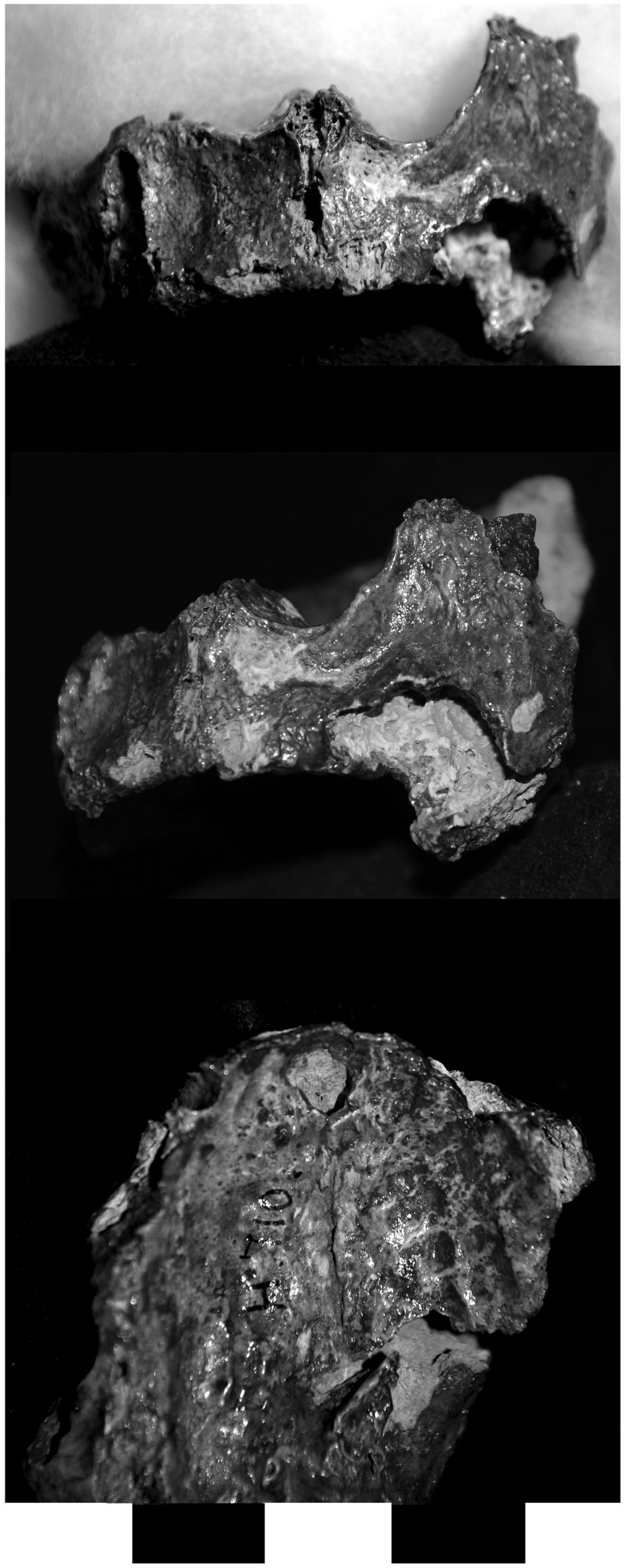

Figure 11. Changes to the maxilla in H. 710 that are consistent with the diagnosis of tuberculosis include abscess formation and destruction of the maxillary alveoli, periosteal reaction in the right maxillary sinus, destruction of the bony palate and initial changes leading to perforation at the midline of the palate (ventral view image on top, left lateral view in center, and inferior view of maxilla on the bottom).
doi: 10.1371/journal.pone.0084814.g011

a cliché in the paleopathology literature. At Harappa, the mortuary context at Area G could be interpreted as evidence for stigma. Epidemiologically, the greatest risk for violence and disease occurred in those individuals who were excluded from the cemetery. Leprosy and traumatic injury co-occur at Area G. However, traumatic injuries, leprosy and tuberculosis also co-occur in the cemetery populations, suggesting that individuals in Area G were not excluded from the cemetery because of disease. A more parsimonious interpretation is that these individuals were more vulnerable to violence and disease because of other aspects of their identity—sex, age, social status, community, and perhaps behavior—that also led to exclusion from the cemetery. It is uncertain whether the people interred here were marginalized because they suffered from an infectious disease, or whether they suffered from a higher prevalence of violence and disease because they were marginalized, impoverished, and stigmatized for some other reason. We favor the latter explanation but deeper analysis of mortuary treatment may help to address some of these questions and is planned for a future study.

Future studies must also involve a deeper investigation of co-occurrence of trauma and infection; co-occurrence of infectious organisms in individual skeletons; and, an analysis of other indicators of developmental stress and growth disruption, which will clarify whether affected individuals demonstrate evidence for chronic deprivation, or stress markers earlier in the life course. More specific information about stigma may also be obtained by analysis of additional skeletal populations from this time period, particularly if contemporary excavations are focused on areas outside the city walls.

Conclusion

Currently we face global climate changes of a projected magnitude unprecedented in the Holocene epoch [132]. We are already experiencing increases in mean atmospheric carbon, land surface temperatures, and sea levels. Perhaps more significantly, as the mean values increase, the weather is becoming more variable, precipitation patterns are changing, and we are experiencing more frequent severe storms [133]. Drought, flooding, and other natural disasters are expected to increase in frequency; uncertainty and unpredictability may eventually make basic goals like subsistence more difficult.

Human security literature predicts that in the current context, when a proportion of the population in a complex society (or "state") is disadvantage by socio-cultural, historical, economic, and political processes, it is these communities who face disproportionate effects from food shortage, reduced access to raw materials, sanitation issues, conflict, and disease [63,85,86,91,92,134–137]. Historically, even relatively minor climatic or environmental changes have led to increasing levels of violence, starvation, epidemics, and/or biodemographic changes in human populations [137–139]. While it is not always the case, resource scarcity, environmental uncertainty, and declining agricultural production in the face of continued population growth have resulted in starvation, violence, and/or emigration many times in prehistory as well (see for example, 140–147).

The human skeletal remains from Harappa examined here demonstrate this association in South Asian prehistory. However, our results should not be misinterpreted as confirming an adaptationist perspective that elevated levels of competition for scarce agro-ecological resources and increased levels of migration during periods of climate change necessarily lead to increases in conflict, interpersonal violence, and negative impacts on human health. Despite claims in popular books [148,149], the fate of human societies is not determined by one or two extrinsic factors. Human communities in the past had a variety of responses to climate change, resource scarcity, and conflict [68,150–150–153]. Biocultural approaches to human prehistory have repeatedly demonstrated that is the social world that determines the meaning of and responses to environmental stressors, and it is the social structure and human agency that determine who will be affected, how, and to what degree [154–157].

Human populations in semi-arid regions of the world, including South Asia, currently face disproportionate impacts from global climate change. The evidence from Harappa offers insights into how such changes impact human societies. South Asians have historically had diverse responses to climate change [144]. At Harappa, the same forces that characterized the process of urbanization and social stratification probably ultimately shaped the collapse. Climate change and exchange relationships may have enhanced immigration to the city of Harappa after 2200 B.C. and the archaeological record suggests that Indus people successfully managed the pressures of climate change, migration, and rapid population growth for centuries prior to 2000 B.C. However, climate change and massive population growth had an increasingly negative impact on the city through time, creating an environmentally, demographically induced pressure point [158]. Centuries of hydro-ecological stress, agro-economic problems, increasingly frequent interruptions of the exchange network, and deterioration of conditions in the city eventually led to massive depopulation around 1900 B.C. Those who remained suffered from increasing rates of interpersonal violence and infection, particularly in marginalized communities who received little protection from a weak, decentralized society. The evidence from Harappa confirms the importance of both social and biological challenges in shaping the fate of human populations dealing with rapid population growth and environmental degradation.

Future archaeological research should further examine the possibility that Harappa offers an historical example of how climate and social changes in a weak and deteriorating "state", or "pre-state" level, complex society can disproportionately impact disadvantaged, marginalized, or vulnerable communities. One question that arises is whether the evidence from Harappa is principally demonstrative of biosocial processes at work in this one city, or whether social differentiation and status differences typified the process of urbanization in other Indus communities. In other words, how typical is this pattern of the Indus civilization as a whole? Archaeologists have long known there was some evidence for interpersonal violence in some of the assemblages from Indus Civilization cities [105,113,159–165]. However, evidence for trauma and pathology has been controversial, much debated, and sometimes minimized as interpretations have been limited to discussions about Aryan Invasion mythology and there has been little attempt to understand how these lesions relate to the intrinsic social forces that were at work in the ancient populations [6,113,166]. Pending further investigation of skeletal material from additional sites like Mohenjo Daro, Lothal, Chanhu Daro, and Kalibangan, it is safe to say that Harappa was not an isolated, peripheral settlement on the fringes of Indus society. It was one of the largest regional centers in the Indus Valley and has often been used as a primary source of information about the Indus Civilization. There is no evidence that Harappan society was markedly different from that of other urban centers, that it was special or deviant in some way, but this question must be examined through a larger, regional survey of paleopathological indicators. Social forces at work at Harappa are to a degree, representative of the larger processes at work in the Indus Civilization as a whole. Additional research on mortuary treatment, trauma, and pathology in other Indus cities is crucial to understanding how short-term strategies for coping with environmental, social and economic changes led to long-term consequences for human populations in South Asian prehistory.

Acknowledgements

Sincere appreciation is extended to Charlotte Roberts and the anonymous reviewers for their comments on the manuscript, which greatly improved the presentation and interpretations offered here. We would like to thank Subhash Walimbe, John Lukacs, Nancy Lovell, Ken Kennedy, Mark Kenoyer and Rita Wright for their support and advice on aspects of Indus archaeology. Any and all mistakes in the manuscript are our own. The authors would also like to extend our appreciation to Kamal K. Misra, A.R. Sankyan, Rana Chakravarty, Shevanti Narayan, Sumanta Basu, Ambi Parasuram, and Laxmi Parasuram for logistical support. Finally, we thank Dilip Roy and Ranjana Ray for their encouragement, support, and assistance.

Author Contributions

Conceived and designed the experiments: GRS. Performed the experiments: GRS KG. Analyzed the data: GRS KEB BC. Contributed reagents/materials/analysis tools: GRS. Wrote the manuscript: GRS VMT.

References

1. Robbins Schug G, Gray K, Mushrif-Tripathy V, Sankhyan AR (2012) A peaceful realm? Trauma and Social Differentiation at Harappa. Int J Paleopathol 2: 136–147.
2. Dales GF, Kenoyer JM (1991) Summaries of five seasons of research at Harappa (District Sahiwal, Punjab, Pakistan) 1986-1990. Harappa Excav 1986-1990: 185–262
3. Kenoyer JM, Dales GF, Fairservis WA, Small T (1998) Ancient cities of the Indus valley civilization. Karachi: Oxford University Press Karachi, Pakistan. 260 p
4. Lahiri N (2000) The decline and fall of the Indus civilization. Delhi: Permanent Black.: 410.
5. McIntosh J (2008) The ancient Indus Valley: new perspectives. Santa Barbara: ABC-CLIO. 459 p
6. Possehl GL (2002) The Indus civilization: A contemporary perspective. Altamira Pr.: 276.
7. Vats MS (1940) Excavations at Harappā, being an account of archaeological excavations at Harappā carried out between the years 1920-21 and 1933-34. Delhi: Government of India Press. 488 p.
8. Wheeler REM (1947) Harappa 1946: The Defenses and Cemetery R-37. Anc India 3: 58–130.
9. Possehl GL (1990) Revolution in the urban revolution: The emergence of Indus urbanization. Annu. Rev Anthr 19: 261–282. doi:10.1146/annurev.an.19.100190.001401.
10. Possehl GL (1998) Sociocultural complexity without the state: the Indus civilization. In: GM FeinmanJ Marcus. Archaic states. Santa Fe: School of American Research. pp. 261–291.
11. Bryson RA (1981) Holocene variations of monsoon rainfall in Rajasthan. Quat Res 16: 135–145. doi:10.1016/0033-5894(81)90041-7.
12. Enzel Y, Ely LL, Mishra S, Ramesh R, Amit R et al. (1999) High-resolution Holocene environmental changes in the Thar Desert, northwestern India. Science 284: 125–128. doi:10.1126/science.284.5411.125. PubMed: 10102808.
13. Madella M, Fuller DQ (2006) Palaeoecology and the Harappan Civilisation of South Asia: a reconsideration. Quat Sci Rev 25: 1283–1301. doi:10.1016/j.quascirev.2005.10.012.
14. Phadtare NR (2000) Sharp decrease in summer monsoon strength 4000–3500 cal yr BP in the Central Higher Himalaya of India based on pollen evidence from alpine peat. Quat Res 53: 122–129. doi:10.1006/qres.1999.2108.
15. Migowski C, Stein M, Prasad S, Negendank JF, Agnon A (2006) Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. Quat Res 66: 421–431. doi:10.1016/j.yqres.2006.06.010.
16. Wright HE (1993) Global Climates: Since the Last Glacial Maximum. Minneapolis: Univ Minnesota Press. 569 pp.
17. Singh P, Bengtsson L (2004) Hydrological sensitivity of a large Himalayan basin to climate change. Hydrol Process 18: 2363–2385. doi:10.1002/hyp.1468.
18. Von Rad U (1999) A 5000-yr record of climate change in varved sediments from the Oxygen Minimum Zone off Pakistan Northeastern Arabian Sea. Quat Res 51: 39–53. doi:10.1006/qres.1998.2016.
19. Dales GF (1962) The Role of Natural Forces in the Ancient Indus Valley and Baluchichistan. In: R Woodbury. Irrigation in Desert Lands, Anthr Pap No 62. Salt Lake City: Univ Utah Press.
20. Dales GF (1965) Civilization and floods in the Indus Valley. Expedition 7: 10–19.
21. Dales GF, Raikes RL (1968) The Mohenjo-Daro Floods: A Rejoinder! Am Anthr 70: 957–961.
22. Raikes RL, Dyson RH Jr (1961) The Prehistoric Climate of Baluchistan and the Indus Valley1. Am Anthr 63: 265–281. doi:10.1525/aa.1961.63.2.02a00020.
23. Raikes RL (1964) The end of the ancient cities of the Indus. Am Anthr 66: 284–299. doi:10.1525/aa.1964.66.2.02a00040.
24. Raikes RL, Dales GF (1986) Reposte to Wasson’s sedimentological basis of the Mohenjo-Daro flood hypothesis. Man Environ ottobre, 1986: 33–44.
25. Lal BB (1968) A Deluge? Which Deluge? Yet Another Facet of the Problem of the Copper Hoard Culture. Am Anthr 70: 857–863.
26. Possehl GL (1997) The transformation of the Indus civilization. J World Prehistory 11: 425–472. doi:10.1007/BF02220556.
27. Possehl GL (2000) Drying up of the Sarasvati: environmental disruption in South Asian prehistory. Environ Disaster Archaeol Hum Response: 7.
28. Farooqui A, Gaur AS, Prasad V (2013) Climate, Vegetation and Ecology during Harappan Period: Excavations at Kanjetar and Kaj, Mid-Saurashtra coast, Gujarat. J Archaeol Sci 40: 2631-2647. doi:10.1016/j.jas.2013.02.005.
29. Giosan L, Clift PD, Macklin MG, Fuller DQ, Constantinescu S et al. (2012) Fluvial landscapes of the Harappan civilization. Proc Natl Acad Sci U S A 109: E1688–E1694. Available: http://www.pnas.org/content/early/2012/05/24/1112743109. Accessed: 2 August 2013 doi:10.1073/pnas.1112743109. PubMed: 22645375.
30. Prasad S, Enzel Y (2006) Holocene paleoclimates of India. Quat Res 66: 442–453. doi:10.1016/j.yqres.2006.05.008.
31. Schuldenrein J, Wright RP, Mughal MR, Khan MA (2004) Landscapes, soils, and mound histories of the Upper Indus Valley, Pakistan: new

insights on the Holocene environments near ancient Harappa. J Archaeol Sci 31: 777–797. doi:10.1016/j.jas.2003.10.015.
32. Wright RP, Bryson RA, Schuldenrein J (2008) Water supply and history: Harappa and the Beas regional survey. Antiquity 82: 37-48.
33. Caratini C (1991) A major change at ca. 3500 years BP in the vegetation of the Western Ghats in North Kanara, Karnataka. Curr Sci 61: 669–672.
34. Caratini C (1994) A less humid climate since ca. 3500 yr B.P. from marine cores off Karwar, western India. Palaeogeogr Palaeoclim Palaeoecol 109: 371–384. doi:10.1016/0031-0182(94)90186-4.
35. DeMenocal PB, others (2001) Cultural responses to climate change during the late Holocene. Science 292: 667–673.
36. Fiorentino G, Caracuta V, Calcagnile L, D'Elia M, Matthiae P et al. (2008) Third millennium BC climate change in Syria highlighted by Carbon stable isotope analysis of 14 C-AMS dated plant remains from Ebla. Palaeogeogr Palaeoclim Palaeoecol 266: 51–58. doi:10.1016/j.palaeo.2008.03.034.
37. Frahm E, Feinberg JM (2013) Environment and collapse: Eastern Anatolian obsidians at Urkesh (Tell Mozan, Syria) and the third-millennium Mesopotamian urban crisis. J Archaeol Sci 40: 1866–1878. doi:10.1016/j.jas.2012.11.026.
38. Masi A, Sadori L, Baneschi I, Siani AM, Zanchetta G (2013) Stable isotope analysis of archaeological oak charcoal from eastern Anatolia as a marker of mid-Holocene climate change. Plant Biol 15: 83–92. doi:10.1111/j.1438-8677.2012.00669.x. PubMed: 23009712.
39. Mayewski PA, Rohling EE, Curt Stager J, Karlen W, Maasch KA et al. (2004) Holocene climate variability. Quat Res 62: 243–255. doi:10.1016/j.yqres.2004.07.001.
40. Staubwasser M, Weiss H (2006) Holocene climate and cultural evolution in late prehistoric-early historic West Asia. Quat Res 66: 372–387. doi:10.1016/j.yqres.2006.09.001.
41. Kenoyer JM (1997) Early city-states in South Asia: comparing the Harappan phase and Early Historic period. Archaeol City-States Cross-Cult Approaches: 51–70.
42. Kenoyer JM (2008) Indus urbanism: New perspectives on its origin and character. In: J MarcusJA Sabloff. The Ancient City: New Perspectives on Urbanism in Old and New Worlds. Santa Fe: School of Advanced Research Press: 183–208.
43. Ratnagar S (1981) Encounters: The Westerly Trade of the Harappa Civilization. Delhi; New York: Oxford University Press. 294 pp.
44. Wright RP (2010) The Ancient Indus: Urbanism, Economy, and Society. New York: Cambridge University Press. 396 pp.
45. Good IL, Kenoyer JM, Meadow RH (2009) New evidence for early silk in the Indus Civilization. Archaeometry 51: 457–466. doi:10.1111/j.1475-4754.2008.00454.x.
46. Kenoyer JM (1991) Ornament styles of the Indus valley tradition: evidence from recent excavations at Harappa, Pakistan. Paléorient 17: 79–98. doi:10.3406/paleo.1991.4553.
47. Kenoyer JM (1997) Trade and technology of the Indus Valley: new insights from Harappa, Pakistan. World Archaeol 29: 262–280. doi:10.1080/00438243.1997.9980377.
48. Rao SR (1965) Shipping and maritime trade of the Indus people. Expedition 7: 30–37.
49. Wright RP, Lentz DL, Beaubien HF, Kimbrough CK (2012) New evidence for jute (Corchorus capsularis L.) in the Indus civilization. Archaeol Anthr Sci 4: 137–143.
50. Kenoyer JM (2005) Bead Technologies at Harappa, 3300-1900 BC: A Comparative Summary. In Jarrige C, Lefèvre V. South Asian Archaeology 2001. Paris: Editions Recherche sur les Civilisations - ADPF. 2 volumes, 713 p
51. Kenoyer JM, Meadow RH (1997) New Inscribed Objects from Harappa Excavations. Lahore Mus Bull IX: 1-20.
52. Meadow RH (1991) Harappa excavations 1986-1990: a multidisciplinary approach to Third Millenium urbanism. Madison: Prehistory Press. 275 pp.
53. Cullen HM, Kaplan A, Arkin PA (2002) Impact of the North Atlantic Oscillation on Middle Eastern climate and streamflow. Clim Change 55: 315–338. doi:10.1023/A:1020518305517.
54. Cullen HM, Demenocal PB (2000) North Atlantic influence on Tigris–Euphrates streamflow. Int J Climatol 20: 853–863. doi:10.1002/1097-0088(20000630)20:8.
55. Hassan FA (1997) The dynamics of a riverine civilization: a geoarchaeological perspective on the Nile Valley, Egypt. World Archaeol 29: 51–74. doi:10.1080/00438243.1997.9980363.
56. Gupta SP (1982) The Late Harappan: a study in cultural dynamics. Harappan Civilization. Delhi: Oxford IBH. pp. 51–59.
57. Misra VN (1984). Climate, a Factor in the Rise and Fall of the Indus Civilization-Evidence from Rajasthan and Beyond: 1984: 461–490
58. Shinde V (1985) Kaothe—A Late Harappan settlement in the central Tapi basin. Bull Deccan Coll Res Inst 44: 173–177.
59. Shinde V (1991) The Late Harappan Culture in Maharashtra, India: A study of settlement and subsistence patterns. South Asian Stud 7: 91–96. doi:10.1080/02666030.1991.9628427.
60. Mughal MR (1989) Jhukar and the Late Harappan cultural mosaic of the Greater Indus Valley. South Asian Archaeol: 213–222.
61. Bhan KK (1992) Late Harappan Gujarat. East Anthr 45: 173–192.
62. Mughal DMR (1990) The decline of the Indus Civilization and the Late Harappan period in the Indus Valley. Lahore Mus Bull III: 1-17.
63. Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I et al. (2009) Are there social limits to adaptation to climate change? Clim Change 93: 335–354. doi:10.1007/s10584-008-9520-z.
64. Brooks N, Grist N, Brown K (2009) Development futures in the context of climate change: Challenging the present and learning from the past. Dev Policy Rev 27: 741–765. doi:10.1111/j.1467-7679.2009.00468.x.
65. Judkins G, Smith M, Keys E (2008) Determinism within human–environment research and the rediscovery of environmental causation. Geogr J 174: 17–29. doi:10.1111/j.1475-4959.2008.00265.x.
66. Costanza R, Graumlich L, Steffen W, Crumley C, Dearing J et al. (2007) Sustainability or collapse: What can we learn from integrating the history of humans and the rest of nature? Ambio 36: 522-527. Available online at: doi: 10.1579/0044-7447(2007)36[522:SOCWCW]2.0.CO;2. PubMed: 18074887
67. McAnany PA, Yoffee N (2010) Why We Question Collapse and Study Human Resilience, Ecological Vulnerability, and the Aftermath of Empire. In PA McAnanyN Yoffee. Questioning Collapse: Human Resilience, Ecological Vulnerability, and the Aftermath of Empire. New York: Cambridge University Press. pp 1–17.
68. Rosen AM (2007) Civilizing climate: The social impact of climate change in the ancient Near East. Walnut Creek: AltaMira Press. 224 pp.
69. Wossink A (2009) Challenging Climate Change: Competition and Co-Operation Among Pastoralists and Agriculturalists in Northern Mesopotamia (C. 3000-1600 BC). Leiden: Sidestone Press. 200 p.
70. Kenoyer JM, Price TD, Burton JH (2013) A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. J Archaeol Sci 40: 2286-2297. doi:10.1016/j.jas.2012.12.040.
71. Kenoyer JM (1991) The Indus valley tradition of Pakistan and western India. J World Prehistory 5: 331–385. doi:10.1007/BF00978474.
72. Shaffer JG, Lichtenstein DA (2005) South Asian archaeology and the myth of Indo-Aryan invasions. In L BryantLL Patton. The Indo-Aryan Controversy: evidence and inference in Indian history. London: Routledge. p. 522.
73. Gupta P, Dutta PC, Basu A (1962) Human skeletal remains from Harappa. New Delhi, India: Anthropological Survey of India, Memoire: 74.
74. Roberts C, Manchester K (2005) The Archaeology of Disease. Ithaca: Cornell University Press. 243 pp.
75. Barnes I, Duda A, Pybus OG, Thomas MG (2011) Ancient urbanization predicts genetic resistance to tuberculosis. Evolution 65: 842–848. doi:10.1111/j.1558-5646.2010.01132.x. PubMed: 20840594.
76. Monot M, Honoré N, Garnier T, Araoz R, Coppée J-Y et al. (2005) On the Origin of Leprosy. Science 308: 1040–1042. doi:10.1126/science/1109759. PubMed: 15894530.
77. Taylor GM, Blau S, Mays S, Monot M, Lee OYC et al. (2009) Mycobacterium leprae genotype amplified from an archaeological case of lepromatous leprosy in Central Asia. J Archaeol Sci 36: 2408–2414. doi:10.1016/j.jas.2009.06.026.
78. Hirsh AE, Tsolaki AG, DeRiemer K, Feldman MW, Small PM (2004) Stable association between strains of Mycobacterium tuberculosis and their human host populations. Proc Natl Acad Sci 101: 4871–4876. Accessed: 2 Aug 2013
79. Hershkovitz I, Donoghue HD, Minnikin DE, Besra GS, Lee OYC et al. (2008) Detection and molecular characterization of 9000-year-old Mycobacterium tuberculosis from a Neolithic settlement in the Eastern Mediterranean. PLOS ONE 3: e3426. doi:10.1371/journal.pone.0003426. PubMed: 18923677.
80. Zink A, Haas CJ, Reischl U, Szeimies U, Nerlich AG (2001) Molecular analysis of skeletal tuberculosis in an ancient Egyptian population. J Med Microbiol 50: 355–366. PubMed: 11289521.
81. Pinhasi R, Foley R, Donoghue HD (2005) Reconsidering the Antiquity of Leprosy. Science 312: 846.
82. Robbins G, Tripathy VM, Misra VN, Mohanty RK, Shinde VS et al. (2009) Ancient skeletal evidence for leprosy in India (2000 BC). PLOS ONE 4: e5669. doi:10.1371/journal.pone.0005669. PubMed: 19479078.

83. Cork E (2005) Peaceful Harappans? Reviewing the evidence for the absence of warfare in the Indus Civilisation of north-west India and Pakistan (c. 2500-1900 BC). Antiquity 79: 411-423.
84. Parry ML, IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability: Working Group I Contribution to the Fourth Assessment Report of the IPCC. New York: Cambridge University Press. 976 pp.
85. Nordaas R, Gleditsch NP (2007) Climate change and conflict. Polit Geogr 26: 627–638. doi:10.1016/j.polgeo.2007.06.003.
86. Gleditsch NP, Nordas R, Salehyan I (2007) Climate change and conflict: the migration link. International Peace Academy. Available: http://www.ipacademy.org. Accessed 2 Aug 2013
87. Gleditsch NP (2012) Whither the weather? Climate change and conflict. J Peace Res 49: 3–9. doi:10.1177/0022343311431288.
88. Leichenko RM, O'Brien KL (2002) The dynamics of rural vulnerability to global change: the case of southern Africa. Mitig Adapt Strat Glob Change 7: 1–18. doi:10.1023/A:1015860421954.
89. O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G et al. (2004) Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Change 14: 303–313. doi:10.1016/j.gloenvcha.2004.01.001.
90. Raleigh C, Urdal H (2007) Climate change, environmental degradation and armed conflict. Polit Geogr 26: 674–694. doi:10.1016/j.polgeo.2007.06.005.
91. Adger WN (2006) Vulnerability. Glob Environ Change 16: 268–281. doi:10.1016/j.gloenvcha.2006.02.006.
92. Barnett J, Adger WN (2007) Climate change, human security and violent conflict. Polit Geogr 26: 639–655. doi:10.1016/j.polgeo.2007.03.003.
93. Kleinman A, Das V, Lock MM (1997) Social suffering. Berkeley: University of California Press. 404 pp.
94. Galtung J (1969) Violence, peace, and peace research. J Peace Res 6: 167–191. doi:10.1177/002234336900600301.
95. Farmer P (1997) Social scientists and the new tuberculosis. Soc Sci Med 44: 347–358. doi:10.1016/S0277-9536(96)00143-8. PubMed: 9004369.
96. Farmer P (1999) Pathologies of power: rethinking health and human rights. Am J Public Health 89: 1486–1496. doi:10.2105/AJPH.89.10.1486. PubMed: 10511828.
97. Farmer P (2001) Infections and inequalities: the modern plagues. Berkeley: University of California Press.
98. Farmer P, Bourgois P, ScheperHughes N, Fassin D, Green L et al. (2004) An Anthropology of Structural Violence 1. Curr Anthr 45: 305–325. doi:10.1086/382250.
99. Meskell L (2000) Writing the body in archaeology. Read Body Represent Remains Archaeol Rec: 13–21.
100. Meskell L, Preucel RW (2004) Identities. Companion. Journal of Soc Archaeol: 121–141.
101. Joyce RA (2005) Archaeology of the body. Annu. Rev Anthr 34: 139–158. doi:10.1146/annurev.anthro.33.070203.143729.
102. Hemphill BE, Lukacs JR (1991) Hegelian logic and the Harappan civilization: an investigation of Harappan biological affinities in light of recent biological and archaeological research. South Asian Archaeol: 11.
103. Lovell NC (1994) Spinal arthritis and physical stress at Bronze Age Harappa. Am J Phys Anthropol 93: 149–164. doi:10.1002/ajpa.1330930202. PubMed: 8147433.
104. Lovell NC (1997) Anaemia in the ancient Indus Valley. Int J Osteoarchaeol 7: 115–123. doi:10.1002/(SICI)1099-1212(199703)7:2.
105. Lovell NC (1989) Society and disease in prehistoric South Asia. Old problems and new perspectives in the archaeology of South Asia. Wisconsin Archaeology Reports. Madison: Department of Anthropology, University of Wisconsin.
106. Lukacs JR (1992) Dental paleopathology and agricultural intensification in South Asia: new evidence from Bronze Age Harappa. Am J Phys Anthropol 87: 133–150. doi:10.1002/ajpa.1330870202. PubMed: 1543240.
107. Lukacs JR (2007) Interpreting biological diversity in South Asian prehistory: Early Holocene population affinities and subsistence adaptations. The Evolution and History of Human Populations in South Asia. Springer. pp. 271–296.
108. Kenoyer JK, Meadow RH (1994) Harappa excavations 1993: The city wall and inscribed materials. 1994. Harappa excavations 1993: The city wall and inscribed materials. In Parpola A, Koskikallio P, editors. South Asian Archaeology 1993. Helsinki: Suomalainen Tiedeakatemia. pp 451-470
109. Rissman P (1988) Public displays and private values: a guide to buried wealth in Harappan archaeology. World Archaeol 20: 209–228. doi:10.1080/00438243.1988.9980068.
110. Dutta PC (1975) The Harappans: A Bioanthropological Study of the Skeletons Discovered at Harappa. Kolkata: University of Calcutta. 197 pp.
111. Bernhard W, Lukacs JR, Kennedy KAR (1998) Two previously undescribed human skeletons from prehistoric Harappa, Pakistan. Homo 49: 21–54.
112. Kennedy KAR, Lukacs JR, Hemphill BE, Lovell NC (1993) Scaphocephaly in a prehistoric skeleton from Harappa, Pakistan. Anthropol Anz 51: 1–29. PubMed: 8476271.
113. Kennedy KAR (2000) God-apes and Fossil Men: Paleoanthropology of South Asia. University of Michigan Press. 514 pp.
114. Moorrees CFA, Fanning EA, Hunt EE (1963) Formation and resorption of three deciduous teeth in children. Am J Phys Anthropol 21: 205–213. doi:10.1002/ajpa.1330210212. PubMed: 14110696.
115. Moorrees CFA (1963) Age variation of formation stages for ten permanent teeth. J Dent Res 42: 1490–1502. doi:10.1177/00220345630420062701. PubMed: 14081973.
116. Scheuer JL (2000) Developmental juvenile osteology. New York: Academic Press.
117. Buikstra JE, Ubelaker DH (1994) Standards for data collection from human skeletal remains. Proceedings of a seminar at the Field Museum of Natural History. Vol. 68. Fayetteville: Arkansas Archaeological Survey. 347p
118. Lovejoy CO (1985) Dental wear in the Libben population: its functional pattern and role in the determination of adult skeletal age at death. Am J Phys Anthropol 68: 47–56. doi:10.1002/ajpa.1330680105. PubMed: 4061601.
119. Auferheide AC, Rodriguez-Martin C (1998) Cambridge Encyclopedia of Human Paleopathology. Cambridge: Cambridge University Press. 478 pp.
120. Roberts C, Manchester K (2007) The archaeology of disease. Ithaca: Cornell University Press. 338 pp.
121. Ortner DJ (2003) Identification of pathological conditions in human skeletal remains. New York: Academic Press. 645 pp.
122. Resnick D (2002) Osteomyelitis, septic arthritis, and soft tissue infection: organisms. Diagnosis of Bone and Joint Disorders, Vol. 3. Michigan: W.B. Saunders. pp. 2510–2624.
123. Andersen JG, Manchester K (1992) The rhinomaxillary syndrome in leprosy: A clinical, radiological and paleopathological study. Int J Osteoarchaeol 2: 121–129. doi:10.1002/oa.1390020204.
124. Matos V, Santos AL (2006) On the trail of pulmonary tuberculosis based on rib lesions: Results from the human identified skeletal collection from the Museu Bocage (Lisbon, Portugal). Am J Phys Anthropol 130: 190–200. doi:10.1002/ajpa.20309. PubMed: 16365860.
125. Moller-Christensen V (1961) Bone Changes in Leprosy. Copenhagen: Munksgaard. 51 pp.
126. Møller-Christensen V (1978) Leprosy Changes of the Skull. Odense University Press. 148 pp.
127. Resnick D (2002) Diagnosis of Bone and Joint Disorders. Philadelphia: W.B. Saunders. 1066 pp.
128. Manchester K (1984) Tuberculosis and leprosy in antiquity: an interpretation. Med Hist 28: 162–173. doi:10.1017/S0025727300035705. PubMed: 6387342.
129. Weston DA (2008) Investigating the specificity of periosteal reactions in pathology museum specimens. Am J Phys Anthropol 137: 48–59. doi:10.1002/ajpa.20839. PubMed: 18398845.
130. Rogers J, Waldron T (1989) Infections in palaeopathology: the basis of classification according to most probable cause. J Archaeol Sci 16: 611–625. doi:10.1016/0305-4403(89)90026-5.
131. Roberts C (2011) The Bioarchaeology of Leprosy and Tuberculosis. Soc Bioarchaeology: 252–281.
132. Change IPOC (2007) Climate change 2007: the physical science basis. Agenda 6. Available: http://www.slvwd.com/agendas/Full/2007/06-07-07/Item%2010b.pdf. Accessed: 27 May 2013
133. Rupa Kumar K, Sahai AK, Krishna Kumar K, Patwardhan SK, Mishra PK et al. (2006) High-resolution climate change scenarios for India for the 21st century. Curr Sci 90: 334–345.
134. Barnett J (2003) Security and climate change. Glob Environ Change 13: 7–17. doi:10.1016/S0959-3780(02)00080-8.
135. Costello A, Abbas M, Allen A, Ball S, Bell S, et al. (2009) Managing the health effects of climate change. Lancet Lond Engl 373: 1693–1733.
136. Zhang DD, Brecke P, Lee HF, He YQ, Zhang J (2007) Global climate change, war, and population decline in recent human history. Proc Natl Acad Sci of the USA 104: 19214–19219. Available: http://www.pnas.org/content/104/49/19214.full. Accessed: 27 May 2013 doi:10.1073/pnas.0703073104. PubMed: 18048343.
137. Zhang DD, Lee HF, Wang C, Li B, Pei Q et al. (2011) The causality analysis of climate change and large scale huma crisis. Proc Natl Acad Sci of the USA 108: 17296–17301. Available: http://www.pnas.org/

content/108/42/17296.short. Accessed 27 May 2013 doi:10.1073/pnas.1104268108. PubMed: 21969578.
138. Jones BA, Grace D, Kock R, Alonso S, Rushton J et al. (2013) Zoonosis emergence linked to agricultural intensification and environmental change. Proc Natl Acad Sci U S A 110: 8399–8404. Available: http://www.pnas.org/content/early/2013/05/08/1208059110. Accessed: 27 May 2013 doi:10.1073/pnas.1208059110. PubMed: 23671097.
139. Matthew RA, Gaulin T (2001) Conflict or cooperation? The social and political impacts of resource scarcity on small island states. Glob Environ Polit 1: 48–70. doi:10.1162/152638001750336596.
140. Ember CR, Ember M (1992) Resource Unpredictability, Mistrust, and War A Cross-Cultural Study. J Confl Resolut 36: 242–262.
141. Kellner CM (2002) Coping with environmental and social challenges in prehistoric Peru: bioarchaeological analyses of Nasca populations. npublished Dissertation, University of California-Santa Barbara.
142. Lambert PM (1997) Patterns of violence in prehistoric hunter-gatherer societies of coastal southern California. In D MartinD Frayer. Troubled Times: Violence and Warfare in the Past. Langhorne: Gordon and Breach. p. 376.
143. Klaus H (2013) The Bioarchaeology of Structural Violence: A Theoretical Model and a Case Study. In D MartinRP HarrodVR Perez. The Bioarchaeology of Violence. Gainesville: University Press of Florida. p. 291.
144. Robbins Schug G (2011) Bioarchaeology and Climate Change: A View from South Asian Prehistory. Gainesville: University Press of Florida. 180 pp.
145. Torres-Rouff C, Junqueira MAC (2006) Interpersonal violence in prehistoric San Pedro de Atacama, Chile: Behavioral implications of environmental stress. Am J Phys Anthropol 130: 60–70. doi:10.1002/ajpa.20315. PubMed: 16353221.
146. Walker PL (1989) Cranial injuries as evidence of violence in prehistoric southern California. Am J Phys Anthropol 80: 313–323. doi:10.1002/ajpa.1330800305. PubMed: 2686461.
147. Walker PL (2001) A bioarchaeological perspective on the history of violence. Annu. Rev Anthr: 573–596.
148. Diamond J (2005) Collapse: How societies choose to succeed or fail. New York: Viking Press. 575 pp.
149. Diamond JM (1998) Guns, Germs and Steel: A Short History of Everbody for the Last 13000 Years. New York: WW Norton. 480 pp.
150. McAnany PA, Yoffee N (2010) Questioning collapse: human resilience, ecological vulnerability, and the aftermath of empire. New York: Cambridge University Press. 374 pp.
151. McIntosh RJ, Tainter JA, McIntosh SK (2000) The way the wind blows: climate, history, and human action. New York: Columbia University Press. 413 pp.
152. Minnegal M, Dwyer PD (2000) Responses to a drought in the interior lowlands of Papua New Guinea: a comparison of Bedamuni and Kubo-Konai. Hum Ecol 28: 493–526. doi:10.1023/A:1026483630039.
153. Salehyan I (2008) From climate change to conflict? No consensus yet. J Peace Res 45: 315–326. doi:10.1177/0022343308088812.
154. Judd M (2004) Trauma in the city of Kerma: ancient versus modern injury patterns. Int J Osteoarchaeol 14: 34–51.
155. Knudson KJ, Stojanowski CM (2008) New Directions in Bioarchaeology: Recent Contributions to the Study of Human. Social Identities - J Archaeol Res 16: 397–432.
156. Agarwal SC, Glencross BA (2011) Social Bioarchaeology. John Wiley & Sons. 473 pp.
157. Buikstra JE, Beck LA (2006) Bioarchaeology: the contextual analysis of human remains. Elsevier Academic Press. 630 pp.
158. Myers N, Kent J (1995) Environmental exodus: an emergent crisis in the global arena. Climate Institute. Available: http://bases.bireme.br/cgi-bin/wxislind.exe/iah/online/?IsisScript=iah/iah.xis&src=google&base=REPIDISCA&lang=p&nextAction=lnk&exprSearch=56307&indexSearch=ID. Accessed: 28 May 2013
159. Kennedy KAR (1984) Trauma and disease in the ancient Harappans. In M WheelerBB LalSP Gupta. Frontiers of the Indus civilization. New Delhi: Books and Books. p. 545.
160. Kennedy KAR (2002) Biological Anthropology of Human Skeletons from Harappa. Indian Archaeol Retrosp 2: 293–316.
161. Sharma A (1999) The departed Harappans of Kalibangan. New Delhi: Sundeep Prakashan: 121.
162. Kennedy KAR (1992) Biological anthropology of human skeletons from Harappa: 1928 to 1988. East Anthr 45: 55–85.
163. Kennedy KAR (1982) Skulls, Aryans and flowing drains: the interface of archaeology and skeletal biology in the study of the Harappan civilization. Harappan Civiliz: 289–295.
164. Kennedy KAR (1976) Biological anthropology of prehistoric populations in South Asia: a survey of current research efforts. In KAR KennedyGL Possehl. Ecological Backgrounds of South Asian Prehistory. Ithaca: Cornell University Press, Cornell Occassional Papers and Theses, no. 4. pp 166–178
165. Kennedy KAR (1982) Paleodemographic perspectives of social structural change in Harappan society. In S PastnerL Flam. Anthropology in Pakistan: recent cultural and archaeological perspectives. Ithaca: Cornell UNiversity Press, South Asia Occasional Papers and Theses, no. 8. pp 211–217
166. Lukacs JR (1994) The osteological paradox and the Indus Civilization: Problems inferring health from human skeletons at Harappa. In GF DalesJM Kenoyer. From Sumer to; Meluhha contributions to the archaeology of South and West Asia in memory of George Franklin Dales, Jr. Madison: Wisconsin Archeological Reports:143–155.