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Bioarchaeological Analysis of Qoli Darvish (Iran): Reflections on Climate and Subsistence Economy in the Qom Plain during the Third and Second Millennia BCE

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Abstract

The present study is based on the bioarchaeological analysis of animal and botanical remains from the Qoli Darvish site in the Qom Plain, aiming to reconstruct the climate and subsistence economy of the communities settled in this region during the third and second millennia BCE. The dataset comprises over four thousand animal bone fragments recovered from the occupational layers of periods II to VI at the site. The identified animals include domestic and wild herbivores, while identified botanical remains are mostly composed cereal. Taxonomic and anatomical analyses of the bones and botanical remains provide valuable insights into the economic structure, dietary habits, animal husbandry and plant cultivation practices, and reflections on climatic changes. The results of these studies suggest that, contrary to the present arid and desert-like landscape of the Qom Plain, the region experienced a relatively more humid climate during the investigated period sufficient to support herding and agricultural activities. Evidence of bone modifications reveals further details regarding human activities and the way ancient communities exploited environmental resources. This research highlights the significance of organic remains analysis in reconstructing past economy and understanding subsistence behaviours in prehistoric societies.

Keywords: Bioarchaeology, Qom Plain, Qoli Darvish, Bronze Age, Subsistence, Climate Reconstruction.

Article Type: Research Article

Introduction

Bioarchaeological studies have, over recent decades, become a cornerstone of interdisciplinary research in archaeology. By examining animal remains, such studies enable the analysis of economic, dietary, environmental, and cultural behaviours of past human societies. Bioarchaeology not only allows for the identification of domestic and wild animal and plant species, but also provides valuable data on dietary patterns, agropastoral practices, exploitation of biological resources, and the reconstruction of past natural landscapes. The Qoli Darvish site in the Qom Plain, which features a continuous sequence of occupation from the Early Bronze Age to the onset of the Iron Age (Periods II to VI), is considered one of the richest and most significant archaeological sites on the Iranian Cen-

tral Plateau (Sarlak 2011: 285). The data obtained from excavations at this site, especially faunal and botanical remains, offer a substantial foundation for analysing subsistence patterns and reconstructing past ecosystems.

This study integrates comprehensive bioarchaeological data, drawing on the analysis of over 4,193 faunal bone fragments and macro-botanical remains recovered from the site.[1] By focusing on taxonomic, pathological, and morphological data, it aims to present a clearer picture of human–animal-plant interactions and their implications for understanding climate and subsistence economy structures in the region. The integration of archaeozoological and archaeobotanical data (Sarlak, in press) contributes to a more comprehensive understanding of dietary habits and subsistence strategies. Together, these lines of evidence facilitate a more robust reconstruction of the natural and climatic landscape of the Qom Plain throughout the third and second millennia BCE.

The Geography of Qoli Darvish: Environmental and Climatic Features

The Qoli Darvish site is situated in the central part of the Qom Plain, on the southern outskirts of the city of Qom. It lies at 50°53′ E longitude and 34°38′ N latitude, with an elevation of 935 metres above sea level. As one of the major settlement sites of the Qom Plain, Qoli Darvish falls within the Central Plateau cultural-geographical zone of Iran (Figure. 1), and its natural landscape generally conforms to the broader environmental and cultural patterns of this region (Sarlak 2010: 13; 2011:15). Due to its proximity to the desert, the Qom Plain is characterised by an arid to semi-arid climate. Significant temperature fluctuations, high levels of atmospheric dryness, and marked variability in rainfall are among the principal climatic features of this area. Winds blowing from the east (the desert side) greatly contribute to increased dust levels, reduced humidity, and higher summer temperatures (Tabatabaei Majd 2002: 77). Despite the arid conditions, Qom's location to the west of the Qomrud alluvial fan has endowed the region with relatively rich groundwater resources. Consequently, most of the agricultural lands in the eastern and south-eastern parts of Qom, including Jamkaran and Qolī Darvīsh, have historically been cultivated using both irrigation and dry farming techniques. This situation has, since antiquity, encouraged the use of Qanats and canals for water supply and agricultural irrigation (Sarlak 2010: 15). However, recent expansion of agricultural activities and the increasing encroachment of modern infrastructure around the Qolī Darvīsh site pose serious threats to its archaeological integrity. As visible in the satellite imagery and 3D reconstruction of the mound (Figure. 2), cultivation and land-use changes have approached dangerously close to the boundaries of the site, undermining both its preservation and potential for future research.

Topographically, while the Qom Plain appears relatively flat, its margins, particularly in the south, south-west, and south-east, are composed of rolling hills and elevated terrain. The nearest elevations to Qolī Darvīsh include the Do-Baradaran, Yazdan, Khezr, Qez Qal'eh-Sī, Kolah Qāzī, and Nardaghi Mountains, all reaching altitudes of around 2,000 metres and overlooking the Jamkaran area. These highlands contribute to moderating the temperature and humidity in the southern zone of the plain, compared to the eastern and northern parts (Modarresi Tabatabaei 1956: 115). As shown in Figure 3, Qolī Darvīsh is situated near the city of Qom, within the expansive Qom Plain. The map emphasizes its proximity to the south-western mountains and illustrates the distribution of other contemporane-

[1]This article is based on the analysis of more than 4,193 faunal bone fragments recovered during the excavations at Qoli Darvish under the direction of Siamak Sarlak. The faunal assemblage was subsequently transferred to and curated in the National Museum of Iran, where it has been stored and made available for continued study (Sarlak 2002, 2004; Khazaeli *et al*. 2017). The study of these faunal remains was carried out in the Osteology Department of the National Museum of Iran between 2014 and 2015 under the supervision of Marjan Mashkour and her collaborative research team, including Roya Khazaeli, Homa Fathi, Sanaz Beizaee Doost, and Sarieh Amiri, who have contributed to the analytical frameworks applied to these prehistoric materials. A subset of 200 faunal bone fragments from the Qoli Darvish assemblage was analysed by Sheyda Ashrafi at the University of Tehran as part of the broader analytical history of the material. Botanical remains from Qoli Darvish were analysed by Zohreh Shirazi at the Archaeobotanical Laboratory, World Heritage Base of Shahr-i Sokhta and Regional Museum of South East Iran. Finally, Interpretative and comparative archaeological insights are also informed by Mehdi Mortazavi and Fariba Mosapour Negari, whose long-standing involvement in Qoli Darvish–related research and familiarity with its excavation history under Sarlak underpin their ongoing engagement with a separate analytical project on additional faunal materials from the same site; these materials are not included in the present study.

ous sites across the plain. Also visible are the Salt Lake (Daryāche-ye Namak) and the Qomrud River, which have long influenced settlement and hydrology in the region.

The predominant air currents in the Qom and Jamkaran region flow from north to south and from west to east, though secondary wind patterns from the south-west to north-east and south-east to north-west also occur. One of the best-known local winds is the Sharyari wind, originating from the Lut Desert, which carries dust and occasional scattered rainfall. Wind activity, particularly south-eastern currents blowing toward the north-west from the Central Desert, is a key agent of natural sedimentation across the Qom Plain. This plays a significant role in the formation and transformation of archaeological sites such as Qolī Darvīsh and influences their architectural characteristics (Sarlak 2010: 16).

These geographical and climatic features of Qoli Darvish provide valuable data for both modern and ancient bioarchaeological research. Understanding the climate and possible vegetation cover during the occupational phases of the site, based on proximity to water resources, soil types, and surrounding elevations, can shed light on the types of animals that may have inhabited the area and how ancient populations interacted with them. The analysis of animal remains found at the site, when considered alongside environmental data, clarifies hunting strategies, pastoral practices, and patterns of animal exploitation in this settlement. For instance, the presence of saline-alkaline soils in parts of the plain (Kardavani 2012: 226; Sarlak 2010: 15) may have influenced the types of livestock maintained, such as camels, goats, and sheep. Moreover, proximity to mountainous terrain may have created suitable habitats for specific fauna and flora species. In addition, examining the present-day environmental conditions of Qoli Darvish and its surroundings offers a useful baseline for comparison with past conditions. Climatic and ecological changes over time likely influenced the region's biodiversity. The current vegetation cover and existing water sources help us understand the area's present-day habitat potential and support studies aimed at preserving its biological diversity. Ultimately, a nuanced understanding of the geographical and climatic characteristics of Qoli Darvish forms a crucial foundation for interpreting

Figure. 1: *Map of Iran showing archaeological sites with an emphasis on the Bronze Age (After: Alizadeh et al. 2013: 150).*

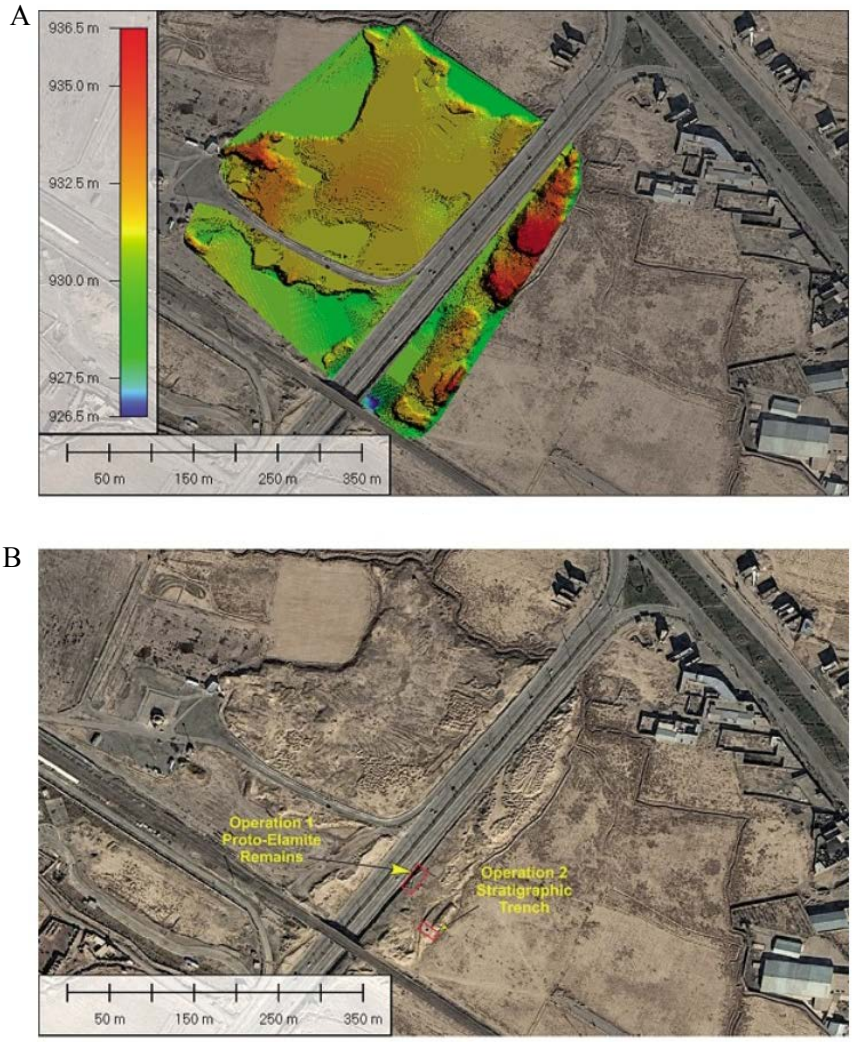

Figure. 2: *Qolī Darvīsh site: (**A**) 3D reconstruction of the mound based on surface data; (**B**)Satellite image showing the surrounding landscape and ongoing land use. The image illustrates the proximity of modern agricultural fields to the ancient site (After: Alizadeh et al. 2013: 152).*

archaeological findings, especially those related to bioarchaeology. It enables us to draw a more comprehensive picture of human–environment interactions throughout the history of this region.

Material Provenience

This research aims to analyse patterns of natural resource exploitation at the Qoli Darvish site in Qom during the third and second millennia BCE. The dataset comprises over 4,193 faunal bone fragments, reflect the taxonomic diversity and anatomical representation of medium- to large-sized mammals at site. This collection, recovered through archaeological excavations from the occupational layers, specifically at the sanctuary complex (Figure .4), of Periods II to VI at the site (Sarlak 2003;2004). Chronologically, these layers span from the late fourth millennium to the second half of the second millennium BCE (Sarlak 2010, 2011; Alizadeh *et al.* 2013; Sarlak and Hessari 2018).

During the excavation, all bones were hand-picked, and the deposits were dry-sieved through 3 cm and 1 cm meshes. Particular care was taken to recover even highly fragmented bones and microfauna remains. Additional microvertebrate bones were retrieved during flotation of samples for charred botanicals using a 2 mm mesh.

In the initial phase, all faunal remains were curated and registered according to their stratigraphic

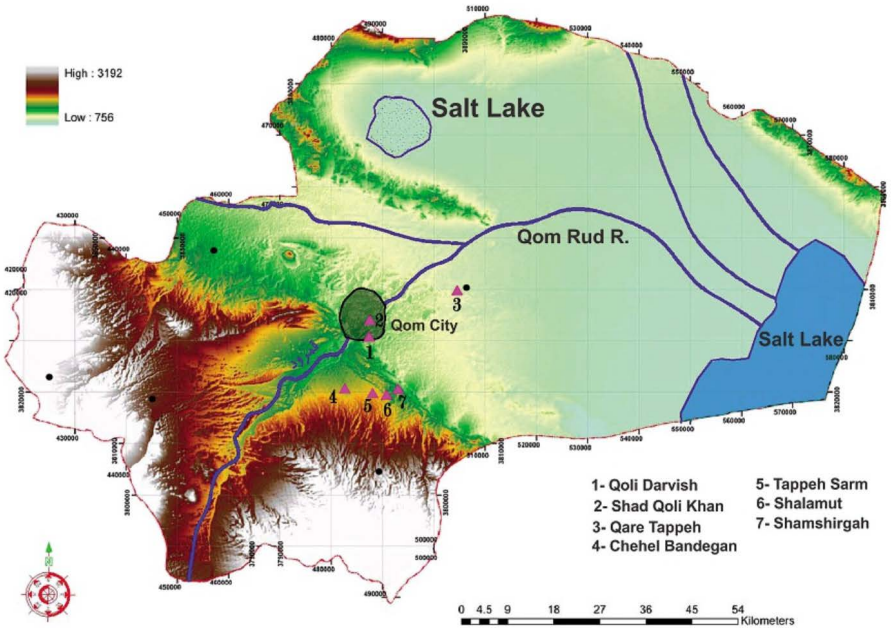

Figure. 3: *. Location of the Qolī Darvīsh site near the city of Qom, within the Qom Plain (After: Alizadeh et al. 2013: 152).*

layer and spatial context. Subsequent analyses included taxonomic identification, morphological examination, and pathological assessment. To gain a more comprehensive understanding of the environmental context, the faunal and botanical data were examined in relation to climatic, geographical, and ecological information from the Qom region. Additionally, in limited cases, archaeobotanical data as well as ceramic and architectural findings were considered to aid in reconstructing dietary habits and subsistence strategies (Sarlak in press).

Cultural Sequence and Chronology of Qoli Darvish (Periods II to VI)

In order to interpret the bioarchaeological remains recovered from Qoli Darvish during Periods II to VI, it is essential to understand the broader archaeological context in which these data are situated. The present section has been included to provide such a contextual foundation. The Qoli Darvish site is recognised as a key Bronze Age reference site in the Qom Plain. Stratigraphic studies conducted at this site, particularly in the stepped trenches AS.35 (on the eastern flank) and P.15 (on the western side) (Figure. 5), have revealed a relatively complete cultural and chronological sequence extending from the late fourth millennium to the latter half of the second millennium BCE, all within a continuous occupational setting (Table. 1 and see also Pollard *et al*. 2013; Fazeli Nashli *et al*. 2022).

Figure. 4: *Ritual spaces of the Qoli Darvish sanctuary complex.(**A**) Southern section of the sanctuary (Trench T.15:406), heavily concentrated with ceramic sherds and animal bones. Excavated during the fourth season (2002). (**B**) Radius-ulna and humerus of a human in the central section of the sanctuary (Trench T.15:405), excavated during the sixth season (After: Sarlak 2004).*

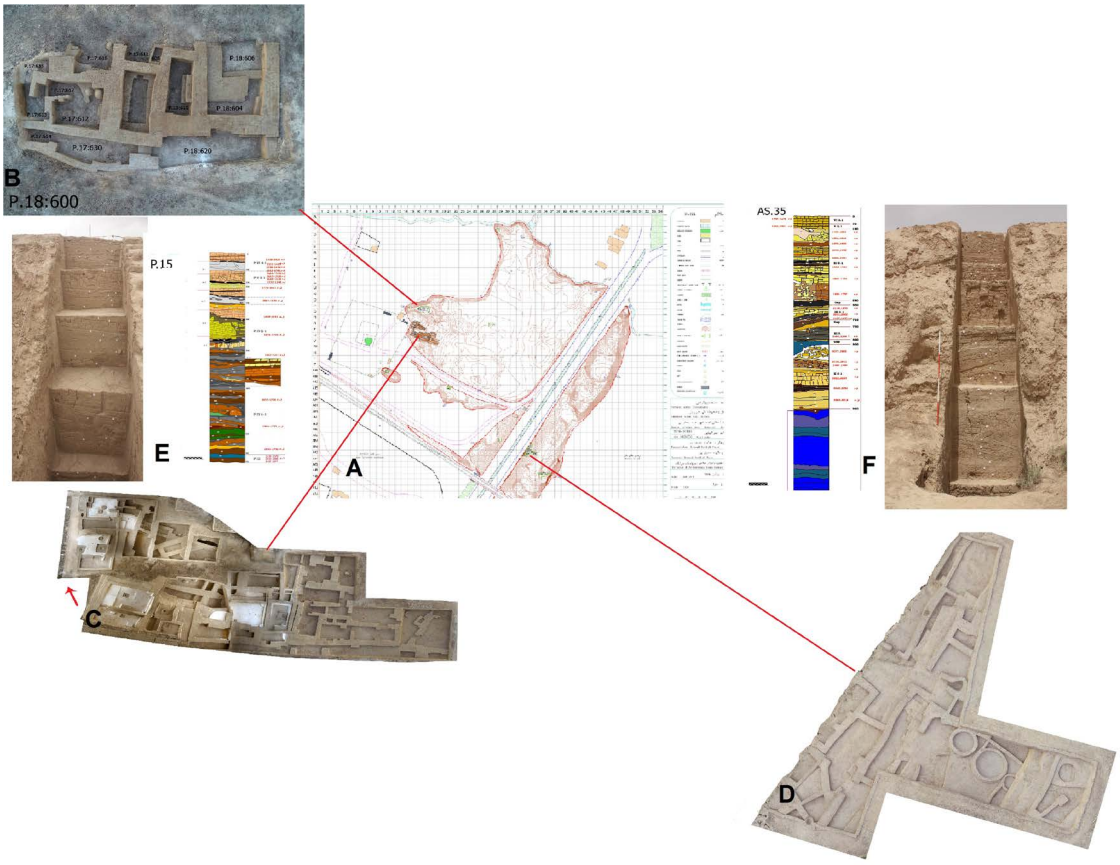

Figure. 5: *Information regarding the excavation areas and the distribution of architectural remains and faunal evidence at the Qoli Darvish site: (**A**) Topographic map of Qoli Darvish, showing the location of excavation trenches and probes.(**B**) Architectural remains of the Early Iron Age (Period VI), containing evidence of animal bones.(**C**) Architectural remains from the Late Bronze Age and the transitional phase to the Iron Age (Periods IV–V), featuring the highest concentration of animal bones, likely associated with ritual activities and the presence of a sanctuary.(**D**) Architectural remains of the Early Bronze Age (corresponding to the beginning of the Elamite Period II), containing faunal evidence. (**E**) Stratigraphic section P15 on the western edge of the site (covering Periods IIIb–VI), containing animal bone remains.(**F**) Stratigraphic section AS35 on the southeastern edge of the site (covering Periods II–VI), containing animal bone remains (After: Sarlak 2016; 2017; 2018)*

This temporal framework encompasses the following phases: Period II (Proto-Elamite/Early Bronze I), Period IIIA (Early Bronze II, featuring elements of the Kura–Araxes cultural horizon), Period IIIB3-1 (Middle Bronze Age), Period IV (Late Bronze Age), and Periods V and VI (representing the transition from the Late Bronze Age to the onset of the Iron Age).

A notable feature of Qoli Darvish is the uneven spatial distribution of occupational layers across the site. For instance, the settlement of Period II and the richest cultural deposits of Period IIIA are largely confined to the south-eastern fringe of the site. In contrast, the occupational sequence of Period IIIB3-1 appears to be more prevalent in the eastern sector, whereas from Period IV onward, habitation extended across the entire site (Table. 2; Figure. 5) (Sarlak 2011: 285–300). This variable pattern of distribution underscores the importance of employing detailed stratigraphic methodologies, such as spiral stratigraphy or patchwork stratigraphy, to ensure an accurate understanding of the site's occupational sequence.

Characteristics of the Occupational Phases (Periods II to VI)

Period II (Proto-Elamite – Early Bronze I): Architectural remains from this phase have been identified in the eastern sector of the site, comprising five successive construction stages built directly

Table. 1: *Results of absolute dating and comparison with relative dating of the Qoli Darvish*

Sample name	Context	CAL 1-Sigma	CAL 2-Sigma	Material	Excavators dating
Qoli Darvish	AW.39:721	Cal BCE 3010-2917	Cal BCE 3077-2908	Charcoal	Early Bronze Age
Qoli Darvish	AX.38:726	Cal BCE 3357-3127	Cal BCE 3363-3106	Charcoal	Early Bronze Age
Qoli Darvish	AX.38:703	Cal BCE 3264-3024	Cal BCE 3228-2945	Charcoal	Early Bronze Age
Qoli Darvish	AB.17:602	Cal BCE 2115-1973	Cal BCE 2131-1954	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	AB.17:604	Cal BCE 2131-1986	Cal BCE 2137-1977	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	V.17:809	Cal BCE 1874-1747	Cal BCE 1880-1700	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	V.17:803	Cal BCE 1744-1691	Cal BCE 1864-1646	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	V.18:807	Cal BCE 1886-1776	Cal BCE 1900-1755	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	V.18:812	Cal BCE 1875-1750	Cal BCE 1881-1701	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	V.19:805	Cal BCE 1870-1698	Cal BCE 1878-1693	Charcoal	Late Bronz-Early Iron Age
Qoli Darvish	Z.18:612	Cal BCE 1870-1698	Cal BCE 1877-1693	Charcoal	Early Iron Age
Qoli Darvish	Z.19:604	Cal BCE 1637-1536	Cal BCE 1663-1530	Charcoal	Early Iron Age
Qoli Darvish	Z.18:630	Cal BCE 1938-1835	Cal BCE 1953-1776	Charcoal	Early Iron Age
Qoli Darvish	Z.18:632	Cal BCE 1681-1616	Cal BCE 1732-1548	Charcoal	Early Iron Age
Qoli Darvish	Z.18606	Cal BCE 1606-1506	Cal BCE 1612-1501	Charcoal	Early Iron Age

Table. 2: *Summary of the characteristics of the occupational phases at Qoli Darvish (Periods II–VI)*

Period	Phase Name	Predominant Area of Occupation	Approximate Thickness of Deposits
II	Proto-Elamite – Early Bronze Age I	Southeastern margin	Up to 3 m
IIIA	Early Bronze Age II – Kura-Araxes culture	Eastern sector	Up to 1 m
IIIB3–1	Middle Bronze Age	Eastern and western sectors	ca. 0.5–1 m
IV	Late Bronze Age	Entire site	(Up to 6 m
V	Transition from Late Bronze Age to Early Iron Age	Entire site	ca. 1 m
VI	Early Iron Age	Entire site	ca. 2.5 m

upon the sterile soil. In extensive excavations, the cultural deposits of this period reach a thickness of approximately 3 metres. Interestingly, no evidence of this phase was detected in the western trench (P.15) (Figure. 5d)

Period IIIA (Early Bronze II – Kura–Araxes Cultural Horizon): Deposits from this period were identified in the eastern stratigraphic trench with an average thickness of around 40 centimetres, and approximately 100 centimetres in the broader eastern excavation areas. These deposits include three distinct architectural phases. The lack of substantial evidence for this period in the western trench is also noteworthy (Figure. 5d).

Period IIIB3–1 (Middle Bronze Age): This phase is represented by around 1 metre of cultural deposits in the eastern trench and approximately 0.5 metres in the western trench. In the large-scale excavations of the eastern area, the architectural remains from this period reach a thickness of about 1 metre and include three consecutive building phases (Figure. 5d).

Periods IV, V, and VI (Late Bronze Age to the Early Iron Age): These three periods reflect a continuous cultural and occupational sequence across the entire site. In the western trench (P.15), at least six main architectural stages (along with four subsidiary phases) have been identified for Period IV, three stages for Period V, and four stages for Period VI. The combined thickness of the deposits for these phases in this trench is estimated at approximately 8.5 metres. Similarly, in the eastern trench (AS.35), six architectural stages from Period IV, three from Period V, and two from Period VI have been recorded, amounting to a total thickness of about 5 metres (Figure. 5b,c) (Sarlak 2011: 240–249).

These occupational layers, particularly those associated with Period II, not only demonstrate a local developmental trajectory but also align with broader patterns observed in other significant Proto-Elamite centres across the Iranian Plateau. Key sites with at least some elements of Proto-Elamite material culture include Susa, Senjar, and Tal-i Ghazir/ Tall-e Geser in Khuzestan; Malyan in Fars; Sialk and Arisman in Isfahan; Yahya in Kerman; Qoli Darvish, Ozbaki, and Sofalin in central and north-central Iran; and Shahr-i- Sokhta in Sistan (Figure . 6) (Matthews and Fazeli Nashli 2022). The inclusion of Qoli Darvish among these sites highlights its importance as part of this expansive cultural horizon, reinforcing its relevance in reconstructing the dynamics of the Proto-Elamite phenomenon. One possible explanation for the widespread similarities observed among these Proto-Elamite sites lies in the existence of long-distance exchange networks, particularly those linking the Iranian Plateau's central and northern zones with the specialised communities of southeastern Iran. Key centres such as Shahdad, Yahya, and Shahr-i- Sokhta are known for their advanced craft specialization, especially in ceramic and metallurgical production, and their active roles in interregional exchange during the late fourth and early third millennia BCE (Mortazavi 2005, 2007; Fazeli Nashli *et al*. 2012; Mosapour Negari 2022). Although direct evidence of interaction between Qoli Darvish and these southeastern sites remains to be fully substantiated, its inclusion among the Proto-Elamite sphere suggests potential connections that merit further investigation. The emerging picture positions Qoli Darvish as a potentially significant participant in these broader exchange networks, possibly engaging in long-distance trade and cultural interaction during the Proto-Elamite horizon.

A Short Account of the Faunal Remains from Periods II–VI in Qoli Darvish

A total of 4,193 animal bone fragments recovered during the first and third excavation seasons, with detailed distributions presented in Table 3. These remains span a chronological range from the Early Bronze Age to the beginning of the Iron Age (Periods II to VI at Qoli Darvish), and reflect a diversity of domestic and wild animal species that presented in the region. The majority of these remains belong to mammals, with a smaller portion attributed to reptiles. Among the mammals, herbivores (even-toed ungulates), odd-toed ungulates, and Carnivores were identified. (Table. 4; Figure .7). Bovids constitutes the largest portion of the assemblage. From this family, 194 bone fragments were attributed to domestic cattle. The sheep and goats are also well represented, with 135 specimens identified as domestic sheep, 230 as domestic goat, and 1,012 unidentified remains of sheep and goats. Additionally, 136 bone fragments were identified as belonging to the gazelle. Two fragments from red deer and three fragments from wild boar were also recovered. Also, 20 bone fragments belonged to equids, and three bones to canids (Khazaeli *et al.* 2017).

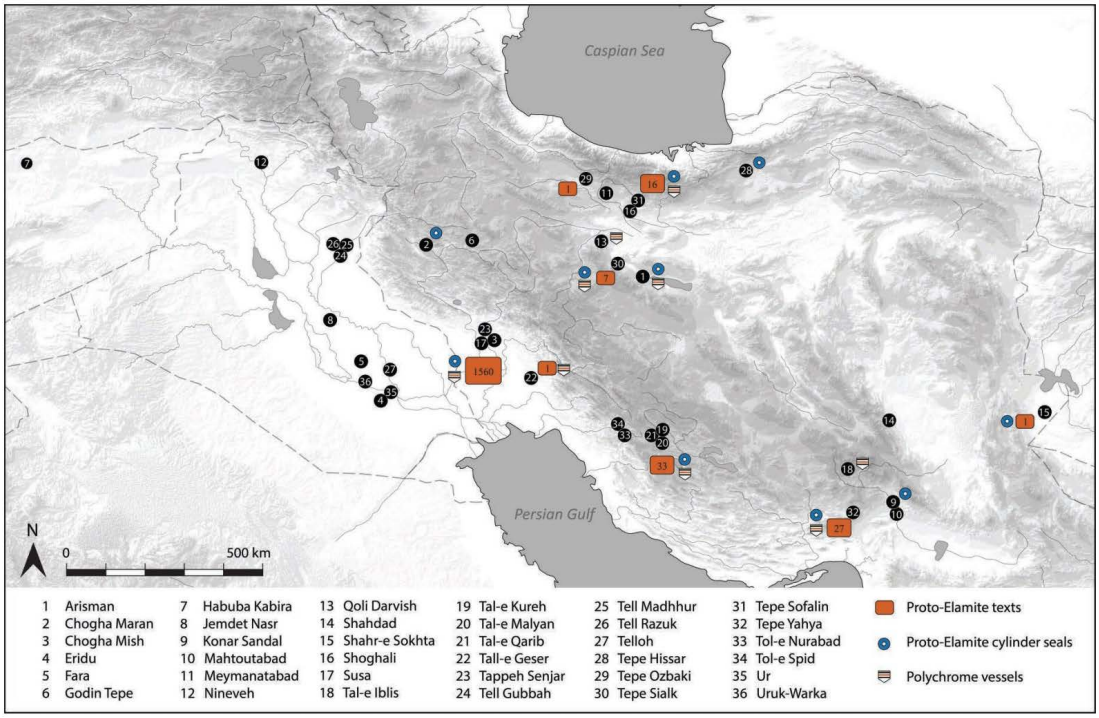

Figure. 6 : *Archaeological sites of Proto-Elamite Iran and contemporary Mesopotamia (After: Matthews and Fazeli Nashli 2022: 190).*

Table. 3: *Summary of faunal remains recovered from seasons I and III of excavations at Qoli Darvish.*

Season	Trench	No. of Fragments	Weight (g)
I	AW	1,483	11,345.6
I	AX	803	11,345.6
III	AE	65	1,238.8
III	AF	94	1,199.5
III	AV	274	2,451.3
III	BA	595	3,777.6
III	GA	20	201.5
III	I	55	1,020.7
III	II	386	3,472.2
III	III	79	1,437.14
III	Z	289	2,274.0
Total	**11**	**4143**	**39764**

The majority of the identified faunal assemblage from Qoli Darvish consists of domestic taxa, particularly sheep, goat and cattle which together comprise over 90% of the total NISP. Sheep / goat remains dominate the assemblage with 79%, followed closely by cattle at 11%. Other taxa such as boar, dog, equids, deer, rodent, bird, fish, and tortoise appear in much smaller proportions. The temporal distribution indicates that most of the remains date to the Early Bronze Age, with notable but lesser representation from the Elamite and Middle Bronze Age, Middle and Late Bronze Age, and Iron Age phases. The presence of a few wild species and small animals suggests some degree of ecological diversity in the area (Table. 5; Figure. 8).

Table. 4: *Classification and frequency of animal species identified at the archaeological site of Qoli Darvish (After: Khazaeli et al. 2017 and modified by the Authors)*

Class	Order	Family/Subfamily	Species	Persian Name	Number of Specimens
Mammalia	Artiodactyla	Bovidae	*Bos taurus*	Cattle (domestic)	194
Mammalia	Artiodactyla	Bovidae – Capri-nae	*Ovis aries*	Sheep (domestic)	135
Mammalia	Artiodactyla	Bovidae – Capri-nae	*Capra hircus*	Goat (domestic)	230
Mammalia	Artiodactyla	Bovidae – Capri-nae	-	Sheep / goat	1012
Mammalia	Artiodactyla	Bovidae	*Gazella subgut-turosa*	Goitered gazelle	136
Mammalia	Artiodactyla	Cervidae	*Cervus elaphus*	Red deer (Maral)	2
Mammalia	Artiodactyla	Suidae	*Sus scrofa*	Wild boar	3
Mammalia	Perissodactyla	Equidae	*Equus sp.*	Equids	20
Mammalia	Carnivora	Canidae	*Canis familiaris*	Dog (domestic)	3
Reptilia	Testudines	Testudinidae	*Testudo sp.*	Tortoise	1

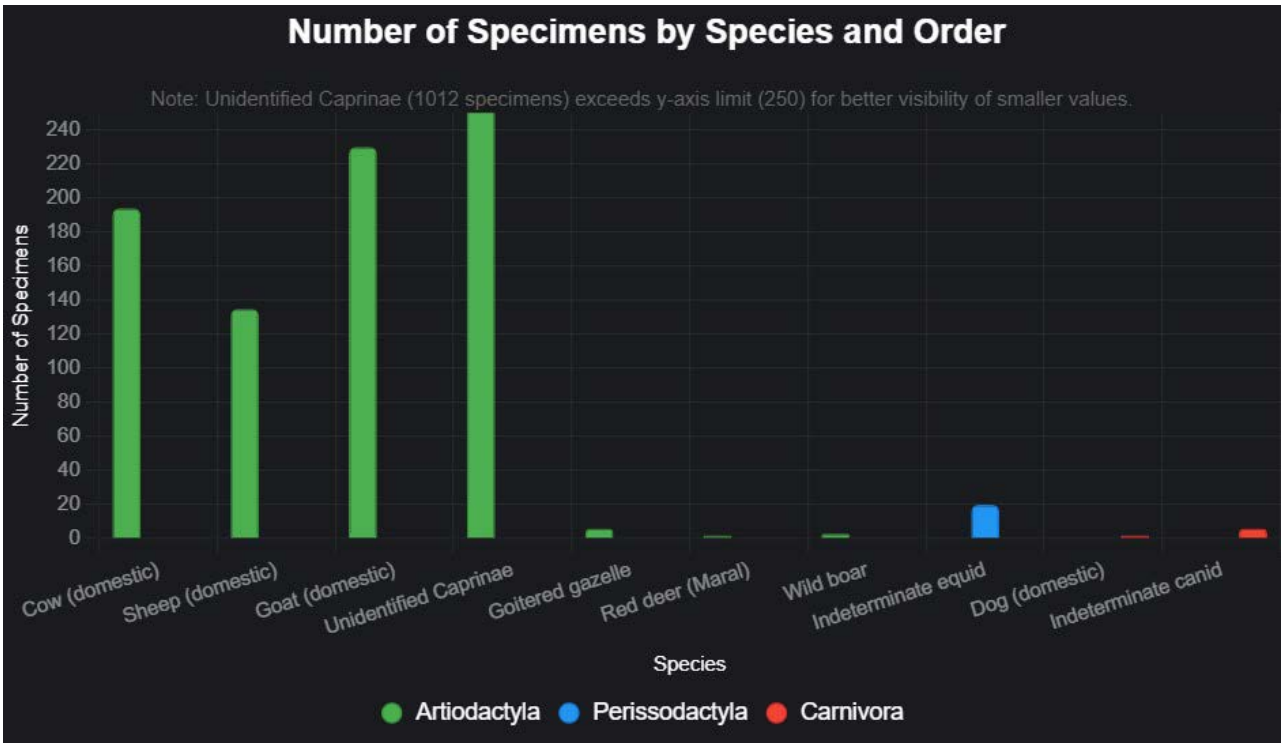

Figure. 7: *Distribution of specimen counts by species and taxonomic Order.*

Period V Assemblage

In a separate study of the bone assemblage from Period V (the Bronze Age to Iron Age transition), 1303 faunal fragments are currently being investigated by Sahar Samghani, a PhD candidate in Archaeology at the University of Sistan and Baluchestan. This research is being conducted within the framework of her doctoral dissertation under the supervision of Fariba Mosapour Negari as the first supervisor and Mehdi Mortazavi as the second supervisor, with Siamak Sarlak serving as the first advisor and Fatemeh Naseri as the second advisor. The study aims to identify faunal species, investigate their genetic and environmental relationships, and reconstruct the palaeoenvironmental and palaeoclimatic conditions of the region during the Late Bronze Age–Early Iron Age transition. The results of this ongoing research are beyond the scope of the present paper and are therefore not discussed here.

Table. 5: *The frequency of identified and unidentified faunal remains by chronological phases at Qoli Darvish. Abbreviations used:**EBA**: Early Bronze Age. **E** and **MBA**: Elamite and Middle Bronze Age.**M** and **LBA**: Middle and Late Bronze Age.**LBA**: Late Bronze Age.**IA**: Iron Age (unspecified). **IA I / IA II**: Iron Age I and II. No Info: Unassigned to a specific phase*

NISP	EBA	E and MBA	M and LBA	LBA	LBA 3 / Early IA I	IA	IA II	No Info	Total
Sheep/Goat	61.5	48.4	50.0	28.1	37.9	62.8	28.6	64.0	58.3
Sheep	7.1	3.2	0.0	9.4	5.3	11.7	14.3	2.7	7.8
Goat	13.7	12.9	0.0	12.5	24.2	8.4	42.9	13.3	13.2
Cattle	7.3	9.7	50.0	39.6	20.0	13.2	0.0	10.7	11.2
Boar	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Red deer	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1
Equids	0.3	0.0	0.0	10.4	3.2	0.9	0.0	1.3	1.2
Gazelle	9.5	25.8	0.0	0.0	9.5	2.4	14.3	8.0	7.8
Dog	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Tortoise	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1
Total NISP	100	100	100	100	100	100	100	100	100
% Identifed to Unin-dentified	**29.4**	**31.3**	**44.4**	**40.2**	**22.3**	**32.5**	**50.0**	**19.2**	**41.4**

Figure. 8: *Selected animal bones. (**A**): Horn core of domestic goat; (**B**): Lower premolar teeth of an equid; (**C**): Lower first and second molar teeth of an old equid; (**D**): Maxilla of dog, Qoli Darvish (After: Sarlak in press).*

Evolution of Subsistence Along Different Periods in Qoli Darvish

The distribution of species across the archaeological record from the Early Bronze Age (EBA) to the end of the Iron Age (IA II) provides valuable insights into continuity, changes, or declines in faunal presence, particularly at the transition from the Late Bronze Age (LBA) to the Early Iron Age (LBA 3/ Early IA). Analyzing the data from Table 6, which consolidates weight measurements and percentages of identified and unidentified bone samples, reveals distinct patterns.

From the EBA (20.5%) through the Elamite and Middle Bronze Age (E and MBA, 5.4%) and Middle and Late Bronze Age (M and LBA, 8.9%), there is a noticeable fluctuation in faunal remains, with the LBA showing the highest concentration (21.0%), at this period. The animal remains are less represented during the transition period from LBA 3 to Early IA. The Iron Age (IA, 0.3%) and Iron Age II (IA II, 2.5%) show a gradual increase, though the percentages remain low compared to the Bronze Age peaks.

The transition from the LBA to LBA 3/Early IA is particularly significant. This decrease of bone remain deposits, could be caused by the cultural shifts or the function of site in this transitional period... Continuity is evident in the presence of species across all periods, but the data implies that some may have diminished, while others possibly emerged or persisted in smaller numbers. In conclusion, the faunal record shows a complex evolution, with a notable decline at the end of the Bronze Age and a tentative resurgence in the Iron Age, suggesting both continuity and significant turnover in species composition. However, this hypothesis can be highly impacted by taphonomic conditions and the scale of excavations between different periods at the site.

Various anthropogenic modifications observed on faunal remains from the Qoli Darvish site during the Bronze and Iron Ages (Table. 7; Figure. 9).

In both periods, domestic sheep and goat are the dominant taxa, accounting for the majority of modifications and traces. However, the extent of cut-marks on sheep and goats bones is markedly higher in the Bronze Age (Figure. 9).

These patterns, as visualized in figure 10, support the hypothesis that subsistence-related activities were more prevalent or more archaeologically visible in the Bronze Age phase of occupation at the site.

The bone assemblage of Period V shows evidence of fractures, cuts, and burns (Figure. 11), suggesting human activities such as butchery and marrow extraction.

Herding Activities in Qoli Darvish

One of the key methodologies in zooarchaeological studies of seasonal mobility and animal management is the determination of slaughter age through dental wear analysis a technique long established as a reliable means of age estimation. The age at which animals were culled is influenced by multiple factors, including the relative economic value of various animal products (meat, milk, wool) (Payne 1973) (Table. 8). In meat-oriented systems, young males were often slaughtered upon reaching optimal weight, while only a limited number were retained for breeding. The average male-to-female breeding ratio for sheep and goats was approximately 1:40–50, and castration was commonly practiced shortly before slaughter to increase weight gain.

In this study, all complete mandibles and isolated teeth from Period II were recorded in detail. Key data included species identification, laterality (right or left), and specific tooth type. Lower jaw teeth analyzed comprised premolars (P2, P3, P4), molars (M1, M2, M3), and deciduous teeth (dp3, dp4). Age estimation was conducted using the dental wear stages proposed by Payne (1973), assigning each specimen to one of nine wear classes (A–I). Additionally, the tooth measurement method developed by Helmer and Vigne (2004) was employed, which aligns with Payne's classification system and serves as a complementary approach. Together, these techniques enhanced the reliability of the age profiles generated.

A total of 212 caprine teeth from Period II were analysed, 24 attributed to domestic sheep and 23 to domestic goats (Figure. 12). The age distribution revealed a absence of specimens under six months of age, which may reflect several factors:

(1) the poor preservation of smaller and more fragile dental remains,
(2) recovery bias during excavation, or
(3) socio-economic factors influencing herd management.

During the Early Bronze Age, the development of larger settlements, population growth, and increasing social complexity likely led to a shift in animal

Table. 6: *Combined weight and percentage distribution of animal bone remains.*

Category	EBA	E and MBA	M and LBA	LBA	LBA 3/ Early IA	IA	IA II	No Information	Total Weight NISP	Total (Unidentified Bones)	Grand Total
Weight NISP (g)	6782	1778	2934.5	6942.3	75.7	100.1	818.6	1833.2	21566.3	-	33137.4
Percentage (%)	20.5%	5.4%	8.9%	21.0%	0.2%	0.3%	2.5%	5.5%	65.1%	-	100.0%
Weight NISP (Unidentified Bones) (g)	31.9	8.2	13.6	32.2	0.4	0.5	3.8	4.6	100.0	33137.4	65.1
Percentage (%)	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.3%	100.0%	-

Table. 7: *Distribution of bone modifications during the Bronze and Iron Ages.*

Bronze Age							
Species	**Cuts**	**Fractures**	**Burns**	**Polishing**	**Tool Marks**	**Other Modifications**	**Total**
Sheep/Goats	21.5	7.9	8.8	8.8	13.6	39.5	100.0
Cattle	100.0	0.0	0.0	0.0	0.0	0.0	100.0
Total modification on each category	22.2	7.8	8.7	8.7	13.5	39.1	100.0
Iron Age							
Species	**Cuts**	**Fractures**	**Burns**	**Polishing**	**Tool Marks**	**Other Modifications**	**Total**
Sheep/Goats	Cuts	10.6	13.3	8.8	17.7	35.4	100.0
Cattle	100.0	0.0	0.0	0.0	0.0	0.0	100.0
Total modification on each category	15.7	10.4	13.0	8.7	17.4	34.8	100.0

Figure. 9: *Selected animal bones. (**A**) Cut marks on the talus bone of goat; (**B**) burnt metacarpal bone of cattle; (**C**) Carapace fragments of a tortoise, Qoli Darvish (After: Sarlak, in press)*

husbandry away from domestic contexts. Herding may have occurred outside residential zones, with the assemblage reflecting disposal areas primarily associated with meat processing rather than on-site animal rearing.

Archaeobotanical Evidence from Qoli Darvish and its Implications for Understanding the Ecological and Subsistence Patterns of the Qom Plain

Although this article primarily focuses on faunal data, the results of archaeobotanical investigations significantly contribute to ecological analysis, climate reconstruction, and the understanding of the subsistence systems of communities inhabiting Qoli Darvish during the third and second millennia BCE. In one of the architectural units dated to Period VI, identified as a kitchen or food-processing area based on features such as a clay oven (sāj), a small grain storage pit (tāpu), various grinding implements (handstones and pestles), and ceramic storage jars, a considerable quantity of carbonised cereal grains was uncovered. These grains were retrieved from within a mudbrick tāpu lined with gypsum on the floor and walls (Sarlak 2005).

The archaeobotanical analysis was conducted at the laboratory of the Shahr-i- Sokhta World Heritage Site using an NSZ810 stereomicroscope at 80× magnification. A total of 342 charred grains, both whole and fragmented, were examined, with three primary species identified:
1.Emmer wheat (*Triticum dicoccum*),
2.Hulled barley (*Hordeum vulgare*),
3.Naked barley (*Hordeum vulgare var. nudum*) (Table 9; Figures 13, 14 and 15) (Sarlak, in press).

Several grains, due to fragmentation or damage, could not be identified to species level and were categorised as "unidentified cereals" (*Cerealia*). These identifications indicate that the inhabitants of Qoli Darvish cultivated and consumed domesticated cereal species rooted in the Neolithic agricultural traditions of the Fertile Crescent. Archaeological evidence suggests that these species particularly emmer wheat and domesticated barley were initially domesticated in the late Neolithic in the Zagros and southeastern Anatolia and later spread to the Iranian Plateau (Harris *et al.* 2010: 226; Brookes *et al*. 1982: 281; Blumer and Byrne 1991: 23).

Wild barley specimens have also been documented from Mesolithic contexts, such as in the Kamishan Cave of Behshahr (11,771–10,682 BCE) (Vahdati Nasab and Nikzad 2016: 14). Furthermore, early Neolithic settlements such as Sheikh-e Abad and Chogha Golan in the central Zagros yielded evidence of both wild and domesticated cereal cultivation, representing the transitional process from

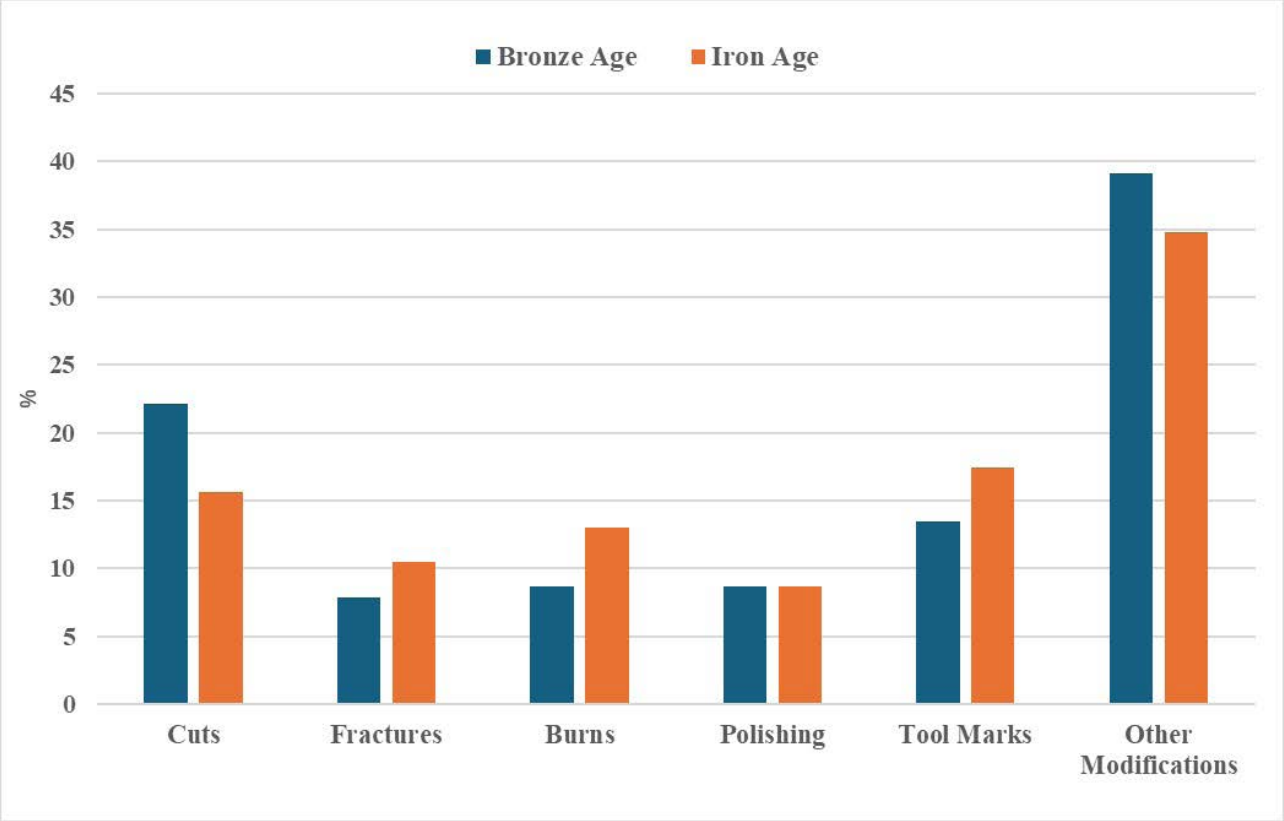

Figure. 10: *Comparison of bone modifications and traces between Bronze and Iron Ages.*

Figure. 11: Left*: Burning marks on the various animal bone remains;* ***Right****: Cut marks on bone remains, cervical vertebra of sheep/goat, Qoli Darvish, Period V (After: Sarlak, in press).*

Table. 8: *Age classification of sheep and goats based on tooth eruption and wear (After: Payne 1973)*

Age Class	Approx.Age(months)	Description
A	0-2	Eruption of deciduous teeth(dp3,dp4)
B	2-6	Fully erupted deciduous teth
C	6-12	Beginning og permanent tooth replacement
D	12-18	Eruption of M1 and partial M2
E	18-24	Naticeable wear on M1; full M2 eruption
F	24-30	Advanced wear on M2; P4 eruption begins
G	30-36	Further wear on M2; M3 eruption starts
H	36-48	Full M3 eruption; heavy wear on M1
I	48+	Severe wear on all molars

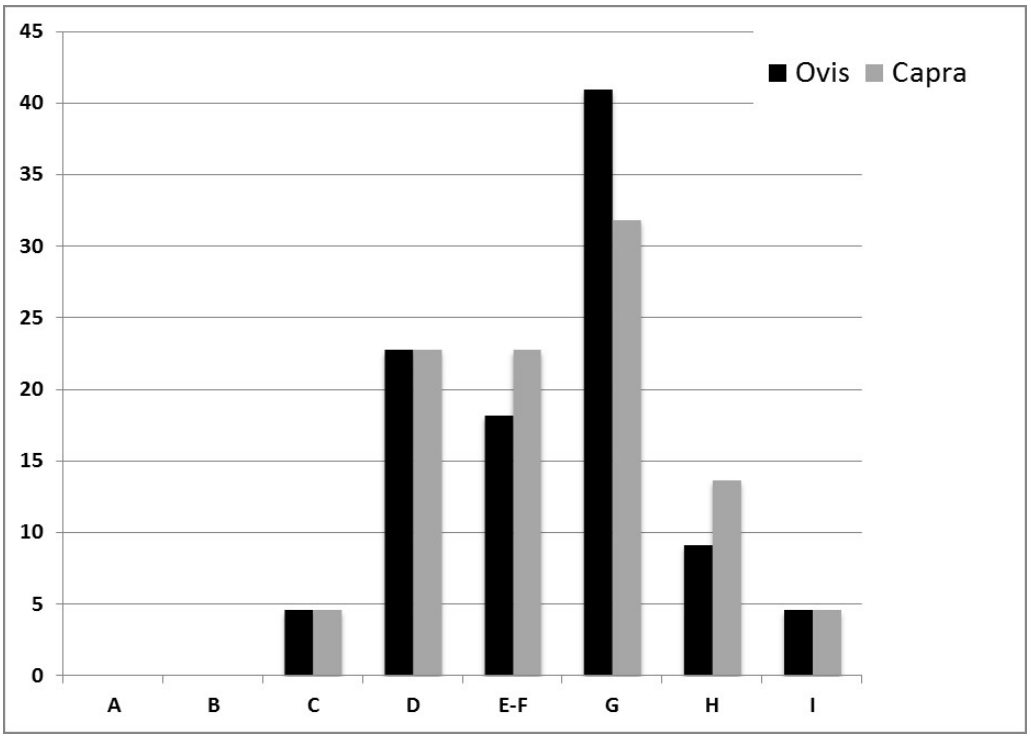

Figure. 12: *Age-at-death distribution of domestic sheep and goats from Period II based on mandibular tooth wear.*

foraging to managed agriculture (Matthews et al. 2009: 82; Whitlan *et al*. 2013: 179; Shillito and Elliott 2009: 186; Riehl *et al*. 2013: 65). The cereal taxa identified at Qoli Darvish likely originated from the Zagros region and gradually reached the Central Plateau through the transmission of agricultural knowledge or seed exchange. This suggests that the Qom Plain was not itself a centre of initial domestication (Harris *et al.* 2010: 226).

Comparative evidence from climatically similar regions such as the Kashan Plain, specifically from Sialk, also indicates that emmer wheat, hulled, and naked barley were staple cereals during the third and second millennia BCE (Tengberg and Malek Shahmirzadi 2004: 111). This suggests a shared agricultural tradition between Qom and Kashan, offering insight into drought-resistant crops, environmental adaptation, and regional subsistence strategies. In sum, the archaeobotanical data from Qoli Darvish not only confirm the presence of a cereal-based agricultural system but also reflect a semi-arid environment with limited yet sustainable potential for traditional farming. These environmental conditions align well with the patterns observed in the site's faunal assemblage.

Discussion

The zooarchaeological and complementary archaeobotanical data from the Qoli Darvish site offer a multifaceted perspective on the interplay between climate and subsistence strategies in the Qom Plain during the third and second millennia BCE. This section integrates the faunal and botanical evidence to reconstruct the environmental conditions, human-animal-plant interactions, and the adaptive resilience of the communities inhabiting this semi-arid region.

Animal and plant remains from Periods II to VI, suggest different conditions from the present arid to semi-desert environment of the Qom Plain. The presence of wild species such as red deer, boar in the Bronze Age, indicates a more humid environment with diverse habitats, including woodlands and grasslands, likely supported by proximity to the Qomrud River and groundwater resources (Sarlak 2010: 15). While during the Iron Age, the climatic deterioration is reflected in the archaeobotanical evidence, where drought-resistant cereals like emmer wheat and hulled/naked barley dominated, suggesting adaptation to a semi-arid landscape with limited water availability.

The presence of hydrophilic plant taxa (e.g., Scirpus, Carex) in certain contexts points to localized wetland environments, potentially near the site's architectural units, such as the Period VI kitchen area with its grain storage pit (tāpu) (Sarlak 2005). This indicates seasonal water availability that supported both agriculture and pastoralism, a pattern

Table 9: *Archaeobotanical Remains from Qoli Darvish Site (After: Sarlak, in press).*

Row	Plant Species	Scientific Name	Conservation Status	Quantity
1	Unidentified Cereals	Cerealia	Fragmented	90
2	Emmer Wheat	Triticum dicoccum	Intact	21
3	Hulled Barley	Hordeum vulgare	Intact	48
4	Naked Barley	Hordeum vulgare var. nudum	Intact	75
Total				**342**

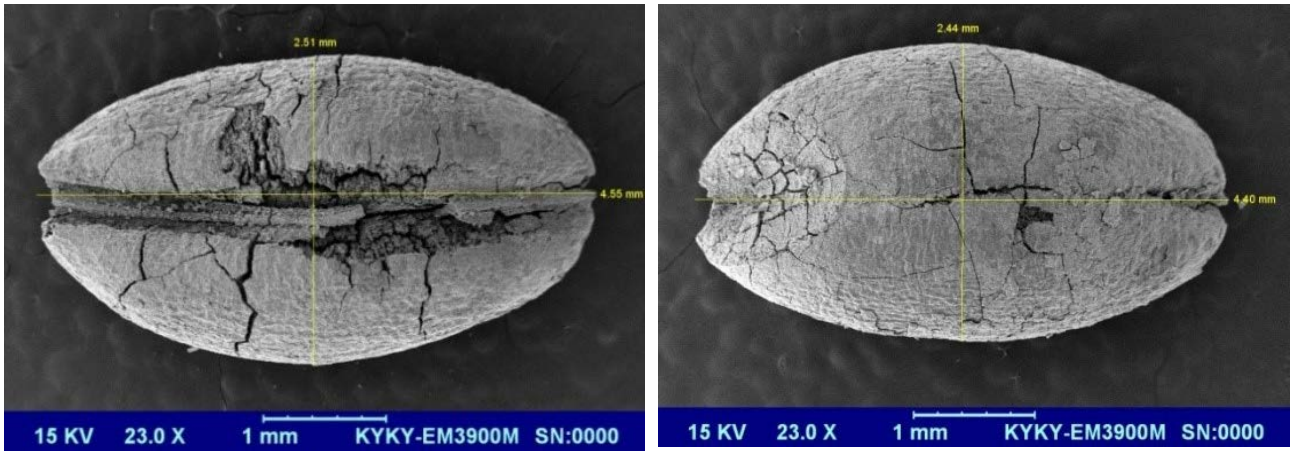

Figure. 13: *Emmer wheat grain (Triticum dicoccum) from Qoli Darvish (ventral and dorsal views), site QD, Trench Z.19 (After: Sarlak, in press)*

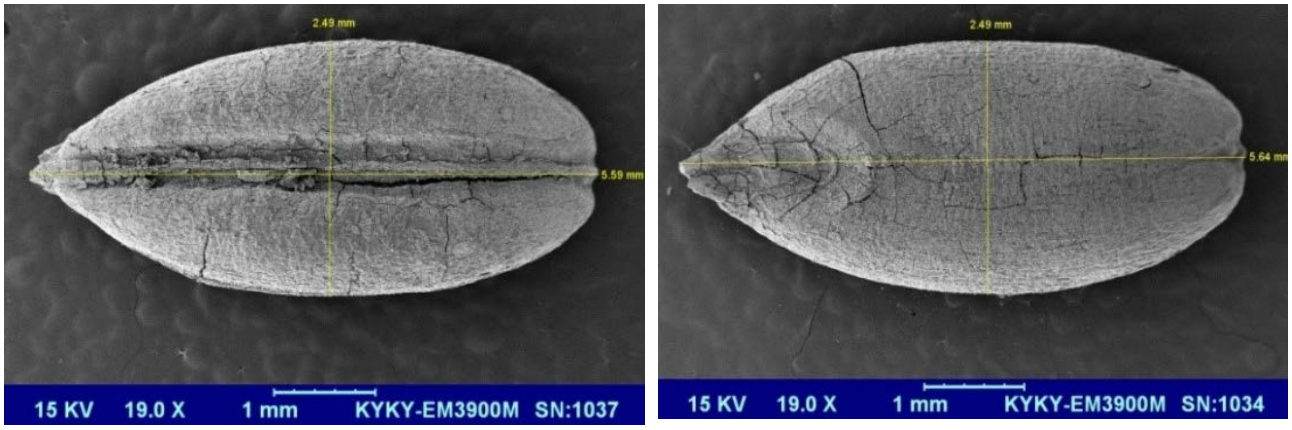

Figure. 14: *Hulled barley grain (Hordeum vulgare) from Qoli Darvish (ventral and dorsal views), site QD, Trench Z.19 (After: Sarlak, in press)*

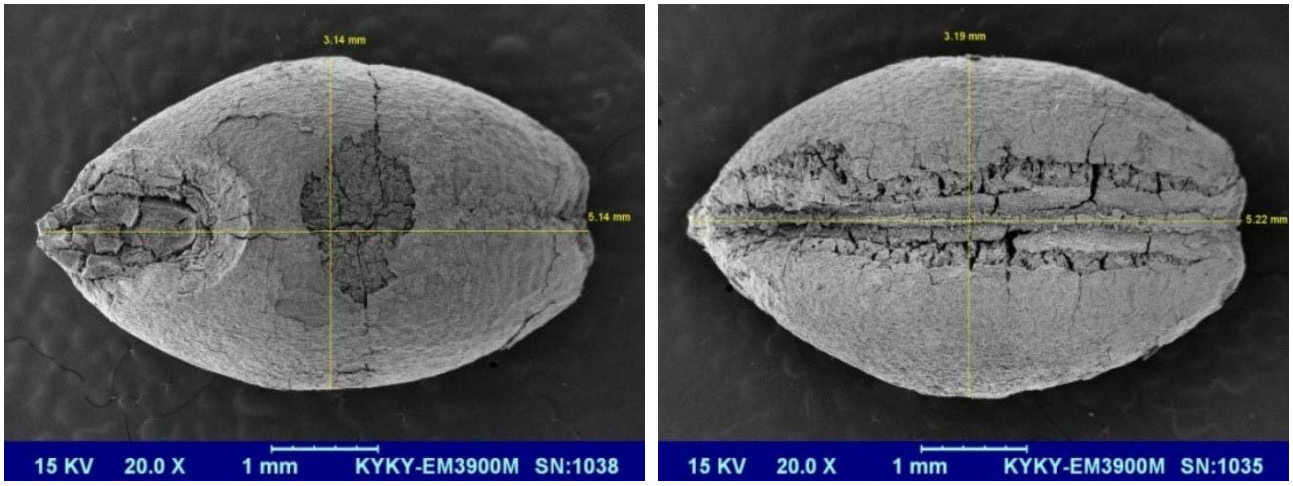

Figure. 15: *Naked barley grain (Hordeum vulgare var. nudum) from Qoli Darvish (ventral and dorsal views), site QD, Trench Z.19 (After: Sarlak, in press)*

consistent with the faunal evidence of cattle rearing, which requires more moisture than caprines. The absence of arboreal remains suggests either limited exploitation of local woody species or reliance on regional exchange networks, a hypothesis that warrants further palynological investigation.

The subsistence economy at Qoli Darvish was characterized by a mixed agro-pastoral economy, with the abundance of domestic taxa, sheep / goat and cattle and cereal cultivation, reflects this integrated economy.

The demographic profile, show the prevalence of animals of 18 to30 months age and a focus on meat production during optimal grazing seasons (summer-autumn), along with milk and wool productions. The higher frequency of anthropogenic modifications and traces in the Bronze Age, including cut marks, burns, and bone modifications for tools indicates butchery and bone processing, possibly linked to a more important population and resource availability during this period.

The importance of cattle in the subsistence after sheep and goat, and pathologies related to agricultural use, could be an indication of a landscape with sufficient water and pasture, contrasting with nowadays arid conditions (Mashkour 2003, Sarlak 2011). The presence of equids and dogs suggest additional roles in transport and guarding, while wild species like deer and boar reflect hunting, possibly from woodland edges.

The integration of faunal and botanical data reveals a resilient economy adapted to climatic variability. The cultivation of cereals on low-organic soils, supplemented by pulses, indicates a diversified diet and fallow-based agriculture, enhancing resilience against drought. The Period V transition faunal remains, suggests ecological changes.

Socio-culturally, Qoli Darvish's alignment with Proto-Elamite sites (e.g., Sialk, Susa) and its participation in exchange networks (Matthews and Fazeli Nashli 2022) imply that subsistence economy strategies were influenced by regional interactions. The decline in wild species and modifications and traces from the Bronze to Iron Age may reflect population growth, sedentism, and a shift from domestic to specialized pastoralism, as suggested by the Period II focus and limited Iron Age data (Sarlak 2011: 285-300).

The zooarchaeological and archaeobotanical evidence from Qoli Darvish paints a picture of a once-humid Qom Plain supporting a diverse environmental resource, which adapted to increasing aridity through mixed farming and selective animal exploitation. The transition from the Bronze to Iron Age marks a pivotal shift, with reduced biodiversity and intensified human modification reflecting environmental and sociocultural changes. This analysis underscores the value of integrated archaeozoological and archaeobotanical studies in understanding past human resilience and informing sustainable practices in modern semi-arid regions.

Conclusion

This study presents a comprehensive reconstruction of the environmental conditions and subsistence strategies of prehistoric communities in the Qom Plain, based on integrated bioarchaeological evidence from the Qoli Darvish site. The data spanning the third and second millennia BCE reveal a resilient and adaptive socio-ecological system, in which animal husbandry particularly the management of sheep, goats, and cattle formed the cornerstone of local economies. The morphological continuity observed in caprine remains, along with age-at-death profiles focused on meat production, points to a stable and deliberate process of domestication and herd management across the Bronze and Iron Ages. Climatic shifts, especially the transition from a relatively humid Bronze Age to a more arid Early Iron Age, are reflected in the changing composition of faunal and floral remains. The emergence of drought-tolerant species, the disappearance of certain wild taxa, and the marked decline in faunal biomass collectively indicate increasing environmental stress and a corresponding shift in resource exploitation strategies. These changes underscore the capacity of ancient communities to adapt their subsistence practices in response to ecological pressures.

The archaeobotanical record further substantiates the presence of a mixed agro-pastoral economy, characterised by cereal cultivation on nutrient-poor soils, limited pulse production, and exploitation of seasonal wetlands for irrigation and grazing. The scarcity of arboreal remains suggests restricted access to woodland resources, potentially offset by

regional exchange networks. Such economic diversification and landscape use strategies likely enhanced the resilience of local communities in the face of climatic variability.

Culturally, the integration of Qoli Darvish into the broader Proto-Elamite interaction sphere indicates participation in long-distance exchange systems, which may have facilitated the circulation of goods, ideas, and subsistence technologies. The reduction in faunal diversity and intensity of bone modifications over time may reflect demographic growth, increased sedentism, and a gradual shift toward more specialized pastoralism, especially during the underrepresented Iron Age phases.

Taken together, the evidence portrays the Qom Plain during the third and second millennia BCE as a dynamic and productive landscape, in stark contrast to its current arid state. The study highlights the critical value of bioarchaeological approaches in reconstructing past human-environment interactions and in illuminating long-term strategies of adaptation and resilience. Future interdisciplinary research particularly palynological analysis and expanded Iron Age investigations will be essential to further refine our understanding of these processes and their implications for sustainable resource management in present-day semi-arid regions.

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