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Paleoenvironments in Late Pleistocene Sicily

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Abstract

This thesis explores eleven archaeological sites on the island of Sicily to further understand the paleoenvironment of the island at the time of early human occupation. Utilizing faunal records, we have analyzed the indicator taxa at each site, conducted a habitat weighting analysis, and performed several multivariate tests to determine what the paleoenvironment of Late Pleistocene Sicily may have looked like. Based on the taxa that existed on the island during the Late Pleistocene, we have determined that Sicily likely had a temperate environment and contained habitats that are no longer abundant in the present day.

Introduction

Sicily is the largest island in the Mediterranean Sea. It sits off the southwestern coast of Italy, approximately two miles (3.2 kilometers) off the coast of Calabria. Today, Sicily's climate is consistent with the Csa Köppen climate, a Mediterranean climate that consists of hot dry summers and moderate winters, with some areas that are semi-arid (Figure B) (Climate Data). Present evidence suggests that Sicily first became occupied by modern humans around 16,000 years ago. At this time, the island of Sicily was connected to mainland Italy by a land bridge. It is theorized that the shallow areas of the Strait of Messina were once a dry connection between Sicily and what is now Calabria for a maximum of 8,000 years. This land bridge likely formed around 25,000 years ago cal BP until roughly 17,000 years ago cal BP (Antonioli et. al. 2016). The presence of this land bridge is consistent with the earliest possible presence of humans on the island, suggesting that, despite humans having the ability to explore and colonize previously unoccupied lands by boat in other parts of the world, this did not occur in the Mediterranean at this time (Antonioli et. al. 2016; Patania and Tryon 2023). The presence of a land bridge confirms that the present-day coastline was several kilometers inland during the early occupation of the island.

Figure A: location of Sicily (yellow) in relation to the rest of Italy (Badami 2021).

Figure B: Köppen climate of Italy, with Sicily circled in red (D'Amico et. al. 2019)

This thesis contributes to Ilaria Patania and Dr. Christian Tryon's larger project of exploring the timing of the initial occupation of Sicily, as well as the early environmental setting of the island. This information will contribute to a larger discussion of island occupation and seafaring patterns in the Mediterranean and, ultimately, the overall dispersal of modern humans out of Africa (Patania and Tryon 2022). In addition to this, a greater understanding of the when, how, and why modern humans dispersed out of Africa and colonized the

Mediterranean, as well as how humans interact with their environment on a large island, like Sicily will be achieved (Patania and Tryon 2022). This thesis specifically will explore information related to the possible paleoenvironments of Sicily during the Late Pleistocene, an epoch that spans from roughly 130,000 years ago until roughly 12,000 years ago. Throughout this paper, the Upper Paleolithic is often referenced in congruence with the Late Pleistocene epoch; this period encompasses the end of the Late Pleistocene epoch, spanning from roughly 45,000 years ago until roughly 12,000 years ago. Utilizing habitat data obtained by analyzing species present at eleven Paleolithic cave sites on the island, we have sought to illustrate what the environment of Sicily may have looked like at this time. Understanding Sicily's environment at the time of its initial colonization will help us better understand how early populations on the island lived and how that environment differs from the one that exists today. With the information gathered from Sicily's archaeological record, questions about how human populations spread across the world and how they adapt to unique, endemic environments, such as islands, will be answered. This information is essential to gaining a greater understanding of modern humans.

This thesis specifically examines faunal records on the island of Sicily. This is because faunal records are generally useful in reconstructing an area's paleoenvironment; in addition to this, faunal records are the only abundant option available for reconstructing Sicily's paleoenvironment. Other options for reconstructing an area's paleoenvironment are not available for Sicily at this time. Paleoenvironmental conditions are determined by assuming that the fauna that is being examined had the same ecological tolerances in the past that it does today. This concept is known as "uniformitarianism" (Faith and Lyman 2019). We are currently familiar with the ecological preferences for extant species, so it is generally possible for us to predict the preferences of these species with near certainty (Faith and Lyman 2019). Because a species can evolve over time to have different ecological tolerances, researchers will consider the ecological preferences of other faunal remains present to determine if there has been a change in a species' preference over time. If multiple species present appear to have the same ecological preferences in the present, it is assumed that they had the same preferences in the past (Faith and Lyman 2019). Utilizing what we know today, we are able to reconstruct the environmental conditions of the past using information gathered from faunal records from any given area.

In terms of extinct species, it is assumed that a species has a similar ecological tolerance to their closest living relative; we will revisit this when we examine *Equus hydruntinus*, an extinct equid whose ecological preferences we reconstructed using the preferences of living equids today (Faith and Lyman 2019).

While there are other methods of reconstructing an area's paleoenvironment, faunal records are the most abundant archaeological record available at the sites we have examined; other reliable records, such as pollen records, are infrequent or non-existent. Our best option for reconstructing Sicily's paleoenvironment, in terms of accuracy and availability, is to examine faunal records from our given sites.

Sites and Species Within the Analytical Sample

Sites

Below are the eleven sites that were examined during our research. They are all roughly the same in age and have been organized into three different subsections: the island sites, the northern sites, and the southern sites. The island sites, located on the Aegadian Islands off the western coast of Sicily, are Levanzo/Genovesi, Grotta delle Uccerie, and Grotta d'Oriente. The northern sites, located on the northern portion of the island, are Grotta dell'Uzzo, Castello, and San Teodoro. Lastly, the southern sites, located in the southeastern part of Sicily, are Pedagaggi, Giovanna, San Corrado, Fontana Nuova, and Corruggi. For Levanzo/Genovesi, San Teodoro, Grotta delle Uccerie, and Grotta d'Oriente, we examined specific layers rather than the entirety of the site. This is due to those specific layers being the most relevant to our research, with other, younger levels being beyond the scope of our investigation of the early occupation of Sicily. If a site description states that we will not be examining specific layers, it is because the entirety of the available information for the site is relevant to our research; that is, the site consists solely of early deposits relevant to the initial colonization of the island.

This section outlines the specific taxa found at each site and the number of identified specimens (NISP) of each taxon. In addition to this, we outline the total NISP and the total number of taxa found at each site.

Figure C: map of sites, created using Google Earth.

Island Sites

Levanzo/Genovesi

First excavated by Paolo Graziosi in 1953, the site of Levanzo/Genovesi is located approximately 30m above sea level on the island of Levanzo, a small island that is a part of the Aegadian Islands off the west coast of Sicily (Vigliardi 1982). It lies on the western coast of the island. At the time of its occupation, these islands were likely connected to mainland Sicily (assumption based on glaciation at the time). The entrance of the cave overlooks the Mediterranean. This site dates to roughly 12–13,000 years ago and is a Palaeolithic/Neolithic site (Martini et. al. 2007). Vigliardi uses the term "la nicchia," which translates to "niche," to describe the opening to the cave. The niche is about 2.8m wide and 3.3m long (Vigliardi 1982). The site is known for its cave art and Palaeolithic engravings and paintings (Vigliardi 1982).

The precise dimensions of this site have not been reported. For our research, we did not examine specific layers for this site. This site has a variety of different names, but it is generally referred to as Levanzo or Genovesi. For this paper, this site will be referred to as Levanzo/Genovesi to acknowledge the multiple names it has.

Species Name	Common Name	Number of Identified Specimens (NISP)
Sus scrofa ferus	wild boar	4
Cervus elaphus	red deer	129
Bos primigenius	auroch	32
Equus hydruntinus	wild ass	17
Crocuta spelaea	cave hyena	
Vulpes vulpes	red fox	6
Arvicola italicus	Italian water vole	2
Caretta caretta	Loggerhead sea turtle	
Emys orbicularius	European pond turtle	1
Homo sapiens	human	1
Puffinus diomedea	Scopoli's shearwater	1
Falco peregrinus	peregrine falcon	1
Alectoris graeca	rock partridge	2
Otis tarda	great bustard	1
Columba oenas	stock dove	1
Coracias garrulus	European roller	1
Aves		7
Micromammiferi indeterminabili		6
	Total NISP:	212
	Total Number of Taxa:	16

Figure D: faunal chart for Levanzo/Genovesi (Strato 3 – tagli 5 and 6) (Vigliardi 1982)

Grotta delle Uccerie

Grotta delle Uccerie sits at an elevation of 78m above sea level on Isola di Favignana, another island that is a part of the Aegadian Islands off the west coast of Sicily. It is located on the northern coast of the island, northeast of Balate (Martini et. al. 2007). For our research, we will be examining Strata 4D of this site, a layer that dates to 16,201–15,418 cal BP (Di Maida 2020). The Epigravettian cave is divided into two horizons (an upper and a lower horizon). Both areas of the cave have the same types of lithic artifacts (Martini et. al. 2007).

For our research, we will be examining Strata 4D of this site. Specific excavators for this site have not been reported. Specific dimensions for this site have not been reported.

Species Name	Common Name	Number of Identified Specimens (NISP)
Sus scrofa	wild boar	41
Cervus elaphus	red deer	6
Bos primigenius	auroch	28
Equus hydruntinus	wild ass	57
Vulpes vulpes	red fox	3
Lepus sp.	unidentified Lepus	1
	Total NISP:	136
	Total Number of Taxa:	6

Figure E: faunal chart for Grotta delle Uccerie (Strata 4D) (Martini et. al. 2007)

Grotta d'Oriente

Grotta d'Oriente was first discovered by Giovanni Mannino in 1969 (D'Amore et. al. 2010). The site sits at an elevation of approximately 50m above sea level on Isola di Favignana. It is located west of Favignana, roughly a kilometer from the coast D'Amore et. al. 2010). Grotta d'Oriente is a Palaeo-Mesolithic site, although precise dates have not been reported (D'Amore et. al. 2010). At the time of the publishing of D'Amore et. al., three graves had been excavated at the site, (2010). The cave was likely a seasonal occupation site for hunter-gatherers during the Last Upper Paleolithic (D'Amore et. al. 2010).

For our research, we will be examining Strato 7 of this site. Specific excavators for this site have not been reported. Specific dimensions for this site have not been reported.

Species Name	Common Name	Number of Identified Specimens (NISP)
Sus scrofa	wild boar	2
Cervus elaphus	red deer	104
Bos primigenius	auroch	9
Equus hydruntinus	wild ass	14
Vulpes vulpes	red fox	11
Emys orbicularius	European pond turtle	9
Artiodactyla		5
Erinaceus europaeus	European hedgehod	11
	Total NISP:	165
	Total Number of Taxa:	8

Figure F: faunal chart for Grotta d'Oriente (Strato 7) (Martini et. al. 2007)

Northern Sites

Grotta dell'Uzzo

Grotta dell'Uzzo sits at an elevation of 98m above sea level in Cala Tonnarella dell'Uzzo, located in the northwestern part of the island west of Palermo. It is a coastal site (Yu et. al. 2022). The site was occupied beginning in the late Upper Paleolithic and was occupied continuously during the Mesolithic up to the Middle Neolithic, however, there are traces of later occupation (Yu et. al. 2022). For our research, we are examining materials found approximately 1m below a date of 11,100 years ago cal BP (Mannino et. al. 2015). Remains of *Homo sapiens* have been excavated at the site; they have been dated to approximately 10,750–6,660 cal BP (Yu et. al. 2022).

For our research, we will be examining Strato Basale 33–48 of this site. Specific excavators for this site have not been reported. Specific dimensions for this site have not been reported.

Species Name	Common Name	Number of Identified Specimens (NISP)
Bos primigenius	auroch	10
Sus scrofa	wild boar	6
Vulpes vulpes	red fox	6
Canis cf. lupus	wolf	3
Cervus sp.	unidentified Cervus	357
Ursus sp.	unidentified Ursus	1
Martes sp.	unidentified Martes	1
Mustela cf. nivalis	least weasel	2
Microtus (*Terricola*) sp.	vole	7
Apodemus sp.	unidentified Apodemus	1
Erinaceus europaeus	European hedgehog	6
Bufo bufo	frog	3
Podiceps cristatus	great crested grebe	1
Falco tinnunculus	common kestrel	4
Alectoris graeca	rock partridge	49
Rallus aquaticus	western water rail	1
Crex crex	corncrake	3
Columba livia	rock dove	21
Asio otis	northern long-eared owl	1
Strix aluco	tawny owl	1
Apus apus	common swift	1
Garrulus glandarius	Eurasian jay	10
Pyrrhocorax pyrrhocorax	red-billed chough	6
Pyrrhocorax graculus	yellow-billed chough	9
Corvus monedula	Eurasian jackdaw	2
Corvus cornix	hooded crow	1
Corvus corax	common raven	1
	Total NISP:	514
	Total Number of Taxa:	27

Figure G: faunal chart for Grotta dell'Uzzo (Strato Basale 33-48) (Tagliacozzo 1993)

Castello

While specific excavators for this site have not been recorded, initial excavations of the site began at the start of the 20th century. Based on the approximate location of this site determined using Google Earth, Castello sits at an elevation of approximately 42m above sea level. It is a coastal site east of Palermo, in the town of Termini Imerese. It is approximately 200m from the coast (Drudi 2014).

Excavations have suggested that different hunter-gatherer groups have occupied the cave at various occasions for various periods of time, and that *Cervus elaphus*, *Bos primigenius*, *Sus scrofa*, and *Equus hydruntinus* were commonly hunted (Drudi 2014). Backed points that are like those found at San Teodoro (Layer D) have been uncovered at the site; these backed points likely date to between 14,000 and 12,000 cal BP (Drudi 2014).

For our research, specific layers will not be analyzed. Specific excavators for this site have not been reported. A specific age for this site has not been reported. Specific dimensions for this site have not been reported.

Species Name	Common Name	Number of Identified Specimens (NISP)
Fish (Pisces)		1
turtle		1
Aves indet.		2
Anserinae sp.	swan or goose	1
Columna palumba	common wood pigeon	1
Anser sp.	grey goose	3
Branta sp.	black goose	1
Pastor roseus	rosy starling	1
Erinaceus sp.	European hedgehog	1
Lepus sp.	hare	1
Vulpes sp.	fox	5
Sus scrofa	wild boar	5
Bos primigenius	auroch	9
Cervus elaphus	red deer	52
Homo sapiens	human	21
Equus hydruntinus	wild ass	52
	Total NISP:	157
	Total Number of Taxa:	16

Figure H: faunal chart for Castello (Regàlia 1907)

San Teodoro

San Teodoro was first explored and excavated in 1859 by Barone Franceso Anca (D'Amore et. al. 2009). San Teodoro is a cave located in the northeastern coast of Sicily just outside of the coastal town of Acquedolci (Garilli et. al. 2020). San Teodoro is located approximately 135m above sea level and lies approximately 2km from the coast in the present day (D'Amore et. al. 2009). At the time of its occupation, it was likely located about 6km from the shore (Garilli et. al. 2020). Human remains, uncovered in Layer C of this site, have been dated to approximately 14,000–10,000 years cal BP, providing a rough age range for this site (D'Amore et. al. 2009). San Teodoro is in an area of the island that has a high density of Paleolithic and Mesolithic cave sites (Garilli et. al. 2020). The cave itself is about 60m long, 20m wide, and up to 20m tall in certain parts (D'Amore et. al. 2009). Faunal remains, lithic artifacts, and the oldest known human skeletal samples on the island have been found at this site (D'Amore et. al. 2009). Six of the seven individuals uncovered at the site date to approximately 14,000–10,000 years BP, with Individual 5 being of a more recent, unknown age (D'Amore et. al. 2009).

For our research, we will be examining Layer D of this site. This site occurs below the layer (Layer C) in which the human remains were discovered. This means that Layer D is older than Layer C.

Species Name	Common Name	Number of Identified Specimens (NISP)
Cervus elaphus	red deer	127
Equus hydruntinus	wild ass	1
Sus scrofa	wild boar	26
Bos primigenius	auroch	49
Vulpes vulpes	red deer	1
	Total NISP:	204
	Total Number of Taxa:	5

Figure I: faunal chart for San Teodoro (Layer D) (Garilli et. al. 2020)

Southern Sites

Pedagaggi

Based on the approximate location of this site determined using Google Earth, Pedagaggi sits at an elevation of 320m above sea level just northwest of Syracuse. The site faces east (Di Geronimo 1981). The site has a maximum width of 15m and is roughly 3–4m deep. The site is enclosed by a wall of overlapping boulders and the vault of the cave is blackened by fires created by humans who took refuge in the cave (Di Geronimo 1981). Fragments of bone, both human and non-human, pottery, and flint have been uncovered at the site; while it has been reported that these materials are Paleolithic, a specific age has not been recorded (Di Geronimo 1981). The lithics at this site are comparable to the industries of two other sites we have examined: San Teodoro and Corruggi (Di Geronimo 1981).

For our research, we examined an assemblage from an unnamed layer that is of a homogenous appearance and is approximately 50cm thick (Di Geronimo 1981). Specific excavators for this site have not been reported. A specific age for this site has not been reported.

Species Name	Common Name	Number of Identified Specimens (NISP)
Bufo bufo	common toad	1
Aves indet.		1
cfr. *Lynx lynx*	Eurasian lynx	1
Equus hydruntinus	wild ass	15
Sus scrofa	wild boar	12
Cervus elaphus	red deer	11
Cervidae gen. et sp. indet.		1
Bos primigenius	auroch	7
	Total NISP:	49
	Total Number of Taxa:	8

Figure J: faunal chart for Pedaggagi (Gliozzi and Kotsakis 1986)

Giovanna

Giovanna was discovered by local farmers in an olive grove. The site was excavated by Luigi Bernabó Brea in an unspecified year (Bernabó Brea 1965). Based on the approximate location of this site determined using Google Earth, Giovanna sits at an elevation of roughly 13m above sea level. Giovanna is a small karst cave at Contradea Spinagallo (Alessio et. al. 1976). The cave is 30m from the edge of the provincial Syracuse-Canicattini road that leads to Cassibile (Bernabó Brea 1965). Materials excavated at the site date to the Upper Paleolithic cultural horizon. Holocene and Pleistocene fauna have also been found at the site (Alessio et. al. 1976).

The cave is small, with an opening of approximately 4 x 4 meters, making it difficult to locate. The cave itself is oval (Bernabó Brea 1965). The opening to the cave is in the middle of the southeastern side of the cave. Upon entering the cave, one will enter a small cavity that is low in height; researchers are unable to stand up straight (Bernabó Brea 1965). Only certain portions of the cave had been excavated at the time of the publishing of this source; work has stopped at a large boulder that has been placed in the cave, blocking off the second level of the cave (Bernabó Brea 1965). At the time of the publishing of this source, excavations had already removed most of the prehistoric deposit, and it was evident that the cultural layer of the cave continued downward past the boulder (Bernabó Brea 1965).

For our research, we will be examining an unnamed layer of this site. This layer is described as being an earthen layer about 60cm thick; it contains Pleistocene fauna associated with the Upper Paleolithic (Cardini 1971).

Species Name	Common Name	Present/Absent
Bos primigenius	auroch	P
Cervus elaphus	red deer	P
Capra (*hircus*?)	domestic goat	P
Equus hydruntinus	wild ass	P
Sus scrofa	wild boar	P
Vulpes vulpes	red fox	P
Canis lupus	wolf	P
Microfauna		P
Molluscks		P
	Total Number of Taxa:	9

Figure K: faunal chart for Giovanna (Cardini 1971)

San Corrado

San Corrado sits at an elevation of 318m above sea level, just southwest of Syracuse. According to an approximation determined using Google Earth, the site sits about 32km from the coast. The site dates to roughly 16,000–14,000 years BP. (D'Amore et. al. 2009). The site shows evidence for early human occupation; however, specific details are not reported. This site was potentially constructed by hand in a rock wall about 12m tall (Bernabó Brea 1950). The cave is located about 50m above a large trough next to the Ruccheri and Caltagirone roads. The entrance to the cave is about 6m, and inside the cave, there is a crack that is 2.50 wide; this crack is thought to be where early peoples took refuge during the Paleolithic times (Bernabó Brea 1950).

For our research, we will not be examining a specific layer of the site. Specific excavators for the site have not been reported.

Species Name	Common Name	Present/Absent
Cervus elaphus	red deer	P
Cervus sp. (cf. *C. elaphus*)	probably red deer	P
Equus cf. (*Asinus*) *hydruntinus*	probably wild ass	P
Equus sp.	unidentified Equus	P
Sus scrofa	wild boar	P
Ovis aries	sheep	P
	Total Number of Taxa:	6

Figure L: faunal chart for San Corrado (Bernabó Brea 1950)

Fontana Nuova

The site was first excavated by Vincenzo Grimaldi di Calamenzana in late 1913. He discovered lithics and human remains at the site, however, he reburied the human remains after discovering them (Di Maida et. al. 2019). The site was rediscovered by Luigi Bernabó Brea in 1949. After reconstructing the original stratigraphy of the site, he concluded that the assemblage likely dated to the Upper Paleolithic; it was later determined that the assemblage specifically dated to the

Aurignacian industry (Di Maida et. al. 2019). The site is located northeast of Marina di Ragusa (Bernabó Brea 1950). It sits 145m above sea level in the southeastern portion of Sicily on the right bank on the mouth of the Irininio River (Bernabó Brea 1950). According to an approximation determined using Google Earth, the site sits about 27km from the coast. The site is located at the top of a steep massif, defined as a group of mountains separate from other groups of mountains. It is speculated that this massif was the old coast of Sicily (Bernabó Brea 1950). The niche is 8m wide, roughly 3m tall, and about 2m deep (Bernabó Brea 1950). Animal remains, traces of charcoal, and broken bone fragments have been found at the site (Bernabó Brea 1950). The site contains human remains and lithics that date roughly to the Mesolithic, although some artifacts may be from the Upper Paleolithic (Di Maida et. al. 2019).

For our research, we will not be examining a specific layer of the site.

Species Name	Common Name	Present/Absent
Homo sapiens	human	P
Cervus elaphus	red fox	P
Bos primigenius	auroch	P
Bos sp.	unidentified Bos	P
Sus scrofa	wild boar	P
Vulpes vulgaris	fox	P
Canis familiaris	domestic dog	P
Testudo sp.	unidentified Testudo	P
	Total Number of Taxa:	8

Figure M: faunal chart for Fontana Nuova (Bernabó Brea 1950, DiMaida et. al. 2019)

Corruggi

Excavations at Corruggi site date back to 1898 with P. Orsi, who excavated each stratigraphic level of the site using selective sampling techniques (Villari 1995). Corruggi is located 2m above sea level on the southeastern coast of Sicily. It is located south of Marzamemi, east of Pachino, and north of Torrefano. Its opening faces Vulpiglia beach. This Upper Paleolithic cave is 50m from the shore in the upper portion of the bank; at the time of its initial occupation, it was likely further from the shore, however, this approximate location has not been recorded (Bernabó Brea 1949, Villari 1995). The rocky bank is currently located near a marsh (Villari 1995). The chamber of the cave is currently 4 by 4m and is just tall enough for an adult to stand in. The maximum depth of the cave is approximately 7m deep (Bernabó Brea 1949).

The site contains fauna from the Late Pleistocene, including *E. hydruntinus*; ceramics at the site come from both the Mesolithic and Middle Neolithic periods. There is also evidence of a lithic industry from the Epigravettian tradition (Villari 1995).

For our research, we will be examining the combined totals from the Orsi and Bernabó Brea excavations from levels 3–9 as reported in Villari (1995).

Species Name	Common Name	Number of Identified Specimens (NISP)
Equus hydruntinus	wild ass	8
Equus sp.	unidentified Equus	21
Bos primigenius	auroch	2
Bos sp.	unidentified Bos	5
Cervus elaphus	red deer	87
Sus scrofa	wild boar	6
Canis lupus	wolf	2
Canis familiaris	domestic dog	1
Vulpes vulpes	fox	43
Felis silvestris	European wildcat	7
Oryctolagus cuniculus huxleyi	European rabbit	13
Erinaceus europaeus	European hedgehog	1
Microtus (*Terricola*)	vole	2
Homo sp.	unidentified Homo	1
Canis v. Vulpes		1
Emys orbicularis	European pond turtle	31
Testudo hermanni	Hermann's tortoise	8
Lacerta viridis	European green lizard	1
Bufo sp.	unidentified Bufo	1
Molluschi terrigeni n.d.	terrigenous mollusks	434
Patella carulea		292
Patella carulea L. var. *subplana* Poitiez e Michaud		144
Patella ferruginea		9
Patella lusitanica		8
Columbella rustica		2
Ostrea sp.		1
Patella sp.		1
Monodonta turbinata		38
Pisania maculosa		1
Cerythium vulgatum		1
Acanthocardia tubercolata		56
Tapes decussatus		1
	Mammiferi marini	29
	Mammiferi non determinati	450
	not determined	2
	Total NISP:	1710
	Total Number of Taxa:	32

Figure N: faunal chart for Corruggi (Bernabó Brea 1949, Bernabó Brea 1950, Villari 1995)

Taxa of Interest

For our research, we focused on the following taxa: *Equus hydruntinus*, *Vulpes vulpes*, *Sus scrofa*, *Cervus elaphus*, and *Bos primigenius*. These five taxa are the most abundant in our sample, making up 44% of the total number of identified species (NISP) of our sites. As previously stated, we have chosen to focus on faunal data to reconstruct Sicily's paleoenvironment because utilizing faunal records based on the present-day preferences of these taxa has proven to be an accurate indicator of what a given region's paleoenvironment may have looked like. Sicily also has a limited number of paleoenvironmental records, such as pollen records, available for the Late Pleistocene. Faunal records are the most abundant record available for Sicily currently.

It is important to note that most of these taxa are extinct or no longer present in Sicily in the present day. This is likely due to environmental changes on the island over time.

Equus hydruntinus

The *Equus hydruntinus*, also known as the European wild ass, is an extinct animal that lived across Europe and the Middle East during the Middle and Late Pleistocene (Catalano et. al. 2020). The wild ass was first documented in Italy during the Late Middle Pleistocene, where its remains were most frequent in the central-southern part of the country (Catalano et. al. 2020). Its appearance in Italy marks the Middle Aurelian faunal assemblage (Boulbes and van Asperen 2019). It is documented in Italy until the Holocene when it became extinct (Catalano et. al. 2020).

The first evidence of the wild ass in Sicily dates to 12–23ka cal. BP, and it is possible that it arrived on the island via a land bridge (Catalano et. al. 2020).

The wild ass was likely adapted to semi-arid, steppic conditions. While it could tolerate the cold, it shows a preference for temperate environments. Researchers have come to this conclusion because the wild ass had a short muzzle compared to other equids, an adaptation that indicates that it lived in a colder climate (Boulbes and van Asperen 2019). This information reveals what type of climate Italy may have had during the Middle–Late Pleistocene. It was adapted to dry Mediterranean conditions. Unlike other equids, the wild ass did not depend on open landscapes, however, it may have preferred open landscapes (Boulbes and van Asperen 2019).

The wild ass began to go extinct during the Last Glacial Maximum (LGM) (Boulbes and van Asperen 2019). At this time, we only have a few examples of the wild ass in Holocene records throughout Europe, indicating that it was rare after the end of the LGM. Its range was also limited at this time; it only ranged as far north as the southernmost extent of the LGM and was mostly restricted to the south of Europe (Cardini 1971).

The global extinction date for the wild ass was likely during a larger extinction phenomenon that occurred during the Iron Age; however, the species began to go extinct sporadically during the Bronze Age (Cardini 1971).

Vulpes vulpes

The common name for *Vulpes vulpes* is the red fox. These animals live in forests, shrublands, grasslands, inland wetlands, and non-extreme deserts (IUCN Red List). Their natural habitat is a dry, mixed landscape with scrub and woodlands; however, they can be found on moorlands, mountains, sand dunes, and farmland. They can be found up to 4,500m above sea level (IUCN Red List). They have a wide geographic range; they can be found across the entire northern hemisphere between the Arctic Circle to southern North America, Europe, northern Africa, the Eurasian steppes, India, and Japan. They are extant on the island of Sicily today (IUCN Red List). The red fox is no longer present in Sicily.

While information specific to Sicily is unavailable, the red fox was often hunted for its teeth and fur in other locations, such as in the Swabian Jura in Germany (Baumann et. al. 2020). Their teeth, and the teeth of other carnivores in general, were often used to make pendants during the Middle to Upper Paleolithic. This has been determined by analyzing the number of perforated carnivore teeth found at various archaeological cave sites (Baumann et. al. 2020). Red foxes, at this time, were likely not hunted for meat, but rather for their other attributes.

Sus scrofa

The common name for *Sus scrofa* is the wild boar. Today, these animals live in forest, savannas, shrublands, grasslands, inland wetlands, and deserts across Eurasia and North Africa, including on the island of Sicily (IUCN Red List). Wild boar can live in a variety of temperate and tropical climates, including semi-deserts, tropical rainforests, temperate woodlands, grasslands, and reed jungles (IUCN Red List). In terms of Europe, wild boar generally prefer broadleaved or evergreen oak forests, however, they also can live in steppe habitats and Mediterranean shrubland (18). In Europe, wild boar can live up to 2,400m above sea level (IUCN Red List). Wild boar are omnivorous, however, they primarily eat plants (fruit, seeds, roots, and tubers) and are generally not nocturnal (IUCN Red List). Wild boar are gregarious, meaning that they form herds of varying size (IUCN Red List).

Cervus elaphus

The common name for *Cervus elaphus* is the red deer. While they are generally found in mountainous regions these animals live in forests, shrubland, grassland, and various rocky areas, such as inland cliffs and mountain peaks. More specifically, the red deer enjoys open deciduous, mixed deciduous-coniferous, and coniferous woodlands, in addition to upland moors, open mountainous areas, Mediterranean maquis scrub, natural grasslands, pastures, and meadows. Its preferred habitat is a broadleaved woodland interspersed with large meadows (IUCN Red List). In woodland habitats, the red deer’s diet consists of shrubs and tree shoots. In other habitats, it will eat grasses, sedges, fruit, and seeds (IUCN Red List). It can be found in regions up to 2,800 above sea level (IUCN Red List). The red deer is no longer present in Sicily.

Bos primigenius

The common name for *Bos primigenius* is the auroch. It is now extinct. Prior to its extinction, it lived across Eurasia and parts of Northern Africa (Wright 2013). It is believed to have lived in forests, grasslands, and inland wetlands. It preferred swamps, swamp forests, river valleys, river deltas, and bogs. It also may have lived in drier forests and open parkland (IUCN Red List). It is believed that, in Europe, aurochs lived in wetter forests (IUCN Red List). The auroch is accepted by academics as the ancestor to the domestic cows that exist today (Wright 2013).

Aurochs roamed Europe until the 13th century. At this point, most aurochs had disappeared from the continent, with only a few herds existing in eastern Europe. The last herd lived in a marshy area in a deciduous woodland southwest of modern-day Warsaw, Poland. The last auroch died in 1627 (Wright 2013).

Methods

Presence, absence, and indicator taxa

We compiled a list of faunal remains found at each site in relevant strata, defined as strata that has been dated to the time period that we are studying, and the number of identified specimens (NISP) of each species.

For this portion of our study, we examined indicator taxa found at our sites. The indicator taxa that we examined were *Equus hydruntinus* and *Cervus elaphus*. Equids (*E. hydruntinus*) and red deer (*C. elaphus*) are known as indicator taxa, meaning that their presence can give us an idea of what types of habitats were present at a site. Indicator taxa are stenotopic, meaning that they can only tolerate specific ecological conditions. This means that, when they occur in an assemblage, it signifies a particular environment at the time of the accumulation and deposition of the remains (Faith and Lyman 2019). Equids are indicators of open habitats, such as grasslands, savannas, and shrublands, while red deer are indicators of closed habitats, such as forests, as they feed in these habitats and retreat there when they are threatened.

We considered the equid to red deer ratio at each site. In doing so, we were following the example of Stiner and Munro (2011). In their study, which examined Franchthi Cave in Peloponnese, Greece, the shift in equid to red deer was a useful proxy to track the shift from an open habitat to a closed habitat. This cave has a similar archaeological record to many of the sites on Sicily used in this study, as it has a shoreline of variable size due to sea level change, so we determined that examining the equid to red deer ratio for each of our sites may yield a similar result. Our ratios were determined by using the NISP for each species at each site, and then simplifying the ratio to a number that was easier to work with. For example, in the case of Levanzo/Genovesi, the NISP for equids was 17, while the NISP for red deer was 129. This gives us a ratio of 17:129, or 1:7.6 simplified. The proportion, based on these data, is 0.13. This process was repeated for each site that had data for equids and red deer.

Habitat weighting

Our second method of analysis was conducting habitat weighting, following a modified version of Peter Andrews's method (Evans et. al. 1981).\

Taxa	Forest	Grassland	Savanna	Shrubland	Wetlands (inland)	Rocky areas	Desert	Semi-aquatic
Equus hydruntinus		present	present	present				
Vulpes vulpes	present	present		present	present		present	
Sus scrofa	present	present	present	present	present		present	
Cervus elaphus	present	present		present		present		
Bos primigenius	present	present			present			

Figure O: table outlining the habitat preferences for E. hydruntinus, V. vulpes, S. scrofa, C. elaphus, and B. primigenius.

After creating a list of the species that were excavated and their respective NISPs, we utilized the IUCN Red List of Threatened Species to determine the habitats that each specific species tended to live in. We eliminated artificial habitats, as it is unlikely that artificial habitats of the kind existed during the Late Pleistocene. Once the habitats were identified, we created a table for each site that compiled each habitat that was presumably at each site. This was determined by examining the possible habitats for large mammals at the site, most commonly *E. hydruntinus*, *C. elaphus*, *S. scrofa*, and *B. primigenius*. The habitats for this table were determined using the IUCN Red List for each species, with the only exception being for the extinct taxon, *E. hydruntinus*. For this taxon, we made our own best estimates based on the comparisons of extant equid and information from Boulbes and van Asperen (2019). We estimated that this taxon likely existed in grasslands, savannas, and shrublands. We then determined the total NISP in each possible habitat, and then summed each total to get a grand total for each site. We then divided the total NISP in the possible habitat by the grand total to obtain a proportion for each site. We then multiplied this proportion by 100 to get a percentage, thereby determining the habitat weight for each possible habitat at each site. Lastly, we made a master table of the habitat weightings for each site.

Our habitat weighting approach is a simplified one, as we did not try to estimate the proportion of time that the animal spent in each habitat, unlike the original habitat weightings done by Peter Andrews (Evans et. al. 1981). Instead, we assumed an equal probability for the presence of each habitat in which the animal occurred, essentially using it as an indicator species for the possible presence of each habitat type in which the animal occurs today, with some estimation of its abundance on the landscape. This approach makes fewer assumptions about habitat preferences for animals in the past, as the current ranges and apparent preferences are likely impacted by more recent dense populations of industrialized nations relying on extensive landscape transformations required for intensive agriculture.

For example, at the site of Levanzo/Genovesi, the NISP for *S. scrofa* is four. *S. scrofa*, according to the IUCN Red List, lives in forests, grasslands, savannas, shrublands, wetlands, and deserts. In the respective table for Levanzo/Genovesi, each of those habitat categories was given a value of four, the NISP for *S. scrofa* at that site. We repeated this for every large mammal species; for Levanzo/Genovesi, this was *S. scrofa* (NISP = 4), *B. primigenius* (NISP = 32), *C. elaphus* (NISP = 129), *E. hydruntinus* (NISP = 17), and *V. vulpes* (NISP = 6). We then summed the total NISP for each habitat present at this site (forest = 171, grassland = 188, savanna = 21, shrubland = 156, wetlands = 42, rocky areas = 129, and deserts = 10), and divided it by the total value for all possible habitats for this site (717). We then expressed this as a proportion, giving us percentages for each habitat (forest = 23.85, grassland = 26.22, savanna = 2.93, shrubland = 21.76, wetlands = 5.86, rocky areas = 17.99, and deserts = 1.39). We cannot determine if all these habitats were unequivocally present at Levanzo/Genovesi, however, these numbers give us an idea of the likely environment of this site. Based on the percentages, there is a high likelihood of open areas, such as grasslands, savannas, and shrublands, at the site. There may have been some forests, and less proportions of other areas.

We were unable to perform habitat weights for Giovanna, San Corrado, and Fontana Nuova due to the lack of numerical data for these sites. These sites only had presence/absence data available, meaning that species were only marked as being present at the site without listing the NISP for that species. As a result, these sites are not included in our final habitat weighting table, however, these sites did indicate the presence of the same range of taxa as the sites that we did include in our numerical data analysis.

Multivariate approaches

Lastly, we ran statistical analyses to determine if there was a relationship between the elevation of each site, an approximation made using Google Earth. We did this because temperature and moisture availability, and thus habitat type, are often controlled by elevation. We also examined the equid to deer ratio of each site, as well as if there was a relationship between the equid to deer ratio and the number of backed points found at each site, using data compiled by Peyton Carroll and provided courtesy of her. We did so because an initial exploration of the frequency of backed points suggested the presence of some geographic structuring, and we were interested to see if it might track the sorts of habitat differences captured by the equid to deer ratios. We also ran a linear regression to test if the sample diversity of each site is driven by sample size, or NISP, as it is often the case among faunal samples (Faith and Lyman 2019). To do so, we utilized the Social Science Statistics calculators to run our tests and Excel to create our charts, as well as PAST4 for the data for the relationship between a site's equid to deer ratio and number of backed points (Hammer et. al. 2001). The last multivariate analysis we ran was a principal components analysis (PCA) to analyze the similarities between our sites.

Results

Presence, absence, and indicator taxa

Site Name	Elevation (meters)	Equid NISP	Deer NISP	Ratio
Levanzo/Genovesi (Strato 3 – tagli 5 and 6)	30	17	129	0.13
San Teodoro (Layer D)	140	1	127	0.01
Corruggi	2	28	87	0.32
Grotta delle Uccerie (Strata 4D)	78	57	41	1.39
Pedaggagi	320	15	11	1.36
Grotta d'Oriente (Strato 7)	50	14	104	0.13
Grotta dell'Uzzo (Strato Basale 33–48)	98	0	357	0
Castello	42	52	52	1
Fontana Nuova	145	n/a	n/a	n/a
Giovanna	13	n/a	n/a	n/a
San Corrado	318	n/a	n/a	n/a

Figure P: table outlining the approximate elevation for each site, as well as the NISP for E. hydrintinus and C. elaphus, and the equid/deer ratio. NISP information was not available for Fontana Nuova, Giovanna, and San

As previously stated, our equid (*E. hydruntinus*) to red deer (*C. elaphus*) ratio was constructed to determine if there was a greater likelihood of an open or closed habitat at any given site based on the present-day preferences of red deer and equids in general. Based on our results, there is not enough evidence to draw a strong conclusion on what type of habitats are present at any given site. It can be argued at Levanzo/Genovesi, San Teodoro, Grotta d'Oriente, and Grotta dell'Uzzo that there is a likelihood of closed habitats, such as forests, at those sites, as there is a high number of red deer compared to equids at those sites. This claim would be consistent with what was determined with our habitat weights, as Levanzo/Genovesi scored 23.85 for forests, while San Teodoro scored 24.79, Grotta d'Oriente scored 22.46, and Grotta dell'Uzzo scored 24.82 for a forest environment, however, our habitat weighting data still showed a high likelihood for open habitats at each of those sites, rendering these results inconclusive. A further problem is the generally poor chronology of these sites; it is possible that, for some sites, equids were locally extinct for the specific strata that we examined.

It is important to note that DiMaida et. al. (2019), in their analyses of *C. elaphus,* indicated that some of the Sicilian red deer may have had substantially more grass-rich diets than other red deer populations in Europe. This implies that open habitats may have been abundant, and maybe even preferred, by red deer populations in this area. This also demonstrates that we must not rule out the possibility that animals may have adapted to their environment because today they prefer a different habitat than what was present at the time.

Habitat weighting

Site Name	Forest	Grass-land	Savanna	Shrub-land	Wet-lands (inland)	Rocky areas	Desert	Semi-aquatic
Levanzo/Genovesi (Strato 3 – tagli 5 and 6)	23.85	26.22	2.93	21.76	5.86	17.99	1.39	0
San Teodoro (Layer D)	24.79	24.91	3.3	18.93	9.28	15.51	3.3	0
Corruggi	20.19	23.96	4.58	23.28	8.48	12.92	6.59	0
Pedaggagi	16.48	24.73	14.84	20.88	10.44	6.04	6.59	0
Grotta delle Uccerie (Strata 4D)	16.6	28.72	13.4	22.77	7.87	8.72	1.91	0
Grotta d'Oriente (Strato 7)	22.46	24.96	2.85	23.35	3.92	18.54	2.32	1.6
Grotta dell'Uzzo (Strato Basale 33–48)	24.82	24.82	0.39	24.17	1.62	23.39	0.78	0
Castello	15.92	27.58	12.78	25.56	4.26	11.66	2.24	0

Figure Q: master table of the habitat weights for Levanzo/Genovesi, San Teodoro, Corruggi, Pedaggagi, Grotta delle Uccerie, Grotta d'OPriente, Grotta dell'Uzzo, and Castello. Fontana Nuova, San Corrado, and Giovanna are not included due to the lack of numerical data.

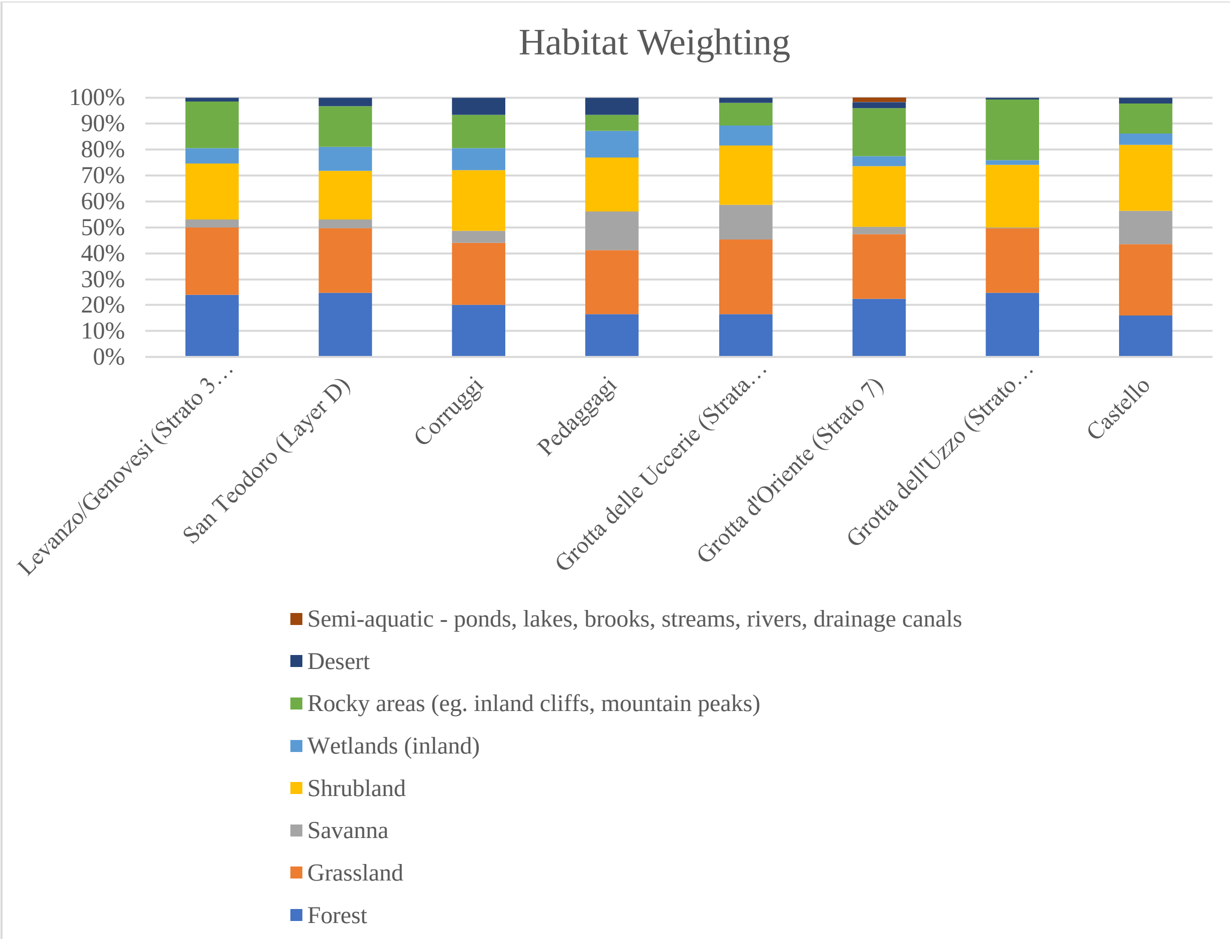

Figure R: habitat weighting distribution for Levanzo/Genovesi, San Teodoro, Corruggi, Pedaggagi, Grotta delle Uccerie, Grotta d'OPriente, Grotta dell'Uzzo, and Castello. Fontana Nuova, San Corrado, and Giovanna are not included due to the lack of numerical data.

Our habitat weighting data allows us to envision the potential environment of each site. Starting with Levanzo/Genovesi, our data shows high percentages of animals that, in the present-day, prefer forests, grasslands, and shrublands, with rocky areas, such as inland cliffs and mountain peaks, being a close fourth. Because of this information, it can be inferred that, during the Late Pleistocene, this site likely was a mix of shrubland, forest, and grassland. The same can be said for San Teodoro, Corruggi, Pedagaggi, Grotta d'Oriente, Grotta dell'Uzzo, and Castello. Pedaggagi and Castello also have high likelihoods for a savanna-like environment; Pedaggagi had some evidence for inland wetlands as well. Data from Grotta dell'Uccerie shows evidence of shrubland, grassland, savanna, and forest, with lower percentages of the other environmental conditions. Overall, during the Late Pleistocene, Sicily likely had a variety of open environments, such as savannas, grasslands, and shrublands. There also were likely some forested areas, and sparce instances of inland wetlands and rocky areas. Deserts were unlikely, and semi-aquatic environments, such as ponds, lakes, streams, brooks, and rivers, were seemingly nonexistent. Today, these environments are rare on the island.

It should be noted that our focus on large mammals for our habitat weighting may have resulted in us missing key parts of the environment. For example, some sites, such as Levanzo/Genovesi, Grotta d'Oriente, and Corruggi, contain reptiles, such as *Emys orbicularius*, or the European pond turtle. The European pond turtle is abundant in inland wetlands and coastal environments, ecological conditions that were underrepresented in our results (IUCN Red List). Because not every taxon that was present at each site was examined in our research, it is likely that certain habitats that were likely present, such as inland wetlands, were missed.

Multivariate approaches

Elevation against equid/deer ratio

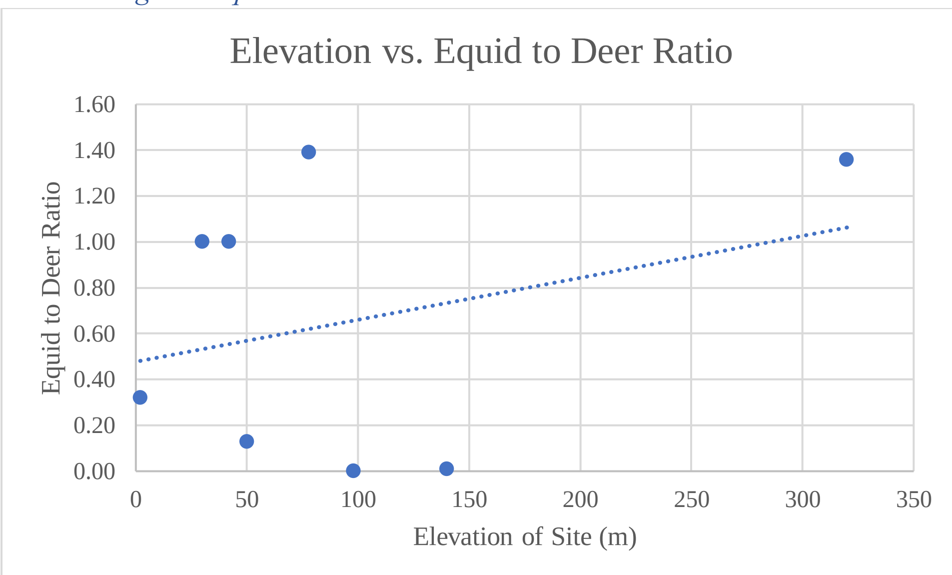

Figure S: graph showing the relationship between the elevation of a site (in meters) and its equid to deer ratio, excluding Fontana Nuova, Giovanna, and San Corrado.due to lack of information.

Figure S shows the relationship between the elevation of each site (in meters) and the corresponding equid to deer ratio. The relationship between a site's elevation and its equid to deer ratio is not significant ($r^2 = 0.09$, $p = 0.82$). There is no clear linear relationship between the two variables. While the equid to deer ratio may track open and closed habitats, at least within our sample, the abundance of open and closed habitats does not seem to vary with elevation.

Equid/deer ratio against backed points

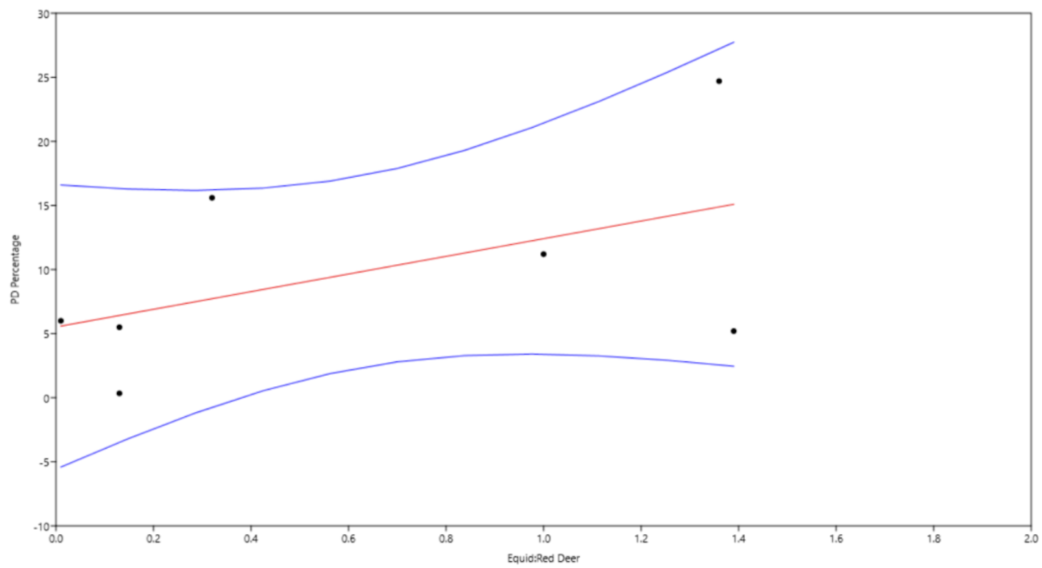

Figure T: graph showing the relationship between a site's equid to deer ratio and the number of back points found at the site, excluding Fontana Nuova, Giovanna, and San Corrado, due to lack of information. Graph created using PAST4 (Hammer et. al. 2001).

Using data for backed points, referred to in the graph as "PD" (*punto dorso* = backed points) and the equid to deer ratios we determined, we have deduced that our data exhibits a general positive relationship between these two variables; as the number of equids increases, the number of backed points increases as well (Figure T). The linear relationship is not statistically significant, although it is suggestive ($r^2 = 0.26$, $t = 1.27$, $p = 0.24$), something to further explore with larger sample sizes. There is a slight positive correlation between the two variables.

The data for the backed points was compiled by Peyton Carroll using published sources.

Sample diversity against sample size (NISP)

Site Name	NISP	Number of Taxa
Levanzo/Genovesi (Strato 3 – tagli 5 and 6)	136	6
San Teodoro (Layer D)	204	5
Corruggi	1710	32
Grotta delle Uccerie (Strata 4D)	136	6
Pedaggagi	49	8
Grotta d'Oriente (Strato 7)	165	8
Grotta dell'Uzzo (Strato Basale 33–48)	514	27
Castello	157	16
Fontana Nuova	n/a	8
Giovanna	n/a	9
San Corrado	n/a	6

Figure U: table that determines the available NISP for each site, as well as the number of taxa at each site.

Our last multivariate test that we ran examined sample diversity against sample size, or NISP, at each site that contained numerical data. Figure U displays the NISP of each site, as well as the number of taxa determined to be at each site. This test excluded Fontana Nuova, Giovanna, and San Corrado, as information about the NISP at those sites was unavailable. These data suggest that sample size does play a role in sample diversity in Late Pleistocene Sicily ($r^2 = 0.696$, $p = 0.055$). It has been documented previously that species richness is dependent on the NISP of a site (Faith and Lyman 2019). According to Faith and Lyman, analyzing the taxa between assemblages can be more beneficial in revealing differences in sampling "than it is to reveal ecologically meaningful differences in richness," unless the sample sizes between assemblages are identical (Faith and Lyman 2019:203). Future explorations of ecological richness at these sites should take this issue into consideration.

PCA analysis

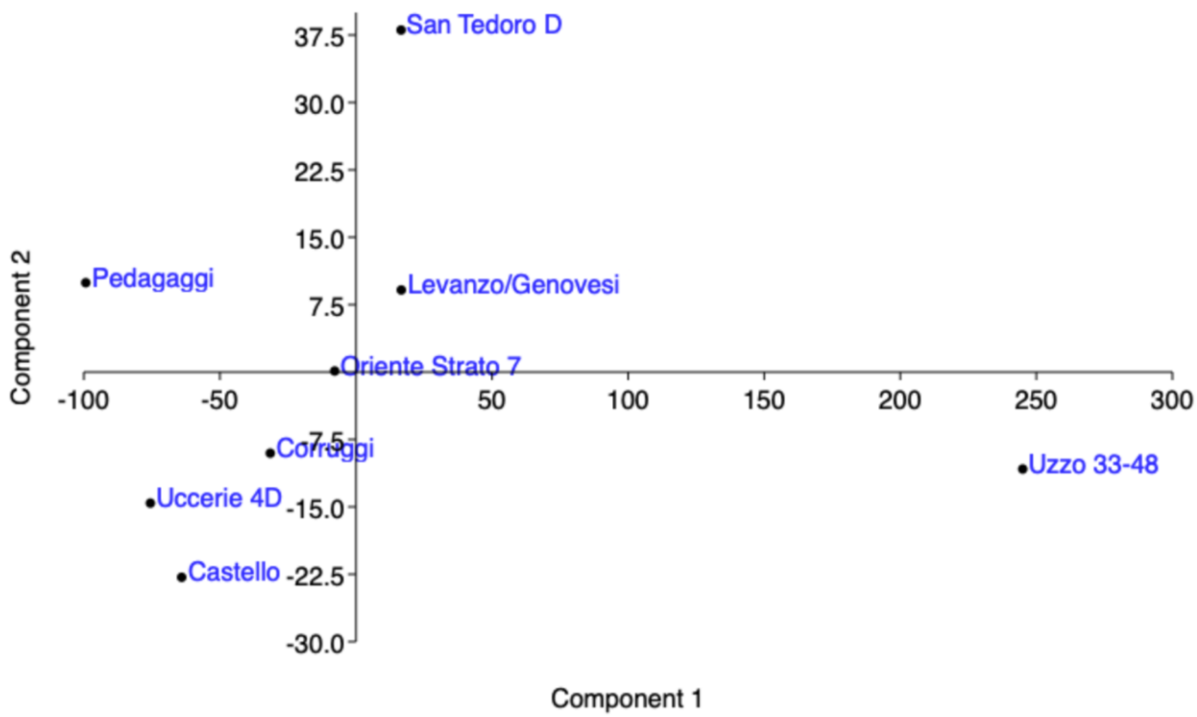

Figure V: PCA analysis for each site, excluding Fontana Nuova, Giovanna, and San Corrado, due to lack of numerical information. Graph created using PAST4 (Hammer et. al. 2001).

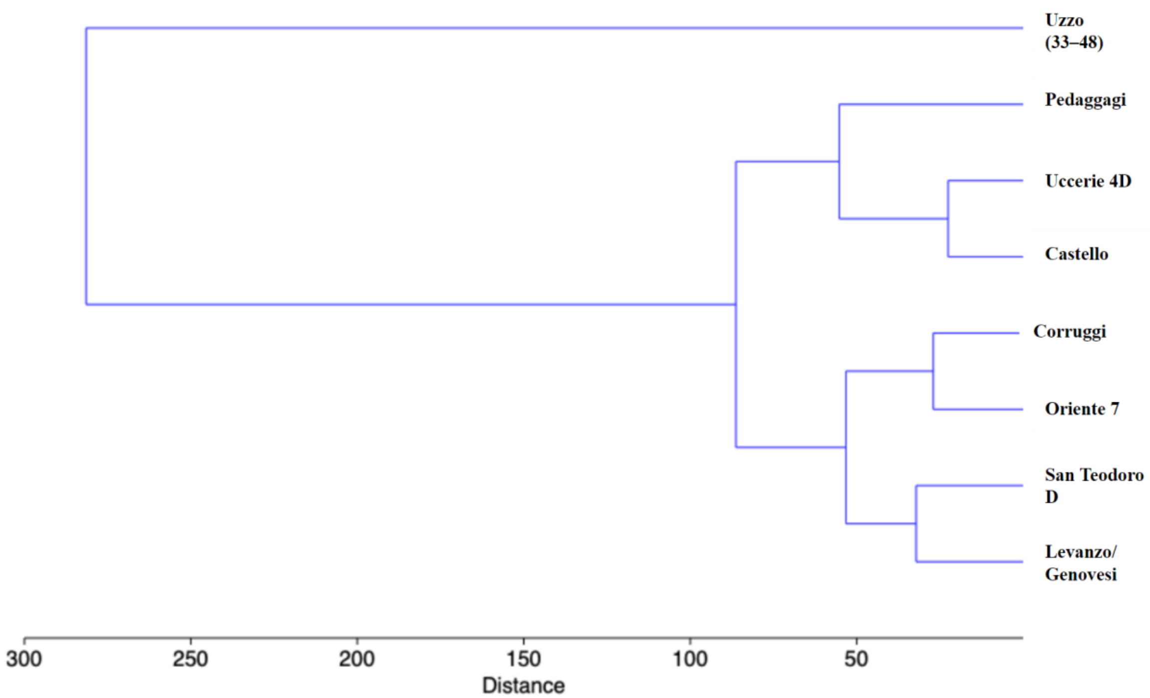

Figure W: cluster analysis for each site, excluding Fontana Nuova, Giovanna, and San Corrado, due to lack of numerical information. Graph created using PAST4 (Hammer et. al. 2001).

The above figures highlight our principal components analysis (PCA) for our sites, excluding Fontana Nuova, Giovanna, and San Corrado, in other to determine which sites are similar to each other in terms of taxa. This approach allows for the ordination of samples according to the taxa present at each respective site (Faith and Lyman 2019). We then performed a cluster analysis to determine if there were obvious spatial clusters between the sites. Both analyses show no obvious geographic patterns among the sites, although both approaches suggest that Grotta dell'Uzzo is unlike the other sites we analyzed.

Conclusion

Our study sought to reconstruct the paleoenvironment of Late Pleistocene Sicily utilizing faunal records. With the data we collected using the faunal records of eleven cave sites on the island, we analyzed the indicator taxa (*E. hyndruntinus* and *C. elaphus*) of each site, conducted a habitat weighting analysis, and analyzed several multivariate methods to obtain information about what the paleoenvironment of Sicily may have been like.

Based on the indicator taxa found at each site, as well as the habitat weighting data, it is evident that Sicily during the Late Pleistocene epoch likely had a temperate climate with a variety of open habitats, such as shrublands, savannas, and grasslands, with some evidence of rocky areas and forests. Generalized climate models suggest that Sicily in the LGM was cooler and drier than the present. What we tried to reconstruct from the fauna was what the local environments and habitats may have been like during the Late Pleistocene in Sicily because we know that the modern-day vegetation on the island is heavily impacted by human agriculture, including domesticated animals and farmland. An additional question was whether there was a geographic difference in these habitats across the island. Based on our information, there is no strong evidence of distinct localized habitats on the island during the Late Pleistocene period.

As previously stated, our conclusions are likely skewed to an unknown extent, as we only examined the common large mammals at each site. Smaller mammals, reptiles, amphibians, and marine taxa were not included in our research; had they been considered, our conclusions may be shifted. This is true for sites, such as Pedaggagi, which is on top of a mountain, but scored low for rocky areas in our habitat weighting analysis. Future studies should further examine the faunal remains at each site because, as of right now, the archaeological records overall for cave sites in Sicily are weak. The sparsity of information about these sites will impact data and conclusions drawn from said data because the quality of the data available is poor. Future approaches may also consider more in-depth analyses of the sites, as most of data was collected from a paleontological perspective rather than zooarchaeological perspective.

Future studies may also consider analyzing Italy as a whole; because Sicily is an island, it may simply be too small of a sample to draw strong conclusions from.

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