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CREATING STABLE ISOTOPIC DATABASE OF FAUNAL REMAINS – BRONZE AGE ITALY

Ana Davitashvili

University of Warsaw. Departmet of Bioarchaeology. Faculty of Archaeology. Warsaw
Piazzale Aldo Moro, 5
00185, Rome
Anadavitashvili0@gmail.com
https://orcid.org/0009-0005-7903-7715

ABSTRACT: This article presents a zooarchaeological isotopic database for Bronze Age Italy, based on previously published isotopic studies. It integrates 209 samples from both, domesticated and wild animals, across Northern, Central, and Southern Italy. The primary aim of the study is to provide comprehensive description of isotopic data covering historical, archaeological, biological, zooarchaeological, geological information in one compile file. It offers a wide-ranging analysis of animal and plant consumption patterns across Italy during the Bronze Age, highlighting differences and similarities across the Italian peninsula and islands. The article underlines isotopic databases as a crucial source for meta-analytical research of prehistorical lifestyle, underscoring their significance in archaeological studies and providing multi-layered insights into prehistoric human-animal interactions. Furthermore, it presents a vital importance of zooarchaeology, as a discipline to investigate human dietary and husbandry practices. Statistical methods are applied to visualize and interpret the isotopic data in order to enhance the clarity and accuracy of dietary and socio-economic dynamics in Bronze Age Italy. After gathering isotopic studies and organizing them in an excel file based on various criteria, statistical tests for multiple comparison analysis of isotopic ratios were performed using the SPSS software. The Results suggest marked regional differences in diet, with Northern Italy showing early evidence of C_4 plant cultivation, such as millet, while Central and Southern Italy maintained a reliance on traditional cereals like wheat and barley (C_3 plants).

KEYWORDS: ^{13}C, ^{15}N, ^{34}S, Paleodiet, Zooarchaeology, Bronze Age, Italy

The Bronze Age in Italy spans roughly from 2300 BCE to 900 BCE, marking a significant transition from the earlier Copper Age (or Chalcolithic) into a period of increased technological, economic, and social complexity. The period can be broadly divided into three key regions: The Northern region, which includes the Po and Alpine valleys; Central Italy; and The Southern region, including Sicily and the islands (Nicolis, 2013, p. 692–694). The distinctive characteristics of this period includes widespread use of bronze, an alloy of copper and tin, which fundamentally changed the production of tools, weapons, and ornaments. This innovation enabled the creation of more durable and specialized implements, marking a clear distinction from the Copper Age, where tools were primarily made from pure copper (Fokkens, Fontijin, 2013, p. 563–565).

Along with the technological advancements in metallurgy, Bronze Age witnessed the development of new weapons such as daggers, swords, and spears, as well as novel decorative ornaments. These materials and designs were not seen during the Copper Age, suggesting a shift towards more complex forms of material culture. The period also witnessed improvements in farming tools, which further facilitated agricultural production. The Bronze Age in Italy also saw notable advancements in pottery techniques, with ceramics becoming more refined and increasingly decorated with geometric patterns and motifs. These advancements reflect broader shifts in production practices, as local artisans began to specialize in ceramics and metalworking (Holloway, Lukesh, 2015, p. 133–144).

Furthermore, small, agriculturally-based villages began to increase in both: size and population. Early settlements were typically located on hilltops for defensive purposes, a characteristic of the Middle Bronze Age (c. 1700–1300 BCE). However, as the period progressed, larger, more complex settlements were established on flat land. These villages were characterized by larger houses, often circular or rectangular in shape, and constructed with a combination of wood and clay (Nicolis, 2013, p. 695). This shift in settlement patterns reflects the growing social complexity and the need for more extensive communal living arrangements.

The social structure of Bronze Age Italy also began to evolve. The increasing complexity of settlements and the accumulation of wealth led to the emergence of social stratification. Evidence from grave goods suggests the presence of an elite class, whose wealth and status were reflected in the quality and quantity of items buried with them. These goods, such as fine pottery, metalwork, and weapons, indicate that certain individuals or families held greater economic and social power than others (Cavazzuti, Arena, 2020, p. 69–72).

Economically, the Bronze Age saw important developments in agriculture and animal husbandry. New crops, including millets, were introduced and cultivated alongside traditional crops like, wheat and barley. The domestication of livestock became a key component of the economy, with animals being used not only for consumption but also for the production of secondary products such as wool and dairy. As hunting gradually declined, agriculture, animal husbandry, and specialized production of pottery and metalwork emerged as the primary economic activities (Bartosiewicz, 2022, p. 69–70).

Paleodietary analysis is the study of past diets. It encompasses archaeology, zooarchaeology, archaeobotany, food residue analysis, and stable isotopic investigations. In reality, it is more than just the study of historical food intake; it is also the study of the interactions between animals and humans (Pate, 1994, p.189). Stable isotopic analysis is one approach used to analyze the paleodiet of remains, which is becoming increasingly relevant for scientists studying animal husbandry, food, and mobility (Davitashvili, 2023, p. 2).Isotopes are engaged in various archaeological questions including human-animal interrelationships, food consumption, crop adaptation, husbandry practices, ecological subsistence, and infant feeding (DeNiro, Epstein, 1978, p. 341). After consumption of plants, animals use the carbon, nitrogen and sulfur, that composes plant tissues to construct their own tissues through biochemical processes. Carbon, nitrogen and sulfur are enriched in heavier isotopes at each step of the food web, which can be used to assess the relative role of various food groups to past human diets using quantitative methods (Tafuri et al., 2023).

"By measuring the proportion of C_3 versus C_4 diets in the population is essential to productively investigate dietary dependence on different kinds of plants" (Davitashvili, 2023, p. 11). $\delta^{13}C$ (‰) values can distinguish between C_3 (-28–22‰), C_4 (-14–16‰), and CAM (-11–9‰) plants and their consumers, as carbon fractionation varies across photosynthetic pathways and ecosystems (O'Leary, 1988, p. 330–331). Furthermore, trophic level with nitrogen stable analysis and environmental relationships through sulfur (Zerkle et. al, 2009, p. 292). Great part of the isotopic studies focuses on the reconstruction of past diets using collagen, as it. is usually well preserved in archaeological contexts (Katzenberg, 2009, p. 416) and is the most abundant protein in bones (Pate, 1994, p. 163–164).

The research presented in this article is part of the author's master's thesis (Investigating diet of Nogarole Camponi (Northern Italy) through carbon, nitrogen and sulfur isotope analysis of animal bone collagen), written during her studies. As such, some quotations and paraphrasing from the thesis will be included to incorporate the relevant data into this article. Research will rely on published zooarchaeological isotopic data from different archaeological sites of Peninsula region in the period of Bronze Age. One of the main objectives of this research is to show the significance of studying faunal remains through isotopic analysis to reconstruct past life. Furthermore, this research will lay out the main advantages of zooarchaeology as an independent science for examination of past diets and, to represent the significant role of database in studying and analyzing past. The database presented in this study is built on prior research, and includes archaeological sites from all around Italy. It includes supportive information that offer taxonomic characterization of the samples, their geographical coordinates, chronology, current location, species, genera, trophic category, family, ecosystem, sampled element and isotope ratios of bone collagen. This Database can be used in different research purposes, including but not limited to: reconstruction of past human and animal diet, husbandry strategies, spatial mobility, detection of Bronze Age period. Furthermore, study underlines the importance of database as a tool for interdisciplinary studies to mark regional similarities and differences through Italy in Bronze age. One complied isotopic dataset provides wide range of historical, palaeobotanical, zooarchaeological, biological and geological information, which allows researchers to address various questions simultaneously. To construct the dataset, we collected and organized published articles and theses according to specific criteria, which are discussed in the following chapters. Additionally, statistical software was employed to analyze the isotopic markers identified in each article. Graphs and plots were used to visualize the results and facilitate interpretation, particularly with regard to identifying regional and species-related differences and similarities.

ZOOARCHAEOLOGY

Importance of Zooarchaeology

Studies of faunal remains, which were formerly extremely rare, are becoming increasingly accessible. Such studies involve qualitative osteological approaches, which include the gathering of taxonomic data and bone alteration (Gifford, Gonzalez, 2018, p. 3–4). Among the goals of zooarchaeology are the identification of species, sex, and age, as well as the study of ancient ecological phenomena, economics, diet, taxonomic relationships, health status, human choices, and actions related to the use of animals for food and secondary uses such as milk, wool, or other purposes (Birch, 2013, p. 81–83). However, studying animals to understand their significance in the development of many complex cultures is undeniably significant for diverse time periods in archaeology's history. Furthermore, diverse fields, such as paleontology, ecology, biological anthropology, and geology provide different viewpoints to Zooarchaeology (Zangrado et al., 2014, p. 127–133; Davitashvili, 2023, p. 4).

While comparing isotopic analysis of animal bones against that of human bones, there will be clear advantages. First and foremost, faunal remains are abundant at most sites, allowing scientists to collect samples. Furthermore, faunal remains provide information not only about the diet but also about environmental variables and local flora. It delves deeper into plant cultivation dating back to the prehistoric period. As an example, in some cases, we find traces of plants consumed by animals, yet, not by humans, revealing how and when the plants were cultivated (Matsubayashia, Tayasu, 2019, p. 37–38).

"Besides dietary factors, stable isotopes such as strontium are an applicable method to study mobility in animals, which is important to observe site formations, seasonal uses, and migration processes. One of the most important parts of discussing some topics with stable isotopes of animals is to have an integrated knowledge of ecology, physiology, and osteology in order to interpret isotopic data" (Davitashvili, 2023, p. 5; O'Cooner, 2000, p. 41–43). Also, important animal husbandry practices vary by species. This provides us with more information about human behavior and socio-religious actions. Some domesticated herbivores do not require location changes, so they can be kept in one spot for eating, making them simple to keep and govern. Others, on the other hand, are more mobile, require frequent pasture changes, and are typically let to graze. Grazing in animal agriculture refers to allowing animals to consume wild vegetation outside. On therefore, rather than being fed as they are on feedlots or in the confined regions of industrial farms, the animals can look for and consume the products they want within a specified space (R.H. Hart et al. 1993, p. 85–86) Cattle, according to these definitions, are animals that can be kept in one location, provided they receive the necessary food, without the need to travel long distances. In contrast, goats and sheep require changing pastures. Goats are browsers, meaning they prefer eating tree leaves and shrubs, which makes their dietary needs different from those of sheep or cattle. Another factor is that goats tend to be more defensive in nature; they are capable of traveling easily and can navigate steep hills without difficulty, making them more difficult for predators to catch. This also makes them harder to manage, as they need more space to find suitable plant-based food. Sheep, however, are more vulnerable to predators and require constant care (Garcia et al., 2012, p. 49–64; Davitashvili, 2023, p. 25–26).

Animal exploitation in Bronze Age

Animal exploitation was widespread in Bronze Age Europe. With demographic changes and the growth of settlements, it became crucial to diversify animal resources and consumption (Bartosiewicz, 2022, p. 73). As a result, archaeozoology has become a key discipline, helping to explore cultural and temporal divisions in archaeology. Both quantitative and qualitative analyses must be conducted with precision using systematically organized datasets to prevent confusion and errors in future research (Davitashvili, 2023, p. 25). For example, distinctions between the bones of sheep and goat are hardly identifiable, and this creates difficulties for using them in data. There are various publications with morphological criteria for those species, which have improved with time. Despite this, it is still problematic for some researchers, thus it is frequently put combined, as sheep/goat, for example in the most published publications that are used in this database (Jeanjean et. al, 2022, p. 1–2). Also, incompatible reporting of renewable wild animal products can be confused with hunting (O'Conner, 2000, p. 37–38). Also, incompatible reporting of renewable wild animal products can be confused with hunting (O'Conner, 2000, p. 37–38). Although there are some uncertainties, the analysis of animal remains and the use of databases are essential for reconstructing the lifestyles of past populations and understanding the evolution of the Bronze Age, which is the primary focus here. The abundance of domesticated animals played a significant role in the economy of Bronze Age societies. The ways in which animals were used and exploited varied across both time periods and regions (Roblíčková, 2003, p. 480–491). For example, cattle made up 49% of the domesticated animals, followed by sheep and goats at 31%, and pigs at 20%. These proportions varied across different regions, indicating that the domestication of animals was influenced by environmental conditions and the type of settlement. The local environment played a critical role in the distribution of animals, their adaptation to human populations, and their use in daily life (Davitashvili, 2023, p. 25; Bartosiewicz, 2022, p. 73). Even small variations in altitude affected the variety of species present. This suggests that the climate and environmental factors contributed to the widespread domestication of animals, particularly in regions like Italy during the Bronze Age. Cattle remains accounted for more than 75% of the total weight of bones found in many settlements. The domestication of horses is particularly noteworthy, as horses were fully domesticated during the Bronze Age, while the exploitation of other animals began in the Neolithic period. In Northern Europe, many horses were initially wild, with horse domestication becoming more widespread around 3500 BCE (Davitashvili, 2023, p. 26; Bertolini, Hohenstein, 2016). "As an argument, we can bring up the horse milk residues on the Bronze Age pottery from northern Europe. The role of horse became more essential in the middle bronze ages, which might be connected to the mobile way of life" (Davitashvili, 2023, p. 26). Sheep and goats were also vital domesticated animals during this time. The increase in their numbers in the Early Bronze Age is believed to be linked to climate changes, as these animals thrive in dry grassland habitats. This is one reason why pigs were less common than caprines. Moreover, caprines were easier to trade and tax than pigs. In northern Italy's Terramara plains, the proportion of sheep and goats increased to 40% in the Middle Bronze Age. Mutton was a significant part of the diet, and pigs were also frequently consumed. In Hungary's Vartya culture, only 15% of pig bones came from fully grown animals, with the majority slaughtered before reaching adulthood. This reflects the importance of mutton in the diet, although pigs were also popular. In the Terramara region of northern Italy, goats adapted well to the mountainous environment and poor soils, making them a widespread domesticated animal. Dogs, too, were common in settlements and burials throughout Italy (Cremaschi, 2006). Zooarchaeological studies also identified wild species such as red and roe deer, wild boar, fox, and hare (Vretemak, 2010). These findings are crucial for understanding the botanical and ecological aspects of past environments (Davitashvili, 2023, p. 26).

Justification of creating Faunal isotopic database of Bronze age Italy

The creation of databases is also crucial and essential process in the study of stable isotopes. The collection, sorting, and consolidation of data into common databases allow researchers to easily access information that is accurate and constantly up-to-date. It also enables comparisons with materials from other sites, leading to more reliable conclusions based on the broader context of regional studies. The development of these databases involves academic personal from various parts of the world, centralizing a large amount of information, which enhances collaboration among researchers.

During our stable isotopic studies of faunal remains from Nogarole Camponi (northern Italy, Bronze Age), we encountered the realization that in order to gain a more comprehensive understanding of the site's dietary practices, it is crucial to consider the broader regional context. However, it became evident that there is a notable lack of compiled isotopic databases of faunal remains within this region. Due to this fact we raised the idea of creation faunal database of Bronze Age Italy. It helped us to make wider insights into discussion part of our specific studying area. This is why we believe that faunal isotopic database of Bronze age Italy will be helpful for the researchers working in this field.

One of the largest stable isotope database is IsoArch, which includes more than 65,000 entries on human, animal, and plant data. This platform supports the development of interdisciplinary research and allows for comparisons of dietary habits across different periods, social classes, or regions, which ultimately forms a fundamental basis for reconstructing paleo-dietary patterns.

Furthermore, there are several more studies of compiling the isotopic information in one dataset, which is very helpful for the researchers who are interested in the current chronology or context. One of it is *Isotòpia,* the isotopic database for classical antiquity (Formichella et. al., 2024). This is open access dataset for all interested researchers accumulated over 36,000 entries of human, animal and plant samples dated from 800 BCE to 500 CE. The most important part of this database is that it fills the gap of isotopic measurements of plants and animals for late antiquity.

Another important stable isotopic database should be considered *Isotoporum Medii Aevi (*Coccoza et. al., 2022). It is a multi-Isotope database for Medieval Europe, which gathers 50,000 isotopic measurements for bioarchaeological samples. This database is very useful for paleoenvironmental and climatic studies. Beside this, the main usage of the database is to identify the different lifestyle of humans based on their diets in different geographical locations within Europe and the role of food in historical transitions.

METHODS

Quality criteria for data

I have assembled a database containing stable carbon, nitrogen and sulfur isotope ratios from animal tissues sampled solely within Italy territory in Bronze Age period. These ratios are reported without applying any trophic discrimination factor and checked several times before used it to match quality criteria standards. Additionally, tissue preservation is of paramount importance in this context, since bioarchaeological material undergo changes in soil (White, Hannus, 1983, p. 316–322), various methods are used to assess tissue preservation, such as evaluating collagen yield and elemental criteria for assessing contamination. In collagen, the most commonly used organic tissue for stable isotope analysis of carbon, nitrogen, and sulfur, elemental criteria are used to assess foreign contaminants and collagen yield (%) after extraction from bone and teeth (Klinken, 1999, p. 687–695). Carbon, nitrogen, and sulfur content (%) and atomic ratios (C:N, C:S, N:S) are commonly used elemental preservation indicators. According to DeNiro and Ambrose quality criteria standard is accessible when C/N atomic ratio is between 2.9 and 3.6 (DeNiro, 1985, p. 806– 809). "The C/N ratio can be calculated as the percentage of C divided by the percentage of N and multiplied by 14/12 due to the atomic weight difference (%C/%Nx14/12)" (Davitashvili, 2023, p. 38; Ambrose, DeNiro, 1986, p. 397–398). In the case of Sulfur, it is accessible when and C/S ranges from 300 to 900 and N/S from 100 and 300 for Mammals and C/S ranges from 125 to 225 and N/S from 40 to 80 for fish (Nehlich, Richards, 2019, p. 56–75).

Species, genera, classes and family names were checked against the "Global Biodiversity Information Facility" using the "rgbif".org.

Geographical coordinates were meticulously verified using Google Earth Pro for precise archaeological site locations. In cases where the article lacked this information, coordinates were extracted directly from the software.

Data structure and sources

Database covers published stable isotopic measurements ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) from the entire Bronze Age Italy. It is relied on scholarly publications, archaeological reports, and academic dissertations written in English or Italian. It includes 13 publications from 2009 to 2022 that cover the Italian region during the Bronze Age (full list given in supplementary information). The main methodology was to collect literature, primarily through Google Scholar, with the keywords "stable isotopes of faunal remains," "Italy Bronze Age", and "Animal Studies from Italy region." After collecting the data, it was checked several times before being grouped into sections in an excel file. All the links of the publications are available in the Database.

Faunal database from Peninsula region is presented in a single file containing an Excel with several columns. it accounts for the reference to the original publication with their link, geographical orientations (Longitude, Latitude), exact location, name of the archaeological sites, chronology of the archaeological site, animal diet habit (herbivore or carnivore), species, groups, ecosystem, genera, family, class, habitant, elements, and isotopic measurements as published in different studies. Some of them were based on just carbon and nitrogen studies, while others have access of Sulfur analysis too. Moreover, it's important to note the underlying information regarding the classification of dietary guilds. Herbivores primarily consume producers, such as plants, algae, or phytoplankton. Omnivores, on the other hand, have a varied diet consisting of both animal and plant-based foods in differing proportions. Carnivores exclusively feed on other animals. Additionally, a baseline used in database was established for each habitat type, including terrestrial, freshwater, and marine environments.

Aside from classification of animal guilds, the database is also divided by location. Samples come from throughout the Peninsula and employed at various archaeological sites in Italy's north, south, and center regions in total at 23 archaeological sites reported in the literature. This made it easier for us to compare statistical results and discuss them. Each archaeological site is accurately measured, whether from a publication or using Google Earth Pro to determine longitude and latitude. Furthermore, for visualization purposes, created a map of all archaeological sites in the QGIS program (fig. 1).

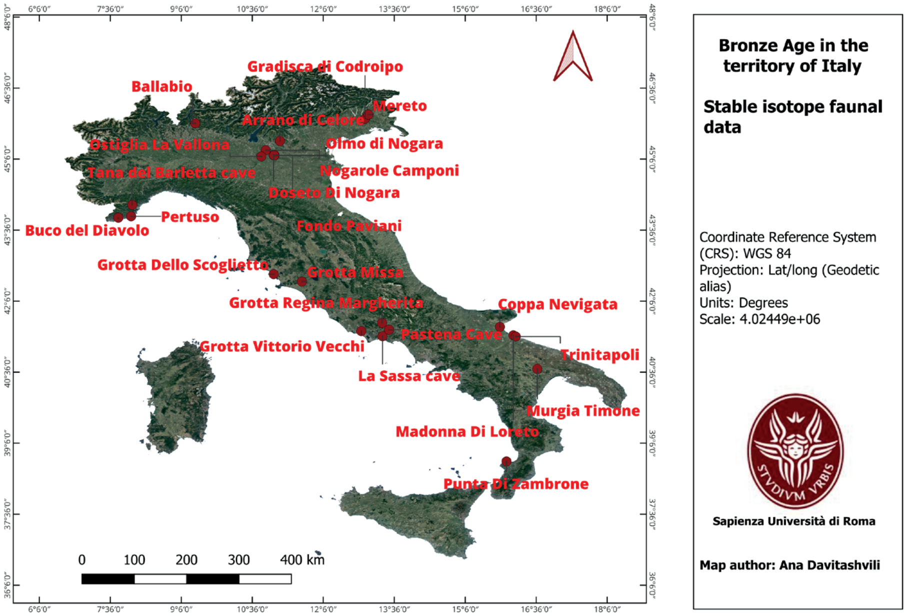

Fig. 1. List of sites mentioned: Ballabio, Gradisca di Codroipo, Arrano di Celore, Mereto, Olmo di Nogara, Ostiglia La Vallona, Tana Del Barletta cave, Doseto Di Nogara, Pertuso, Buco Del Diavolo, Fondo Paviani, Grotta Dello Scogliato, Grotta Missa, Grotta Regina Margherita, Coppa Navigata, Pastena cave, Grotta VITTORIO Vecchi, La Sassa cave, Trinitapoli, Murgia Timone, Madonna Di lorento, Punta Di Zambrone (QGIS mapping) (Ana Davitashvili) (edited from Davitashvili, 2023)

Description of Data

The Faunal Isotopic Database from the Italy comprises 209 observations of $\delta^{13}C$ and $\delta^{15}N$, along with 15 observations of $\delta^{34}S$, derived from sampled animals. These animal samples encompass both wild and domesticated species, including cattle, sheep/goat, dog, pig, deer, horse, marine and freshwater fish, hare, and fox. All entries originate from the vertebrate group, with the phylum identified as Chordata. The dataset encompasses a total of 10 families, 10 species, 2 classes, and 10 genera.

The majority of samples originate from terrestrial ecosystems, with only 3 samples from freshwater environments and 1 from marine habitats. The data presented encompasses both coastal and continental areas. A primary observation is the lack of isotopic information for many fauna species. Additionally, some of the references do not provide sampling details such as the bone element used. Furthermore, descriptions are often limited in terms of sex and age categorization In the Database columns are filtered according to Archaeological site, to be easier for access to the readers.

Statistical tests

"Isotopic measurements collected in the database were plotted and statistically explored. Descriptive statistics were calculated (standard deviation, mean, median, minimum and maximum for each species for the qualitative and quantitative analysis) with Excel 2013. A Chi-square test for comparisons between frequencies was run to check the type of distribution (normal vs non normal). The ideal uncertainty for repeated should be <0.2‰ for both carbon and nitrogen. Scatter plots were used to represent values for two different numeric variables, in order to observe relationships between them. Normal Distribution, also called Gaussian distribution is a symmetric mean, showing that data near the mean are more frequent than data far from the mean" (Davitashvili, 2023, p. 35; Patel, Read, 1996, p. 66–73).

"A Box Plot is a method for descriptive statistics, where numerical data with their quartiles are presented graphically. Each plot is divided into four quartiles. Quartiles are cut points and they divide the range of probability distribution into continuous intervals. For the Box plot, Nitrogen, Carbon and Sulfur values were filtered according to geographical territories to see the consumption of food in each location. This helps to analyze the data more precisely and facilitates possible interpretations (Nuzzo, 2016, p. 268–270).

Following the plotting of data through a Box plot, we ran some statistical tests. Firstly, it was necessary to identify whether the distribution was normal or not using the Shapiro-Wilk test. The aim of the test is to understand if the sample is normally distributed. If the p-value is less than 0.05 then the null hypothesis is rejected, and data is not normally distributed. The samples should not be less than 2 for the Shapiro-Wilk test to work. In the case of our Database, carbon values distribution was not normal, while nitrogen's was. To compare distributions for statistical analysis we used different tests: for carbon, a Kruskall Wallis H test (multiple groups) and for nitrogen One-way ANOVA" (Davitashvili, 2023, p. 36).

Ultimately, the statistical tools enabled us to conduct pairwise comparisons between different geographical locations. They provided insights into which regions had a broad distribution of foods and allowed for meaningful interpretations. Furthermore, these tools facilitated the visualization of the data, offering a clearer way to comprehend and present the findings.

RESULTS AND DISCUSSION (POINT OF USE)

The faunal isotopic data presented in this article can serve multiple research objectives, including: 1) investigating animal husbandry practices in Italy during the Bronze Age, 2) supporting palaeobotanical studies, and 3) analyzing the Bronze Age as a period of the introduction of new crops and agricultural practices in Italy. This dataset provides an opportunity to track dietary variations across regions, from Northern Italy to the southern islands. It also allows for comparative interpretations between animal species, which are crucial for understanding the herding and breeding practices of prehistoric populations**.** To show these possibilities, as an example, I would like to present the results and discussion part based on the statistical methods which were done on the isotopic markers found in the articles from the database.

“Tables 1 and 2 report the descriptive statistics for each species. According to the results, the mean, standard deviation, median, minimum, and maximum are shown here. The mean $\delta^{13}C$ for all fauna is -20.2‰ with a range from -18.3‰ to -21.9‰ (tbl. 2). The mean $\delta^{15}N$ value for all fauna is 6.1‰ with the range from 1.4‰ to 10.5‰ (tbl. 1)” (Davitashvili, 2023, p. 47).

Tbl. 1. Descriptive Statistics of Nitrogen from database (Bronze Age Italy)
(edited from Davitashvili, 2023)

			Mean d15N				
	Number of samples	**Mean**	**1SD**	**2SD**	**Median**	**Mini-mum**	**Maxi-mum**
Bos Central	10	5.5	1.5	2.9	5.4	4.3	9
Bos North	30	5.3	1.5	3.1	5.1	2.9	9
Bos South	12	6.0	1.3	2.5	6.2	3.4	7.7
Canis Central	5	6.2	0.6	1.2	6.7	5.6	6.7
Canis North	5	7.5	1.1	2.1	7.5	6.7	8.2
Canis South	6	7.2	1.1	2.2	7.5	5.3	8.3
Cervus Central	4	4.6	0.6	1.2	4.3	4.2	5.3
Cervus North	4	4.9	1.1	2.2	4.9	3.2	6.3
Cervus South	12	4.8	2.3	4.6	5.2	0	7.2
Cyprinidae Ind. North	3	10.6	2.4	4.9	11.1	7.9	12.7
Epinephelus South	1	5.8			5.8	5.8	5.8
Equus North	2	4	0.7	1.4	4	3.5	4.5
Lepus North	3	2.5	1.5	3.0	2.5	1.4	3.5
Lepus South	1	4.9			4.9	4.9	4.9
Ovis Vel Capra Central	17	4.4	1.0	1.9	4.5	1.9	5.8
Ovis Vel Capra North	40	4.6	1.6	3.3	4.4	2.3	8.3
Ovis Vel Capra South	10	6.8	0.9	1.9	6.9	5.6	8.5
Sus Central	9	4.9	0.9	1.9	5.1	2.9	5.9

Sus North	25	5.9	2.0	4.0	5.2	3.2	9.7
Sus South	9	5.8	1.7	3.3	5.8	3.0	8.7
Vulpes Central	3	7.7	0.3	0.5	7.7	7.5	8

Tbl. 2. Descriptive Statistics of Carbon from database (Bronze Age Italy)
(edited from Daviatshvili, 2023)

			Mean d13 C				
	Number of samples	**Mean**	**1SD**	**2SD**	**Median**	**Mini-mum**	**Maxi-mum**
Bos Central	10	-20.6	1.2	2.5	-20.5	-22.5	-18.3
Bos North	35	-19.6	1.5	3.1	-19.4	-22.1	-15.5
Bos South	12	-19.9	1.4	2.9	-20.52	-21.21	-17
Canis Central	5	-19.4	0.9	1.9	-19.5	-20.5	-18.2
Canis North	5	-19.8	0.3	0.6	-19.8	-20	-19.6
Canis South	6	-18.3	1.7	3.5	-18.8	-20.04	-16.1
Cervus Central	4	-21.4	0.9	1.8	-20.9	-22.4	-20.8
Cervus North	4	-20.0	1.5	3.0	-20.9	-20.9	-17.4
Cervus South	12	-17.7	6.7	13.4	-20.23	-21.23	0
Freshwater fish	3	-22.6	2.1	4.2	-22.7	-24.7	-20.5
Marine fish	1	-18.2			-18.2	-18.2	-18.2
Equus North	2	-20.1	0.1	0.3	-20.1	-20.2	-20
Lepus North	3	-21.1	1.2	2.4	-21.05	-21.9	-20.2
Lepus South	1	-20.9			-20.9	-20.9	-20.9
Ovis Vel Capra Central	17	-20.9	0.8	1.6	-21.05	-22	-19.2
Ovis Vel Capra North	40	-20.3	1.1	2.2	-20.5	-22	-16.7
Ovis Vel Capra South	10	-19.6	1.8	3.5	-20.17	-20.7	-14.9
Sus Central	9	-21.0	0.4	0.8	-20.95	-21.7	-20.4
Sus North	25	-18.4	3.7	7.3	-20.4	-21.4	-11
Sus South	9	-20.2	1.2	2.4	-20.44	-21.49	-16.5
Vulpes Central	3	-19.5	0.9	1.7	-19	-20.5	-19

On the diagram, all of these are put together. Scatter plots demonstrate the importance of species connections (fig. 2).

The scatter plots show that the average of carbon value for all species are mostly on the same level. The ratio of stable isotopes within dogs, pigs and deer has minor differences but still they all have low carbon values than other species. In the case of nitrogen there are more differences. When we compare species, we can see that Northern pike has the highest nitrogen value, which is not surprising given the longer food chain in water organism and the fact that nitrogen values for fish are always higher when compared to terrestrial animals. Dogs and foxes have the highest nitrogen levels after fish, likely due to their omnivorous diet. Then we have pigs, sheep/goat, marine fish, cattle respectively and lastly the hare with minimal nitrogen ratio 1.4‰. What is more, Nitrogen analyses do not show location-specific frequency.

To discuss, when comparing dogs and deer to pigs, pig isotope values should be higher than those shown in the figure, as pigs are also omnivores with nitrogen

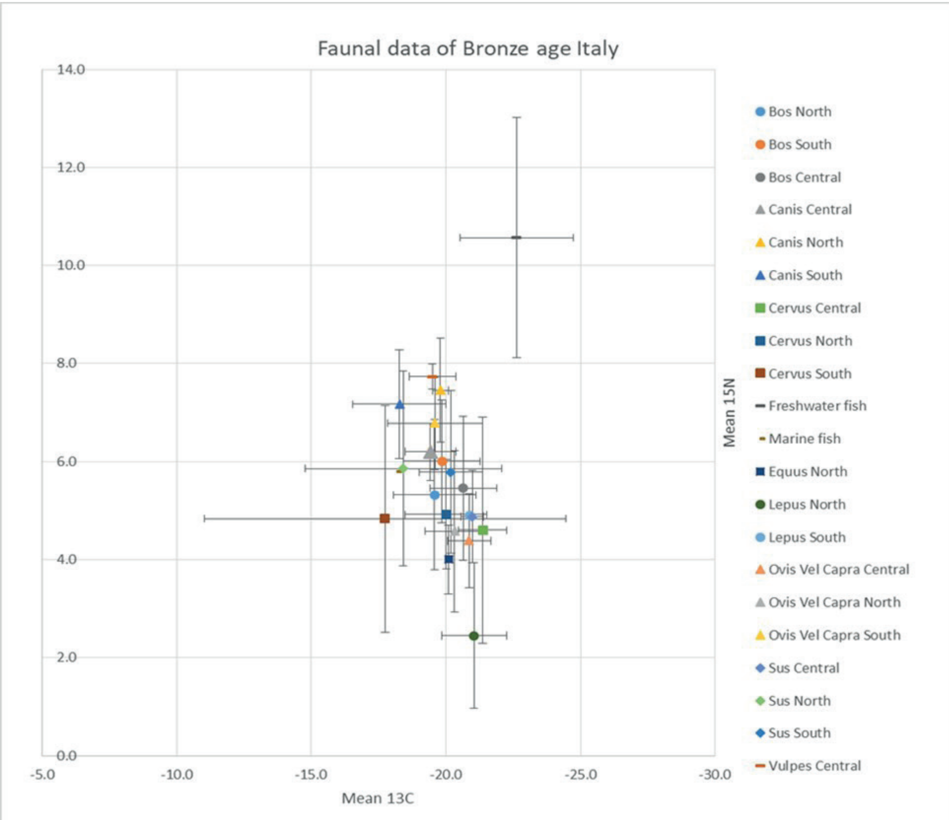

Fig. 2. Scatter plot of faunal database (Bronze Age Italy territory) (Ana Davitashvili)
(edited from Davitashvili, 2023)

values similar to dogs and deer. This may give rise to the idea that pigs were fed by humans, specifically with plants, that they were kept animals, and that they did not roam freely. While dogs should eat the leftovers or hunt on their own. Overall, statistics show that the main agricultural product of Bronze Age animals was C3 plants, such as wheat, with only a few traces of millet found in the northern regions. According to Tafuri et al. (2009), the archaeological sites of Fondo Paviani and Olmo di Nogara were among the first in Europe to cultivate millet as a significant crop. Since the database includes not only early Bronze Age settlements but also those from the middle and late periods, a question arises: why is there so little evidence of millet, despite the fact that humans were already familiar with the plant and beginning to use it? One possible explanation is that early millet cultivation was still in its developmental stages, and animals were still being fed wheat. This argument is supported by the observation that pigs, dogs, and deer show a higher concentration of millet in their remains than other animals. Among domesticated animals, pigs and dogs have diets most similar to humans, which suggests that they (dog, pig) may have been fed millet earlier than other species, while deer should be consuming millet in wild ecosystem. Another important factor to consider is the lack of zooarchaeological samples, which would provide more detailed information on this topic. This highlights the critical need for studies in zooarchaeology, particularly those using stable isotopes, to better understand aspects of cultivation, animal husbandry, human mobility, and other socio-ecological dynamics.

Since stable isotope analysis on faunal remains is becoming increasingly popular for studying various aspects of past scenarios, this database will provide up-to-date knowledge of crop adaptation strategies, husbandry practices, climate variables, and additional information about population lifeways dating back to the Bronze Age Period. It will be particularly useful for researchers studying stable isotopes in the Peninsula region. Furthermore, the database should be expanded over time with new results to obtain complete information about the fauna of the Bronze Age peninsula region.

Data Availability statement

The author confirms that the entire Bronze Age Italy Faunal data set is available in online publication of this article as a free access link:

https://docs.google.com/spreadsheets/d/1iI0GqRWBQRo7wWJ70lORwIMJPId-S_z--/edit?gid=174792371#gid=174792371

Conflict of Interest

The author declares no conflict of interest.

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CREATING STABLE ISOTOPIC DATABASE OF FAUNAL REMAINS – BRONZE AGE ITALY

Summary

The article presents a comprehensive zooarchaeological isotopic database focusing on the Bronze Age period in Italy. This database comprises 209 samples from domesticated and wild animals across various regions of North, South, and Central Italy, accompanied by precise archaeological locations. The database is relied on scholarly publications, archaeological reports, and academic dissertations written in English or Italian, totally 13 publications from 2009 to 2022. It is presented in a single file containing an Excel with several columns. it accounts for the reference to the original publication with their link, geographical orientations (Longitude, Latitude), exact

location, name of the archaeological sites, chronology of the archaeological site, animal diet habit (herbivore or carnivore), species, groups, ecosystem, genera, family, class, elements, and isotopic measurements as published in different studies facilitating a comprehensive examination of the Bronze Age fauna in Italy.

The primary objective of this dataset is to underscore the significance of zooarchaeology as an independent discipline for investigating past diets, crop cultivation, and husbandry practices, thereby shedding light on the interactions between humans and animals during this period. Stable isotope analysis, a crucial tool in paleodietary studies, allows researchers to explore the dietary habits of past societies. Furthermore, it discusses the methodological approach employed in collecting and analyzing the data, including the preservation criteria for collagen, which is essential for stable isotope analysis. Database also provides insights into the distribution and utilization of different animal species during the Bronze Age, showcasing the varying degrees of domestication and exploitation across different regions of Italy. Statistical analyses conducted using the database reveal important trends in faunal isotopic compositions, indicating the predominance of C_3 plants in the diets of Bronze Age animals, especially in south part of Italy. The results also suggest potential shifts in crop cultivation practices, with implications for understanding agricultural strategies and human-animal interactions during this period.

Overall, the article underscores the value of zooarchaeological isotopic databases in advancing our understanding of past societies and their relationships with the natural environment. It serves as a valuable resource for researchers studying stable isotopes in the Bronze Age Peninsula region and lays the groundwork for future investigations into ancient diets, agricultural practices, and socio-ecological dynamics.