TOWARD AN EMBODIED IMPERIALIZATION OF LIFE: INVESTIGATING THE DIFFERENTIAL IMPACT OF IMPERIALISM ON 19TH CENTURY FRENCH AND RUSSIAN SOLDIER BIOLOGY

by

Sammantha Nicole Holder

(Under the Direction of Laurie Reitsema)

ABSTRACT

In this dissertation, I investigated how 19th century European imperial expansion and maintenance strategies shaped imperial army recruiting and provisioning practices, which in turn shaped imperial soldier biology through the mechanism of diet. Research focused on reconstructing the longer-term and later life diets of Napoleonic and Russian soldiers. Specifically, I used stable isotope analysis of bulk collagen on the ribs and femora of soldiers from Napoleon’s Grand Army (NGA) from the mass gravesite of Šiaurės miestelis, Vilnius, Lithuania (n=53) and Imperial Russian Army (IRA) soldiers from a cemetery at Mindaugo Gatvėje, Vilnius, Lithuania (n=41). I also employed amino acid compound specific stable isotope analysis (AA-CSIA) of a subset of NGA soldiers (n=20), capturing the full range of stable carbon and nitrogen isotope values at the bulk level. The results indicate that NGA soldiers consumed more heterogenous diets prior to and during military service and more of them experienced diet shifts later in life with military service than IRA soldiers. These diet differences can be attributed to differences French and Russian imperialism. France was actively expanding through warfare during the period of study with soldiers originating from and serving in campaigns across Europe, whereas Russia was focused on maintaining its imperial borders and young men were conscripted from the core of the empire and served primarily in eastern Europe. This study demonstrates how variability in imperial strategies differentially impacts the lives of imperial soldiers, who are often overlooked in studies of imperialism.

INDEX WORDS: Biological anthropology, Bioarchaeology, Stable Isotope Analysis, Imperialism, Warfare, Europe, Lithuania, France, Russia

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DEDICATION

To my grandmother, Nancy. Without you, none of this would be possible.

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CHAPTER 1

INTRODUCTION

RESEARCH CONTEXT

Dramatic political and economic transformations characterized late 18th and early 19th century Europe including imperialism and colonialism, urbanization, political revolution and warfare, and the onset of the Industrial Revolution (e.g., Crouzet, 1964; Hobsbawm, 1962; Roessler & Miklos, 2003). Each of these transformations was sparked by or sparked unequal power relations that had a significant impact on local biologies and cultures (Betsinger & DeWitte, 2020; Floud & Steckel, 2008; Komlos, 1998; Said, 1994; Wolf, 1982). They also had a significant impact on the biology of soldiers commissioned (forcibly or voluntarily) with expanding and maintaining European empires often in the forms of disease and diet (Berti, 2020; Cook, 2001; Curtin, 1998; Evans, 1988; Rodrigues, 2014; Talty, 2009). In this dissertation thesis, I explore the invisible ways that early 19th century imperialism shaped the biology of soldiers that served in Napoleon's Grand Army or *Grande Armée* (NGA) and the Imperial Russian Army (IRA) by tracking change in diet over time using biochemical markers of multiple skeletal elements that reflect different periods of time in a person's life.

Human diet provides insight into an individual person's life as what a person eats reflects nutritional needs, environmental constraints, individual preference, identity, and sociopolitical and economic processes (Anderson, 2014). Diet can be particularly useful for understanding social organization, power, control, and agency (Hastorf, 2017). Imperialism can reshape dietary practices through forced enculturation and reorganizing food economies by controlling labor practices and limiting access to food resources (Amin, 1977, 2012; Wolf, 1982). In this project, I explore how 19th century imperial expansion and maintenance strategies shaped soldier biology through the mechanism of diet. Specifically, I track changes in diet long-term to later life diet among soldiers that served in NGA and

IRA. I integrate a theoretical framework that draws on critical social theory from science and technology studies (STS) and social epidemiology with stable isotope analysis of different skeletal elements to contribute to the literature on the bioarchaeology of imperialism and warfare by examining how Napoleonic and Russian soldier diet and nutrition was shaped by imperial expansion and maintenance through recruiting and provisioning practices.

THEORETICAL AND ANTHROPOLOGICAL SIGNIFICANCE

This research contributes to anthropological knowledge in three domains: 1) the role of social structures in shaping human biology, 2) how imperialism and warfare shapes human biology, and 3) a multi-scalar, synchronic and diachronic, and comparative approach to studying change and maintenance in human behavior.

Biological anthropologists frequently employ biocultural frameworks to examine human biology in the present and the past (e.g., Goodman, Brooke Thomas, Swedlund, & Armelagos, 1988; Goodman & Leatherman, 1998). Biocultural frameworks stress the interactions between culture, social structures, and physical environments in shaping human biology (Zuckerman & Armelagos, 2011). Within this domain, political-economic approaches to critical social theory emphasize that “the roles of political and economic variables add to an understanding of the kinds of factors affecting human biology” (Blakey, 1988, p. 494). Theoretical frameworks, concepts, and topics in this area include structural violence (de la Cova, 2012; Klaus, 2012; Nystrom, 2014; Robbins Schug, Gray, Mushrif-Tripathy, & Sankhyan, 2012; Stone, 2012), intersectionality (Mant, de la Cova, & Brickley, 2021; Yaussy, 2019), marginalization (Mant & Holland, 2019), social control (Harrod, 2017), politicization of the dead (Pérez, 2012), and poetics of violence (Pérez, 2016). What these different approaches have in common is examining how domination and control that exist within hierarchies of power shaped the lived experiences and biological outcomes of marginalized individuals or groups. In this dissertation research, I draw on political-economically grounded critical social theory from the field of STS, a largely untapped body of literature in bioarchaeology that offers new questions and framings to studies of human biology, past and present.

A focus on soldier diet provides a novel means to explore the impact of imperialism and warfare on bodies as diet is influenced not only by nutritional needs, but by ecological and cultural processes (Anderson, 2014). Both imperialism and warfare shape diet by controlling access to food resources, reorganizing food economies, and other structural mechanisms that create or exacerbate existing inequalities (Klaus, 2012; Tung, 2012). While imperialism and warfare are intimately intertwined as imperial expansion and maintenance frequently occurs through interpersonal violence and warfare, they are often treated separately in the bioarchaeological literature (for exceptions see Andrushko & Torres, 2011; Tung, 2007, 2012; Tung, Miller, DeSantis, Sharp, & Kelly, 2016), especially when it comes to dietary studies. The separate treatment of imperialism and warfare in bioarchaeology in studies that focus on diet has led to a false binary in the literature where imperialism research focuses on local communities under imperial rule and comparisons between core versus periphery and warfare focuses predominantly on documentation, particularly when focusing on the recent past. Imperialism-focused bioarchaeological research has found changes in diet among some groups under imperial rule (Kellner & Schoeninger, 2008), maintenance of diet among other groups under imperial rule (Buzon, Conlee, Simonetti, & Bowen, 2012; Toyne, Church, Tello, & Gamarra, 2017; Tung & Knudson, 2018), and variation among sites within an empire (Crowe et al., 2010; Killgrove & Tykot, 2013). Warfare-focused bioarchaeological research tends to focus on reconstructing typical soldier diets and diet variation (Emery, Prowse, Schwarcz, & Brickley, 2015; Holder, Dupras, Jankauskas, Williams, & Schultz, 2017; Raynor & Kennett, 2008; Roberts et al., 2012). Both are important as not all imperial control happens through physical violence and warfare and not all warfare occurs to expand and maintain imperial territories. However, bringing together these two bodies of literature to study imperial soldiers offers another avenue to explore how imperialism and imperial warfare variably impact different groups with greater nuance than tropes that depict soldiers as mere tools of interpersonal violence by imperial nations.

This project integrates multi-scalar, synchronic and diachronic, and comparative approaches to studying change and maintenance in human behavior. By exploring changes in diet over time by comparing different skeletal elements that capture different periods in a single person’s life, this project addresses how imperial control over soldier lives operates at the individual level. By exploring diet heterogeneity over time (again by comparing different skeletal elements), this project address imperial control at the group level. Additionally, comparing diet heterogeneity at a single point in time, I explore change over time beyond a single person or population as is common in diachronic bioarchaeological studies (e.g., Beaumont & Montgomery, 2016; Lamb, Evans, Buckley, & Appleby, 2014; Reitsema & Vercellotti, 2012; Sealy, Armstrong, & Schrire, 1995). This multi-scalar, -temporal, and comparative perspective improves current understandings of the implications of imperialism on human bodies in the past by speaking to broader patterns how imperialism shapes soldier biology through both recruiting and provisioning practices.

BRIEF DESCRIPTION OF MATERIALS AND METHODS

Stable carbon and nitrogen isotope analysis of archaeological bone collagen is a well-established method of diet reconstruction of protein consumption in past human populations (DeNiro & Epstein, 1978, 1981; van der Merwe & Vogel, 1978; Vogel & van Der Merwe, 1977). Stable carbon isotope values vary systematically between classes of plants with different photosynthetic pathways and across ecosystems. For example, C_3 plants (e.g., most fruits and vegetables and some grains such as wheat, barley, rye) exhibit $\delta^{13}C$ values that are lower than C_4 plants (e.g., millet, corn, sorghum, sugar)(Bender, 1971; B. N. Smith & Epstein, 1971). Marine plants and fish have higher $\delta^{13}C$ values than terrestrial C_3 plants and freshwater fish but overlap with terrestrial C_4 plants (Fuller, Müldner, Van Neer, Ervynck, & Richards, 2012; Park & Epstein, 1961; Schoeninger & DeNiro, 1984). Stable nitrogen isotope values increase systematically with trophic level (Minagawa & Wada, 1984), providing insight into plant versus animal protein consumption. The latter can also be useful in distinguishing consumer diets between ecosystems as marine ecosystems tend to have more trophic levels and there are source differences in nitrogen in waters (Schoeninger & DeNiro, 1984; Sigman, Karsh, & Casciotti, 2009).

Compound-specific stable isotope analysis of individual amino acids (AA-CSIA) has become increasing utilized as an alternative to the analysis of bulk tissues to reconstruct diet in past human populations (e.g., Fogel & Tuross, 2003; Jarman et al., 2017; Styring, Sealy, & Evershed, 2010). This method has several benefits over stable isotope analysis of bulk tissues: data can be compared across an array of temporal and geographic contexts (Honch, McCullagh, & Hedges, 2012), diet can be reconstructed in the absence of a faunal baseline (Naito, Chikaraishi, Ohkouchi, Drucker, & Bocherens, 2013), and the potential impact of manured plants on reconstructing human trophic levels can be addressed (Styring et al., 2015).

Three skeletal samples from late 18th to early 19th century Europe are included in this study. Study samples include NGA soldiers from the site of Šiaurės miestelis, Vilnius, Lithuania, IRA soldiers from the site of Mindaugo gatvėje, Vilnius, Lithuania, and British Royal Navy (BRN) sailors from the sites of Haslar, Gosport, UK (n=20), Plymouth, UK (n=50). Isotopic data for BRN sailors comes from Roberts et al. (2012) and is primarily utilized for intergroup comparisons. All other samples were prepared and analyzed in the present study.

Siaurės miestelis

This mass gravesite is located in “North Town”, Vilnius, north of the city center. It was initially discovered during a construction project on the site of a former Soviet Union Army barracks in 2001 and excavated in Spring and Fall 2002 (Signoli et al., 2004). The area contains barracks built in the 19th century that at various times in the 19th and 20th centuries housed soldiers from the IRA, Polish soldiers, and served as a USSR military base. Material remains indicated the mass grave contained the remains of soldiers associated with Napoleon’s multi-ethnic Grand Army that died during the Russian Campaign retreat in 1812. An estimated 20,000 or more soldiers died in Lithuania alone during the retreat (Austin, 2000), with this site being one of several mass graves suspected throughout the city. Buttons and uniform fragments indicate the presence of approximately 40 French army regiments, primarily infantry and cavalry, along with Italian, Polish, and Bavarian regiments (Signoli et al., 2004).

The mass grave was situated in a trench initially dug by Napoleonic soldiers in July 1812 during their march to Russia (Signoli et al., 2004). The trenches served as defensive fortifications during their advance to Russia. An initial trench measuring 40 m long and 10 m wide was excavated in March and April 2002 by a team of Lithuanian and French archaeologists and anthropologists. An extension of the trench was discovered in Spring 2002 and was excavated by the Lithuanian team in September 2002. Of the 3269 individuals excavated, most of the skeletal material was reinterred at the local Antakalnis military cemetery. A small portion of skeletal material was retained at the Department of Anatomy, Histology and Anthropology, Faculty of Medicine at Vilnius University as a legacy collection, a collection of material from past archaeological excavations that is curated for future research. Whole skeletons were not retained as part of the collection. Rather, a limited amount of skeletal material, primarily ribs and limb bones, was retained by the original investigators based on level of preservation and completeness of individual elements. Skeletal preservation showed no geographic patterning within the mass grave that would suggest that the best-preserved skeletons are a biased sample in terms of geographic origin, rank, or particular corps membership (Frank, 2001).

All skeletal material for this study comes from Plotas 3. A total of 53 individuals were included in this study based on the presence of both a femur and rib. Age and sex were estimated using standard methods following Buikstra and Ubelaker (1994). Fifty-two individuals were estimated to be male and one was estimated to be probable male. Age at death estimates ranged from 15-18 years to 40-50 years.

Mindaugo Gatvėje

This cemetery is located in Naujamiestis (“New Town”), Vilnius, west of the city center. It was discovered in 2000 in preparation of construction of a residential house. Forty-four tombs with individual skeletons buried in coffins and an additional 26 individuals buried in common pits, some without coffins were discovered in the 1360 m^2 study area (Daminaitis, 2000). All of the individuals in this cemetery are estimated to be male and age at death estimates ranges from 15-17 years to 45-50 years (following Buikstra & Ubelaker, 1994). The presence of lime on most of the skeletal remains indicates these individuals likely died during the cholera outbreak of 1831. Based on cemetery demography and location, and the discovery of orthodox crosses in five burials and medallions in two others, archaeologists determined the historic cemetery to be that of IRA soldiers sent from the southern region of the Russian Empire to Lithuania during 1830-1831 uprising (Daminaitis, 2000). Forty-one individuals were selected for the present study based on presence of both ribs and femora.

RESEARCH QUESTIONS, HYPOTHESES, & EXPECTATIONS

This project investigates the following research question: How did 19th century European imperial expansion and maintenance shape imperial soldier biology? Viewing diet as a mechanism through which biology changes, I employ stable isotope methods of different skeletal elements to reconstruct changes in or maintenance of diet long-term among soldiers that served in NGA and IRA (and compare to BRN) to investigate how 19th century imperial expansion and maintenance strategies shaped recruiting and provisioning practices, which in turn shaped soldier diets. I use diachronic comparisons of individuals and within groups and synchronic comparisons across groups to speak to broader patterns of imperial strategies, practices, and diet change (Table 1). The following sub-questions are used to address the overarching question of this research:

Sub-question 1*: Is there a change in longer-term diet later in life at the individual level?* This question examines how military service in the context of imperial expansion and maintenance differentially impacted the biology of individual soldiers. This impact may occur as a change in diet because of the provisioning of rations that differed from pre-military diet and lifestyles. This impact may alternatively occur as a maintenance of diet because of the provisioning of rations that were like pre-military diet. However, investigating change in diet using stable isotope values of different skeletal elements is not a straightforward process as differences in stable isotope values between different skeletal elements of the same individual may not simply reflect changes in the isotope composition of foods consumed. Physiological differences (Reitsema, 2013), environmental differences and cultural practices (Szpak, 2014; van Klinken, Richards, & Hedges, 2000), and differences in sample preparation and analysis across laboratories can contribute to stable isotope variation in bone collagen (Chesson, Chau, & Edwards, early view; Chisholm, Nelson, Hobson, Schwarcz, & Knyf, 1983; Jørkov, Heinemeier, & Lynnerup, 2007; Pestle, Crowley, & Weirauch, 2014). I use minimum meaningful difference (MMD) in $\delta^{13}C$ and $\delta^{15}N$ values between femora and ribs to overcome differences that may be the result of preparation or machine error across analytical runs (see Pestle et al., 2014). I hypothesize that there was a change in diet for at least 25% of Napoleonic soldiers (Chapter 3) but not Russian soldiers (Chapter 5). If there was a change in soldier diet later in life, then I expect that $\Delta_{\text{femur-rib}}$ will be greater than or equal to the MMD threshold (0.6‰ for $\delta^{13}C$ and 0.9‰ for $\delta^{15}N$).

Sub-question 2: *Does diet become more homogenous later in life at the group level?* This question examines whether military service had a homogenizing effect on diet within armies. Military service may have had a homogenizing effect through the provisioning of rations and shared lifestyles among soldiers. Alternatively, military service may have maintained diet heterogeneity among soldiers through differences in rations within armies, flexibility in food provisioning strategies, and/or what foods were available at different locations and contexts of service. I hypothesize that diet becomes more homogenous among NGA soldiers (Chapter 3) but is similarly homogenous among IRA soldiers (Chapter 5). If there was a change in diet heterogeneity with military service, then I expect that there will be a significant difference in the dispersal of femoral and rib $\delta^{13}C$ and $\delta^{15}N$ values (measured through variance) using an F-test.

Sub-question 3: *Are there differences in diet heterogeneity among groups?* This question examines whether different imperial strategies resulted in differences in diet heterogeneity among military groups. Differences in how soldiers were provisioned and where they served may have led to differences in diet heterogeneity among groups. Militaries that had more flexibility in provisioning, relied on soldier supplementation of diet, and stationed soldiers in more distant territories may have had greater diet heterogeneity than those with greater control over soldier provisioning and that stationed soldiers within the borders of empires. I hypothesize that there are differences in later life diet heterogeneity among NGA soldiers, IRA soldiers, and BRN sailors. If there are differences in diet heterogeneity among these groups, then there will be significant differences in stable isotope value variance in ribs, which will be determined using an F-test.

The hypotheses and expectations outlined above are based on historical records that describe how NGA, IRA, and BRN servicemen were recruited, where they served, and how they were provisioned. The French and British empires recruited from a broader array of socioeconomic backgrounds and geographic origins than the Russian empire, which primarily recruited peasants from Russia proper (Beskrovny, 1996; Lambert, 2000, 2004; Tozzi, 2016; Wirtschafter, 1990). Additionally, as the French and British empires were actively expanding through warfare, the NGA and BRN participated on campaigns across Europe (Chamberlain, 2000; Gates, 1997). The Russian empire was focused more on maintaining its empire during the period of study and IRA troops were stationed primarily within the Russian Empire in Eastern Europe (Wirtschafter, 1990). Lastly, whereas NGA and IRA both provisioned soldiers by purchasing rations locally and relied on soldiers to supplement their rations, the BRN had more rigid provisioning practices that involved transporting rations on navy ships (Beskrovny, 1996; Esdaile, 2008; Lavery, 1998). These three factors likely shaped long-term and later-life diet at the individual, group, and across group levels. These factors and how they inform the hypotheses above are described in greater detail in Chapters 3 and 5.

CHAPTER OUTLINE

Chapter 2 provides a brief overview of the areas of literature that contextualize this dissertation: imperialism and warfare. I begin this chapter with an overview of contemporary and bioarchaeological research on the impact of military service and warfare on soldier bodies, ending the section with a summary of previous bioarchaeological research on Napoleonic soldiers. Next, I discuss research on imperialism and what bioarchaeology contributes to understanding its impacts on human biology. The section that follows focuses on theory in bioarchaeology including a brief historical overview of field and intellectual trajectories. This lays the groundwork for situating the theoretical framework for this dissertation into broader conversation with current trends in bioarchaeology. I end the chapter by describing the historical context of early 19th century French and Russian imperialism and outlining the theoretical framework for this dissertation.

The objective of Chapter 3 is to explore the impact of imperial expansion and warfare on the diets of NGA soldiers. Long-term diet varied both in terms of plant grains and vegetables and animal products, which reflects the recruiting practices of imperial France. Universal conscription in France and annexed territories and troops supplied by allies from across Europe including Italy, Spain, and Germany lead to a heterogenous army with an array of dietary histories. Military service reshaped NGA soldier diet toward more C_3-based grains and vegetables and greater access to meat protein for some individuals. Changes detected in diet are likely due to the prescribing of rations, what foods were locally available on military campaigns, and how soldiers supplemented their diets. Similar variation in diet and changes in diet were detected in BRN sailors indicating that imperial expansion and warfare resulted in diverse recruiting and provisioning practices.

Chapter 4 dives into the issue of sample heterogeneity and the challenges it creates in reconstructing diet. In that chapter, I use AA-CSIA on a subset of NGA soldiers to examine whether freshwater fish, marine fish, or C_4 plant foods made a significant contribution to diet for some soldiers that may be masked by bulk values and whether manuring practices during this time period confound trophic interpretations. AA-CSIA results support interpretations from Chapter 3 that Napoleonic soldier diets consisted primarily of C_3 plant foods and terrestrial animals, with significant C_4 inputs for some individuals. Environmental conditions, rather than diet, may be a primary driver for isotopic heterogeneity in this sample. Additionally, while manuring of arable land does not impact interpretations of trophic level based on stable isotope values of individual amino acids, nitrogen-fixing plants do present challenges to interpretation.

The objective of Chapter 5 is to explore the impact of imperial maintenance on the diets of IRA soldiers. Long-term diet consisted primarily of C_3 plant grains and vegetables, animal products, and freshwater fish, which reflects the recruiting practices of imperial Russia. Conscription disproportionately affected peasants and towns people in Russia proper, which likely accounts for the homogeneity in dietary histories. Long-term diet trends were maintained with military service. Comparison with NGA soldiers and BRN indicates that empires which were actively expanding through warfare had greater diet variation and change compared to the IRA, which focused on imperial maintenance. Again, these differences are likely a reflection of more diverse military groups being recruited during warfare, serving in a variety of locations with different foods available, and how each group was provisioned through rationing and soldier supplementation.

Chapter 6 summarizes the findings from Chapters 3-5 and how they speak to the embodied imperialization of soldier life. I also discuss the contributions of the findings of this research to theory, bioarchaeology, and to studies of imperialism and warfare. This is followed by a brief discussion of study limitations and future directions. I end with concluding remarks reiterating the findings of this dissertation and implications for understanding 19th century European imperialism.

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Table 1.1. Explanation of intra-individual, intra-group, and inter-group comparisons made on different temporal scales.

		Population scale		
		Individual	**Group**	**Across groups**
Temporal scale	**Synchronic**			Comparison of later life diet heterogeneity across NGA, IRA, BRN as evidenced by rib $\delta^{13}C$ and $\delta^{15}N$ variance.
	Diachronic	Comparison of longer-term and later life diet of individual Napoleonic and Russian soldiers as evidenced by $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$.	Comparison of long-term and later life diet heterogeneity of Napoleonic and Russian armies as evidenced by rib and femur $\delta^{13}C$ and $\delta^{15}N$ variance.	

CHAPTER 2

IMPERIALISM, WARFARE, AND SOLDIER BODIES: LITERATURE REVIEW, HISTORICAL CONTEXT, AND THEORETICAL FRAMEWORK

Imperialism is a species in a genus of dominance and power relationships

Johan Galtung, "A Structural Theory of Imperialism"

INTRODUCTION

In this chapter, I draw on Michelle Murphy's theorizing of the *economization of life* (2017) and Nancy Krieger's theorizing of *embodiment* (2005, 2011) to develop my own theoretical framework of the *embodied imperialization of life* that connects strategies for 19th century French imperial expansion and Russian imperial maintenance to recruiting and provisioning practices to individual soldier bodies. I bring together literature on imperialism and warfare, two bodies of work that although intimately related are often addressed separately. Nineteenth century European imperialism is both the historical context and a broader social process that speaks to the impacts of power and domination on colonizers and those colonized; however, research on imperialism frequently overlooks the impacts on soldiers tasked with establishing, expanding, and maintaining empires. On the other hand, the literature on warfare emphasizes the impact of military service and warfare on soldier bodies and is one mechanism through which imperial domination occurs. However, bringing together these two bodies of literature to study imperial soldiers offers another avenue to explore how imperialism and imperial warfare variably impact different groups with greater nuance than tropes that depict soldiers as mere tools of interpersonal violence by imperial nations.

I begin this chapter with an overview of contemporary and bioarchaeological research on the impact of military service and warfare on soldier bodies, ending the section with a summary of previous bioarchaeological research on Napoleonic soldiers. To my knowledge, this is first bioarchaeological study on 19th century Russian soldiers. Next, I discuss research on imperialism and what bioarchaeology contributes to understanding its impacts on human biology. The section that follows focuses on theory in bioarchaeology including a brief historical overview of field and intellectual trajectories. I end the chapter by describing the historical context and theoretical framework that situate this dissertation research project.

WARFARE AND SOLDIER BODIES

Warfare, defined here as "organized lethal violence by members of one group against members of another group" (Fuentes, 2012, p.130), is deeply intertwined with human social history as one of many human capacities (e.g., cooperation, avoidance) for relationships between different groups of people (Handley & Mathew, 2020; Kissel & Kim, 2019). Collective violence, such as warfare, has a widely-documented adverse impact on human biology and health (Zwi, Garfield, & Loretti, 2002). Health impacts of warfare on military and civilian populations include increased mortality, morbidity, and disability (Zwi et al., 2002). These impacts result from malnutrition, elevated contact with infectious disease, and physical and psychosocial stress (Sledzik & Sandberg, 2005; Zwi et al., 2002).

Research on the impact of warfare on contemporary soldier bodies has focused on mental health and psychological stress, chemical and biological weapons, infectious disease, and non-battle injuries (Joellenbeck, Russell, & Guze, 1999). Mental health and psychosocial stress (Buckley, Mozley, Bedard, Dewulf, & Greif, 2004; Friedman, Schnurr, & McDonagh-Coyle, 1994; Hoge et al., 2004; Kazis et al., 1998) and chemical and biological weapons (Karalliedde, Wheeler, Maclehose, & Murray, 2000) in particular have received considerable attention. There has been some research into soldier diet and nutrition (e.g., Austin, McLellan, Farina, McGraw, & Lieberman, 2016; Farina et al., 2017). Much of the work in this area comes out of the U.S. Army Research Institute of Environmental Medicine's Military Nutrition Division (e.g., Karl et al., 2019; Lieberman et al., 2016; T. J. Smith et al., 2013).

Biological anthropologists, human biologists, and critical medical anthropologists studying the impacts of warfare on soldier bodies contribute more nuanced understandings by connecting warfare to broader social, political, and economic processes (Panter-Brick, 2010). For example, the edited volume *The War Machine and Global Health* (Singer & Hodge, 2010) takes a critical medical anthropological approach to a series of case studies that examine the role of military industrial complex on soldier and civilian health. The case studies examine soldier and civilian morbidity and mortality in the broader context of the impacts of war on the natural and social environments people exist within. Like much of the research outside of anthropology, much of the research on soldiers focuses on the psychosocial stress and impacts associated with warfare (Betancourt, Agnew-Blais, Gilman, Williams, & Ellis, 2010; Kohrt et al., 2010, 2008; MacLeish, 2012; Zefferman & Mathew, 2020). While this overview focuses on the impacts of warfare on soldier bodies, there is a vast body of literature in anthropology that provides more holistic understandings of the totality of warfare on civilians and refugees who experience physical and sexual violence, psychosocial stress, and displacement as a result of warfare (e.g., Clarkin, 2008, 2019; Green, 1998; Rodney & Mulligan, 2014). Additionally, anthropologists whose work is situated in science and technology studies (STS) critically unsettle the frameworks used to diagnose health conditions and the role of public health and biomedicine in perpetuating violence in warfare contexts (Pinto-García, 2021; Pinto García, 2019).

Bioarchaeological studies provide temporal depth to our understanding of warfare's adverse impacts on the health of soldiers through skeletal evidence, which is direct and individualized. Skeletal trauma, paleopathological conditions, and dietary data are the primary sources of skeletal evidence for warfare and its impacts on soldier biology. Skeletal trauma provides the most direct evidence of interpersonal violence in the context of warfare (e.g., Brødholt & Holck, 2012; Cunha & Silva, 1997; Gaudio et al., 2015; Jordana et al., 2009; Kjellström, 2005; Liston & Baker, 1996; Meyer, 2003; Mikulski, Schutkowski, Smith, Doumet-Serhal, & Mitchell, 2021; Serafin, Lope, & González, 2014; Steadman, 2008; Walker, 1989). These studies typically examine patterns and type of skeletal trauma to identify type(s) of weapons used, reconstruct types of combat, and the demography of the victims. Bioarchaeologists use this evidence to speak to specific types of violence a warfare context ranging from raids and surprise attacks to ritualized violence to battles. In some cases, however, bioarchaeologists use the lack of skeletal evidence of trauma to counter long-held narratives of warfare and conquest (e.g., Mayes & Joyce, 2017). Paleopathological studies investigate the impacts of military service and warfare on soldier health (e.g., Gaudio et al., 2015; Jankauskas, Miliauskienė, & Kuncevičius, 2014). These studies focus on the disease burden associated with military service and warfare. They demonstrate that interpersonal violence is not the only, and in many instances in human history, not the primary cause of morbidity and mortality among soldiers in war times. Lastly, several bioarchaeological studies of warfare have focused on reconstructing military diet using stable isotope analysis (e.g., Emery, Prowse, Schwarcz, & Brickley, 2015; Raynor & Kennett, 2008; Roberts et al., 2012). These studies demonstrate the invisible and more mundane impacts of military service and warfare on human biology.

Several recent volumes and review articles dedicated to the bioarchaeology of warfare reflect a growing trend toward theoretically informed and hypothesis-driven research (Christopher Knüsel & Smith, 2014; Martin & Harrod, 2015; Martin, Harrod, & Pérez, 2012). This type of research incorporates skeletal evidence, contextual evidence, and social theory to formulate and test hypotheses (Martin & Harrod, 2015). Among the themes bioarchaeologists of war are exploring are demography (Redfern & Chamberlain, 2011), military organization (Sparacello, D'Ercole, & Coppa, 2015), military formation and identity (Reinberger et al., 2021), and the participation of women in war (Bengtson & O'Gorman, 2017; Holder, Reitsema, Dupras, & Jankauskas, 2016).

The bioarchaeology of Napoleon's Grand Army

There is growing body of research on the bioarchaeology of the Napoleonic Wars including international conferences and peer-reviewed publications. The 1st International Conference on Osteoarchaeology of the Napoleonic Battlefields, held in 1999 at the University of Camerino, brought together researchers from across Europe to compare findings relating to the study of human skeletal remains from mass gravesites associated with various campaigns of the Napoleonic Wars including studies in present-day Czech Republic, Spain, and Italy (see Etxeberria, 1999; Horáčková & Vargová, 1999; Miquel-Feucht, Polo-Cerdá, & Villalaín-Blanco, 1999; Rollo, 1999). Much of the published works also focuses on (mass)grave sites associated with battles including the Siege of Akko in 1799 in Acre, Israel (Berman, Zias, & Schick, 1997), Battles of Zürich in 1799 in Zürich, Switzerland (Meyer, 2003), and Battle of Aspern in 1809 in Vienna, Austria (Binder & Quade, 2018; Quade & Binder, 2018). The focus of these studies mirror trends in the bioarchaeology of warfare as a whole, with most focusing on traumatic injuries and paleopathological conditions associated with military service and warfare.

The Russian Campaign of 1812 is particularly well-studied. Two mass gravesites have received considerable attention: Kaliningrad (previously Königsberg), Russia and Šiaurės miestelis, Vilnius, Lithuania. At Kaliningrad, studies have ranged from preliminary analyses of stature, skeletal trauma, and pathological conditions (Buzhilova, Rigeade, Shvedchikova, Ardagna, & Dutour, 2009; Dutour & Buzhilova, 2014), creation of a digital library of paleopathology and trauma (Coqueugniot, Dutailly, Desbarats, Buzhilova, & Dutour, 2013), and a preliminary microbiological study of soldier dental pulp (Bédarida, Dutour, Buzhilova, de Micco, & Biagini, 2011). At Šiaurės miestelis, studies have ranged from descriptions of excavation and preliminary analyses (Jankauskas, 2012; Signoli et al., 2004), studies of oral health and diet (Palubeckaitė et al., 2006), comparisons of dental status and stature between Napoleonic soldiers and World War I German soldiers (Jankauskas, Palubeckaitė-Miliauskienė, Barkus, & Urbanavičius, 2007; Palubeckaitė-Miliauskienė & Jankauskas, 2007), and identification of typhus and trench fever in the dental pulp of soldiers and lice discovered in the mass grave (Raoult et al., 2006). Since joining the project in 2011, my own collaborative research at Šiaurės miestelis has focused on characterizing the longer-term diet of Napoleonic soldiers (Holder, Dupras, Jankauskas, Williams, & Schultz, 2017), preliminary analysis of changes in diet military service (Holder, Reitsema, Dupras, & Jankauskas, 2020), and the impact of childhood growth disruptions on growth outcomes (Holder, Miliauskienė, Jankauskas, & Dupras, 2021).

Together, this body of work provides a more holistic understanding of the visible and invisible impacts of the Napoleonic Wars on soldier biology. Trauma analyses reveal the devastating interpersonal violence experienced by soldiers during and after battle, with injuries caused by ballistic weapons and swords. These analyses also reveal the efforts to save soldiers through the discovery of healing and healed amputations. Paleopathological analyses speak to the cumulative effects of activities such horseback riding and marching on soldier bodies, especially the wear and tear of joints. These studies illuminate the death toll of infectious diseases on Napoleonic soldiers, confirming historical accounts of the deadly typhus epidemic the Russian Campaign of 1812 retreat. Studies of dental status and stature exemplify the adage of healthy young men transformed into sickly soldiers through the physical and mental tolls of warfare. Lastly, studies of diet reveal how seemingly mundane daily habits can transform the biology of soldiers in a warfare context.

IMPERIALISM AND (SOLDIER) BODIES

Imperialism is a process whereby empires are established and maintained (Doyle, 1986) and it is ubiquitous across space and time in the last 5,000 years of human history (Alcock, D'Altroy, Morrison, & Sinopoli, 2001; Garnsey & Whittaker, 1978). I follow Subrahmanyam's "minimal" approach (2001) to defining empires:

> (1) as states with an extensive geographical spread, embracing more than one cultural domain and ecozone; (2) as states powered by an ideological motor that claimed extensive, at times even universal, forms of dominance, rather than mere control of a compact domain; (3) as states where the idea of suzerainty was a crucial component of political articulation, and where the monarch was defined not merely as king, but as "king over kings,' with an explicit notion of hierarchy in which various levels of sovereignty, both "from above" and "from below," were involved (p. 43).

Imperial dominance occurs "by force, by political collaboration, by economic, social, or cultural dependence" (Doyle, 1986, p. 45). Imperialism begets settler colonialism, whereby imperial settlements are implanted on distant territory (Said, 1994). Key to the process of expanding empires and establishing distant colonies is the transformation of land into property or as la paperson calls it "the great colonizing trick that paves the way for capitalist accumulation" (2017, p. 1).

Bioarchaeological studies of imperialism examine the differential impacts of imperialism on human biology in the past through power, control, and domination. Themes explored in the bioarchaeology of imperialism include migration, resettlement, and consolidation, collapse, diet and health, and violence and warfare. The first theme is migration, resettlement, and consolidation, where bioarchaeologists employ biodistance or isotopic analyses to identify migrants into the imperial core or periphery areas (e.g., Andrushko, Buzon, Simonetti, & Creaser, 2009; Bethard, 2013; Daverman, 2011; Haun & Carrasco, 2010; Tung & Knudson, 2011; White, Spence, Longstaffe, & Law, 2000). These studies often focus on resettlement of entire communities, specialized groups, and individuals to examine how empires influenced the movement and resettlement of people through force, networks of exchange and trade, or changes in marriage residence patterns. The second area is collapse, which focuses on how shifts in power with the collapse of empires impact health, violence, and accidental injuries through paleopathological and trauma analyses (Andrushko & Sanchez-Chopitea, 2020; Schrader & Buzon, 2017). Third is studies of the impact on imperialism on the diet and health of local populations (Andrushko, Torres, & Viviana, 2006; Bey, Andrushko, & Bélisle, 2021; Eng, 2007; Killgrove & Tykot, 2013; Marklein, 2020; Prowse, Schwarcz, Saunders, Macchiarelli, & Bondioli, 2004; Williams & Murphy, 2013). In some cases, bioarchaeologists examine a single site subsumed by an empire or a city within the imperial core. In other cases, bioarchaeologists make comparisons between sites based on imperial core versus periphery, in different ecological settings (e.g., coastal versus inland), or between status groups. The fourth area is violence and warfare associated with imperial expansion and domination of people under imperial control (Andrushko & Torres, 2011; Buzon & Richman, 2007; Lessa & Mendonça de Souza, 2004; Šlaus et al., 2018; Tung, 2007, 2008, 2012). While some studies of imperial warfare mirror that of warfare more broadly by analyzing patterns of skeletal trauma, the former tend to take a more diachronic approach by comparing rates and patterns of trauma over time. Others demonstrate the role of violence more beyond face-to-face combat (e.g., display of trophy heads). This work demonstrates the ubiquity of violence as a strategy for imperial expansion and control.

THEORY IN BIOARCHAEOLOGY

Bioarchaeology emerged as a sub-sub-discipline of anthropology from the intersection between processual archaeology and skeletal biology in the late 1970s (Armelagos, 2003). Jane Buikstra defined bioarchaeology as a multidisciplinary field that integrates skeletal and contextual data to investigate questions about social organization, activity patterns, paleodemography, mobility and exchange, and diet and paleopathology (1977). From its emergence, bioarchaeologists focused on intersections of biology, culture, and environment, referred to collectively as biocultural approaches. Biocultural approaches to bioarchaeology stress “the dynamic interactions between humans and their larger social, cultural, and physical environments” (Zuckerman & Armelagos, 2011, p. 20). These approaches were taken up by bioarchaeologists in three primary domains: adaptationist approaches, contextual approaches that focus on social identity, and critical social theory approaches (primarily political-economic). There have been many different ways to subcategorize and numbers of subcategories in the historicizing the intellectual history of bioarchaeology including waves of engagement or development (Agarwal & Glencross, 2011a; Zuckerman & Armelagos, 2011), tribes (Rakita, 2014), and bioarchaeologies (Stojanowski & Duncan, 2015), but the section below captures how I think of the theoretical trajectories in bioarchaeology.

The first major biocultural approach is adaptationist, which focuses on how local environments and evolutionary forces shape local biologies and cultures. Several recent reviews historicize this approach in bioarchaeology (C. M. Cheverko, Prince-Buitenhuys, & Hubbe, 2021; Rakita, 2014; Zuckerman & Armelagos, 2011). This approach is also akin to Stojanowski and Duncan's (2015) characterization of a natural science approach to bioarchaeology and Rakita's (2014) biological adaptation tribe. These types of studies integrate aspects of social forces co-shaping local biologies to varying degrees, most frequently by comparing categories of age, sex, and social status (derived from grave goods and burial style and location) or exploring changes in the health and disease with transitions (e.g., agricultural) (Armelagos, Goodman, Harper, & Blakey, 2009; Bleuze, Wheeler, Williams, & Dupras, 2014; Larsen, 1981; Schug & Goldman, 2014). Some of my own work falls in this domain of research, with a previous study where my colleagues I integrated life history theory, the developmental origins of health and disease, and life course approach to explore plasticity in growth disruptions and outcomes of Napoleonic soldiers (Holder et al., 2021).

The second major area within a biocultural approach focuses on contextualizing human skeletal remains and reconstructing lifestyles, focusing on social identities and (sometimes) integrating social theory (Martin, Harrod, & Pérez, 2013). Theory provides a framework for guiding, describing, and interpreting bioarchaeological research and articulating its broader significance beyond individual case studies (Martin & Harrod, 2015). For me, this encapsulates both social science and humanistic approaches described by Stojanowski & Duncan (2015). This domain of bioarchaeological research encompasses a vast array of topics (see Agarwal & Glencross, 2011) including social identities and status (Knudson & Stojanowski, 2008), ethnogenesis (Knudson & Stojanowski, 2009), care (Tilley, 2015; Tilley & Schrenk, 2017), individuals and osteobiography (Palkovich & Stodder, 2012), embodiment (Blom, 2005), disability and impairment (Byrnes & Muller, 2017), kinship (Johnson & Paul, 2016), and diaspora (Blakey, 2001).

The third major area of the biocultural approach integrates critical theory, often drawing from political-economic perspectives on health inequalities (Blakey, early view; Goodman & Leatherman, 1998). This approach emphasizes that "the roles of political and economic variables add to an understanding of the kinds of factors affecting human biology" (Blakey, 1988, p. 494). Central to this approach is an emphasis on social relations influencing access, connections between local and global, historical context, human agency, understanding the positioning of the researched and researcher (Goodman & Leatherman, 1998). What these different approaches have in common is examining how domination and control that exist within hierarchies of power differentially shaped the lived experiences and biological outcomes of marginalized individuals or groups. Theoretical frameworks, concepts, and topics in this area include structural violence (de la Cova, 2012; Klaus, 2012; Nystrom, 2014; Robbins Schug, Gray, Mushrif-Tripathy, & Sankhyan, 2012; Stone, 2012), intersectionality (Mant, de la Cova, & Brickley, 2021; Yaussy, 2019), marginalization (Mant & Holland, 2019), social control (Harrod, 2017), politicization of the dead (Pérez, 2012), and poetics of violence (Pérez, 2016).

A largely untapped domain of theory that could inform bioarchaeological research comes from STS, an interdisciplinary field that examines the complex relationships between science, technology, and society. Within this vast and complex field are STS scholars (re-)theorizing human and non-human bodies, behavior, and relationships (e.g., Frost, 2016; Mol, 2021; Murphy, 2006; Tsing, Swanson, Gan, & Bubandt, 2017). This dissertation research is situated within the third area of biocultural approaches focused on political-economic perspectives within critical social theory, drawing from STS and social epidemiology literatures. I draw on STS scholar and historian Michelle Murphy's theorizing of *economization of life* (2017) to frame how imperial soldier life was valued and supported in so far as their labor contributed to accumulation of land, labor, and resources. I also draw on social epidemiologist Nancy Krieger's theorizing of *embodiment* (2005, 2011) as a link between the valuation of soldier life, recruitment and provisioning practices, and the differential impact these practices had on soldier diet.

HISTORICAL CONTEXT: 19TH CENTURY FRENCH AND RUSSIAN IMPERIALISM

The historical context of this dissertation is early 19th century French and Russian imperialism on the European continent. France and Russia differed substantially in their approaches to imperialism during this time. In this section, I describe French imperial expansion and Russian imperial maintenance and soldier recruitment and provisioning for both armies. This section lays the foundation for the final section of this chapter, which outlines my theoretical framework.

French imperial expansion and recruitment in the early 19th century

In 1804, Napoleon crowned himself Emperor of France. Over the next decade until his final defeat in 1815, Napoleon was embattled in a series of conflicts between the French Empire and an array of European powers, known as the Napoleonic Wars, resulting in the deployment of the Grand Army on campaigns across Europe including Poland, Prussia, Austria, Portugal, Spain, and Russia (Esdaile, 2008). From 1804-1812, Napoleon annexed territory in central Italy from the Kingdom of Italy (1808-1811), the Dalmatian provinces from Austria (1809), the North Sea coast from the Kingdom of Holland (1810-1811) (Broers, 2002). Additionally, Napoleon acquired several dependent states, several of which were ruled by his brothers and brother-in-law: Kingdom of Naples, Confederation of the Rhine, Duchy of Warsaw, Kingdom of Italy, Kingdom of Spain, and Switzerland. By the onset of the Russian Campaign of 1812, Napoleon controlled or was allied with much of continental Europe (see Figure 2.1).

Mass conscription in France, *levée en masse*, began in 1793 under the revolutionary government and continued for the next 21 years (Blanton, 2009). It became annual in 1799, affecting 20-25-year-old men initially (Forrest, 2002). The process of military conscription varied depending on level of conflict, with periods of heavy conflict seeing higher rates of conscription (Forrest, 2002). Annual conscription disproportionately impacted young men from lower socioeconomic classes because higher class conscripts could pay a replacement (*suppléant*) to serve in their place (Blanton, 2009). From 1806 to 1810, 25,000 out of 556,000 (4.5%) conscripts were actually replacements, not the person originally conscripted for service (Woloch, 1986).

In 1807, the Grand Army began incorporating foreign regiments that served on principal campaigns, which included allies and annexed regions (Elting, 1988). Conscription of soldiers from annexed territories varied by both how young men were conscripted and how they were incorporated into the Grand Army. Conscripts from annexed territories were either integrated into regular regiments or battalions or native regiments were maintained (Tozzi, 2016). Foreign regiments, battalions, and legions separate from those supplied by allied and annexed states were also recruited into service during this time (Tozzi, 2016).

For the Russian Campaign of 1812, NGA was comprised of approximately 675,000 soldiers from the French Army (including annexed territories), dependent states, and allies (Nicolson, 1985). Approximately one-third of the troops were French; the other two-thirds were ethnically German (Austrians, Prussians, Bavarians, Saxons, Westphalians, and others), Polish, Lithuanian, Italian, Illyrian, Spanish, and Portuguese (Riehn, 1990; Riley, 2007). Of the French troops in the Grand Army, a majority were conscripts, many of whom were young and lacked adequate training (Riehn, 1990).

NGA soldier provisioning and diet

Provisioning the Grand Army during the campaigns of the Napoleonic Wars was the responsibility of the Ministry of the Administration of War (Elting, 1988). Napoleonic soldiers were supposed to be equipped with four days of rations, with additional supplies provided by battalions transporting flour for bread (Riehn, 1990). Official daily rations for soldiers on campaign consisted of bread made from wheat and rye, "fresh" meat (usually beef), rice or dried vegetables (usually beans, peas, or lentils), salt, wine, and when available vinegar and brandy (Crowdy, 2015; Elting, 1988).

However, during the numerous and distant campaigns of the Napoleonic Wars, adequate provisioning of soldiers was a recurring problem (Nafziger, 1988). Adequate animal protein consumption was particularly problematic, with horses and cats as a source of meat in times of desperation (P. B. Austin, 2000; Forrest, 2002). To overcome this problem, French soldiers became efficient foragers and from these practices, Napoleon came to rely on this “living off the land” strategy, which became soldiers’ strategy to supplement Grand Army rationing (Rothenberg, 1981).

Russian imperial maintenance and recruitment in the early to mid-19th century

The Russian Empire extended its boarders through imperial expansion several times in the late 18th and early 19th centuries. Imperial acquisitions included territory in Lithuania and Poland through the three partitions of the Polish-Lithuanian Commonwealth (1772, 1793, and 1795), the annexation of Finland in 1809, Bessarabia in 1812, and the Duchy of Warsaw (which became the Kingdom of Poland) in 1815 (Miller, 2015). The defeat of the Grand Army in the Russian Campaign of 1812 solidified Russia’s position as a European imperial power (Taylor, 2003). Upon the retreat of Napoleon’s Grand Army from Moscow in October 1812, the Imperial Russian Army pursued the Grand Army through Europe, defeating them in Germany in 1813 and successfully invading France in 1814 (MacKenzie, 1994). Following the Congress of Vienna (1814-1815), Russia imperial expansion and warfare largely ceased until the Crimean War began in 1853 (Wirtschafter, 1990).

Recruitment in 19th century Russia occurred through two mechanisms: volunteering and conscription (Mikaberidze, 2009). Conscription occurred through a levy raised on poll-tax paying Russian men (Wirtschafter, 1990). Twenty-eight conscription levies, which provided nearly two million men for service in the army and navy, were held in the first quarter of the 19th century (Beskrovny, 1996). Conscription disproportionately affected peasants and town-dwellers in Russia proper, with almost 20% of Russia’s male population exempted due to socioeconomic class and estate status (Keep, 1985). Additionally, several annexed territories and ethnic groups received exemptions or could pay money in place of providing men for military service (Wirtschafter, 1990). The period of service was 25 years, with few soldiers living long enough to complete their service and return home (Beskrovny, 1996; Wirtschafter, 1990).

IRA soldier provisioning and diet

Imperial Russian soldier rations typically included grains such as wheat, barley, and rye in the form of bread, rusks, and groats along rations or monies to purchase meat, salt, and liquor (Beskrovny, 1996; Wirtschafter, 1990). However, what a soldier actually ate (versus officially government policy on what soldiers were to be rationed) varied depending on whether soldiers were on campaign, garrisoned in barracks, or quartered with civilians and where they were stationed as supplies were often locally purchased (Wirtschafter, 1990). Most soldiers were quartered with civilians over half the year who were responsible for feeding the soldiers. For peasants who could barely afford to feed themselves, there was little meat or fish to be served, corn was substituted for rye bread, and soldiers often went hungry (Keep, 1985; Wirtschafter, 1990). Soldiers stationed in barracks typically had a more stable diet as supplies were widely available in local markets (Wirtschafter, 1990).

Soldier self-sufficiency (or more accurately group-sufficiency) was a mainstay in the Imperial Russian Army. When the state could not provide adequate supplies, soldiers were paid money directly in lieu of rations to purchase their own food (Keep, 1985). Additionally, less mobile troops such as Guard units would grow food in gardens to supplement their rations (Wirtschafter, 1990).

THEORETICAL FRAMEWORK: EMBODIED IMPERIALIZATION OF LIFE

In this dissertation, I propose a new theoretical approach, *embodied imperialization of life*, that builds on and synthesizes elements of the *economization of life* theorized by Michelle Murphy (2017) and *embodiment* theorized by Nancy Krieger (2005, 2011) to connect the logics of imperialism to strategies for 19th century French imperial expansion and Russian imperial maintenance to recruiting and provisioning practices to individual soldier bodies. In the following section, I begin by describing the *economization of life* and literatures with which it is in conversation. Next, I describe *embodiment theory* and how this work has been applied in bioarchaeology. I end the section by defining an *embodied imperialization of life* and describing its central tenets.

Economization of life

In their book of the same title, Michelle Murphy (2017) theorizes the *economization of life* as a way of differentially valuing and governing human life for the purpose of supporting the economy. Murphy begins by linking "economy and population as objects of governance and intervention" by historciizing the emergence of the macroeconomy and gross domestic product (GDP), demographic transition models, and eugenic modes of contraception (2017, p. 9). Next, they implicate social scientific methods of quantifying, experimenting, and intervening with human reproduction, focusing on the work of transnational non-governmental organizations (NGOs) in family planning and contraception campaigns in Bangladesh that were focused on managing overpopulation. In the final section, Murphy (2017) demonstrates how population control not only occurred through family planning and contraception, but through "invest in a girl" campaigns that used the education of girls to improve a country's economy by providing a skilled a labor force that procreated later, equaling fewer pregnancies. Thus, girls contribute to the economy in two ways: directly through their labor and indirectly by lower population levels (increasing GDP). This completes the arc of the *economization of life*: population gets linked to the macroeconomy (i.e., GDP), making overpopulation an economic problem that can be acted upon through family planning and education interventions imposed in this case on black and brown bodies for the purpose of benefitting white futures. In other words, "*some must not be born so that future others might live more abundantly (consumptively)*" (Murphy, 2017, p. 41 emphasis theirs).

As Murphy (2017) describes it, their research emerges from scholarship in three domains to theorize the *economization of life*. First, Murphy (2017) links their work on tracing the historical linkages between economy and population to the work of others tracking the histories of population including Sanjam Ahluwalia (2008), Alison Bashford (2014), Matthew Connelly (2010), Susan Greenhalgh and Edwin Winckler (Greenhalgh & Winckler, 2005), Betsy Hartmann (1995), Sarah Hodges (2017), Simon Szreter (1993), and UBINIG (1999). Second, Murphy (2017) connects their work on implicating social science methods and economic quantification in population control to work on interrogating numbers and counting (Day, Lury, & Wakeford, 2014; Desrosières, 1998; Kalpagam, 2014; Nelson, 2015). Lastly, Murphy puts their work on population control for the sake of the macroeconomy in conversation with feminist STS scholarship on “the relations between life, reproduction, and capital” (2017, p. 13), a vast body of research, citing the work of Melinda Cooper (2011), Joseph Dumit (2012), Mike Fortun (2008), Sarah Franklin (2003, 2007), and Kaushik Sunder Rajan (2006), among others. Murphy’s *economization of life* (2017) has also been taken up by other scholars of reproduction and family planning (Brunson, 2020).

I draw on Murphy’s theorizing of *economization of life* in developing an *embodied imperialization of life* to implicate the imperial logics and structures responsible for the unequal valuation and precarity of soldier life. In their theorizing of the *economization of life*, Murphy (2017) seeks to move beyond bodies and thinking about reproduction as individual experience. In this dissertation, I want to shift the focus back to individual bodies and experiences. To do this, I draw on *embodiment theory*, which I describe below.

Embodiment theory

Sociopolitical forces, such as imperialism, impact the biology of the body through the process of embodiment (Krieger & Smith, 2004). Embodiment refers to how the environment in which an individual lives, comprising both the social and the ecological, literally become incorporated into an individual’s biology (Krieger, 2005). The body has no “natural pristine state”, it shapes and is shaped by its surroundings (Sofaer, 2006). In this framework, the body becomes a record of lived experience (Ingold, 1998). This perspective of the body circumvents the false dichotomy of mind/body (Buikstra & Scott, 2009) or biological/social and instead views the body as an amalgamation of social and biological process that change over time.

Krieger (2005) argues that pathways to embodiment are concurrently structured by the organization of social structures and biological potentials and constraints. The human skeleton can provide direct information regarding how individuals experience these social and biological pathways (Knudson & Stojanowski, 2008). The human skeleton is a plastic tissue that responds to stresses and placed on it over an individual’s life course through the process of bone remodeling. Plasticity is an adaptive response of organism to its environment expressed as phenotypic changes (Agarwal, 2016). Skeletal plasticity and bone remodeling are the mechanisms that allows an individual's social environment to become incorporated into skeleton. In bioarchaeology, embodiment serves as a means to explore how the social world in which a body exists and interacts with it effects human skeletal biology (Zuckerman, Kamnikar, & Mathena, 2014). Much of the bioarchaeological research on embodiment has focused on the embodiment of aspects of social identity (e.g., Blom, 2005; Heathcote, Diego, Ishida, & Sava, 2012; Tiesler, 2014; White, Longstaffe, Pendergast, & Maxwell, 2009).

Toward an embodied imperialization of (soldier) life

In this dissertation, I take up Murphy's invitation to "propagate the questions posed here into other itineraries" (2017, p. 8). The itinerary of this dissertation is to link the logics, structures, and practices of empire-building to soldier bodies. I re-purpose Murphy's conceptualization of *economization of life* into my own formulation of and *embodied imperialization of life* as the unequal valuation of human life as a form of labor in service of the empire that is operationalized through strategies and structures of support, which have differential impacts on the bodies of imperial subjects. In this sub-section, I describe the tenets of an *embodied imperialization of life* encapsulated in definition above in greater detail. The *embodied imperialization of life* has four primary tenets:

1) **Life is valued as a form of labor to the empire.** This tenet draws from Marxist thought on value, labor, and capitalism (see e..g, Marx, 1919). Rather than focusing on capitalism, I focus here on imperialism as a process steeped in the accumulation of land, labor, and resources. The lives of people under imperial control are valued unevenly in so far as their labor contributes to the empire. In the case of imperial soldiers, their lives are valued for the purpose of establishing, expanding, and maintaining empires, often in the form of violence (in the case of warfare) or the threat of violence (as in occupation).
2) **Some lives are expendable in service of the empire.** This tenet draws inspiration from Murphy that "*some must not be born so that future others might live more abundantly (consumptively)*" (2017, p. 41, emphasis theirs). In *The Economization of Life*, Murphy (2017) focuses on potential

life or life not to be, but this might also be applied death: some must die so that others might live more abundantly. The role of the empire in the expendability of human life is connected to what Mbembe refers to as necropolitics, "the power and the capacity to dictate who may live and who must die" (2003, p. 11, 2019). The expendability of soldier life is evidenced by the millions of lives sacrificed for imperial expansion through warfare. Napoleon is famously spoke of the expendability of soldier: "A man like me troubles himself little about the lives of a million men".

3) **Strategies and structures for supporting the lives of imperial subjects are shaped by imperial context and the unequal valuation of life.** This tenet draws inspiration from Murphy's conceptualization of *distributed reproduction*, a term they develop in the conclusion of *The Economization of Life* (2017). *Distributed reproduction* calls attention to the uneven relations and infrastructures that shape what forms of life are supported to persist, thrive, and alter, and what forms of life are destroyed, injured, constrained" (Murphy, 2017, pp. 141-142). This tenet, drawn from *distributed reproduction*, connects the first two tenets with imperial structures developed to support the lives of imperial subjects. If human lives are valued for their labor and some lives are expendable in service of the empire, then the strategies and structures responsible for the support human lives will vary based on the value placed on the lives and labor of imperial subjects. However, the capacity to support life across distant territories is not unconstrained. Thus, the supporting of life in empires is also constrained by local environmental conditions. Imperial soldier lives were supported during military service through the provisioning of supplies including food, clothing, and weapons to inflict violence. The provisioning of rations varied by whether an army was on campaign or stationed within the borders of an empire (i.e., imperial context). They also varied within the armies based on rank and corps (as evidence of the unequal valuation of life). Differences in the provisioning of rations and the logistical challenges inherent in supporting large armies over great distances resulted in the development of "living off the land" practices to supplement rations.

4) **Imperial strategies and structures may differentially impact individual bodies.** This tenet draws on the *body politic* (Scheper-Hughes & Lock, 1987) to link the three preceding tenets to the bodies of imperial subjects. For imperial soldiers, flexibility in the provisioning of rations and living off the practices created the potential for differences in diet of soldiers within and between armies. Their diets (in the form of isotopes of elements) were literally used to build the tissues of these soldiers, where 200 years later, I reconstruct their diet to speak to *embodied imperialization of life*.

CONCLUSION

This chapter serves as the foundation for the remaining chapters of this dissertation, describing the literature, theoretical, and historical contexts with which this work articulates. I began by bringing summarizing the impact of warfare and imperialism on (soldier) bodies past and present. Next, I provided an overview of theoretical orientations in bioarchaeology, identifying STS as a domain of literature from which bioarchaeologists can develop new questions and theoretical frameworks. This is followed by a summary of the historical context: 19th century French and Russian imperialism. I end the chapter with my theoretical framework, drawing from STS and social epidemiology to link imperial logics and structures to individual soldier bodies through diet.

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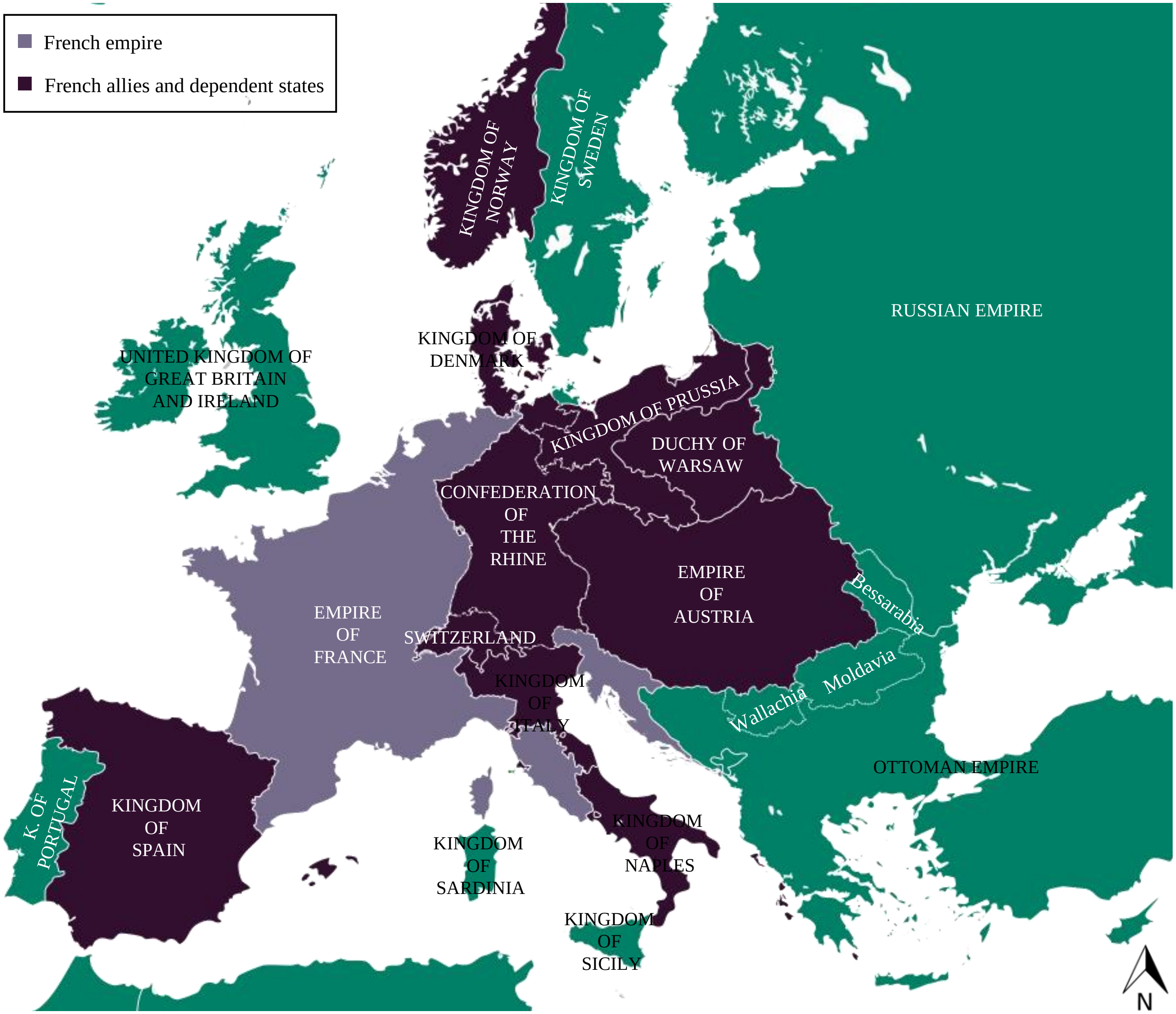

Figure 2.1. Map of French Empire and allies in 1812. Not to scale.

CHAPTER 3

INVESTIGATING THE IMPACT OF IMPERIAL EXPANSION AND WARFARE ON NAPOLEONIC SOLDIER DIET USING STABLE ISOTOPE ANALYSIS[1]

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[1] Holder, S., Reitsema, L., Dupras, T., Piličiauskienė, G., Mari, K., & Jankauskas, R. To be submitted to *American Journal of Physical Anthropology*.

ABSTRACT

Objectives: The purpose of this research is to track changes in diet and diet heterogeneity of Napoleonic soldiers that died during the Russian Campaign retreat of 1812 to investigate how imperialism reshaped the biology of soldiers tasked with expanding the borders of empires.

Materials and Methods: Using stable carbon and nitrogen isotope ratio analysis of femur and rib bone collagen, I reconstruct changes in the diets of Napoleon's Grand Army soldiers from the mass gravesite of Šiaurės miestelis, Vilnius, Lithuania (n=53).

Results: $\Delta^{13}C_{\text{rib-femur}}$ range from -4.1‰ to 0.2‰ with a mean of -0.5 ± 0.7‰ and $\Delta^{15}N_{\text{rib-femur}}$ range from -0.5‰ to 1.7‰ with a mean of 0.3 ± 0.5‰. $\delta^{13}C$ and $\delta^{15}N$ value variance of ribs and femora are not statistically significantly different ($\delta^{13}C$: $p = 0.900$; $\delta^{15}N$: $p = 0.138$).

Discussion: The diets of 40% (21 out of 53) of soldiers changed later in life toward greater consumption of grains, vegetables, and terrestrial animal products. However, diet did not become more homogenous later in life among soldiers in NGA. Later life diet heterogeneity is similar to contemporaneous British Royal Navy sailors from the site of Plymouth, UK. These finding indicate that while the diets of several individuals changed with military service, diet heterogeneity at the group level was maintained by military provisioning and soldier supplementation practices that varied across campaigns and landscapes.

Key words: imperialism, embodiment, historical bioarchaeology, diet heterogeneity

INTRODUCTION

Dramatic political and economic transformations characterized late 18th and early 19th century Europe including imperialism and colonization, revolution and warfare, and the Industrial Revolution (Crouzet, 1964; Hobsbawm, 1962; Roessler & Miklos, 2003). Each of these transformations was sparked by or sparked unequal power relations that had a significant impact on local biologies and cultures (Black, 1990; Blum & McLaughlin, 2019; Komlos, 1998). They also had a significant impact on the biology of soldiers commissioned (forcibly or voluntarily) with expanding and maintaining European empires often in the forms of poor sanitation, dietary decline, disease exposure, and stresses associated with human combat (Cook, 2001; Curtin, 1998; Evans, 1988; Sledzik & Sandberg, 2005; Talty, 2009). Human diet serves as a useful proxy for examining the impact of imperialism on soldier biology as what a person eats is not only driven by nutritional needs and environmental constraints, but it is also driven by socioeconomic and political processes governing access and by cultural factors linked to identity and individual preference (E. N. Anderson, 2014; Hastorf, 2017). In regard to access, diet can be a powerful tool to examine how soldiers were differentially supported on the numerous and distant campaigns of late 18th and early 19th century European imperial wars.

Because of the dearth of historical documentation, Napoleon's Grand Army (NGA) soldiers are ideally suited to investigate NGA provisioning and soldier supplementation practices. During the late 18th and early 19th centuries, Napoleon amassed a large multi-national army to serve on numerous campaigns across Europe into Egypt and parts of Eurasia (Esdaile, 2008). NGA was made up of conscripts, mercenaries, soldiers, and officers from France proper, allied nation-states, and annexed territories that typically served in numerous campaigns due to near constant conflict (Elting, 1988; Forrest, 2002; Rothenberg, 1981; Tozzi, 2016). Additionally, NGA was a diverse group, embodying a range of socioeconomic backgrounds and geographic origins (Riehn, 1990). Supporting this large and diverse group was a constant logical challenge during the numerous and distant campaigns of the Napoleonic Wars. While NGA provisioned rations, the army also came to rely on soldier "living off the land" practices of foraging, stealing, and buying foods supplement their rations (Nafziger, 1988; Rothenberg, 1981). Given the diversity of soldier backgrounds and flexibility in provisioning practices, characterizing how military service in the context of imperial expansion and warfare (re)shaped soldier diets is challenging using historical documents alone.

Here, I reconstruct individual soldier diet change and changes in diet heterogeneity among NGA soldiers from the mass grave site of Šiaurės miestelis, Lithuania that died during the Russian Campaign of 1812 retreat using stable isotope ratio analysis of femur and rib bone collagen. Additionally, I compare later life diet heterogeneity between NGA and British Royal Navy sailors from two sites in the UK using data published in Roberts et al. (2012) to investigate patterns in provisioning and supplementation between military groups actively expanding their empires through warfare.

French imperial expansion, soldier recruitment, and provisioning practices

The French Empire expanded its territory on the European continent through forced annexation and allyship (Broers, 2002). This approach to imperial expansion resulted in near-constant military conflicts and the deployment of NGA on campaigns across Europe including Poland, Prussia, Austria, Portugal, Spain, and Russia (Esdaile, 2008). From 1804-1812, Napoleon annexed territory in central Italy from the Kingdom of Italy (1808-1811), the Dalmatian provinces from Austria (1809), and the North Sea coast from the Kingdom of Holland (1810-1811) (Broers, 2002). Additionally, Napoleon acquired several dependent states, several of which were ruled by his brothers and brother-in-law: Kingdom of Naples, Confederation of the Rhine, Duchy of Warsaw, Kingdom of Italy, Kingdom of Spain, and Switzerland. By the onset of the Russian Campaign of 1812, Napoleon controlled or was allied with much of continental Europe (see Figure 2.1).

Mass conscription, *levée en masse*, began in France in 1793 under the revolutionary government and continued for the next 21 years (Blanton, 2009). It became annual in 1799, affecting 20-25-year-old men initially (Forrest, 2002). In 1802, Napoleon established NGA, consisting of conscripted French soldiers and allied troops operating under his command (Rothenberg, 1981). NGA began incorporating foreign regiments that served on principal campaigns, which included allies and annexed regions, in 1807 (Elting, 1988). Conscription of soldiers from annexed territories varied by both how young men were conscripted and how they were incorporated into the Grand Army. Conscripts from annexed territories were either integrated into regular regiments or battalions or native regiments were maintained (Tozzi, 2016). Foreign regiments, battalions, and legions separate from those supplied by allied and annexed states were also recruited into service during this time (Tozzi, 2016).

NGA soldiers required supplies including food, shelter, and clothing to support them on these distant campaigns. Provisioning NGA during the campaigns of the Napoleonic Wars was the responsibility of the Ministry of the Administration of War (Elting, 1988). Napoleonic soldiers were to be equipped with four days of rations, with some additional foodstuffs provided by battalions (*le train*) transporting flour for bread (Riehn, 1990; Zamoyski, 2004). NGA relied heavily upon local resources during distant campaign using local contractors to purchase foods, requisition foods, or replenish supplies at local magazines (Riehn, 1990). Official daily rations for soldiers on campaign were supposed to consist of bread made from wheat and rye, meat (usually beef), rice or dried vegetables (usually beans, peas, or lentils), salt, wine, and when available vinegar and brandy (Crowdy, 2015; Elting, 1988). However, during the numerous and distant campaigns of the Napoleonic Wars and in part related to reliance on locally acquired foods, adequate provisioning of soldiers was a recurring problem (Nafziger, 1988). Adequate animal protein consumption was particularly problematic, with horses and cats as a source of meat in times of desperation (Austin, 2000; Forrest, 2002). The problem of adequate provisioning did not affect segments of NGA equally. For example, imperial guardsmen were only group in the French army equipped with permanent supply chains ensuring more consistent and higher quality food than the typical soldier (Rothenberg, 1981). To overcome this problem, French soldiers became efficient foragers and from these practices, Napoleon came to rely on this “living off the land” strategy, which became soldiers’ strategy to supplement NGA rationing (Nafziger, 1988; Rothenberg, 1981). Soldiers also supplemented their rations by purchasing food from sutlers (*vivandières* and *cantinières*) traveling with NGA or from merchants at local markets (Cardoza, 2010).

Russian Campaign of 1812

In 1812, Napoleon invaded Russia under the guise of protecting Poland from Russian invasion. The Russian Campaign of 1812 commenced in April of 1812 with NGA composed of approximately 675,000 soldiers (Nicolson, 1985). For this campaign, NGA was made of the French Army (including annexed territories), dependent states, and allies (Nicolson, 1985). Approximately one-third of the troops were French; the other two-thirds were ethnically German (Austrians, Prussians, Bavarians, Saxons, Westphalians, and others), Poles and Lithuanians, and Italians, Illyrians, Spaniards, and Portuguese (Riehn, 1990; Riley, 2007). Of the French troops in the Grand Army, a majority were conscripts, many of whom were young and lacked adequate training (Riehn, 1990).

NGA arrived in Moscow in October of 1812 and retreated 35 days later after failing to engage with the Russian czar’s army and on account of dwindling supplies. The disastrous retreat resulted in massive mortality due to hypothermia, starvation, and typhus as temperatures sank and supplies ran out (Bourgogne, 2002). An estimated 75,000 soldiers perished in present-day Lithuania alone with over 27,000 of them in Vilnius (Vaškevičiūtė & Zabiela, 2016). Napoleon's provisioning strategies and policies failed during the Russian Campaign, especially during the retreat (Nafziger, 1988). Although French soldiers were efficient foragers, organized foraging systems broke down during the chaos of the Napoleonic retreat; this situation was exacerbated by Russia's policy of burning the landscape to prevent foreign invaders from accessing local resources. Thousands of soldiers died upon arrival in Vilnius. Initially the bodies of dead Napoleonic soldiers were burned but were eventually collected and buried in mass graves throughout the city instead (Frank, 2001).

Historical accounts of the Napoleonic Wars provide valuable insight into the structure of NGA, Napoleon's strategies in warfare, and the successes and failures of the Napoleonic Wars. This information is captured in military records and the diaries and letters of literate officers and civilians. The lives and experiences of young conscripts and soldiers, who were often illiterate, are invisible in these historical narratives beyond accounts of their tragic deaths. However, research on skeletal remains offers a means to make visible the experiences of those that are largely absent or play only a minor role in historical narratives (Zuckerman et al., 2014). Thus, I seek to make visible the lives of individual NGA soldiers by investigating how French imperial expansion through warfare becomes embodied through daily dietary practices by reconstructing changes in diet detected through stable isotope ratio analysis of bone collagen.

Stable isotope analysis in bioarchaeology

Stable isotope analysis of archaeological bone and teeth is a well-established method of diet reconstruction (DeNiro & Epstein, 1978, 1981; van der Merwe & Vogel, 1978; Vogel & van Der Merwe, 1977). Bone collagen primarily indicates source of protein in the diet (Ambrose & Norr, 1993; Fernandes, Nadeau, & Grootes, 2012). The utility of this method stems from the differences in stable isotope values at the base of the food web between different classes of plants and those grown in different microenvironments, and the systematic increase in stable isotope values as isotopes move through the food chain. Stable carbon isotope values can be used to differentiate between different classes of plants as

C_3 plant values are typically lower than C_4 and crassulacean acid metabolism (CAM) plants (Bender, 1971; DeNiro, 1987; Smith & Epstein, 1971). Marine resources have higher $\delta^{13}C$ values than terrestrial C_3 plants and most freshwater fish and terrestrial animals, but that overlap with terrestrial C_4 and CAM plants (Fuller, Müldner, Van Neer, Ervynck, & Richards, 2012; Park & Epstein, 1961; Schoeninger & DeNiro, 1984). Stable nitrogen isotope ratios generally reflect trophic level (Minagawa & Wada, 1984). They can also be useful in distinguishing between terrestrial and marine food sources as marine ecosystems tend to have more trophic levels and source differences in nitrogen in waters (Schoeninger & DeNiro, 1984; Sigman, Karsh, & Casciotti, 2009). Nitrogen isotope ratios can also vary based on environmental factors such as temperature, aridity, soil salinity, and agricultural practices (Szpak, 2014). Consumer nitrogen isotope ratios are approximately 3-5‰ higher than dietary resources (Schoeninger & DeNiro, 1984) and carbon isotope ratios are approximately 5‰ higher than plants consumed and 1‰ higher than the bone collagen animals consumed (Schoeninger, 1989). Diet-tissue (or tissue-tissue in the case of animal to human bone collagen) space is caused by fractionation as stable isotopes move through the food web (Ambrose & Norr, 1993). Stable isotope ratios are represented as delta (δ) values and are reported as per mil (‰) comparative to international standards (Atmospheric nitrogen for $\delta^{15}N$ and Vienna Pee Dee Belemnite for $\delta^{13}C$). Isotope ratios are calculated using the following equation: $\delta = (R_{sample} - R_{standard}) / R_{standard} \times 1000$, where R is the ratio of heavier to lighter isotopes.

Stable isotope analysis of different skeletal elements can be used to track changes in diet over the course of a person's life. Bone turnover, defined as the volume of replacement per unit of time (e.g., percentage per year), occurs through remodeling and differs between skeletal elements based on factors such as surface area to volume ratio and mechanical loading (Parfitt, 2002). The femur, which is large and made up primarily of cortical bone, takes 10 to 30+ years to remodel, depending on age, activity level, and other factors (Hedges, Clement, Thomas, & O'Connell, 2007). Ribs, which are much smaller and contain relatively more trabecular bone, take four to 25 years to remodel (Stout & Paine, 1994). Although there is considerable overlap in remodeling times, femoral isotope ratios likely reflect a longer-term dietary average and rib isotope ratios like reflect a dietary average over the later years of a person's life (Sealy, Armstrong, & Schrire, 1995). Comparing diet reconstructed from femora and ribs in a single individual will provide insight into the extent to which soldier diet changed later in life, presumably capturing the period of military service.

Research methodology: Question, measures, and expectations

In this research, I investigate the following research question: How did French imperial expansion and warfare shape NGA soldier biology? Diet is one mechanism through which biology changes and is influenced by military service in imperial context through the provisioning of rations and shared lifestyles while on campaign. I measure stable carbon and nitrogen isotope ratios in femur bone to reconstruct longer-term diet and rib bone collagen to reconstruct later life diet. I compare isotope ratios in these two bones to track the degree to which diet changed or did not change, addressing individual and group levels.

At the individual level, change in diet is defined as a change in the proportion of isotopically distinguishable foods (i.e., marine, freshwater, terrestrial C_3, and terrestrial C_4). However, investigating change in diet using stable isotope values of different skeletal elements is not a straightforward process as differences in stable isotope values between different skeletal elements of the same individual may not simply reflect changes in the isotope composition of foods consumed. Physiological differences (Reitsema, 2013), environmental differences and cultural practices (Szpak, 2014; van Klinken, Richards, & Hedges, 2000), and differences in sample preparation and analysis across laboratories can contribute to stable isotope variation in bone collagen (Chesson, Chau, & Edwards, early view; Chisholm, Nelson, Hobson, Schwarcz, & Knyf, 1983; Jørkov, Heinemeier, & Lynnerup, 2007; Pestle, Crowley, & Weirauch, 2014). In the present study, rib and femur samples were analyzed at the same laboratory. However, they were analyzed over eight sessions on three elemental analyzers coupled to continuous flow isotope ratio mass spectrometers (EA-IRMS) over the course of three years. This may introduce some variation in stable isotope data.

I use minimal meaningful difference (MMD), developed by William Pestle and colleagues (2014), to establish a more conservative threshold for meaningful difference between femur and rib stable isotope ratios. I interpret values beyond the MMD as evidence of changes in diet but return to the issue of non-dietary factors (physiological, environmental, and cultural) that may lead to differences in stable isotope values in the femur and rib bones of a single individual in the interpretive challenges section. MMD was developed to establish a threshold for meaningful differences in stable isotope ratios from different laboratories or when comparing stable isotope results ratios across studies. MMD is calculated by taking the average of the sum of pairwise differences for an element and adding four times the average standard deviation for each laboratory. The MMD established by Pestle and colleagues (2014) is 0.6‰ for $\delta^{13}C$ and 0.9‰ for $\delta^{15}N$.

There may be a change in diet for some NGA soldiers. If there was a change in diet with military service, then I expect $\Delta_{\text{rib-femur}}$ will be greater than or equal to MMD, 0.6‰ for $\delta^{13}C$ and 0.9‰ for $\delta^{15}N$. Previous research with this sample shows a wide range of both $\delta^{13}C$ and $\delta^{15}N$ values of femoral bone collagen, which my colleagues and I interpreted as indicative of C_4 plant and/or marine food consumption and variation in terrestrial meat consumption (Holder, Dupras, Jankauskas, Williams, & Schultz, 2017). As rations were supposed to consist of C_3 grains and vegetables and terrestrial animal meat, I expect a negative change in the $\delta^{13}C$ values of soldiers who consumed C_4 grains or marine foods prior to military service. Additionally, as soldiers with lower socioeconomic status likely had limited access to terrestrial meat sources prior to military service, I expect in those with lower $\delta^{15}N_{\text{femur}}$ values to higher $\delta^{15}N_{\text{ribs}}$ as meat was supposed to be a regular part of rations.

At the group-level, change is investigated as a change in diet heterogeneity among soldiers within NGA. I use variance in stable isotope ratios as a proxy for diet variation. Variance is a measure of data dispersion and is the average of the squared differences between individual samples and the mean (Hand, 2008). It is preferable to range as it is less sensitive to outliers and sample size. The reasons I use variance instead of a mean shift are two-fold. First, a shift is investigated at the individual-level. Second, mean stable isotope values are not necessarily informative when studying heterogenous groups such as multi-national armies with differing geographic origins and socioeconomic backgrounds, and who served in different places across Europe and were of different ranks and corps.

There may be a change in diet variation toward a more homogenized diet with military service. If there was a change in diet variation with military service, then I expect there will be a statistically significant difference in the variance of femoral and rib $\delta^{13}C$ and $\delta^{15}N$ values. Previous research shows considerable dietary variation among NGA soldiers compared to other European and contemporaneous military samples, as evidenced by the wide dispersal of $\delta^{13}C$ and $\delta^{15}N$ values of femoral bone collagen (Holder et al., 2017). As mentioned above, official daily rations for soldiers on campaign were supposed to consist of bread made from wheat and rye and rice or dried vegetables, all of which are C_3 plants, and meat. This could lead to a homogenization of diet among soldiers during military service. However, rations varied by rank and corps, with imperial guardsmen being the only group with a consistent supply chain leading to better and more consistent rations than their counterparts and officers being prescribed larger rations than the average soldier (Elting, 1988; Rothenberg, 1981). Thus, differences in the provisioning of rations may contribute to diet heterogeneity during military service. Additionally, flexibility in soldier provisioning such as the purchasing of food supplies from local merchants and soldier supplementation through living off the land strategies may be sources of diet heterogeneity. If there was not a change in diet variation with military service (i.e., diet heterogeneity was maintained), then I expect there will be no statistically significant difference in the variance of femoral and rib $\delta^{13}C$ and $\delta^{15}N$ values.

An assumption of this research is that NGA soldier ribs primarily reflect diet during the period of military service. Remodeling rates in ribs vary considerably with age, and thus the ribs of younger individuals may reflect different periods in their life (including time prior to military service) than older individuals. For older soldiers, I do expect that ribs primarily reflect military service as many conscripts became career soldiers and served in multiple campaigns due to the near-constant conflict of the Napoleonic Wars (Forrest, 2002). For younger soldiers, ribs may capture a combination of military and pre-military diet. To investigate this assumption, I compare $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$ across age ranges.

MATERIALS & METHODS

Archaeological context

The skeletal remains in this study come from the mass gravesite of Šiaurės miestelis, located in Vilnius, Lithuania. This site was initially discovered during a construction project in 2001 and material remains indicated the mass grave contained the remains of soldiers associated with Napoleon's multi-ethnic army that died during the Russian Campaign retreat in 1812 (Signoli et al., 2004). Of the 3269 individuals excavated, most of the skeletal material was reinterred at the local Antakalnis military cemetery. Skeletal preservation showed no geographic patterning within the mass grave that would suggest that the best-preserved skeletons are a biased sample in terms of geographic origin, rank, or particular corps membership (Frank, 2001). Ribs and femora were sampled as they were the bones most readily available. Ideally, I would have sampled teeth to capture earlier life diet and ribs to capture changes in diet later in life. However, since most of the skeletal material was reburied in 2006, this was not possible. Fifty-three individuals for which there were both rib and femur bone present were selected for this study. Fifty-two individuals are estimated to be male and one probable male, and age at death estimates ranges from 15-18 to 40-50 years (following Buikstra & Ubelaker, 1994) (Table 3.1).

The presence of animals in a mass gravesite including horses, cattle, sheep, and dogs is somewhat surprising. Historical records indicate that cattle intended to serve as draft animals and food died long before NGA reached Russia (Riehn, 1990). Additionally, soldier diaries and military communications indicate the level of desperation during the retreat related to starvation with soldiers resorting to consuming their horses (Austin, 2000; Forrest, 2002). Thus, it seems unlikely (particularly in the case of cattle, sheep, and horses) that these animals travelled, died, and were buried with NGA. It seems more likely that these animals were local and were discarded in the trench that would become a mass gravesite either before or when NGA soldiers were placed in the grave (G. Piličiauskienė, personal communication). NGA soldiers dug the trench when they set up camp in Vilnius during the initial march to Russia in July 1812 (Signoli et al., 2004), and so it is possible that local animals were discarded there in the intervening months. Nevertheless, nine animals excavated from Šiaurės miestelis were selected for this study to establish a faunal baseline: horse (n=3), cattle, (n=3), sheep (n=2), and dog (n=1).

Sample preparation and analysis

Femur collagen samples (n=78) were prepared at the Laboratory for Bioarchaeological Sciences (LBS) at the University of Central Florida in 2012 and rib collagen samples (n=89) and faunal bone collagen samples (n=9) were prepared at the Bioarchaeology and Biochemistry Laboratory (BBL) at the University of Georgia in 2017-2019. Two femur samples initially prepared at the LBS and were discarded were re-prepared at the BBL. Additionally, 10 femur samples that were not part of the initial study in 2012 were prepared alongside rib samples at the BBL. This resulted in 53 paired ribs and femora and nine faunal bones, all of which were included in this study.

Bone collagen extraction followed a modified version of Longin (1971) outlined in (Holder et al., 2017). First, a small chunk of bone (~0.5-1.0 g) was cut and trabecular bone and the outer surface of cortical bone were removed using a hand-held Dremel® tool. Next, samples were cleaned using tap water and toothbrush, followed by five-minute rounds of ultrasonication using reverse osmosed (RO) water until water was clear. Chemical preparation included lipid removal through three 20-minute rinses in 2:1 $CHCl_3$:CH_3OH (chloroform:methanol), demineralization of sample using 0.5 M HCl (hydrochloric acid), RO water rinses to return pH to neutral (~7), removal of humic and fulvic acid soil contaminants through 20-minute rinses of NaOH (sodium hydroxide) until solution was clear, again rinsing to neutrality using RO water, a short rinse in 0.25 M hydrochloric acid, which was finally replaced with RO water. The water-soluble collagen was then place in the oven at 90° C for 16-24 hours, centrifugated at 2400 rpm for 10 minutes, and collagen containing liquid transferred to dram vials via pipette. Femur samples were oven dried at 90° C for at least 16 hours, whereas rib samples were frozen at -80° C for 10 minutes and freeze dried for 24-48 hours. All samples were homogenized before being weighed and submitted for analysis. To ensure there were no isotopic differences between oven drying and freeze-drying samples, I ran five replicates prepared by oven drying and five replicates prepared by freeze drying for two samples. The difference in mean for both samples for $\delta^{13}C < 0.02$ and $\delta^{15}N \leq 0.1$ and were not statistically significant

(NAP-K006 $\delta^{13}C$: t = -0.5774, df = 5.619, p-value = 0.586, $\delta^{15}N$: t = 1.402, df = 7.089, p-value = 0.203; NAP-K176 $\delta^{13}C$: t = -0.327, df = 7.418, p-value = 0.753, $\delta^{15}N$: t = -0.554, df = 6.760, p-value = 0.597).

Femur samples were initially analyzed at the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University in 2012. I sent previously analyzed femur collagen samples and all rib collagen samples for analysis at the Stable Isotope Ecology Laboratory at the Center for Applied Isotope Studies at the University of Georgia. Stable carbon and nitrogen stable isotope and elemental compositions were determined using an EA-IRMS via an open split interface over eight analytical sessions (Table S1). Stable carbon and nitrogen isotopic compositions were calibrated relative to VPDB and AIR scales using NIST1577c and elemental compositions were calibrated using NIST1570a. Precision was determined to be ± 0.12‰ for $\delta^{13}C$ and ± 0.12‰ for $\delta^{15}N$ based on repeated measurements of calibration standards, check standards, and sample replicates (Tables S2-S3). Precision was calculated following a modified version of Appendix G from Szpak, Metcalfe, and Macdonald (2017).

Statistical comparisons were performed in R (R Core Team, 2020) and are considered statistically significant when $p \leq 0.05$. I used parametric (F-test) and non-parametric (Ansari-Bradley test) tests to compare sample variances depending on results of Shapiro Wilks test for normality (Table 3.2).

RESULTS

Collagen quality measures

The following criteria were used to evaluate collagen quality: collagen yield between 1% and 22% (van Klinken, 1999), carbon content (%C) between 13% and 47%, nitrogen content (%N) between 4.8% and 17.3% (Ambrose, 1990), and atomic C:N between 2.9 and 3.6 (DeNiro, 1985) (Tables 3.1 and 3.3). Collagen yield was calculated by dividing collagen weight by dry sample weight (after cleaning but prior to chemical treatments) and multiplying by 100. All faunal samples fall with accepted ranges for quality control criteria. All human samples have collagen yields and atomic C:N within the ranges outlined above. One human individual has femur collagen %C above 47% and %N above 17.3%. Nine human individuals have rib collagen %C above 47% and eight have %N above 17.3%. In the case of carbon, higher content can indicate the addition of organic carbon (van Klinken, 1999). However, all sample carbon content is within 3% of the upper limit and nitrogen is within 1%. Additionally, there is not a strong linear relationship between %C and δ^{13}C (femur: $r^2 = 0.07$, rib: $r^2 = 0.0004$) or %N and δ^{15}N (femur: $r^2 = 0.02$, rib: $r^2 = 0.04$). Thus, all samples are considered to have well-preserved collagen and were included in this study.

Stable carbon and nitrogen isotope data

Stable isotope data from all samples analyzed in this study are presented in Tables 3.1 and 3.3 and Figure 3.2. Terrestrial faunal δ^{13}C values range from -22.3‰ to -20.2‰ with a mean of -21.8 ± 0.7‰ and δ^{15}N values range from 4.5‰ to 7.5‰ with a mean of 6.4 ± 1.1‰. Human femur δ^{13}C range from -20.5‰ to -13.6‰ with a mean of -18.7 ± 1.4‰ and human femur δ^{15}N range from 7.7‰ to 13.7‰ with a mean of 10.6 ± 1.3‰. Human rib δ^{13}C range from -20.4‰ to -15.6‰ with a mean of -19.2 ± 0.9‰ and rib δ^{15}N range from 9.0‰ to 13.3‰ with a mean of 10.9 ± 1.1‰.

$\Delta^{13}C_{\text{rib-femur}}$ range from -4.1‰ to 0.2‰ with a mean of -0.5 ± 0.7‰ and $\Delta^{15}N_{\text{rib-femur}}$ range from -0.5‰ to 1.7‰ with a mean of 0.3 ± 0.5‰ (Figure 3.4). One individual has a $\Delta^{13}C_{\text{rib-femur}}$ of 0, 45 have a negative difference (ribs have lower values), and seven a positive difference (femur has lower values). Six individuals have a $\Delta^{15}N_{\text{rib-femur}}$ of 0, 12 have a negative difference, and 35 have a positive difference. Twenty-one of the 53 individuals in this study have an $\Delta^{13}C_{\text{rib-femur}}$ value (n=16), $\Delta^{15}N_{\text{rib-femur}}$ value (n=7), or both (n=2) on or past the MMD threshold (Figure 3.4). All $\Delta^{13}C_{\text{rib-femur}}$ values on or past the MMD were negative and all $\Delta^{15}N_{\text{rib-femur}}$ value on or past the MMD were positive. $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$ values differ across adjusted age categories (Table 3.4)

Variance in δ^{13}C values of ribs and femora are not statistically significantly different (AB = 1421, p-value = 0.90). Variance in δ^{15}N values of ribs and femora are also not statistically significantly different (F = 1.51, df = 52, p-value = 0.14).

DISCUSSION

Faunal and human diet reconstruction

Animal bones from Šiaurės miestelis facilitate diet reconstruction by establishing a faunal baseline for NGA soldiers. Animal δ^{13}C and δ^{15}N values from Šiaurės miestelis are similar to faunal stable isotope values reported for other 16th to 19th century European sites (Table 3.5). Faunal $\delta^{13}C$ and $\delta^{15}N$ values from Šiaurės miestelis suggest these animals were foddered C_3 grains, with some animals potentially consuming vegetable and meat scraps (see Figure 3.2). Because of the mystery surrounding the context of faunal remains in the mass gravesite and the relatively few sampled in this study, I created a more comprehensive isotope database of Medieval and post-Medieval faunal and fish samples from regions across Europe to capture the array of different diet and environmental factors likely contributing to stable isotope dispersal in this study (Table S4). In Figure 3.5, for fauna, +1‰ has been added to all $\delta^{13}C$ values and +4‰ added to $\delta^{15}N$ values to help visualize NGA soldier diet in relation to fauna.

NGA soldier rib and femur $\delta^{13}C$ and $\delta^{15}N$ values fall within the expected range for predominantly terrestrial plant and animal protein consumers. Those individuals with lower $\delta^{13}C$ values likely consumed grains and vegetables that follow a C_3 photosynthetic pathway such as wheat, barley, and rye. This is not surprising as food rations prescribed during military service and both regions where soldiers originated from and perhaps previously served are dominated by C_3 plant domesticates and terrestrial animal resources. It is also possible that freshwater fish were consumed by those individuals with low $\delta^{13}C$ values. Several individuals have $\delta^{13}C$ and $\delta^{15}N$ values that fall within the expected range for predominantly freshwater fish consumers, although the region where the NGA soldiers fall also overlaps with terrestrial animal consumers. Although not documented as official rations, freshwater fish have served as a source of protein throughout Europe historically (Svanberg & Locker, 2020). Their consumption has been linked to status and nobility in urban centers, religious fasting, and peasantry in rural contexts (Svanberg & Locker, 2020; Van Neer, Ervynck, Bolle, Millner, & Rijnsdorp, 2002). They may have been purchased locally on campaign and/or consumed prior to military service.

Seven individuals have $\delta^{13}C_{femur}$ values and five individuals have $\delta^{13}C_{rib}$ values higher than -18.0‰. All of these individuals have $\delta^{15}N$ values lower than 12.0‰, making marine fish consumption unlikely. Thus, higher $\delta^{13}C$ values are likely due to C_4 plant consumption. The presence of C_4 plants such as sorghum (*Sorhum* sp.), maize (*Zea mays*), and millets (*Setaria italica* and *Panicum miliaceum*) are noted throughout various parts of Europe during the 18th and 19th centuries (E. Anderson & Martin, 1949;

House, 1995; Moreno-Larrazabal, Teira-Brión, Sopelana-Salcedo, Arranz-Otaegui, & Zapata, 2015). Stable isotope studies have also found evidence of C_4 plant consumption has at Medieval and post-Medieval sites throughout Europe (e.g., Alexander, Gerrard, Gutiérrez, & Millard, 2015; Fuller, Márquez-Grant, & Richards, 2010; Iacumin, Galli, Cavalli, & Cecere, 2014; Lugli et al., 2017; Reitsema & Vercellotti, 2012). Because the local faunal baseline is suspect and I used published data from an array of different sites and time periods, I cannot ascertain whether high NGA soldier $\delta^{13}C$ values is the result of soldiers directly consuming C_4 grains and vegetables or of animals foddered on C_4 grains and vegetables.

Reconstructing changes in human diet

The primary goal of this study is to examine how French imperial expansion and warfare shaped imperial NGA soldier biology at the individual and group levels by reconstructing changes in diet. At the individual level, there was a change in diet for 40% of NGA soldiers. All individuals with $\Delta^{13}C_{\text{rib-femur}}$ equal to or exceeding the MMD threshold were toward increased consumption of C_3 plants and all individuals with $\Delta^{15}N_{\text{rib-femur}}$ values equal to or exceeding the MMD threshold were toward increased consumption of terrestrial animal protein (Figure 3.4). Even though $\delta^{13}C$ values are lower and $\delta^{15}N$ values are higher, it is unlikely that this is due to the consumption of freshwater fish as only two individuals exhibit changes in both $\delta^{13}C$ and $\delta^{15}N$ values past the threshold of MMD. This pattern is consistent with NGA soldier diet later in life toward greater terrestrial C_3 plant and animal consumption due to the provisioning of rations and shared lifestyles during military service.

Changes in diet at individual level show some interesting patterns with age. While there are multiple individuals in all five adjusted age ranges that show evidence of diet change as evidenced by $\Delta^{13}C_{\text{rib-femur}}$, most individuals that have $\Delta^{15}N_{\text{rib-femur}}$ past the MMD threshold are in the 25-30 years at death range and all are estimated above 25 years (see Table 3.4). That there were individuals in all age ranges toward greater C_3 plant grain and vegetable consumption indicates that it is possible to detect to diet change even among young conscripts, although a diet change prior to military service cannot be ruled out. That there was only evidence of increased meat consumption among individuals is interesting and warrants further discussion. It is possible that older individuals, who were more likely to be of higher rank and served during multiple campaigns, had greater access to meat than newly conscripted soldiers. This claim is supported by historical documentation of officers and imperial guardsmen receiving larger proportions and more consistent rations (Elting, 1988; Rothenberg, 1981). Additionally, precarity in provisioning soldiers while on campaign was constant problem throughout the Napoleonic Wars (Austin, 2000; Forrest, 2002); it is possible that officers and soldiers of higher rank were more buffered against the logistical challenges of provisioning during these times, receiving meat rations when their lower ranked counterparts did not.

Despite individual-level changes in diet, stable isotope results indicate that longer term diet heterogeneity was maintained later in life as evidenced by similar visual dispersal and variance in both $\delta^{13}C$ and $\delta^{15}N$ values (Figure 3.2). Although official rations consisted exclusively of C_3 grains and vegetables and terrestrial meat protein, actual provisioning practices were relatively flexible as mobility and efficiency were prioritized. Reliance on local resources by the army and individual and collective soldier supplementation strategies to counter food precarity are possible mechanisms for maintaining the array of isotopically diverse diets. As with individual-level diet change, differences in rations across rank and corps may have also contributed to later life diet heterogeneity.

The French Empire was actively expanding on the continent of Europe during the late 18th and early 19th centuries through warfare (Broers, 2002). This resulted in the near-constant deployment of NGA on campaigns across Europe including Poland, Prussia, Austria, Portugal, Spain, and Russia (Esdaile, 2008). The NGA employed flexible provisioning strategies to provision soldiers while on campaign, with soldiers supplementing their rations through living off the land. Together, these practices profoundly reshaped the biology of soldiers serving in NGA through changes in diet maintaining diet heterogeneity.

Comparison with contemporaneous military sample: British Royal Navy sailors

To investigate similarities and differences in relationship between recruiting and diet practices among early 19th century European imperial servicemen, I compared NGA soldier rib $\delta^{13}C$ and $\delta^{15}N$ values with those of late 18th-early 19th century British Royal Navy (BRN) sailors from Haslar, Gosport, UK and early 19th century BRN sailors from Stray Park in Plymouth, UK. Roberts et al. (2012) carried out diet reconstruction of BRN sailors. Here, I use stable isotope results of rib collagen (Plymouth, n=50, Haslar, n=20) published in Tables S1 and S2 of Roberts et al. (2012).

Both groups of BRN sailors come from cemeteries associated with Royal Naval hospitals. The cemeteries at Haslar and Plymouth were composed of seamen and marines, with cooks, carpenters, and prisoners-of-war making up a much smaller proportion (Roberts et al., 2012). Like NGA, the BRN was involved in near constant conflict throughout the late 18th and early 19th centuries with sailors deployed to North America, the Caribbean, India, Australia and New Zealand, and South Africa (Chamberlain, 2000). This required recruiting large numbers of men and supplying them with adequate food supplies over numerous and distant campaigns. The two predominant groups making up sailors in the BRN were seaman who were recruited from ships and ports around the world because of their skills and British marines who either volunteered or were conscripted (A. D. Lambert, 2000, 2004 via Roberts et al., 2012). Unlike NGA, sailor rations were strictly controlled and consisted of bread, beer, beef or pork, peas, oatmeal, butter, cheese, and occasionally stockfish (Rodger, 1986 via Roberts et al. 2012), although local foods were occasionally substituted (Lavery, 1998 via Roberts et al. 2012).

Statistical comparison of rib $\delta^{13}C$ and $\delta^{15}N$ variance indicates that NGA soldier diet heterogeneity differed from BRN sailors at Haslar but was similar to BRN sailors at Plymouth (Table 3.6, Figure 3.6). While BRN sailors at Haslar likely consumed a diet predominant composed of grains and vegetables that follow a C_3 photosynthetic pathway and regular consumption of terrestrial animals, sailors from Plymouth had a much more heterogenous diet in regard to animal protein and C_4 plant consumption, as well as possible marine fish. Like BRN sailors from Plymouth, NGA soldiers also had a more heterogenous diet in regard to meat protein and consumption C_4 plant foods, with possible consumption of freshwater fish.

Isotopic comparisons between NGA soldiers and BRN sailors provides valuable insight into how recruiting and provisioning practices shaped the biology of servicemen in two actively expanding empires engaged in near constant military conflict. Both empires recruited from within and beyond their borders, contributing to diet variation in femur and rib bone collagen samples. Additionally, both militaries reshaped servicemen diet through a combination of prescribed rations, service across Europe and on other continents, and servicemen supplementation.

Interpretive challenges

While I interpreted $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$ values equal to or past the MMD threshold established by Pestle, Crowley, and Weirauch (2014) as indicative of diet change, there are physiological, environmental, and cultural factors that may account for isotopic differences in rib and femur isotope values of the same individual. First, differences in stable isotope fractionation and uptake caused physiological differences such as disease and stress can cause non-diet related stable isotope variation (see review by Reitsema, 2013). Second, environmental differences such as climate, salinity, aridity can cause variation in both carbon and nitrogen stable isotope values (Szpak, 2014; van Klinken et al., 2000). Lastly, cultural practices such as the manuring of arable land can contribute to variation in stable nitrogen isotope values, mimicking meat consumption (Bogaard et al., 2013; Bogaard, Heaton, Poulton, & Merbach, 2007). Each of these factors may be contributing to stable carbon and nitrogen isotope variation at the group level and confound interpretations of changes in stable isotope values at the individual level.

The mass burial context presents challenges in overcoming these issues, but future work may help overcome them. First, distinguishing soldiers by dimensions of identity, such as geographic origins or rank, is not possible given their burial context. Second, while there were faunal remains discovered in the mass grave, they are likely local rather than animals consumed by NGA. Even if there were animals traveling with NGA available for study, those animals would only provide a baseline for the final campaign. This sample is defined by the heterogeneity in geographic origin and its mobility. Establishing a faunal baseline capturing the several years of diet reflected in bone is currently not possible. Thus, I apply compound specific stable isotope analysis of individual amino acids (AA-CSIA) of a subset of individuals in this study (n=20), capturing the range of bulk collagen $\delta^{13}C$ and $\delta^{15}N$ values, to address possible non-dietary factors shaping stable isotope variability (Chapter 4).

CONCLUSION

This research examined how military service during a period of imperial expansion and warfare shaped soldier biology through diet. Stable isotope results reveal that NGA soldier longer-term and later life diet consisted primarily of terrestrial grains, vegetables, and animal products, as expected based on prescribed rations and foods dominating the European landscape. While most soldiers consumed C_3 grains and vegetables, some soldiers also consumed C_4 grains and vegetables prior to and during military service. Freshwater fish consumption is also possible as isotope values overlap with higher trophic terrestrial animals. Future research using compound specific stable isotope analysis of individual amino acids (CS-SIA) may be useful to further distinguish between different food stuffs (see Chapter 4).

While individual-level changes in diet later in life were detected in 40% of NGA soldiers, longer-term diet variation among NGA soldiers was maintained later in life. Although changes occurred in the same direction for all soldiers for both $\delta^{13}C$ and $\delta^{15}N$ values, they were relatively small, which likely explains why despite the consistency in the pattern, diet did not become more homogenous.

Comparison of NGA soldier stable isotope values with two samples of BRN sailors further illuminate patterns in imperial military recruitment and provisioning. NGA soldiers exhibited similar diet heterogeneity as BRN sailors at Plymouth. Additionally, a similar proportion of BRN sailors at Haslar exhibited a change in diet (55%), although changes in $\delta^{13}C$ values occurred in both directions. These similarities demonstrate that despite the intention of universal rations by militaries, soldiers consumed a diverse array of diets during military service, because of either reliance on local contractors or soldier supplementation on distant campaigns ("living off the land"). Thus, actual imperial military provisioning practices were kept flexible to emphasize efficiency over adequate support.

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Table 3.1. Demographic, isotopic, and bone quality data for Napoleon's Grand Army soldiers from the mass gravesite of Šiaurės miestelis.

				Femur Collagen Data						**Rib Collagen Data**							
Sample ID	**Sex**	**Age (Years)**	**Adjusted Age[1] (years)**	**C (%)**	**N (%)**	**Atomic C/N**	**Collagen Yield (%)**	**δ^{13}C (‰) VPDB**	**δ^{15}N (‰) AIR**	**C (%)**	**N (%)**	**Atomic C/N**	**Collagen Yield (%)**	**δ^{13}C (‰) VPDB**	**δ^{15}N (‰) AIR**	**$\Delta^{13}C_{rib\text{-}femur}$**	**$\Delta^{15}N_{rib\text{-}femur}$**
NAP-K006*	M	20-25	20-25	48.4	17.9	3.2	17.9	-19.3	12.3	48.0	18.0	3.1	10.0	-19.8	12.8	-0.5	0.5
NAP-K007	PM	35-40	35-45	45.8	16.5	3.2	17.6	-18.8	11.1	45.1	16.2	3.2	19.4	-19.1	10.9	-0.3	-0.2
NAP-K009	M	20-25	20-25	46.6	16.8	3.2	18.0	-18.3	11.5	47.0	17.5	3.1	19.1	-18.4	11.6	-0.2	0.1
NAP-K010	M	25-30	25-30	42.2	15.2	3.2	16.7	-18.8	10.0	44.5	16.0	3.2	19.7	-18.9	10.1	-0.1	0.1
NAP-K011	M	20+	20-25	41.8	15.0	3.2	12.8	-19.5	10.3	45.0	16.2	3.2	17.8	-19.3	10.6	0.2	0.3
NAP-K012	M	35-45	35-45	41.7	15.0	3.2	13.0	-20.3	10.8	44.3	15.9	3.2	19.0	-20.2	10.9	0.1	0.2
NAP-K013+	M	20-25	20-25	42.7	15.4	3.2	15.6	-19.3	10.7	44.7	16.1	3.2	13.6	-19.3	11.2	0.0	0.5
NAP-K019	M	>40	35-45	45.2	16.3	3.2	17.2	-18.4	9.5	43.2	15.6	3.2	20.7	-19.5	10.8	**-1.1**	**1.3**
NAP-K023	M	20-25	20-25	45.0	16.1	3.3	18.9	-19.0	9.9	44.3	15.9	3.2	13.1	-19.4	9.8	-0.5	0.0
NAP-K025	M	20	15-20	44.7	16.0	3.3	16.4	-18.7	10.4	44.5	16.0	3.2	18.2	-19.1	10.7	-0.4	0.2
NAP-K026	M	25-30	25-30	44.5	15.9	3.3	18.8	-19.7	8.7	45.5	16.4	3.2	20.6	-19.9	10.0	-0.2	**1.3**
NAP-K027	M	20+	20-25	41.9	15.0	3.3	14.0	-19.6	11.9	45.1	16.2	3.2	17.3	-19.7	11.7	-0.1	-0.2
NAP-K034	M	30-35	30-35	42.5	15.3	3.2	16.1	-19.9	10.9	44.5	16.0	3.2	18.9	-19.7	10.9	0.2	0.0
NAP-K037+	M	25-30	25-30	45.6	16.4	3.2	20.5	-19.7	12.4	47.4	17.6	3.1	18.4	-19.8	13.0	-0.1	0.6
NAP-K038	M	35-40	35-45	45.0	16.1	3.3	14.9	-19.6	11.9	47.9	17.8	3.1	14.6	-20.0	12.0	-0.4	0.0
NAP-K044+	M	30-35	30-35	46.2	16.7	3.2	7.3	-19.7	9.0	46.7	16.8	3.2	18.1	-19.6	9.7	0.1	0.7
NAP-K046	M	25-35	25-30	45.8	16.5	3.2	17.1	-18.7	12.2	43.3	16.0	3.2	14.9	-19.3	12.4	**-0.6**	0.2
NAP-K050	M	20-25	20-25	45.3	16.3	3.2	15.6	-19.0	12.6	47.9	17.7	3.1	17.8	-19.4	12.9	-0.4	0.3
NAP-K052	M	25-30	25-30	43.0	15.4	3.3	14.9	-19.9	7.7	46.7	17.3	3.1	16.1	-20.2	9.4	-0.2	**1.7**
NAP-K054	M	40-50	35-45	45.5	16.2	3.3	17.5	-18.4	10.6	45.4	16.3	3.2	18.8	-19.3	10.9	**-0.9**	0.3
NAP-K061	M	20-25	20-25	45.1	16.2	3.3	13.8	-19.3	11.0	45.2	16.2	3.3	6.5	-19.8	10.8	-0.5	-0.2
NAP-K062	M	25-30	25-30	45.1	16.2	3.3	13.7	-19.2	11.3	46.3	16.5	3.3	6.5	-19.4	11.4	-0.2	0.1
NAP-K063	M	25-30	25-30	45.0	16.1	3.3	13.4	-19.3	8.2	43.2	15.9	3.2	15.3	-19.8	9.0	-0.5	0.8

NAP-K065	M	40	35-45	45.7	16.4	3.3	15.0	-13.6	9.4	43.8	15.6	3.3	8.6	-15.6	10.2	**-2.0**	0.8
NAP-K066	M	20-25	20-25	44.2	15.9	3.2	19.5	-19.3	10.3	47.1	16.9	3.2	19.8	-20.1	10.1	**-0.7**	-0.2
NAP-K068	M	18-20	15-20	45.3	16.2	3.3	14.3	-15.9	11.0	46.8	16.9	3.2	16.5	-17.6	11.0	**-1.6**	0.0
NAP-K069	M	25-30	25-30	45.7	16.3	3.3	14.6	-18.2	9.2	46.2	17.1	3.1	20.0	-18.7	9.1	-0.5	-0.1
NAP-K071	M	15-18	15-20	41.8	15.0	3.2	14.2	-20.5	12.2	45.6	16.4	3.2	19.1	-20.4	12.1	0.1	0.0
NAP-K075+	M	30	25-30	46.2	16.6	3.2	16.6	-18.2	8.1	46.9	17.4	3.1	19.7	-18.9	9.3	**-0.8**	**1.2**
NAP-K078	M	25-30	25-30	45.9	16.5	3.3	17.0	-19.1	11.1	47.1	17.0	3.2	22.0	-19.3	10.8	-0.2	-0.3
NAP-K087	M	20-25	20-25	45.4	16.3	3.3	12.8	-19.0	11.6	44.4	16.0	3.2	16.3	-19.4	11.2	-0.4	-0.5
NAP-K091*	M	20-25	20-25	45.6	16.4	3.2	18.0	-19.0	8.6	47.0	17.6	3.1	15.2	-19.3	9.0	-0.4	0.4
NAP-K096	M	30-35	30-35	45.3	16.3	3.2	19.0	-18.5	10.8	44.2	15.9	3.2	17.0	-19.2	10.5	**-0.7**	-0.2
NAP-K102	M	35-45	35-45	42.3	15.2	3.3	10.4	-19.8	10.4	43.3	15.5	3.3	14.2	-19.8	10.8	-0.1	0.4
NAP-K104	M	25-30	25-30	42.4	15.3	3.2	11.8	-16.9	9.7	44.7	16.1	3.2	20.8	-17.7	10.1	**-0.8**	0.4
NAP-K105	M	25-30	25-30	45.2	16.1	3.3	18.0	-14.1	8.7	44.1	15.8	3.3	4.2	-16.3	9.5	**-2.1**	0.7
NAP-K107	M	16-17	15-20	44.9	15.9	3.3	6.6	-19.0	13.7	43.4	16.0	3.2	14.5	-19.7	13.3	**-0.7**	-0.3
NAP-K111	M	20-25	20-25	44.9	16.1	3.3	10.7	-19.2	12.0	46.4	17.2	3.2	11.8	-19.7	11.7	-0.5	-0.3
NAP-K113	M	20-25	20-25	46.9	16.8	3.3	16.5	-19.4	9.5	43.0	15.4	3.3	11.8	-19.7	10.1	-0.3	0.6
NAP-K121	M	20-25	20-25	45.1	16.1	3.3	13.4	-17.9	11.7	47.0	16.9	3.3	18.6	-18.3	11.9	-0.3	0.2
NAP-K125	M	25-30	25-30	41.5	14.8	3.3	4.0	-20.1	8.5	46.0	16.3	3.3	3.2	-20.0	9.7	0.2	**1.2**
NAP-K126+	M	20-25	20-25	45.9	16.6	3.2	6.7	-19.3	11.3	42.6	15.3	3.2	5.3	-20.0	11.8	**-0.7**	0.4
NAP-K128	M	20-25	20-25	46.4	16.8	3.2	13.4	-19.2	12.0	44.0	16.2	3.2	14.9	-19.8	12.0	-0.5	0.1
NAP-K134	M	30-40	35-45	46.5	16.9	3.2	8.7	-19.0	10.7	46.4	16.5	3.3	5.9	-19.3	11.0	-0.3	0.3
NAP-K142	M	30-35	30-35	45.8	16.7	3.2	16.9	-18.4	10.9	49.5	17.4	3.3	6.6	-19.0	11.7	**-0.6**	0.7
NAP-K143	M	25-30	25-30	46.5	16.6	3.3	14.3	-19.0	8.4	43.6	16.0	3.2	4.3	-19.3	9.4	-0.3	**1.0**
NAP-K158*	M	30-35	30-35	45.2	16.4	3.2	14.6	-18.6	10.5	47.1	16.9	3.3	16.5	-19.1	12.2	-0.5	**1.7**
NAP-K159	M	25-30	25-30	44.8	16.1	3.3	11.7	-19.0	11.5	45.2	16.5	3.2	12.2	-19.5	11.6	-0.5	0.1
NAP-K164	M	25-30	25-30	44.3	15.9	3.2	4.7	-18.1	12.1	44.2	16.1	3.2	14.6	-18.8	12.1	**-0.7**	0.0
NAP-K167	M	25	20-25	45.1	16.5	3.2	17.5	-19.9	10.6	44.1	15.9	3.2	16.7	-19.8	11.2	0.1	0.7
NAP-K171	M	25-30	25-30	44.5	16.0	3.3	13.7	-17.8	10.5	44.2	15.9	3.2	16.3	-18.6	10.0	**-0.8**	-0.5
NAP-K176+*	M	35-45	35-45	46.0	16.8	3.2	17.0	-19.2	11.3	45.2	16.2	3.2	18.9	-19.3	11.5	-0.1	0.1

NAP-K182+*	M	25-30	25-30	46.2	16.7	3.2	8.6	-13.9	11.4	47.5	17.1	3.2	-	-18.0	11.1	**-4.1**	-0.3

$\Delta^{13}C_{rib\text{-}femur}$ and $\Delta^{15}N_{rib\text{-}femur}$ values on or past MMD threshold bolded.

+femoral samples run in duplicate, *rib samples run in duplicate

[1] Becuase age range estimates varied in length, I adjusted them to establish consistent age ranges by taking the median of the initial age range estimates and assigning them to the following ranges: 15-20, 20-25, 25-30, 30-35, and 35-45.

Table 3.2. Results of Shapiro Wilks test for normality of stable isotope results for NGA soldiers from the mass gravesite of Šiaurės miestelis and the British Royal Navy hospital cemeteries at Haslar and Plymouth.

	$\delta^{13}C_{femur}$	**$\delta^{15}N_{femuur}$**	**$\delta^{13}C_{rib}$**	**$\delta^{15}N_{rib}$**
NGA	**W = 0.730, p = 1.53e-08**	W = 0.973, p = 0.27	**W = 0.797, p = 4.12e-07**	W = 0.979, p = 0.48
BRN (Haslar)	**-**	**-**	W = 0.971, p = 0.77	W = 0.937, p = 0.21
BRN(Plymouth)	**-**	**-**	W = 0.975, p = 0.38	W = 0.973, p = 0.30

Significant figures bolded.

Table 3.3. Isotopic and bone quality data for faunal remains from the mass gravesite of Šiaurės miestelis.

Sample ID	**Species**		**Bone**	**C (%)**	**N (%)**	**C/N**	**Collagen Yield (%)**	**$\delta^{13}C$ (‰) VPDB**	**$\delta^{15}N$ (‰) AIR**
1	Horse	*Equus ferus caballus*	humerus	43.5	15.8	3.2	18.1	-22.2	7.2
2	Horse	*Equus ferus caballus*	humerus	44.3	16.2	3.2	19.3	-21.8	4.5
3	Horse	*Equus ferus caballus*	humerus	44.7	16.2	3.2	14.2	-21.6	5.3
4	Cattle	*Bos taurus*	tibia	43.2	15.8	3.2	15.6	-22.3	7.1
5	Cattle	*Bos taurus*	tibia	45.3	16.4	3.2	18.3	-21.9	6.6
6	Cattle	*Bos taurus*	tibia	44.0	16.0	3.2	17.0	-22.0	6.9
7	Sheep	*Ovis aries*	humerus	42.8	15.4	3.2	13.1	-22.3	7.1
8	Sheep	*Ovis aries*	humerus	39.7	14.3	3.2	3.7	-21.6	7.5
9+	Dog	*Canis l. familiaris*	mandible	43.3	15.6	3.2	17.0	-20.2	5.2

+duplicates

Table 3.4. Percentage of soldiers for each category showing a change in diet as evidenced by $\Delta^{13}C_{rib\text{-}femur}$ and $\Delta^{15}N_{rib\text{-}femur}$ values.

	Adjusted age categories				
	15-20 years	**20-25 years**	**25-30 years**	**30-35 years**	**35-45 years**
$\Delta^{13}C_{rib\text{-}femur}$	50% (2/4)	12% (2/17)	39% (7/18)	40% (2/5)	33% (3/9)
$\Delta^{15}N_{rib\text{-}femur}$	0% (0/4)	0% (0/17)	28% (5/18)	20% (1/5)	11% (1/9)

Table 3.5. Comparison of stable isotope ratios in fauna from Šiaurės miestelis and contemporary European sites.

Site	**$\delta^{13}C$ range**	**$\delta^{15}N$ range**	**Reference**
Šiaurės miestelis, Vilnius, Lithuania	-22.3‰ to -20.2‰	4.5‰ to 7.5‰	This study
Aalst, Belgium	-22.7‰ to -19.1‰	4.3‰ to 9.7‰	MacRoberts et al., 2020
Vilnius, Lithuania (multiple sites)	-22.3‰ to -19.9‰	5.6‰ to 9.9‰	Chapter 5
Convento dos Lóios and Convento dos Remédios, Portugal	-21.1‰ to -18.8‰	7.0‰ to 9.6‰	Quintelier et al., 2014

Table 3.6. Results of comparison of means and variance between NGA soldier stable isotope values and British Royal Navy sailor stable isotope values.

	$\delta^{13}C_{rib}$	**$\delta^{15}N_{rib}$**
BRN (Haslar)		
Variance	**AB = 1096.5, p = 0.01**	**F = 4.854, num df = 52, denom df = 19, p = 0.0004**
BRN (Plymouth)		
Variance	AB = 1532, p = 0.07	F = 0.625, num df = 52, denom df = 49, p = 0.10

Significant figures bolded.

Figure 3.1. Map showing location of mass gravesite Šiaurės miestelis in Vilnius, Lithuania.

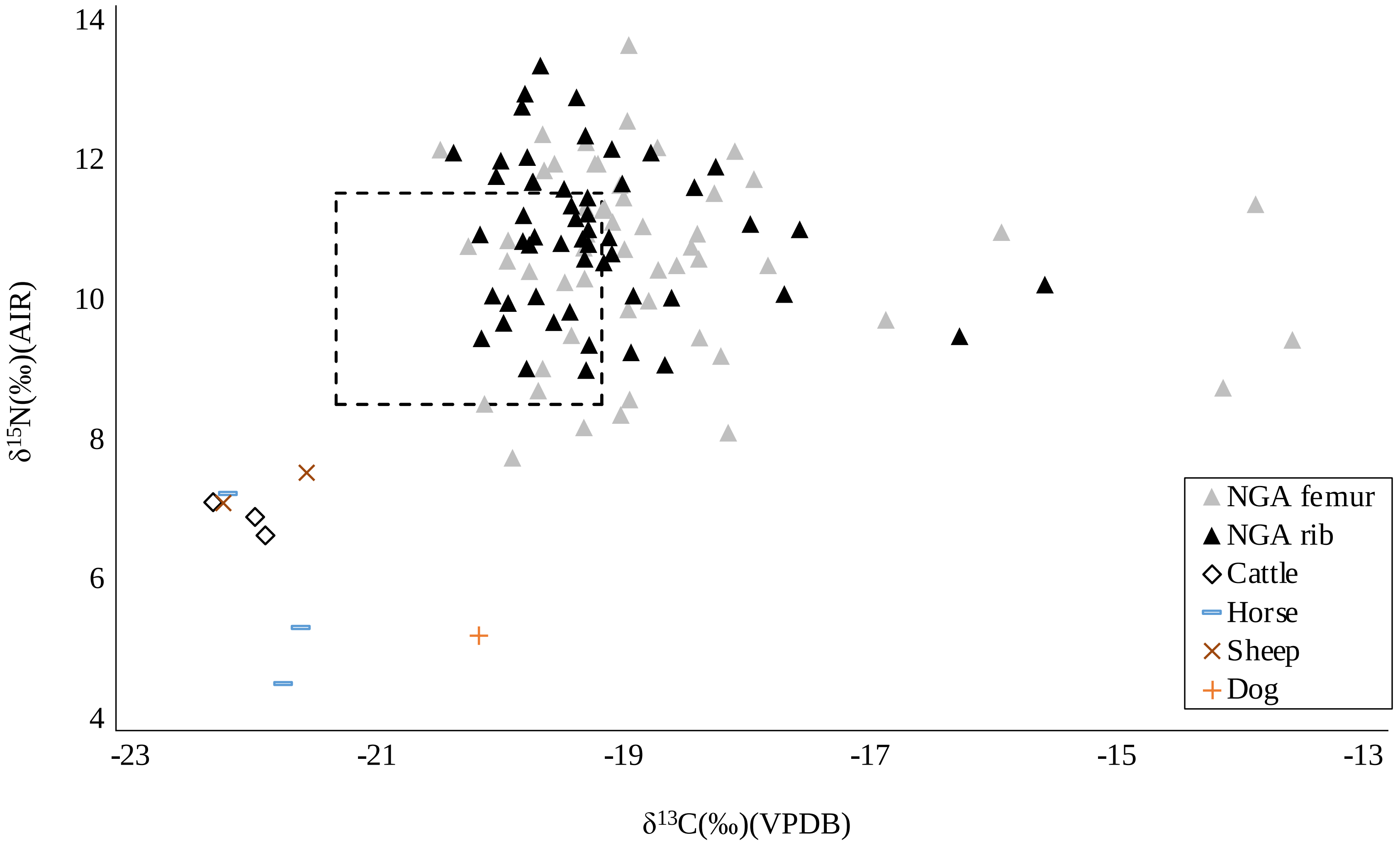

Figure 3.2. Stable carbon and nitrogen isotope data of individual Napoleon's Grand Army (NGA) soldier rib and femur and terrestrial animal bone collagen samples analyzed in this study. The dashed rectangle indicates the range of $\delta^{13}C$ and $\delta^{15}N$ values of terrestrial faunal samples analyzed in this study with one trophic-level enrichment (+1‰ for carbon, +4‰ for nitrogen).

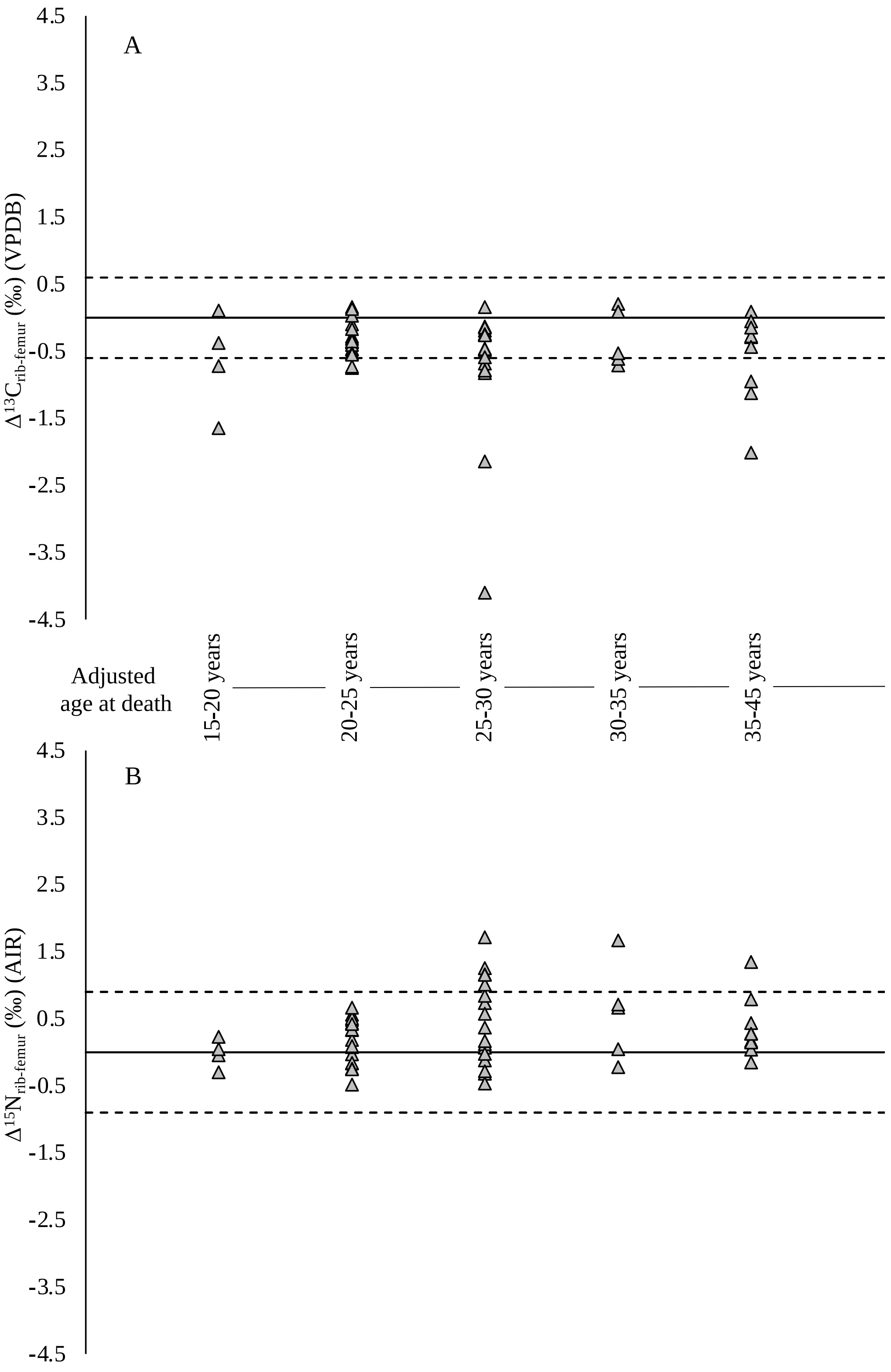

Figure 3.3. Differences in stable carbon (A) and nitrogen (B) isotope values between rib and femur collagen samples for Napoleon's Grand Army (NGA) soldiers by age. Solid line represents a difference of 0 and dotted lines represent minimal meaningful difference (MMD) (0.6‰ for carbon and 0.9‰ for nitrogen).

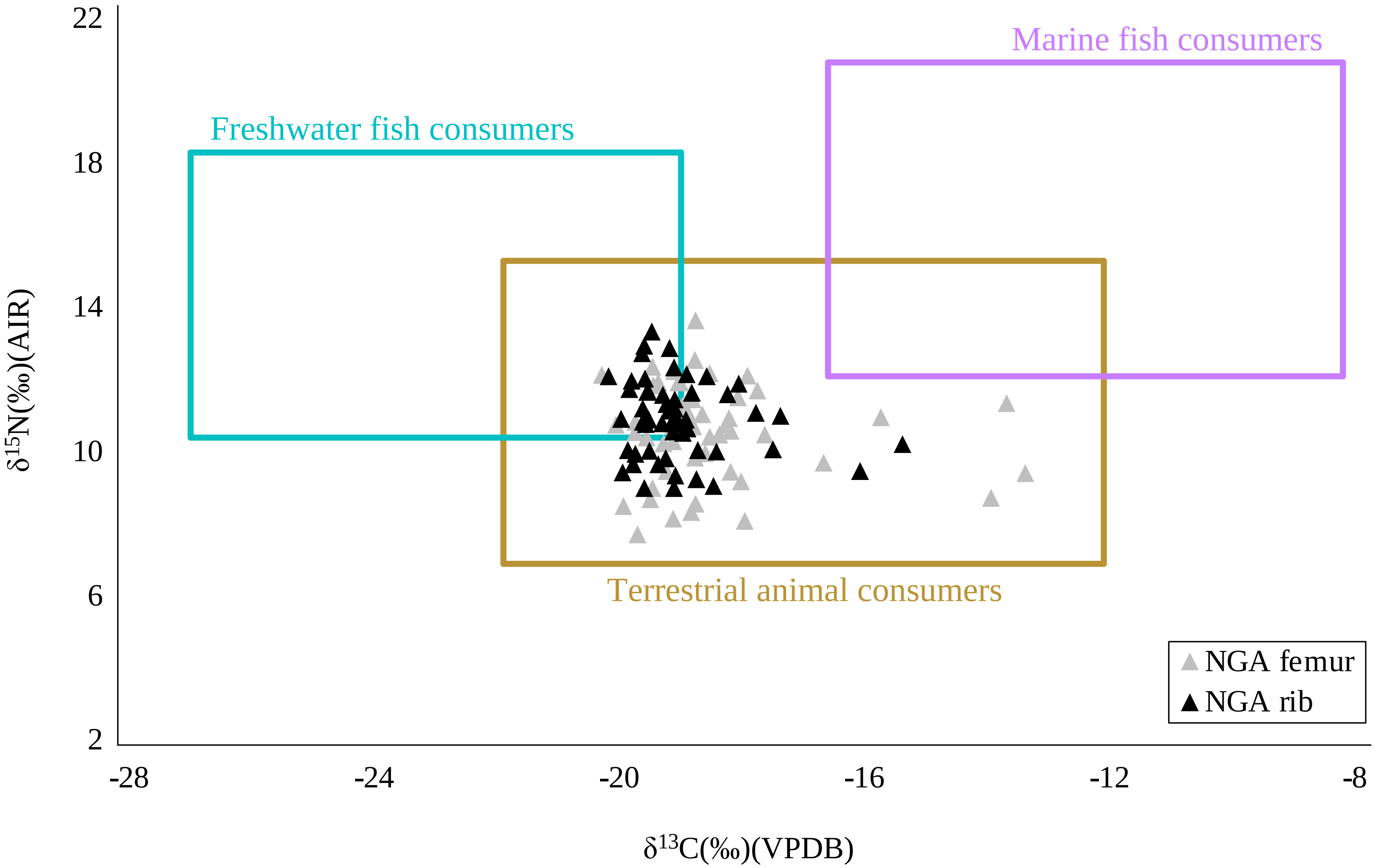

Figure 3.4. Stable carbon and nitrogen isotope data of individual Napoleon's Grand Army (NGA) soldier rib and femur compared to estimates of terrestrial (tan box), freshwater (light blue box), and marine (light purple box) protein consumers. Consumer estimates are based on the minimum and maximum values from published data of terrestrial animals (Alexander et al., 2015; Herrscher et al., 2001; MacRoberts et al., 2020; Müldner et al., 2014; Quintelier et al., 2014; Tomczyk et al., 2020), freshwater fish (Fuller et al., 2012; Reitsema et al., 2010, 2017; Simčenka et al., 2020), and marine fish (Alexander et al., 2015; Barrett et al., 2011; Fuller et al., 2012), plus one trophic-level enrichment (+1‰ for carbon, +4‰ for nitrogen).

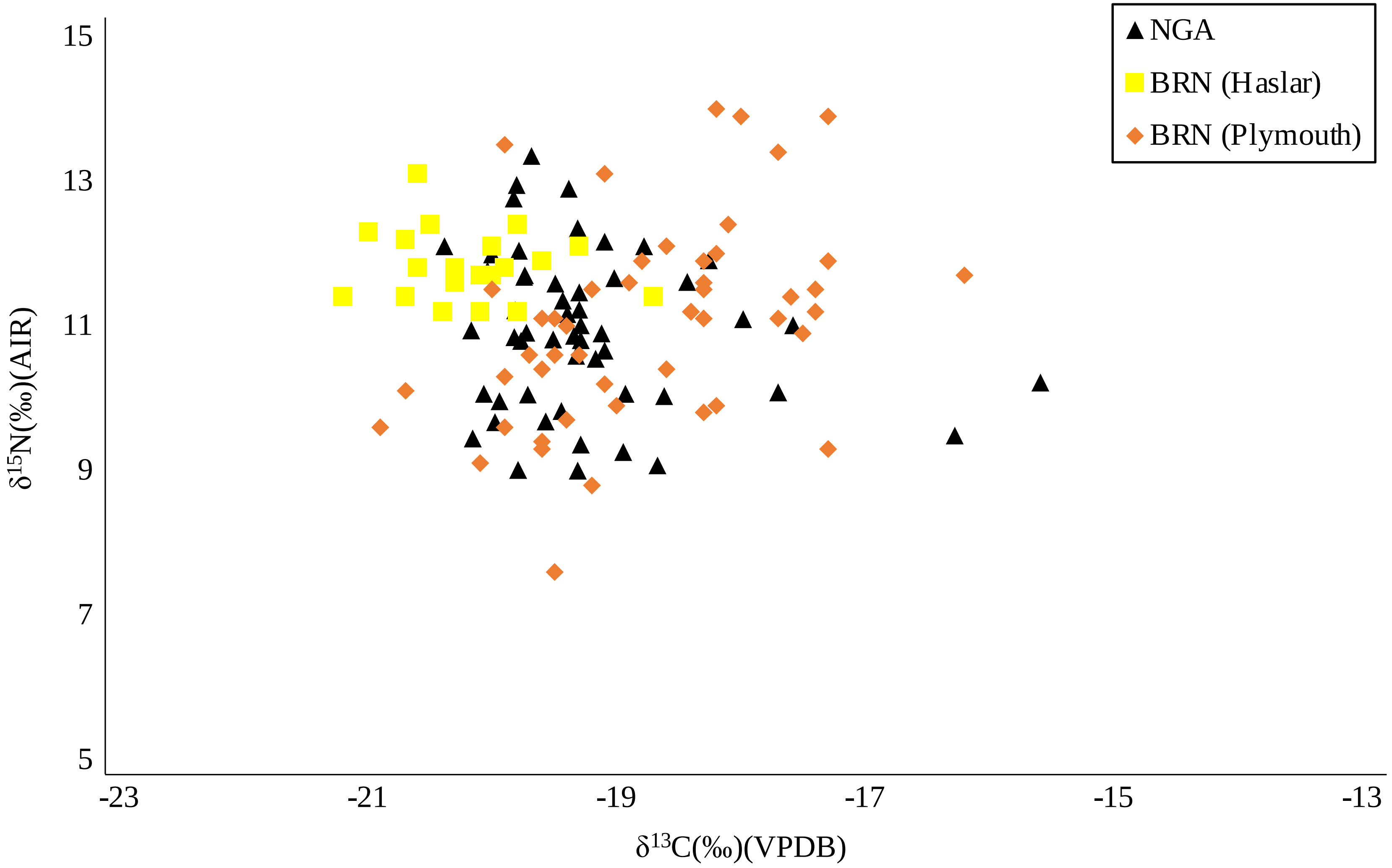

Figure 3.5. Rib bone collagen stable carbon and nitrogen isotope data of Napoleon’s Grand Army (NGA) soldiers from Šiaurės miestelis and British Royal Navy (BRN) sailors from Haslar and Plymouth (Roberts et al., 2012).

SUPPLEMENTARY MATERIALS

Appendix A – Instrumentation, Calibration, and Precision for Isotopic Measurements

This Appendix is modeled after the recommendations of Szpak, Metcalfe, and Macdonald (2017) in Appendix E for reporting calibration and analytical uncertainty in stable isotope measurements. Only precision is calculated here as the Stable Isotope Ecology Laboratory (SIEL) does not calculate known delta values for check standards, thus accuracy and total analytical uncertainty cannot be estimated.

Carbon and nitrogen isotopic and elemental compositions were determined using elemental analyzers coupled to continuous flow mass spectrometers via open split interface at SIEL at the Center for Applied Isotope Studies at the University of Georgia. Instrumentation for each analytical session is presented in Table S3.1.

Table S3.1. Instrumentation for individual analytical sessions.

Session	Mass spectrometer	Elemental analyzer	Interface
1, 2, 5, 6	Thermo Scientific Delta V Advantage	Thermo Scientific Flash2000	Thermo Conflow IV
3, 4, 8	Thermo Scientific Delta V Advantage	Carlo Erba NA1500	Thermo Finnigan Conflow III
7	Thermo Finnigan Delta Plus XP	Thermo Scientific Flash2000	Thermo Conflow IV

Table S3.2 presents the standard deviations for $\delta^{13}C$ and $\delta^{15}N$ values for the check and calibration standards along with the number of standards included in each analytical session. As NIST1570a (spinach leaves) was used to calibrate stable elemental but not isotopic composition, it was treated as a check standard to calculate internal precision for $\delta^{13}C$ and $\delta^{15}N$ values. Using check and calibration standards, measurement precision (the pooled standard deviation of the check and calibration standards) was ±0.12‰ for $\delta^{13}C$ and ±0.10‰ for $\delta^{15}N$ (df=34).

Table S3.2. Mean and standard deviation of all check and calibration standards for all analytical sessions containing data presented in this paper.

Session ID	Standard	n	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Session 1	NIST1577c	3	± 0.03	± 0.12
Session 2	NIST1577c	2	± 0.04	± 0.19
Session 3	NIST1577c	3	± 0.06	± 0.09
Session 4	NIST1577c	3	± 0.06	± 0.00
Session 5	NIST1577c	4	± 0.01	± 0.03
Session 6	NIST1577c	5	± 0.09	± 0.03
Session 7	NIST1577c	2	± 0.09	± 0.02
Session 8	NIST1577c	3	± 0.06	± 0.11
Session 1	NIST1570a	3	± 0.05	± 0.18
Session 2	NIST1570a	2	± 0.02	± 0.27
Session 3	NIST1570a	3	± 0.07	± 0.03
Session 4	NIST1570a	3	± 0.09	± 0.08
Session 5	NIST1570a	4	± 0.10	± 0.11
Session 6	NIST1570a	5	± 0.11	± 0.06
Session 7	NIST1570a	2	± 0.22	± 0.07

Session 8	NIST1570a	3	± 0.35	± 0.05

Twelve percent of the samples were analyzed in duplicate (14/115), the results of which are presented in Table S3.3. The measurement precision specific to the samples (the pooled standard deviation of all samples analyzed in duplicate) was ±0.05‰ for δ^{13}C and ±0.09‰ δ^{15}N (df=10).

Table S3.3. Stable carbon and nitrogen isotopic compositions for all samples analyzed in duplicate. “A” corresponds to first measurement and “B” corresponds to second measurement.

Sample ID	**Session**	**Element**	**$\delta^{13}C_A$**	**$\delta^{13}C_B$**	**$\delta^{15}N_A$**	**$\delta^{15}N_B$**
NAP-K006	1	Rib	-19.87	-19.79	12.71	12.81
NAP-K091	1	Rib	-19.27	-19.35	8.96	9.04
NAP-K109	2	Rib	-18.90	-18.84	9.30	9.26
NAP-K182	3	Rib	-18.03	-17.93	11.07	11.10
NAP-K158	3	Rib	-19.16	-19.04	12.14	12.18
NAP-K176	4	Rib	-19.24	-19.36	11.42	11.50
NAP-K044	5	Femur	-19.67	-19.66	9.06	8.97
NAP-K013	5	Femur	-19.32	-19.34	10.68	10.81
NAP-K037	6	Femur	-19.70	-19.62	12.41	12.34
NAP-K075	6	Femur	-18.12	-18.20	8.10	8.09
NAP-K126	6	Femur	-19.32	-19.32	11.16	11.50
NAP-K182	6	Femur	-13.90	-13.86	11.46	11.29
NAP-K176	7	Femur	-19.15	-19.17	11.28	11.35
9	8	Vertebra	-20.18	-20.19	5.19	5.21

Precision ($u(R_w)$) reported in-text was calculated using Equations 2-3 of Appendix F and calculated in Appendix G of Szpak, Metcalfe, and Macdonald (2017).

Appendix B – Supplementary Data

Table S3.4. Isotopic data used to establish faunal isotope baseline in this study.

Sample ID	Species		Ecosystem	$\delta^{13}C$ (‰) VPDB	$\delta^{15}N$ (‰) AIR	Place	Time period	Reference
1	Horse	*Equus ferus caballus*	Terrestrial	-22.2	7.2	Lithuania	19th c.	
2	Horse	*Equus ferus caballus*	Terrestrial	-21.8	4.5	Lithuania	19th c.	
3	Horse	*Equus ferus caballus*	Terrestrial	-21.6	5.3	Lithuania	19th c.	
4	Cattle	*Bos taurus*	Terrestrial	-22.3	7.1	Lithuania	19th c.	
5	Cattle	*Bos taurus*	Terrestrial	-21.9	6.6	Lithuania	19th c.	
6	Cattle	*Bos taurus*	Terrestrial	-22.0	6.9	Lithuania	19th c.	
7	Sheep	*Ovis aries*	Terrestrial	-22.3	7.1	Lithuania	19th c.	
8	Sheep	*Ovis aries*	Terrestrial	-21.6	7.5	Lithuania	19th c.	
9+	Dog	*Canis l. familiaris*	Terrestrial	-20.2	5.2	Lithuania	19th c.	
16535	Sheep		Terrestrial	-21.1	9.7	Belgium	16th-18th c.	Quintelier et al., 2014
16536	Sheep		Terrestrial	-19.1	4.3	Belgium	16th-18th c.	Quintelier et al., 2014
16537	Sheep		Terrestrial	-21.5	7.9	Belgium	16th-18th c.	Quintelier et al., 2014
16538	Sheep		Terrestrial	-21.7	7.5	Belgium	16th-18th c.	Quintelier et al., 2014
16539	Sheep		Terrestrial	-21.7	6.8	Belgium	16th-18th c.	Quintelier et al., 2014
16540	Cattle		Terrestrial	-22.0	7.4	Belgium	16th-18th c.	Quintelier et al., 2014
16541	Cattle		Terrestrial	-22.0	7.6	Belgium	16th-18th c.	Quintelier et al., 2014
16542	Cattle		Terrestrial	-21.9	6.9	Belgium	16th-18th c.	Quintelier et al., 2014
16543	Cattle		Terrestrial	-21.8	6.0	Belgium	16th-18th c.	Quintelier et al., 2014
16544	Cattle		Terrestrial	-22.7	6.1	Belgium	16th-18th c.	Quintelier et al., 2014
16545	Pig		Terrestrial	-21.5	6.1	Belgium	16th-18th c.	Quintelier et al., 2014
16546	Pig		Terrestrial	-21.5	8.2	Belgium	16th-18th c.	Quintelier et al., 2014
16547	Pig		Terrestrial	-21.7	7.8	Belgium	16th-18th c.	Quintelier et al., 2014
16548	Pig		Terrestrial	-21.7	8.7	Belgium	16th-18th c.	Quintelier et al., 2014
16549	Pig		Terrestrial	-21.6	8.9	Belgium	16th-18th c.	Quintelier et al., 2014

10	Sheep	*Ovis aries*	Terrestrial	-22.3	5.6	Lithuania	late 18th-19th c.	Chapter 5
11	Goat	*Capra hircus*	Terrestrial	-20.8	6.7	Lithuania	late 18th-19th c.	Chapter 5
12	Goat	*Capra hircus*	Terrestrial	-19.9	9.4	Lithuania	late 18th-19th c.	Chapter 5
13	Goat	*Capra hircus*	Terrestrial	-21.2	7.4	Lithuania	late 18th-19th c.	Chapter 5
14	Pig	*Sus scrofa domesticus*	Terrestrial	-21.4	9.4	Lithuania	late 18th-19th c.	Chapter 5
15	Pig	*Sus scrofa domesticus*	Terrestrial	-21.9	7.7	Lithuania	19th c.	Chapter 5
16	Pig	*Sus scrofa domesticus*	Terrestrial	-21.2	9.9	Lithuania	19th c.	Chapter 5
22	Cattle	*Bos taurus*	Terrestrial	-21.8	7.3	Lithuania	19th c.	Chapter 5
23	Cattle	*Bos taurus*	Terrestrial	-21.6	7.5	Lithuania	19th c.	Chapter 5
24	Cattle	*Bos taurus*	Terrestrial	-21.6	5.8	Lithuania	19th c.	Chapter 5
25	Sheep	*Ovis aries*	Terrestrial	-21.0	7.8	Lithuania	19th c.	Chapter 5
26	Sheep	*Ovis aries*	Terrestrial	-21.3	6.0	Lithuania	19th c.	Chapter 5
27	Sheep	*Ovis aries*	Terrestrial	-21.3	7.4	Lithuania	19th c.	Chapter 5
28	Pig	*Sus scrofa domesticus*	Terrestrial	-21.1	9.4	Lithuania	19th c.	Chapter 5
29	Pig	*Sus scrofa domesticus*	Terrestrial	-21.1	9.7	Lithuania	19th c.	Chapter 5
30	Pig	*Sus scrofa domesticus*	Terrestrial	-21.5	8.7	Lithuania	19th c.	Chapter 5
GBC1	Cattle	*Bos taurus*	Terrestrial	-15.2	7.7	Spain	15th-16th c.	Alexander et al. 2015
GBC2	Cattle	*Bos taurus*	Terrestrial	-20.1	5.8	Spain	15th-16th c.	Alexander et al. 2015
GBC3	Cattle	*Bos taurus*	Terrestrial	-19.7	8.5	Spain	15th-16th c.	Alexander et al. 2015
GBC4	Cattle	*Bos taurus*	Terrestrial	-14.3	7.4	Spain	15th-16th c.	Alexander et al. 2015
GBC5	Cattle	*Bos taurus*	Terrestrial	-19.8	5.7	Spain	15th-16th c.	Alexander et al. 2015
GBGa1	Chicken	*Gallus* sp.	Terrestrial	-14.9	10.2	Spain	15th-16th c.	Alexander et al. 2015
GBGa2	Chicken	*Gallus* sp.	Terrestrial	-17.4	8.4	Spain	15th-16th c.	Alexander et al. 2015
GBGa3	Chicken	*Gallus* sp.	Terrestrial	-17.5	8.8	Spain	15th-16th c.	Alexander et al. 2015
GBGa5	Chicken	*Gallus* sp.	Terrestrial	-13.3	9.7	Spain	15th-16th c.	Alexander et al. 2015
GBO1		Ovicaprid	Terrestrial	-19.3	2.9	Spain	15th-16th c.	Alexander et al. 2015

GBO2		Ovicaprid	Terrestrial	-19.2	4.0	Spain	15th-16th c.	Alexander et al. 2015
GBO3		Ovicaprid	Terrestrial	-19.5	4.3	Spain	15th-16th c.	Alexander et al. 2015
GBO4		Ovicaprid	Terrestrial	-19.4	3.3	Spain	15th-16th c.	Alexander et al. 2015
GBO5		Ovicaprid	Terrestrial	-19.5	4.4	Spain	15th-16th c.	Alexander et al. 2015
GBO9		Ovicaprid	Terrestrial	-19.3	3.3	Spain	15th-16th c.	Alexander et al. 2015
GBO6		Ovicaprid	Terrestrial	-19.1	3.8	Spain	15th-16th c.	Alexander et al. 2015
GBO7		Ovicaprid	Terrestrial	-19.1	4.2	Spain	15th-16th c.	Alexander et al. 2015
GBO8		Ovicaprid	Terrestrial	-19.5	5.6	Spain	15th-16th c.	Alexander et al. 2015
GBP1	Pig	*Sus*	Terrestrial	-17.8	6.6	Spain	15th-16th c.	Alexander et al. 2015
107		*Bos* sp.	Terrestrial	-20.9	4.0	France	13th-15th c.	Herrscher et al. 2001
252		*Bos* sp.	Terrestrial	-21.6	4.4	France	13th-15th c.	Herrscher et al. 2001
929		*Bos* sp.	Terrestrial	-21.2	6.6	France	13th-15th c.	Herrscher et al. 2001
RH1168		*Capra* sp.	Terrestrial	-21.5	5.4	France	13th-15th c.	Herrscher et al. 2001
RH1140		*Capra* sp.	Terrestrial	-20.0	3.3	France	13th-15th c.	Herrscher et al. 2001
RH940		*Gallus* sp.	Terrestrial	-20.0	5.2	France	13th-15th c.	Herrscher et al. 2001
546		*Gallus* sp.	Terrestrial	-20.1	6.0	France	13th-15th c.	Herrscher et al. 2001
173		*Ovis aries*	Terrestrial	-21.0	4.6	France	13th-15th c.	Herrscher et al. 2001
522		*Ovis aries*	Terrestrial	-21.0	4.0	France	13th-15th c.	Herrscher et al. 2001
306		*Sus scrofa*	Terrestrial	-20.4	5.9	France	13th-15th c.	Herrscher et al. 2001
RH1177		*Sus scrofa*	Terrestrial	-21.0	4.5	France	13th-15th c.	Herrscher et al. 2001
9.1T	Pig	*Sus domestica*	Terrestrial	-21.7	6.7	Poland	11th-17th c.	Tomczyk et al. 2020
12.1T	Pig	*Sus domestica*	Terrestrial	-20.4	8.2	Poland	11th-17th c.	Tomczyk et al. 2020
20.2T	Pig	*Sus domestica*	Terrestrial	-20.9	8.0	Poland	11th-17th c.	Tomczyk et al. 2020
14.1T	Cattle	*Bos taurus*	Terrestrial	-21.9	4.9	Poland	11th-17th c.	Tomczyk et al. 2020
18.2T	Cattle	*Bos taurus*	Terrestrial	-21.3	8.5	Poland	18th-19th c.	Tomczyk et al. 2020
13.1T	Goat	*Capra hircus*	Terrestrial	-21.3	7.5	Poland	18th-19th c.	Tomczyk et al. 2020
L1	Pig	*Sus* sp.	Terrestrial	-20.5	7.0	Portugal	17th-18th c.	MacRoberts et al. 2020
L2	Pig	*Sus* sp.	Terrestrial	-21.1	8.2	Portugal	17th-18th c.	MacRoberts et al. 2020
L3	Cow	*Bos taurus*	Terrestrial	-20.7	9.6	Portugal	17th-18th c.	MacRoberts et al. 2020

L4	Pig	*Sus* sp.	Terrestrial	-20.2	7.0	Portugal	17th-18th c.	MacRoberts et al. 2020
L5	Cow	*Bos taurus*	Terrestrial	-19.5	7.6	Portugal	17th-18th c.	MacRoberts et al. 2020
R1	Cow	*Bos taurus*	Terrestrial	-20.5	8.5	Portugal	17th-18th c.	MacRoberts et al. 2020
R2	Cow	*Bos taurus*	Terrestrial	-20.0	7.7	Portugal	17th-18th c.	MacRoberts et al. 2020
R3	Hare	*Lepus* sp.	Terrestrial	-18.8	8.0	Portugal	17th-18th c.	MacRoberts et al. 2020
R4	Pig	*Sus* sp.	Terrestrial	-19.8	8.6	Portugal	17th-18th c.	MacRoberts et al. 2020
R6	Cow	*Bos taurus*	Terrestrial	-19.6	8.2	Portugal	17th-18th c.	MacRoberts et al. 2020
BS-RAV-01	Cattle	*Bos* sp.	Terrestrial	-21.5	8.0	Belgium	15th c.	Müldner et al. 2014
BS-RAV-02	Cattle	*Bos* sp.	Terrestrial	-21.4	6.6	Belgium	15th c.	Müldner et al. 2014
BS-RAV-03	Cattle	*Bos* sp.	Terrestrial	-21.9	6.8	Belgium	15th c.	Müldner et al. 2014
BS-RAV-04	Cattle	*Bos* sp.	Terrestrial	-21.9	8.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-11	Cattle	*Bos* sp.	Terrestrial	-21.7	7.5	Belgium	15th c.	Müldner et al. 2014
BS-RAV-12	Cattle	*Bos* sp.	Terrestrial	-22.0	7.1	Belgium	15th c.	Müldner et al. 2014
BS-RAV-13	Cattle	*Bos* sp.	Terrestrial	-21.8	8.0	Belgium	15th c.	Müldner et al. 2014
BS-RAV-33	Cattle	*Bos* sp.	Terrestrial	-21.4	7.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-34	Cattle	*Bos* sp.	Terrestrial	-21.5	8.4	Belgium	15th c.	Müldner et al. 2014
BS-RAV-35	Cattle	*Bos* sp.	Terrestrial	-21.3	7.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-05	Sheep	*Ovis* sp.	Terrestrial	-21.4	9.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-06	Sheep	*Ovis* sp.	Terrestrial	-23.1	10.0	Belgium	15th c.	Müldner et al. 2014
BS-RAV-07	Sheep	*Ovis* sp.	Terrestrial	-21.9	7.8	Belgium	15th c.	Müldner et al. 2014
BS-RAV-08	Sheep	*Ovis* sp.	Terrestrial	-22.2	7.8	Belgium	15th c.	Müldner et al. 2014
BS-RAV-09	Sheep	*Ovis* sp.	Terrestrial	-21.2	7.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-10	Sheep	*Ovis* sp.	Terrestrial	-22.2	7.6	Belgium	15th c.	Müldner et al. 2014
BS-RAV-14	Sheep	*Ovis* sp.	Terrestrial	-22.1	9.1	Belgium	15th c.	Müldner et al. 2014
BS-RAV-15	Sheep	*Ovis* sp.	Terrestrial	-21.9	8.5	Belgium	15th c.	Müldner et al. 2014
BS-RAV-16	Sheep	*Ovis* sp.	Terrestrial	-21.8	8.4	Belgium	15th c.	Müldner et al. 2014
BS-RAV-17	Sheep	*Ovis* sp.	Terrestrial	-22.0	9.8	Belgium	15th c.	Müldner et al. 2014
BS-RAV-18	Sheep	*Ovis* sp.	Terrestrial	-20.4	9.4	Belgium	15th c.	Müldner et al. 2014
BS-RAV-19	Sheep	*Ovis* sp.	Terrestrial	-22.3	8.0	Belgium	15th c.	Müldner et al. 2014

BS-RAV-20	Sheep	*Ovis* sp.	Terrestrial	-21.8	7.9	Belgium	15th c.	Müldner et al. 2014
BS-RAV-21	Sheep	*Ovis* sp.	Terrestrial	-22.1	9.6	Belgium	15th c.	Müldner et al. 2014
BS-RAV-22	Sheep	*Ovis* sp.	Terrestrial	-22.5	9.7	Belgium	15th c.	Müldner et al. 2014
BS-RAV-23	Sheep	*Ovis* sp.	Terrestrial	-22.2	8.2	Belgium	15th c.	Müldner et al. 2014
BS-RAV-24	Sheep	*Ovis* sp.	Terrestrial	-22.3	11.0	Belgium	15th c.	Müldner et al. 2014
BS-RAV-25	Sheep	*Ovis* sp.	Terrestrial	-21.9	6.8	Belgium	15th c.	Müldner et al. 2014
BS-RAV-26	Sheep	*Ovis* sp.	Terrestrial	-21.8	8.5	Belgium	15th c.	Müldner et al. 2014
BS-RAV-27	Sheep	*Ovis* sp.	Terrestrial	-21.3	9.1	Belgium	15th c.	Müldner et al. 2014
BS-RAV-28	Sheep	*Ovis* sp.	Terrestrial	-21.2	9.1	Belgium	15th c.	Müldner et al. 2014
BS-RAV-29	Sheep	*Ovis* sp.	Terrestrial	-21.9	10.1	Belgium	15th c.	Müldner et al. 2014
BS-RAV-30	Sheep	*Ovis* sp.	Terrestrial	-21.1	11.3	Belgium	15th c.	Müldner et al. 2014
BS-RAV-31	Sheep	*Ovis* sp.	Terrestrial	-21.7	7.6	Belgium	15th c.	Müldner et al. 2014
BS-RAV-32	Sheep	*Ovis* sp.	Terrestrial	-21.8	8.6	Belgium	15th c.	Müldner et al. 2014
Min				**-23.1**	**2.9**			
Max				**-13.3**	**11.3**			
F154/03	Fish		Freshwater	-26.5	6.4	Poland	11th-12th c.	Reitsema et al. 2010
F273/03	Fish		Freshwater	-26.4	8.3	Poland	11th-12th c.	Reitsema et al. 2010
F295/05	Fish		Freshwater	-24.7	12.3	Poland	11th-12th c.	Reitsema et al. 2010
F63/05	Fish		Freshwater	-24.5	11.2	Poland	11th-12th c.	Reitsema et al. 2010
-	Roach	*Rutilus rutilus*	Freshwater	-27	12.1	Belgium	17th	Fuller et al. 2012
-	Ide	*Leuciscus idus*	Freshwater	-28.2	13.4	Belgium	17th	Fuller et al. 2012
-	Pike	*Esox lucius*	Freshwater	-25.5	13.7	Belgium	17th	Fuller et al. 2012
-	Roach	*Rutilus rutilus*	Freshwater	-24.4	13.7	Belgium	late 15th - early 16th	Fuller et al. 2012
-	Carp	*Cyprinus carpio f. domestica*	Freshwater	-22.3	11.5	Belgium	late 15th - early 16th	Fuller et al. 2012
-	Carp	*Cyprinus carpio f. domestica*	Freshwater	-20.2	10.3	Belgium	15th	Fuller et al. 2012
-	Pike	*Esox lucius*	Freshwater	-24.6	14.3	Belgium	late 15th - early 16th	Fuller et al. 2012

ŽPVR 10	Bream	*Abramis brama*	Freshwater	-26.3	7.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 11	Zander	*Sander lucioperca*	Freshwater	-27.5	7.8	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 12	Zander	*Sander lucioperca*	Freshwater	-23.4	11.0	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 13	Pike	*Esox lucius*	Freshwater	-25.0	6.8	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 14	Pike	*Esox lucius*	Freshwater	-25.4	12.1	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 41	Bream	*Abramis brama*	Freshwater	-27.8	8.6	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 42	Zander	*Sander lucioperca*	Freshwater	-27.3	11.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 43	Pike	*Esox lucius*	Freshwater	-24.9	9.3	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 45	Perch	*Perca fluviatilis*	Freshwater	-21.4	7.9	Lithuania	16th c.	Simčenka et al. 2020
ŽPVR 46	Perch	*Perca fluviatilis*	Freshwater	-25.4	12.1	Lithuania	17th c.	Simčenka et al. 2020
75-08	Catfish	*Siluris glanis*	Freshwater	-24.1	11.8	Poland	10th-13th c.	Reitsema et al. 2017
547-03	Catfish	*Siluris glanis*	Freshwater	-25.1	12.1	Poland	10th-13th c.	Reitsema et al. 2017
114-08A	Catfish	*Siluris glanis*	Freshwater	-21.6	9.2	Poland	10th-13th c.	Reitsema et al. 2017
274-03	Carp-bream	*Abramis brama*	Freshwater	-23.0	9.4	Poland	10th-13th c.	Reitsema et al. 2017
64-07	Carp-bream	*Abramis brama*	Freshwater	-27.1	8.6	Poland	10th-13th c.	Reitsema et al. 2017
408-03	Tench	*Tinca tinca*	Freshwater	-28.2	8.9	Poland	10th-13th c.	Reitsema et al. 2017
71-04	Aspe	*Aspius aspius*	Freshwater	-24.0	6.6	Poland	10th-13th c.	Reitsema et al. 2017
161-05	Pike	*Esox lucius*	Freshwater	-23.9	7.3	Poland	10th-13th c.	Reitsema et al. 2017
50-98	Pike	*Esox lucius*	Freshwater	-25.6	11.4	Poland	10th-13th c.	Reitsema et al. 2017
100-04	Pike	*Esox lucius*	Freshwater	-25.3	8.9	Poland	10th-13th c.	Reitsema et al. 2017
630-03	Pike-perch	*Sander lucioperca*	Freshwater	-22.3	10.1	Poland	10th-13th c.	Reitsema et al. 2017
4-02	Pike-perch	*Sander lucioperca*	Freshwater	-25.2	12.0	Poland	10th-13th c.	Reitsema et al. 2017
Min				**-28.2**	**6.4**			
Max				**-20.2**	**14.3**			
ABF1		*Mugilidae* sp.	Marine	-10.1	8.1	Spain	11th-12th c.	Alexander et al. 2015
ABF5		*Mugilidae* sp.	Marine	-9.4	9.5	Spain	11th-12th c.	Alexander et al. 2015
ABF6		*Dicentrathus* sp.	Marine	-11.4	12.5	Spain	11th-12th c.	Alexander et al. 2015
ABF4		*Dicentrathus* sp.	Marine	-11.2	12.6	Spain	11th-12th c.	Alexander et al. 2015

ABF3		*Argyrosomus regius*	Marine	-10.8	10.4	Spain	11th-12th c.	Alexander et al. 2015
-	Plaice	*Pleuronectes platessa*	Marine	-14.7	11.2	Belgium	17th	Fuller et al. 2012
-	Plaice	*Pleuronectes platessa*	Marine	-13.4	12.4	Belgium	15th	Fuller et al. 2012
-	Flounder	*Platichthys flesus*	Marine	-15.4	14.3	Belgium	17th	Fuller et al. 2012
-	Halibut	*Hippoglossus hippoglossus*	Marine	-13.6	14.4	Belgium	17th	Fuller et al. 2012
-	Herring	Clupea harengus (herring)	Marine	-15	12	Belgium	17th	Fuller et al. 2012
-	Haddock	*Melanogrammus aeglefinus*	Marine	-14.8	13.6	Belgium	17th	Fuller et al. 2012
-	Haddock	*Melanogrammus aeglefinus*	Marine	-14.9	13.5	Belgium	15th	Fuller et al. 2012
-	Haddock	*Melanogrammus aeglefinus*	Marine	-14.1	14.2	Belgium	15th	Fuller et al. 2012
-	Whiting	*Merlangius merlangus*	Marine	-13.8	15.4	Belgium	17th	Fuller et al. 2012
-	Whiting	*Merlangius merlangus*	Marine	-13.2	14.5	Belgium	15th	Fuller et al. 2012
-	Cod	*Gadus morhua*	Marine	-13	14.9	Belgium	17th	Fuller et al. 2012
1230*	Cod	*Gadus morhua*	Marine	-14.3	16.8	Belgium	Early 16th	Barrett et al. 2011
155*	Cod	*Gadus morhua*	Marine	-13.7	15.5	Belgium	15th	Barrett et al. 2011
159*	Cod	*Gadus morhua*	Marine	-12.6	16.1	Belgium	15th	Barrett et al. 2011
1136	Cod	*Gadus morhua*	Marine	-16	13	Poland	15-16th	Barrett et al. 2011
1139	Cod	*Gadus morhua*	Marine	-17.8	11.8	Poland	15-16th	Barrett et al. 2011
1142	Cod	*Gadus morhua*	Marine	-16.6	11.5	Poland	15-16th	Barrett et al. 2011
1145	Cod	*Gadus morhua*	Marine	-16.9	10.6	Poland	15-16th	Barrett et al. 2011
1152	Cod	*Gadus morhua*	Marine	-17.7	10.6	Poland	16th	Barrett et al. 2011
Min			**-17.8**	**8.1**				
Max			**-9.4**	**16.8**				

CHAPTER 4

COMPOUND SPECIFIC STABLE ISOTOPE ANALYSIS SHOWS PROVISIONING STRATEGIES IN NAPOLEON'S GRAND ARMY PRIOR TO RUSSIAN CAMPAIGN[2]

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[2] Holder, S., Reitsema, L., Dupras, T., Jankauskas, R., Roberts, P., & R., Fernandes. To be submitted to *Science Advances.*

ABSTRACT

Napoleon's multi-national Grand Army was made up of soldiers from diverse backgrounds that served in numerous campaigns across Europe. The heterogeneity of this group and flexibility in provisioning practices presents challenges for traditional methods of reconstructing long-term diet using stable isotope analysis of bulk tissues. I employed amino acid compound specific stable isotope analysis (AA-CSIA) to reconstruct the long-term diets of 20 Napoleonic soldiers from the mass gravesite of Šiaurės miestelis, Vilnius, Lithuania (ca. 1812) to overcome the challenges of traditional methods. Using published data of humans with established diets, I demonstrate that 19 of 20 soldiers consumed primarily terrestrial diet consisting of C_3 plants and animal protein. One soldier's diet had a considerable C_4 input. Using published equations for estimation of trophic position, 19 of 20 soldiers were secondary consumers and the same one individual was a primary consumer. Results indicate that despite heterogeneity in soldier background and service, the diets of these individuals were homogenous. Instead, isotopic heterogeneity at the bulk and amino acid levels is likely an artifact of the differences in local environmental conditions of both the diverse geographic origins and places of military service. The findings of this research demonstrate that differences in stable isotope values within and across populations should not be assumed to be dietary. Rather, environmental, cultural, and physiological differences should be considered in studies of isotope variation.

INTRODUCTION

Early 19th century European imperialism focused on acquiring lands, people, and resources on both distant continents and continental Europe (Said, 1994). Imperial expansion occurred through warfare, allyship, and forced dependence (Doyle, 1986). European imperial expansion altered the diets and nutrition of people under imperial control including local populations and colonists living in the imperial peripheries (Lawrence, 2001; Leong-Salobir, 2014; Rodrigues, 2014). While studies of the impact of imperialism on the diets of local populations and colonists have received considerable attention, the impact of imperial expansion on soldier diets has received far less attention and is the focus of the present study (for exeptions, see Berti, 2020). Reconstructing the diets of imperial soldiers provides a more holistic understanding of how the structures and strategies of imperial nations shaped human biology.

Prior to military service, imperial soldier diet was shaped by what foods were locally available, food preferences and restrictions, and what foods an individual had access to, influenced by socioeconomic status. As imperial soldiers came from geographically diverse regions in Europe, what foods were locally available to them varied, with those who lived in coastal regions or near rivers potentially having greater access to fish. Different regions also had different food traditions (Jianu & Barbu, 2018; Laudan, 2013; Parys, 2013), which were largely shaped by cultural factors such as ethnicity and religion (Coveney, 2006). Additionally, soldiers came from an array of socioeconomic backgrounds, with conscripts disproportionately representing lower classes of society and officers coming from the upper classes; these different backgrounds likely influenced access to high quality protein foods (Baten, 2009). Thus, location, identity, and status likely caused variation in soldier diets prior to military service.

During military service, imperial soldier diet was determined by the provisioning of food rations and soldier supplementation of rations. Food rations refers to foods purchased by the imperial government and portioned out to units or individual soldiers on a daily, weekly, or monthly basis. However, supplying rations for large multi-national armies on distant campaigns was a logistical challenge due to the size and mobility of armies across the landscape (Lynn, 2018; van Creveld, 1978). Responses to these logistical challenges varied across empires, with some militaries employing flexible strategies to stave off starvation. Flexibility in provisioning strategies can lead to variability in soldier diet as what foods were locally available to supply armies and for individual soldiers to supplement their rations varied by location.

Because of the diverse backgrounds of soldiers in multi-national armies and flexibility in provisioning practices and mobility across the landscape during military service, reconstructing the long-term diets of these heterogenous groups is a challenge when using traditional methods of stable isotope analysis of bulk tissues including bone collagen. Compound specific stable isotope analysis of individual amino acids (AA-CSIA) is a useful alternative to stable isotope analysis at the bulk tissue level as it can distinguish between different dietary resources that may be obscured at the bulk level for a heterogenous sample and enables determination of trophic position when faunal samples are not available. Here, I use compound specific stable carbon and nitrogen isotope analysis of individual amino acids (δ^{13}C AA-CSIA and δ^{15}N AA-CSIA) from Napoleon's Grand Army (NGA) soldier rib collagen to address uncertainties regarding the interpretation of diets of NGA soldiers from the mass gravesite of Šiaurės miestelis, Vilnius, Lithuania that were unresolved in previous research at the bulk collagen level (see Chapter 3). Accurately reconstructing the long-term diets of these imperial soldiers is important for understanding how the French Empire's recruiting and provisioning practices shaped soldier biology and demonstrates the need for novel methods when studying heterogenous populations.

Historical context

From 1803 to 1815, NGA was embattled in a series of conflicts between the French Empire and an array of European powers. To supply soldiers for the near constant imperial expansion and warfare of the early 19th century, the French Empire under Napoleon recruited hundreds of thousands of soldiers through forced conscription and volunteering in France proper and annexed regions, allied troops, and hiring of foreign troops (Nicolson, 1985). Conscripts, officers, allied soldiers, and mercenaries that participated in the Russian Campaign of 1812 came from present-day France, Poland, Italy, Spain, Bavaria, Austria, and Germany. Additionally, some of these individuals served in multiple campaigns across Europe including Poland, Prussia, Austria, Portugal, Spain, Italy and in possibly Egypt (Esdaile, 2008).

Prior to military service, imperial soldier diet may have varied depending on their region of origin and socioeconomic status. Cereal grains such as barley, wheat, rye, oats, and wheat in the form of bread dominated the diets of most Europeans prior to 1800, with meat consumption averaging eight ounces per year (Knapp, 1988). However, over the course of the late 18th and early 19th centuries, the diets of non-elites across Europe diversified with greater access to fresh fruits and vegetables, fish, and meats (Knapp, 1988, 1997). While C_3 domesticates were grown in much larger quantities, C_4 grains and vegetables such millet, maize, and sorghum were grown in Europe during this time (Abel, 2013). C_4 grains and vegetables are grown more in eastern, central, and southern Europe than in northern or western Europe in the past (e.g., Gugora, Dupras, Fóthi, & Demény, 2021; Reitsema, Kozłowski, Crews, Katzenberg, & Chudziak, 2017; Reitsema & Vercellotti, 2012; Tafuri, Craig, & Canci, 2009).

During military service, NGA soldiers were supposed to be provisioned with rations of bread, meat, rice or dried vegetables, salt, and alcohol (Crowdy, 2015). Large herds of draft oxen travelled with NGA to provide fresh meat for soldier rations, whereas other foodstuffs were typically purchased from local contractors, requisitioned by the army, or supplied by magazines and fortifications located along campaign routes (Elting, 1988). During the numerous and distant campaigns, adequate provisioning of soldiers was a recurring problem (Nafziger, 1988). To overcome this problem, French soldiers foraged, purchased, and stole food. Napoleon came to rely on these practices, collectively referred to as "living off the land" strategy (Rothenberg, 1981). Despite the capabilities of French soldiers, hunger and starvation remained a recurring problem throughout the Napoleonic Wars with the retreat during the Russian Campaign of 1812 being the costliest example (Nicolson, 1985).

Stable isotope analysis of bulk collagen and stable isotope equifinality

Stable isotope of analysis of bulk bone collagen is a well-established method to reconstruct the diets of past populations (DeNiro & Epstein, 1978, 1981; van der Merwe & Vogel, 1978; Vogel & van Der Merwe, 1977), primarily reflecting protein consumption (Ambrose & Norr, 1993; Fernandes, Nadeau, & Grootes, 2012; Tieszen & Fagre, 1993). The utility of this method stems from the fact that stable isotope ratios of different types of food vary systematically and differences in foods are retained in consumer tissues. There is, however, an isotopic offset between diet and consumer tissues. For bone collagen, consumer stable carbon isotope ratios are approximately 5-6‰ higher than plants and animal meat and 1‰ higher than the bone collagen animals consumed (Schoeninger, 1989). Stable nitrogen isotope ratios in consumer bone collagen are approximately 3-5‰ higher than dietary resources (Schoeninger & DeNiro, 1984), although higher values have been estimated in some studies (O'Connell, Kneale, Tasevska, & Kuhnle, 2012). Using the principles of stable isotope differences in food and offsets, it is possible to reconstruct consumer diet based on the stable isotope values measured in their tissues.

Stable carbon isotope ($\delta^{13}C$) values of consumer tissues can distinguish between broad classes of plants and provide information on the ecosystem of dietary resources. First, plants that use C_3 photosynthetic pathway (e.g., wheat, barley, rye, most vegetables and fruits) exhibit lower $\delta^{13}C$ values than plants that use C_4 photosynthetic pathway (e.g., millet, maize, sorghum) (Bender, 1971; Smith & Epstein, 1971). Second, freshwater plants and animals tend to have lower $\delta^{13}C$ values than marine plants and animals with terrestrial plants and animals typically falling intermediately (Park & Epstein, 1961; Schoeninger & DeNiro, 1984).

Stable nitrogen isotope ($\delta^{15}N$) values of consumer tissues provide information about an individual's trophic position in a food web and between aquatic and terrestrial food webs. First, $\delta^{15}N$ values can distinguish among herbivores (primary consumers), omnivores (primary/secondary consumers), and carnivores (secondary+ consumers) (Minagawa & Wada, 1984) due to the consistent 3-5‰ offset discussed above. Second, $\delta^{15}N$ values of aquatic ecosystem consumers tend to be higher than those of terrestrial ecosystem consumers as the former tend to have a greater number of trophic levels (Schoeninger & DeNiro, 1984) and water chemistry (Sigman, Karsh, & Casciotti, 2009).

Stable isotope analysis of human bone is most effective when an isotopic faunal baseline is established using zooarchaeological remains the same site. This is important because stable isotope values in faunal remains can vary across regions as a result of climatic differences and land and animal management strategies. This is typically achieved by sampling an array of aquatic (freshwater and marine if present) and terrestrial animal species, plotting isotope results on a biplot with humans, and either interpreting results visually or adding trophic enrichment factor to faunal estimate consumer values. More recently, more sophisticated methods have been developed to estimate contributions of different predefined food groups (e.g., terrestrial foods, marine foods) (Fernandes, Grootes, Nadeau, & Nehlich, 2015; Fernandes, Millard, Brabec, Nadeau, & Grootes, 2014; Killian Galván, 2018). When a site-specific faunal baseline cannot be established due to archaeological context and/or the presumed mobility of a population, a baseline can instead be estimated using published data (see Chapters 3 and 5), with recognition of the bias and uncertainty introduced through this approach.

A key challenge to bulk isotope methods of diet reconstruction is isotope equifinality (Bogaard & Outram, 2013; Quinn, 2019; Reitsema & Holder, 2018). Isotope equifinality refers to the problem where multiple dietary, environmental, physiological, or cultural factors can result in a particular isotopic "signature" in consumer tissues (Reitsema & Holder, 2018), thus confounding interpretation. Stable isotope values of different types of dietary resources overlap complicating interpretations of diet. For example, freshwater fish have a wide breadth of both $\delta^{13}C$ and $\delta^{15}N$ values, with lower trophic level fish overlapping with terrestrial herbivores and omnivores foddered on C_3 grains (e.g., Dufour, Bocherens, & Mariotti, 1999). Similarly, marine and terrestrial C_4 plant $\delta^{13}C$ values frequently overlap as do freshwater and terrestrial C_3 plant $\delta^{13}C$ values. Additionally, both carbon and nitrogen isotope values can vary based on environmental factors (temperature, aridity, and soil salinity) and agricultural practices (Szpak, 2014; Tieszen, 1991) and nitrogen with protein stress (Fuller et al., 2004; Hatch et al., 2006; Mekota, Grupe, Ufer, & Cuntz, 2006), which means that variation in stable isotope values may not be entirely attributable to differences in isotopic variability in foods.

The issue of isotopic equifinality emerged in previous research focused on reconstructing the long-term diets of soldiers in NGA through stable isotope analysis of rib collagen (see Chapter 3). Analysis of ribs from 53 soldiers revealed a wide range in both stable carbon (4.8‰) and nitrogen (4.3‰) isotope ratios, with a mean $\delta^{13}C$ value of -19.2‰ ± 0.9‰ and a mean $\delta^{15}N$ value of 10.9‰ ± 1.1‰ (Figure 4.1). I interpreted NGA soldier stable isotope results as diets consisting primarily of terrestrial plant grains and vegetables and animals (see also Figure 4.1). However, several dietary, environmental, physiological, and cultural factors confounded my interpretations. First, freshwater fish consumption could not be ruled out. Officers, soldiers, and mercenaries in the army emanated from and served in regions across Europe including regions along the coast and near rivers, where aquatic foods are readily available. Thus, low trophic fish (marine or freshwater) could not be ruled out as significant contributors to stable isotope ratios in bone. Second, geographic origin and/or place(s) of military service may also have contributed to stable isotope variation because of environmental differences across the landscape (rather than purely dietary). Climatic differences have been shown to account for up to 2 to 4‰ variability in $\delta^{13}C$ values across Europe (van Klinken, van der Plicht, & Hedges, 1994), whereas salinity and aridity have been shown to increase $\delta^{15}N$ values (Britton, Müldner, & Bell, 2008; Heaton, Vogel, von La Chevallerie, & Collett, 1986; Schwarcz, Dupras, & Fairgrieve, 1999). Third, inadequate rationing of foods leading to starvation and protein stress and diarrheal diseases have been documented in this sample (Austin, 2000; Raoult et al., 2006; Talty, 2009), causing negative nitrogen balance, which can lead to higher $\delta^{15}N$ values in body tissues (Fuller et al., 2004; Hatch et al., 2006; Mekota et al., 2006). However, bulk bone collagen stable isotope values reflect the last several years of life. Therefore, it is unlikely that dietary stress or diarrheal disease had a significant impact on NGA soldier rib collagen $\delta^{15}N$ values. Lastly, manuring of arable lands for crop production is historically documented in Europe during this time (Grantham & Grantham, 1989; Molnar, 2003); this practice is known to increase $\delta^{15}N$ values (Bogaard et al., 2013; Bogaard, Heaton, Poulton, & Merbach, 2007). Therefore, grains and vegetables grown in manured soils that consumed regularly prior to or during military service may lead to $\delta^{15}N$ values that mimic consumption of animal protein (terrestrial or aquatic).

AA-CSIA provides a useful alternative to traditional bulk methods that helps avoid some of the issues of stable isotope equifinality. $\delta^{13}C$ AA-CSIA is particularly useful in separating different diets that may overlap at the bulk level, whereas $\delta^{15}N$ AA-CSIA is useful in ascertaining trophic position in the absence of a site-specific faunal baseline. Specifically, I use $\delta^{13}C_{AA}$ values to determine whether aquatic foods were a dietary staple for NGA soldiers and the relationship $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values to estimate trophic position and evaluate the potential impact of manuring on such estimates. AA-CSIA of NGA soldier rib collagen holds the potential for more accurate dietary reconstruction among heterogenous populations, which is essential for understanding the impact of broader social processes on human biology in the past.

Background on AA-CSIA

AA-CSIA can address challenges of bulk tissue stable isotope analysis as individual AAs have different metabolic pathways that occur during biosynthesis in plants and microorganisms (Macko, Fogel, Hare, & Hoering, 1987), leading to different $\delta^{13}C_{AA}$ and $\delta^{15}N_{AA}$ values at the base of the food web.

Moving up the food chain, AA stable isotope ratios of consumers reflect differences at the base of the food chain and fractionation that occurs as AAs are converted to other AAs or intermediates before being incorporated into body tissues (Reeds, 2000), including bone collagen. Of the 20 common AAs in humans, eighteen are detectable in bone collagen, each contributing differing quantities of carbon and nitrogen to bone collagen (Table 4.1) (Herring, 1972; Ho, 1965). It is the weighted averaging of constituent amino acid $\delta^{13}C$ and $\delta^{15}N$ values that leads to bulk $\delta^{13}C$ and $\delta^{15}N$ values in human bone collagen.

There are two types of amino acids in human bone collagen, both of which are useful in dietary studies: essential amino acids (EAAs) and non-essential amino acids (NEAAs) (Womack & Rose, 1947). The eight EAAs are Histidine (His), Isoleucine (Ile), Leucine (Leu), Lysine (Lys), Methionine (Met), Phenylalanine (Phe), Threonine (Thr), and Valine (Val). The 10 NEAAs are Alanine (Ala), Arginine (Arg), Aspartate (Asn), Glutamate (Gln), Glycine (Gly), Hydroxylysine (Hyl), Hydroxyproline (Hyp), Proline (Pro), Serine (Ser), and Tyrosine (Tyr). EAAs cannot be synthesized in the body and must come from the diet, whereas NEAAs can be synthesized in the body or come directly from the diet (Wu, 2009). Some NEAAs require more complex pathways for synthesis, which means that limitations in rate of synthesis may be reached making them “conditionally” essential (Reeds, 2000). The four conditionally essential AAs are Arg, Gly, Pro, Tyr (Chakrabarty & Chakrabarty, 2019). EAAs are routed to body tissue (e.g., bone collagen), while NEAAs can be synthesized from other amino acids, carbohydrates, and lipids (Nelson & Cox, 2005). NEAA routing also occurs; a study by Jim, Jones, Ambrose, & Evershed (2006) indicates that approximately 29.6% of NEAAs and conditional EAAs are routed, reflecting diet rather than de novo biosynthesis.

Early archaeological and animal feeding studies using $\delta^{13}C$ and $\delta^{15}N$ AA-CSIA demonstrated the utility of this method in distinguishing between different diet groups that overlap at the bulk level (Fogel & Tuross, 2003; Fogel, Tuross, Johnson, & Miller, 1997; Hare & Estep, 1983; Hare, Fogel, Stafford, Mitchell, & Hoering, 1991; Ho, 1965; Howland et al., 2003). $\delta^{13}C$ AA-CSIA studies tended to focus on identifying specific AAs or combinations of AAs to distinguish archaeological humans with benchmark diets: C_3 consumers, C_4 consumers, high marine protein (HMP) consumers, high freshwater protein (HFP) consumers. Here, benchmark refers to individuals or sites with both isotope and zooarchaeological data supporting dietary interpretations (Honch, McCullagh, & Hedges, 2012). These studies typically create biplots that compare a small number of AAs.

The AAs most frequently used to separate diet groups in archaeological studies are Gly, Phe, Ser, Thr, Lys, and Val (see Table 4.2). Corr et al. (2005) proposed $\Delta^{13}C_{Gly\text{-}Phe}$ values to distinguish marine from terrestrial diets (see also Choy et al., 2010; Honch et al., 2012; Webb et al., 2015). There is little isotopic fractionation between $\delta^{13}C_{Phe}$ values in diet and consumer tissues (Howland et al., 2003), so $\delta^{13}C_{Phe}$ values in bone collagen should reflect the base of the food web. $\delta^{13}C_{Gly}$ values are higher than other amino acids (Fogel et al., 1997; Hare and Estep, 1983), especially in marine ecosystems (Keil and Fogel, 2001; Corr et al., 2009). Thus, higher $\Delta^{13}C_{Gly\text{-}Phe}$ values (> 15‰) reflect high levels of marine consumption and lower $\Delta^{13}C_{Gly\text{-}Phe}$ values (< 10‰) reflect terrestrial dietary protein (Webb et al., 2015), although Choy et al. (2010) found $\Delta^{13}C_{Gly\text{-}Phe}$ values as high as 14‰ in terrestrial consumers including humans.

Choy et al. (2010) proposed $\Delta^{13}C_{Ser\text{-}Phe}$ and $\delta^{13}C_{Thr}$ values as an alternative to distinguish marine from terrestrial diets. Gly is synthesized from Ser, which is synthesized from 3-phosphoglycerate (McCullagh et al., 2008; Scott et al., 2006), and thus exhibits similar carbon isotope values. The authors suggest Ser as a potential alternative to Gly due its similarities and that Ser exhibited the second largest difference between marine and terrestrial diets in their study (11.1‰). Like Phe, Thr shows little fractionation between diet and consumer tissues (Hare et al., 1991) and like Ser and Gly, Thr exhibited a large difference (~8‰) between marine and terrestrial diets in Choy et al.'s study (2010).

Similar to previous studies, Honch and colleagues (2012) used different combinations of $\delta^{13}C_{AA}$ values to separate benchmark diet groups and tested these combinations on a human population with an unknown diet. As in previous studies, the authors examined the relationships between $\Delta^{13}C_{Gly\text{-}Phe}$ and $\Delta^{13}C_{Val\text{-}Phe,}$ as well as a series of bi-plots with $\delta^{13}C_{Gly}$ vs. $\delta^{13}C_{Pro}$ and $\delta^{13}C_{Val}$ vs. $\delta^{13}C_{Lys}$ to separate C_3 and

C_4 consumers, $\delta^{13}C_{Gly}$ vs. $\delta^{13}C_{Ala}$ to separate C_4 and HMP consumers, and $\delta^{13}C_{Lys}$ vs. $\delta^{13}C_{Val}$ to separate HFP and HMP consumers.

Webb et al. (2015) proposed $\Delta^{13}C_{Gly\text{-}Phe}$, $\Delta^{13}C_{Val\text{-}Phe}$, and $\delta^{13}C_{Lys}$ values to distinguish marine, freshwater, C_3, and C_4 diets. These authors argue that while $\Delta^{13}C_{Gly\text{-}Phe}$ and $\Delta^{13}C_{Val\text{-}Phe}$ can distinguish C_3 and C_4 plant protein consumption, these $\Delta^{13}C$ values must be plotted against $\delta^{13}C_{EAA}$ values to distinguish marine and freshwater protein diets. The authors found that $\delta^{13}C_{Lys}$ values was useful EAA to pair with $\Delta^{13}C_{Gly\text{-}Phe}$ and $\Delta^{13}C_{Val\text{-}Phe}$ to distinguish the four diet categories because $\delta^{13}C_{Lys}$ values tend to be lower in freshwater consumers and lower in marine consumers.

More recently, studies compare $\delta^{13}C_{AA}$ values of individuals with unknown diets to individuals with benchmark diets (Halffman et al., 2020), employ more sophisticated quantitative data methods that integrate a greater number $\delta^{13}C_{AA}$ and $\delta^{15}N_{AA}$ values (Jarman et al., 2017). Most recently, Ma and colleagues (2021) demonstrated that $\delta^{13}C_{AA}$ values can be used to distinguish between different C_4 plants (i.e., maize and millet), while Mora and colleagues (2021) identified $\delta^{13}C_{ser}$ values as a possible means to identify pathologically altered bone.

While some $\delta^{15}N$ AA-CSIA studies focus on distinguishing between different diet groups as is common in $\delta^{13}C$ AA-CSIA studies (Styring, Sealy, & Evershed, 2010), others also focus on estimating trophic position or quantifying animal protein consumption (Naito, Chikaraishi, Ohkouchi, Drucker, & Bocherens, 2013; Naito, Chikaraishi, Ohkouchi, & Yoneda, 2013; Naito, Honch, Chikaraishi, Ohkouchi, & Yoneda, 2010; Styring et al., 2015). $\delta^{15}N$ AA-CSIA is particularly useful in identifying trophic position of human archaeological samples in the absence of a site-specific faunal baseline owing to the relationship between “source” and “trophic” amino acids (Jarman et al., 2017). Source amino acids are nearly identical in producer and consumer tissues, whereas trophic amino acids are enriched in ^{15}N in consumer tissues compared to producers (McClelland & Montoya, 2002; Popp et al., 2007). Thus, the difference between trophic and source amino acids can be used to establish the trophic position of an organism. Source AAs include Gly, His, Lys, Met, Phe, Ser, Thr, and Tyr. Trophic AAs include Ala, aspartic acid (Asp), glutamic acid (Glu), Ile, Leu, Pro, and Val. Source and trophic AAs do not perfectly overlap with essential and non-essential AAs. The trophic shift in some $\delta^{15}N_{AA}$ values and not others is not related to whether that AA is essential or non-essential. Rather, trophic AAs may reflect a metabolic nitrogen pool, where transaminating AAs (Ala, Asp, Leu, Val, and Ile) and Pro exchange nitrogen with Glu and Gln and free ammonia from source AAs (O'Connell, 2017). On the other hand, source AAs can donate nitrogen to the metabolic pool but do not exchange nitrogen with trophic AAs, although Ser and Gly can obtain nitrogen from the metabolic pool (O'Connell, 2017). The relationship between Phe, a source AA, and Glx, a trophic AA, has shown to be particularly helpful in estimating trophic position (Chikaraishi et al., 2009; Chikaraishi, Ogawa, & Ohkouchi, 2010).

MATERIALS AND METHODS

Archaeological samples

Šiaurės miestelis is a mass gravesite located in Vilnius, Lithuania, north of the city center. It was initially discovered during a construction project on the site of a former Soviet Union Army barracks in 2001 and excavated in Spring and Fall 2002 (Signoli et al., 2004). Material remains indicated the mass grave contained the remains of soldiers associated with Napoleon's multi-ethnic Grand Army that died during the Russian Campaign retreat in 1812. Buttons and uniform fragments indicate the presence of approximately 40 French army regiments, primarily infantry and cavalry, along with Italian, Polish, and Bavarian regiments (Signoli et al., 2004). Of the 3269 individuals excavated, most of the skeletal material was reinterred at the local Antakalnis military cemetery. A small portion of skeletal material was retained at the Department of Anatomy, Histology and Anthropology, Faculty of Medicine at Vilnius University as a legacy collection, a collection of material from past archaeological excavations that is curated for future research. Permission for destructive analysis was granted by Vilnius University.

Of the 53 individuals from the mass grave for there were both ribs and femora retained, I sampled the five individuals with the highest bulk rib collagen $\delta^{15}N$ ratios, the five individuals with the lowest bulk rib collagen $\delta^{15}N$ ratios, and ten individuals exhibiting intermediary bulk rib collagen $\delta^{15}N$ ratios (n=20).

Sex and age at death were estimated by a team of Lithuanian and French bioarchaeologists following excavation in 2002 (Signoli et al., 2004). Standard methods were used to estimate sex (i.e., pelvic and skull morphology) and age at death (i.e., epiphyseal fusion, cranial suture closure, etc.) following Buikstra and Ubelaker (1994). All 20 individuals were estimated to be male or probable male and age at death ranged from 16-40 years (Table 4.3).

Sample pretreatment and stable isotope measurements

Collagen extraction

Collagen preparation followed a modified version of Longin (1971), which took place at the Bioarchaeology and Biochemistry Laboratory at the University of Georgia. Lipid extraction was performed due to the level of preservation and recent age of the sample through three 20 minute washes in 2:1 chloroform:methanol (Jim, Ambrose, & Evershed, 2004). Samples were demineralized using washes of 0.5 M HCl, then rinsed to neutrality. Next, soil contaminating acids were removed through 20 min rinses of NaOH until solution was clear and again rinsed to neutrality. Following this step, samples were rinsed in 0.25 M HCl then deionized water and placed in an oven to extract water-soluble collagen. The water-soluble collagen was then placed on a freeze dryer for 48 hours.

Bone collagen $\delta^{13}C$ and $\delta^{15}N$ AA-CSIA

Samples were sent to University of California, Davis Stable Isotope Facility (UCD SIF) for amino acid preparation and analysis following Corr, Bernstan, and Evershed (2007) and modified by Yarnes and Herszage (2017). First bone collagen samples were hydrolyzed using 6M HCl at 150ºC for 70 mins and dried under N_2 headspace. An important note regarding language: Gln and Asn are converted to (Glu) and (Asp) during hydrolysis of proteins. Thus, isotope values of Glu + Gln (Glx) and Asp + Asn (Asx) were measured in this study. Next, samples were derivatized to N-acetyl methyl esters (NACME). NACME derivatives were injected at a 260ºC and separated on an Agilent DB-35 column. Samples were analyzed using gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) on a Thermo Trace GC 1310 gas chromatograph coupled to a Thermo Scientific Delta V Advantage isotope-ratio mass spectrometer via a GC IsoLink II combustion interface. All samples were analyzed in duplicate (two samples in triplicate) and replicates of reference materials were measured every five samples. Ile, His, Met, and Thr of samples were below the limit of quantification, which is not surprising as these amino acids are in very small quantities in bone collagen (i.e., ≤ 2.1%).

Raw isotope values of reference materials and samples were first adjusted using an internal reference material with a known isotopic composition. Next, isotopic data was calibrated using UCD AA1, an internal amino acid reference mixture. Nitrogen isotope data was then scale-normalized to AIR using UCD AA2, a second internal amino acid reference mixture. Carbon isotope data was corrected for exogenous carbon and kinetic isotope effects caused by derivatization (Docherty, Jones, & Evershed, 2001; Yarnes & Herszage, 2017). Accuracy and precision were calculated using UCD AA3, a third internal amino acid reference mixture, GEL (fish skin gelatin reference material), RWB (whale baleen reference material), and SGS (shark muscle reference material). UCD AAs were calibrated separately to AIR and VPDB. All remaining reference materials were calibrated using certified standard reference materials from USGS, NIST, and IAEA. For duplicates of samples, amino acid $\delta^{13}C$ mean of standard deviations was ±0.21‰ and amino acid $\delta^{15}N$ mean of standard deviations was ±0.38‰. For replicates of reference materials, amino acid $\delta^{13}C$ mean of standard deviations was ±0.66‰ and amino acid $\delta^{15}N$ mean of standard deviations was ±0.53‰. Mean absolute accuracy for calibrated reference materials was within ±0.29‰ for $\delta^{13}C$ and ±0.42‰ for $\delta^{15}N$.

Quantitative data analysis

All statistical analyses were conducted using R (R Core Team, 2020), the FactoMineR package for PCA analysis and factoextra and ggplot2 packages for PCA data visualizations (Kassambara & Mundt, 2020; Le, Josse, & Husson, 2008; Wickham, 2016).

$\delta^{13}C$ AA-CSIA

To examine the degree to which C_4 grains and aquatic foods played a role in the diets of NGA soldiers, I ran a principal components analysis (PCA) using published $\delta^{13}C_{AA}$ data of archaeological adult humans with benchmark diets: C_3, C_4, high freshwater protein (HFP), or high marine protein (HMP) consumers. Published data from the benchmark diet groups were used as training data to establish principal components, then applied to NGA soldier data using the predict function. PCA reduces dimensionality in a large number of variables while retaining much of the variance by transforming variables into principal components, which represent different linear combinations of those variables (Jolliffe, 2002).

Prior to running the PCA on training data, I wanted to determine whether published data from studies analyzed using liquid chromatography-IRMS (LC-IRMS) and GC-C-IRMS, and between different derivatization methods for GC-C-IRMS (NACME as used to measure NGA soldier $\delta^{13}C_{AA}$ values vs. N-trifluoroacetyl isopropyl (TFA-IP) esters) were comparable. Using data published in Dunn et al. (2011) and Corr et al. (2005) for set of ten individuals from sites across South Africa who were C_3, C_4, or HMP consumers, I compared the $\delta^{13}C_{AA}$ values among these three methods (Table 4.4). Differences in $\delta^{13}C_{AA}$ values between samples analyzed using GC-C-IRMS with NACME esters and LC-C-IRMS ranged from 0.1 to 6.1. Differences in $\delta^{13}C_{AA}$ values between samples analyzed using GC-C-IRMS with TFA-IP esters and LC-C-IRMS ranged from 0.1 to 6.7. I removed data that was analyzed using GC-C-IRMS with TFA-IP esters because there was no data for Val and Lys, which would mean that these AAs would need to be removed, and several studies have noted incomplete combustion with this method, which can effect resulting data (Corr et al., 2007; Dunn et al., 2011). Because of the large differences in $\delta^{13}C_{AA}$ values for some AAs between GC-C-IRMS with NACME esters and LC-C-IRMS, I applied a correction factor to samples using the latter method. I used the average difference in $\delta^{13}C_{AA}$ values between the two methods for all 10 samples compared in the Dunn et al. (2011) study to determine a separate correction factor for each AA (Table 4.4). I chose to apply a correction factor based on an average of all diet groups for each AA rather than by a correction factor for each AA for each diet group because the Dunn et al. (2011) study did not include HFP consumers and thus a separate correction factor could not be determined for this diet group. I recognize that there may be uncertainty or error introduced by applying a correction factor to HFP consumer values when there were no HFP values used to establish a correction factor in the first place. That is a limitation of this approach but one that could not be avoided.

Next, a PCA cannot be run with missing data. There are several ways to address missing data: remove variables with missing data, remove individuals with missing data, or use estimated values for missing data. I used a combination of the first two approaches. First, Leu, Ser, and Thr were removed because there was no data for Leu for C_4 or HFP consumers, no data for Ser for HFP consumers, and only one $\delta^{13}C_{Thr}$ for HFP consumers. Second, I removed individuals that had one missing value for at least one of the remaining AAs.

Lastly, I removed outliers as PCA can be significantly influenced by outlier values (Jolliffe, 2002). To identify outliers, I ran an initial PCA on corrected $\delta^{13}C_{AA}$ data of humans with benchmark diets and plotted the results (Figure 4.3). Four individuals were removed using this approach, two from C_3 consumers and two from C_4 consumers. A total of 54 individuals with $\delta^{13}C_{AA}$ data published in Dunn et al. (2011), Honch et al. (2012), Raghavan et al. (2010), and Webb et al. (2018) were used for the final PCA (Table 4.5).

$\delta^{15}N$ AA-CSIA

The relationship between $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values is particularly useful in identifying trophic position in aquatic and terrestrial environments (Naito, Chikaraishi, Ohkouchi, Drucker, et al., 2013; Naito et al., 2010; Styring et al., 2010). Chikaraishi and colleagues (2009, 2010) developed a series of equations to calculate trophic position in aquatic and terrestrial ecosystems (C_3 and C_4) using $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values:

$$TP_{Glu/Phe} = [(\delta^{15}N_{Glu} - \delta^{15}N_{Phe} + ß) / TDF] + 1$$

where ß is the difference between $\delta^{15}N_{Glu}$ and $\delta^{15}N_{Phe}$ in primary producers (-3.4 for aquatic, +8.4 for terrestrial C_3, and -0.4 for terrestrial C_4) and TDF is the trophic discrimination factor between each trophic level (7.6) (Chikaraishi et al., 2014). These equations can be used to calculate an organism's trophic position if the diet is known (i.e., aquatic vs. terrestrial C_3 vs. terrestrial C_4) or they can be plotted as lines on scatter plot to estimate trophic position when diet is unknown. This method may be preferential to traditional methods of establishing trophic position using bulk $\delta^{15}N$ values in animal and human bone collagen as bulk values reflect both diet and metabolism, however, a major assumption of an amino acid approach is that humans and the animals they consumed also consumed the same plants (Styring et al., 2015). This assumption may be problematic as different types of plants exhibit a wide range of variation in bulk and amino acid $\delta^{15}N$ values (e.g., Fraser et al., 2011; Styring, Fraser, Bogaard, & Evershed, 2014a; Szpak, 2014).

To estimate trophic position, I plotted $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values of NGA soldiers with trophic lines for aquatic, C_3, and C_4-based diets using equations from Chikaraishi and colleagues (2009, 2010). Additionally, to examine whether the trophic position of NGA soldiers was the result of the consumption of grains and vegetables grown in manured soils, which have been shown to result in higher bulk and AA $\delta^{15}N$ values in plants (Bogaard et al., 2013, 2007; Bol et al., 2005; Fraser et al., 2011; Styring, Fraser, Bogaard, & Evershed, 2014b) and are passed up the food chain to animals and humans (Finucane, 2007; Fraser et al., 2013), I also plotted $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values of barley, bread wheat, broad beans, and peas grown in manured and unmanured soils from two different archaeological sites in Germany published in Styring et al. (2014b).

RESULTS

Bone collagen quality indicators

Bone collagen samples were submitted to the Stable Isotope Ecology Laboratory at the Center for Applied Isotope Studies at the University of Georgia for stable isotope analysis of bulk collagen prior to selection of samples for AA-CSIA. The following criteria were used to evaluate collagen quality: collagen yield between 1% and 22% (van Klinken, 1999), carbon content (%C) between 13% and 47%, nitrogen content (%N) between 4.8% and 17.3% (Ambrose, 1990), and atomic C:N between 2.9 and 3.6 (DeNiro, 1985) (Table 4.6). Collagen yield was calculated by dividing collagen weight by dry sample weight (after cleaning but prior to chemical treatments) and multiplying by 100. All samples have collagen yields and atomic C:N within the ranges outlined above. Five samples have %C above 47% and six samples have %N above 17.3%. In the case of carbon, higher content can indicate the addition of organic carbon (van Klinken, 1999). However, all sample carbon content is within 3% of the upper limit and nitrogen is within 1%. Additionally, there is not a strong linear relationship between %C and $\delta^{13}C$ ($r^2 = 0.0008$) or %N and $\delta^{15}N$ ($r^2 = 0.06$). Thus, all samples are considered to have well-preserved collagen and were included in this study.

The relationship between Pro and Hyp can also be used as quality indicator, where $\delta^{13}C_{Pro}$ (x) $\delta^{13}C_{Hyp}$ (y) and $\delta^{15}N_{Pro}$ (x) and $\delta^{15}N_{Hyp}$ (y) should each form a 1:1 line (Roberts et al., 2018). There is a 1:1 relationship for the samples in this study for both carbon and nitrogen (Table 4.6).

δ^{13}C AA-CSIA

Stable carbon isotope ratios of 12 amino acids were measured in 20 samples, constituting 86.6% of the carbon in collagen. δ^{13}C values of His, Ile, Met, and Tyr were below the limit of quantification and Arg and Hyl cannot be measured using GC-C-IRMS. δ^{13}C values of amino acids ranged from -32.9‰ to -7.2‰. NEAA δ^{13}C values ranged from -23.3‰ to -7.2‰ and EAA values ranged from -32.9‰ to -8.2‰. Average $\delta^{13}C_{EAA}$ values were lower than average $\delta^{13}C_{NEAA}$ values (-23.3‰ vs. -17.4‰).

Nine AAs were used in the PCA: Ala, Asx, Glx, Gly, Hyp, Lys, Phe, Pro, and Val (Tables 4.3 and 4.5). PCA results indicated that 96.2% of variance in $\delta^{13}C_{AA}$ values can be explained by PC 1 and PC 2 (Figure 4.3). Pro, Hyp, Ala have the strongest loadings for PC 1 and Gly, Ala, Val, and Phe have the strongest loadings for PC 2 (Table 4.7). A biplot of PCA results shows clear separation among the four benchmark diet groups with PC 1 separating HMP and C_4 consumers from HFP and C_3 consumers and PC 2 separating aquatic (HFP and HFP) from terrestrial (C_3 and C_4) consumers (Figure 4.4). Fifteen of 20 NGA soldiers overlap with C_3 consumers (i.e., within the C_3 consumer ellipses). One lies slightly beyond C_3 consumers and the remaining four fall between C_3 and C_4 consumers.

δ^{15}N AA-CSIA

Stable nitrogen isotope ratios of 12 amino acids were also measured in 20 samples, constituting 77.7% of the nitrogen in collagen. δ^{15}N values of His, Ile, Met, and Tyr were below the limit of quantification and Arg and Hyl cannot be measured using GC-C-IRMS. δ^{15}N values of amino acids ranged from -15.2‰ to 18.9‰. Source amino acids (Gly, Lys, Phe, Ser, Thr) δ^{13}N values ranged from -15.2‰ to 13.0‰ and trophic amino acid (Ala, Asx, Glx, Leu, Pro, Val) values ranged from 11.0‰ to 18.4‰. Average source amino acid δ^{15}N values were lower than average trophic amino acid δ^{15}N values 4.7‰ vs. 14.7‰).

Two AAs were used to establish trophic estimates of NGA soldiers using equations from Chikaraishi et al. (2009) and Chikaraishi, Ogawa, & Ohkouchi (2010): Glx and Phe (Table 4.3). All but two NGA soldiers fall above on or above TP 3 (C_3) (NAP-K046 and NAP-K143) (Figure 4.5). Eight soldiers fall between the TP 2 C_4 and TP 2 Aquatic lines. No individuals exhibited $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values that fall on or above the TP 2 Aquatic line. For both manured and unmanured soils, barley and bread wheat values published in Styring et al. (2014b) fall along the TP 1 C_3 line, whereas broad beans and peas fall along the TP 2 C_3 line (Figure 4.6).

DISCUSSION

AA-CSIA is a useful alternative to stable isotope analysis at the bulk tissue level as it can better distinguish between different dietary resources (C_3 and C_4 terrestrial, marine, freshwater) that may be obscured at the bulk level for a heterogenous sample and enables determination of trophic position even in the absence of a faunal baseline (Naito, Chikaraishi, Ohkouchi, Drucker, et al., 2013). In the current study, I used AA-CSIA to address uncertainties regarding the interpretation of diets of NGA soldiers from the Šiaurės miestelis that were unresolved at the bulk level. Bulk collagen analysis indicated a diet of terrestrial grains, vegetables, and animal meat, but could not indicate whether freshwater fish were a dietary staple or whether soldiers consumed plant domesticates grown in manured soils. The latter can lead to an overestimation of animal protein consumption (Bogaard et al., 2013, 2007; Fraser et al., 2011). AA-CSIA results support this interpretation, at a finer resolution: diet of NGA soldiers was based on similar amounts of C_3 plants, which could be differentiated somewhat into grains and other plants, and terrestrial animals, with no discernible input from freshwater (or marine) fish. Therefore, despite the wide array of soldier backgrounds, flexibility in NGA food procurement practices, and variability in locally available resources, diets of NGA soldiers were remarkably similar and focused on few food categories.

Separation of benchmark diet groups using $\delta^{13}C$ AA-CSIA

A biplot of PCA results for benchmark diet groups shows clear separation among C_3, C_4, HMP, and HFP consumers. PC 1 separates HMP and C_4 consumers from HFP and C_3 consumers. The AAs that have the strongest loading for PC 1 are Pro, Hyp, and Ala, meaning that these $\delta^{13}C_{AA}$ values have the strongest relationship to PC 1 of the AAs analyzed (Table 4.6). These AAs all have positive loadings, which reflects that HMP and C_4 consumers have higher $\delta^{13}C$ values for these three AAs than HFP and C_3 consumers. $\delta^{13}C_{Pro}$ and $\delta^{13}C_{Hyp}$ values are particularly effective at separating HMP and C_4 consumers from HFP and C_3 consumers. Since Hyp is synthesized from Pro (Wu et al., 2011), it is not surprising that $\delta^{13}C_{Hyp}$ values follow the same pattern. $\delta^{13}C_{Ala}$ separate all four diet groups, which may explain its loadings on both PC 1 and PC 2.

PC 2 separates aquatic (HMP and HFP) from terrestrial (C_3 and C_4) consumers. Gly, Ala, Val, and Phe have the strongest loadings for PC 2 (Table 4.7). All four AAs have positive loadings, which reflects that aquatic consumers have higher $\delta^{13}C$ values for these AAs than terrestrial consumers. That Gly, Val, and Phe have strong positive loadings on PC2 is not surprising as these AAs have been used to distinguish between aquatic and terrestrial diet groups in previous studies (Choy, Smith, Fuller, & Richards, 2010; Corr et al., 2005; Honch et al., 2012; Webb et al., 2015). $\delta^{13}C_{Gly}$ values are higher than other amino acids (Fogel et al., 1997; Hare & Estep, 1983), especially in marine ecosystems (Corr et al., 2009; Keil, Fogel, Keil, & Fogel, 2001).

NGA soldier diet reconstruction from $\delta^{13}C$ AA-CSIA

AA-CSIA of rib bone collagen provides a powerful tool for reconstructing diet over the last several years of life, likely capturing both military and pre-military diets for most of the individuals in this study. Despite the wide range of $\delta^{13}C$ and $\delta^{15}N$ bulk collagen values, $\delta^{13}C$ AA-CSIA results indicate that the soldiers in this study consumed terrestrial foods. PCA results show that most of the NGA soldiers in this study were C_3 consumers. Although C_3 plant domesticates dominated the European landscape (Knapp, 1988), this finding is a bit surprising given the geographic diversity of soldier origins and places of service. C_4 plant consumption, millet in particular, has been documented in historical and bioarchaeological research in parts of southern, central, and eastern Europe (Kučera et al., 2019; Miller, Spengler, & Frachetti, 2016; Pospieszny et al., 2021; Reitsema & Vercellotti, 2012; Tafuri et al., 2009). Three individuals have PC scores intermediate to C_4 consumers, with one individual (NAP-K065) particularly close to a predominantly C_4 diet. It is likely that the three individuals with intermediate PC values, especially NAP-K065, were from or served in these regions for a substantial amount of time.

The following question emerges regarding $\delta^{13}C$ results and interpretations: Do AA isotope values reflect primary consumption of grains in vegetables or consumption of animals foddered on C_3 or C_4 grains and vegetables? The answer to this question is important because NGA soldiers may have consumed a more isotopically diverse diet (i.e., many soldiers may have been eating C_4 grains and vegetables prior to and during military service) but it may be masked by the consumption of animals who were foddered on isotopically homogenous diets. Without a site-specific faunal baseline, this question cannot be addressed using stable isotope analysis of bulk bone collagen.

$\delta^{13}C_{AA}$ values in the bone collagen of Napoleonic soldiers, as omnivores, are likely disproportionately derived from the animals they consumed (Fogel & Tuross, 2003), because meat typically contains higher protein and thus amino acids than most plant foods (Chakrabarty & Chakrabarty, 2019). Additionally, humans are more efficient at digesting meat compared to plant foods (Sizer & Whitney, 2014). Thus, the C_3 and C_4 plant signature likely disproportionately reflect the plant type on which the animals that soldiers consumed were foddered on more than soldier direct plant consumption. $\delta^{15}N$ AA-CSIA results may address the question of direct versus secondary consumption as the relationship between $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values reflect trophic position in the absence of a site-specific faunal baseline (see next section).

Estimating trophic position of NGA soldiers and possible manuring using $\delta^{15}N$ AA-CSIA

Because Phe is a source AA that changes very little as it moves up the food chain and Glx is a trophic AA whose $\delta^{15}N$ value increases as it moves up the food chain (McClelland & Montoya, 2002), the relationship between $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values can be useful in determining whether NGA soldier $\delta^{13}C_{AA}$ values reflect primary or secondary plant grain and vegetable consumption. C_4 plants have lower $\delta^{15}N_{Phe\text{-}Glx}$ values than C_3 plants (+8.4 for C_3 and -0.4 for C_4); it is thought that this difference is the result of "distinct kinetic isotopic effect or the flow rate associated with enzymatic transamination reactions in these producers or the significant difference in the mechanism of assimilation of inorganic nitrogen or biosynthetic pathways of amino acids among these producers" (Chikaraishi et al., 2010, p. 45). Given that most NGA soldiers in this study were C_3 consumers (see Figure 4.4), their $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values indicate that they were secondary consumers (see Figure 4.5), meaning they consumed animals that were foddered on C_3 grains and vegetables. However, as NAP-K065 falls nearer to C_4 consumers (see Figure 4.4), this individual may be a primary consumer, meaning that their $\delta^{13}C_{AA}$ values are the result of directly consuming C_4 grains and vegetables.

Several studies call into question whether meat consumption is overestimated due to ubiquity of manuring soils used to grow plants in the past, which have been shown to increase both bulk and AA $\delta^{15}N$ values (Bogaard et al., 2013, 2007; Fraser et al., 2011; Styring et al., 2014b). To address the question that NGA soldiers with C_3-based diets appear to be secondary consumers due to the consumption of grains and vegetables grown in manured soils, I plotted $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values of barley, bread wheat, broad beans, and peas, all C_3 plants, published in Styring et al. (2014b) grown at two different sites in Germany with Napoleonic soldiers on the Chikaraishi (2009, 2010)-derived trophic position lines. The relationship between barley, bread wheat, broad bean, and pea $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values did not change with manuring (Figure 4.6), meaning that an unmanured and manured plant both fall along same trophic position line. Thus, it appears that manuring of plant domesticates does not affect estimates of trophic position when using $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values.

It is important to note that there are several assumptions regarding the Chikaraishi trophic lines (2009, 2010) and their application in archaeological contexts including the assumption that humans and faunal consumed the same plants and plant parts, whether trophic discrimination factors are consistent moving through the food chain, and site-based differences in $\Delta^{15}N_{Glx-Phe}$ (Styring et al., 2015, 2014b). The latter seems less problematic as although $\Delta^{15}N_{Glx-Phe}$ values differed between the two sites in Styring et al. and colleagues' study (Styring et al., 2014b), the $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values from two different sites (Rothamsted, Germany and Bad Lauchstädt, Germany) still fell on the TP1 C_3 line (Figure 4.6).

However, how a plant obtains nitrogen does appear to impact trophic position estimates and warrants further discussion. Barley and bread wheat are non N_2-fixing plants, which means that their nitrogen comes from the soil. Manuring the soils these plants are grown in causes both $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values to increase, retaining the relationship between them. Thus, barley and bread wheat grain $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values fall along primary TP 1 (primary producer) lines and are two trophic positions below Napoleonic soldiers regardless of whether the plants were grown in manured or unmanured soils (Figure 4.6). Broad beans and peas are N_2-fixing leguminous plants that obtain their nitrogen from the atmosphere. There is no change in $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values with the manuring of soil because these plants are not obtaining their nitrogen from the soil. However, broad beans and peas, both C_3 plants, fall on the TP 2 line; they have similar $\delta^{15}N_{Glx}$ values as non N_2-fixing plants but much lower $\delta^{15}N_{Phe}$. It has been suggested that the metabolic pathway for AA biosynthesis in legumes may differ from non N_2-fixing plants (Styring et al., 2014b), which may explain differences in $\delta^{15}N_{Phe}$ values of these primary producers. Thus, while the problem manuring arable land to grow crops presents to reconstructing diet may be overstated because AA and bulk $\delta^{13}C$ and $\delta^{15}N$ values disproportionately reflect secondary consumption (i.e., consumption of animal meat) due to the higher protein content and ability of the human body to metabolize animal protein more efficiently than plant protein (Sizer & Whitney, 2014), N_2-fixing plants present a challenge for estimating meat consumption among past humans using AA-CSIA.

Taken together, AA-CSIA results indicate that despite the wide dispersal of bulk collagen and amino acid $\delta^{13}C$ and $\delta^{15}N$ values, all the NGA soldiers in this study likely consumed a diet of terrestrial foods. All but one individual (NAP-K065) were secondary consumers, eating animals foddered on C_3 grains and vegetables. Variation in stable isotope values at the bulk collagen level may be explained in part by environmental factors and amino acid metabolism. Climatic differences have been shown to account for up to 2 to 4‰ variability in across Europe (van Klinken et al., 1994), whereas salinity and aridity have been shown to increase $\delta^{15}N$ values (Britton et al., 2008; Heaton et al., 1986; Schwarcz et al., 1999). Particularly in case of $\delta^{13}C$ values, regional differences in climate may account for some of the variation at the bulk and amino acid levels in this study (van Klinken, Richards, & Hedges, 2000). Amino acid metabolism may also account for variation in bulk $\delta^{13}C$ and $\delta^{15}N$ values. It is the weighted averaging of constituent amino acid $\delta^{13}C$ and $\delta^{15}N$ values that leads to bulk $\delta^{13}C$ and $\delta^{15}N$ values in human bone collagen. While variation at the AA level for $\delta^{13}C$ values is driven by how AAs are synthesized during photosynthesis and $\delta^{15}N$ values by how nitrogen enters the plant (via soil or atmosphere), as they move through the food chain, $\delta^{13}C_{AA}$ and $\delta^{15}N_{AA}$ values change as a result of fractionation associated with deamination and synthesis processes (Takizawa et al., 2020). Thus, differences in how AAs are synthesized as they move through the food chain cause variation in bulk isotope values of consumer tissues.

AA-CSIA results have implications for studying the impact of imperialism on the diets of a heterogenous group. The diverse backgrounds, prior places of service, and flexibility in provisioning strategies do not appear to have resulted in heterogenous diets among NGA soldiers that served in the Russian Campaign of 1812. Thus, despite diversity in socioeconomic status and geographic origin, soldiers consumed relatively homogenous diets prior to and during military service. Instead, differences in local environmental conditions such as climate, aridity, and soil salinity created isotopic heterogeneity at the base of the food chain that was passed on to NGA soldiers. Thus, imperialism shaped human biology through the mechanism of diet, not only through the types of foods people had access to (i.e., grains and vegetables, terrestrial animal products, freshwater and marine fish) but through differences in the same types of food related to local environmental conditions. By recruiting soldiers from and deploying them in regions across Europe, the French Empire maintained a biologically heterogenous army of soldiers that is reflected in the dispersal of bulk collagen and amino acid stable isotope values.

CONCLUSION

In this study, I reconstructed the diets of imperial soldiers that served in NGA during the Russian Campaign of 1812 using AA-CSIA to overcome interpretive challenges associated with traditional bulk methods. Despite evidence that soldiers in NGA come from heterogenous backgrounds and likely experienced variation in place(s) and length of military service, and flexibility in provisioning strategies, NGA soldier $\delta^{13}C_{AA}$ and $\delta^{15}N_{AA}$ values indicate that these individuals consumed a relatively homogenous diet of terrestrial grains and vegetables and animal products. Nineteen of 20 individuals ate animals foddered on C_3 grains and vegetables, with one individual (NAP-K065) showing evidence of considerable C_4 plant consumption.

AA-CSIA results have implications for studying the impact of imperialism on the diets of a heterogenous group. By recruiting soldiers from and deploying them in regions across Europe, the French Empire maintained a biologically heterogenous army of soldiers that is reflected in the dispersal of bulk collagen and amino acid stable isotope values. The isotopic heterogeneity detected appears to be the result of differences in local environmental conditions that create isotopic variability at the base of the food web and amino acid metabolism as proteins move through the food chain.

This study also demonstrates that consumption of nitrogen-fixing plants, including legumes, confound interpretations of trophic position using AA-CSIA results. N_2-fixing broad beans and peas exhibit $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values similar to primary consumers, rather than as primary producers which they are. Thus, legume consumers will exhibit $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glx}$ values that place them on the same trophic line as secondary consumers, instead of as primary consumers, which they should be. Therefore, N_2-fixing plants present a challenge for estimating meat consumption among past humans using AA-CSIA.

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Table 4.1. Percentage contribution of each amino acid to carbon and nitrogen of bone collagen. Table adapted from Table 1 of Howland et al. (2003) and Table 4 of Eastoe (1955).

Amino Acid	**Carbon Atom %**	**Nitrogen Atom %**
NEAA		
Gly	16.9	26.2
Pro	14.7	10.1
Hyp	13.2	8.2
Gln	9.7	5.9
Ala	9.3	9.3
Arg	7.9	15.4
Asn	4.7	3.8
Ser	2.2	2.9
Tyr	1.1	0.4
Hyl	1	0.6
EAA		
Lys	4.5	4.6
Leu	3.6	2.1
Phe	3.3	1.2
Val	2.4	1.9
Thr	2.1	1.5
Ile	1.7	1.1
Met	1.1	0.4
His	0.7	1.4

Table 4.2. Studies that use and compare $\delta^{13}C_{AA}$ values to distinguish between different benchmark diet groups.

Diets distinguished	**Amino acids**	**Reference**
HMP vs. terrestrial (C_3 and C_4) consumers	$\Delta^{13}C_{Gly\text{-}Phe}$ vs. $\delta^{15}N_{Bulk}$	Corr et al. 2005, Webb et al. 2018
HMP vs. terrestrial consumers	$\Delta^{13}C_{Ser\text{-}Phe}$ vs. $\delta^{13}C_{Thr}$	Choy et al. 2010
HMP, HFP, C_3, and C_4 consumers	$\Delta^{13}C_{Gly\text{-}Phe}$ vs. $\delta^{13}C_{Lys}$ $\Delta^{13}C_{Val\text{-}Phe}$ vs. $\delta^{13}C_{Lys}$	Webb et al. 2015
HMP, HFP, C_3, and C_4 consumers	$\delta^{13}C_{Val}$ vs. $\delta^{13}C_{Phe}$ $\delta^{13}C_{Phe}$ vs. $\delta^{15}N_{Bulk}$	Webb et al. 2018

Table 4.3. Demographic and $\delta^{13}C_{AA}$ and $\delta^{15}N_{AA}$ values of rib collagen of NGA soldiers from the mass gravesite of Šiaurės miestelis. All samples were run in duplicate (NAP-K091 and NAP-K107 ran in triplicate) and isotope values are reported as means and 1 standard deviation.

Sample ID	**Age (Years)**	**Sex**	**$\delta^{13}C_{AA}$ values**									**$\delta^{15}N_{AA}$ values**	
			Ala	**Asx**	**Glx**	**Gly**	**Hyp**	**Lys**	**Phe**	**Pro**	**Val**	**Glx**	**Phe**
NAP-K006	20-25	M	-19.8	-21.7	-19.5	-14.3	-20.8	-21.2	-28.0	-20.7	-27.7	17.8	10.4
			0.02	0.28	0.02	0.07	0.18	0.22	0.08	0.03	0.22	0.26	0.82
NAP-K007	35-40	PM	-20.5	-22.2	-19.8	-14.1	-20.4	-20.2	-27.5	-20.4	-28.0	16.0	9.0
			0.08	0.26	0.17	0.33	0.26	0.82	0.28	0.19	0.21	0.23	1.23
NAP-K023	20-25	M	-20.6	-22.5	-19.8	-15.2	-21.0	-20.9	-28.4	-20.4	-28.7	15.6	8.1
			0.05	0.24	0.14	0.32	0.27	0.07	0.32	0.07	0.30	0.43	0.81
NAP-K025	20	M	-19.4	-21.4	-18.9	-13.0	-19.8	-21.0	-27.5	-19.8	-27.6	16.3	9.4
			0.02	0.53	0.11	0.00	0.11	0.33	0.00	0.11	0.11	0.33	0.44
NAP-K037	25-30	M	-21.6	-23.3	-20.8	-16.3	-21.2	-24.0	-29.0	-20.5	-29.0	17.2	10.1
			0.39	0.18	0.07	0.14	0.38	0.66	0.69	0.21	0.09	0.94	0.37
NAP-K046	25-35	M	-20.4	-21.9	-19.6	-15.1	-20.7	-22.4	-27.2	-20.6	-28.6	16.8	10.1
			0.33	0.16	0.12	0.16	0.07	0.37	0.14	0.11	0.27	0.01	0.34
NAP-K050	20-25	M	-19.8	-21.7	-19.2	-14.0	-20.4	-22.4	-27.2	-20.2	-28.6	17.4	7.2
			0.19	0.03	0.03	0.22	0.03	0.68	0.00	0.22	0.22	0.23	0.15
NAP-K062	25-30	M	-19.8	-21.9	-19.7	-14.7	-20.2	-21.8	-27.4	-20.3	-27.9	16.1	7.7
			0.17	0.11	0.00	0.09	0.20	0.58	0.01	0.13	0.11	0.23	0.14
NAP-K063	25-30	M	-20.3	-22.0	-19.7	-15.9	-20.4	-23.0	-27.5	-20.7	-28.4	13.9	4.8
			0.05	0.14	0.15	0.03	0.41	0.09	0.27	0.06	0.09	0.01	0.44
NAP-K065	40	M	-15.6	-17.9	-16.3	-13.4	-17.3	-20.4	-23.9	-16.8	-25.1	14.1	6.6
			0.11	0.42	0.31	0.19	0.25	0.60	0.24	0.30	0.18	0.20	0.79
NAP-K069	25-30	M	-15.1	-21.4	-17.9	-11.9	-20.7	-19.8	-27.5	-20.0	-26.2	14.6	6.3
			0.08	0.01	0.10	0.29	0.29	0.02	0.17	0.03	0.25	0.32	0.50
NAP-K075	30	M	-15.2	-20.8	-16.8	-10.8	-19.2	-20.2	-26.1	-18.8	-25.6	13.9	6.8
			0.01	0.20	0.00	0.19	0.30	0.91	0.41	0.15	0.06	0.20	0.44
NAP-K091	20-25	M	-20.4	-22.8	-21.1	-15.1	-20.3	-21.8	-27.5	-21.0	-28.6	13.7	6.8

			0.13	0.06	0.32	0.12	0.28	1.22	0.16	0.10	0.21	0.17	1.05
NAP-K107	16-17	M	-16.0	-20.9	-17.1	-12.2	-19.5	-20.5	-26.9	-19.3	-25.9	18.2	8.6
			0.37	0.10	0.02	0.35	0.42	1.30	0.09	0.06	0.24	0.60	1.26
NAP-K113	20-25	M	-16.8	-21.4	-17.9	-15.4	-20.1	-20.9	-27.3	-19.9	-27.1	14.6	5.2
			0.22	0.32	0.05	0.37	0.01	0.51	0.23	0.14	0.18	0.6	0.27
NAP-K121	20-25	M	-15.6	-20.8	-16.7	-11.0	-18.9	-18.5	-26.9	-19.0	-25.5	17.1	8.2
			0.17	0.20	0.05	0.11	0.43	0.03	0.02	0.09	0.07	0.22	0.94
NAP-K142	30-35	M	-16.4	-20.9	-17.4	-12.9	-19.6	-19.9	-27.0	-19.5	-26.5	16.9	7.6
			0.05	0.07	0.06	0.05	0.14	0.48	0.18	0.05	0.01	0.32	1.05
NAP-K143	25-30	M	-16.3	-22.2	-17.9	-13.2	-20.7	-21.7	-27.1	-20.6	-27.3	13.4	8.2
			0.09	0.26	0.18	0.32	0.15	0.41	0.43	0.15	0.08	0.18	0.11
NAP-K164	25-30	M	-16.2	-21.8	-16.8	-13.0	-19.7	-19.9	-27.8	-20.0	-26.6	16.4	9.5
			0.13	0.32	0.02	0.05	0.57	0.82	0.24	0.13	0.19	0.30	1.01
NAP-K182	25-30	M	-15.6	-21.5	-16.7	-14.7	-18.4	-19.0	-27.1	-19.0	-26.4	15.5	8.4
			0.11	0.13	0.27	0.18	0.23	0.27	0.27	0.19	0.08	0.07	0.98

Table 4.4. Comparison of differences in $\delta^{13}C_{AA}$ values between GC-C-IRMS with NACME esters and LC-IRMS and between GC-C-IRMS with TFA-IP esters and correction factors. Data comes from Tables 2 and 3 in Dunn et al. (2011) and Table 1 from Corr et al. (2005).

		GC-C-IRMS NACME vs. LC-IRMS									**GC-C-IRMS NACME vs. GC-C-IRMS TFA-IP**						
	Diet	$\Delta^{13}C_{Asx}$	$\Delta^{13}C_{Hyp}$	$\Delta^{13}C_{Glx}$	$\Delta^{13}C_{Gly}$	$\Delta^{13}C_{Ala}$	$\Delta^{13}C_{Pro}$	$\Delta^{13}C_{Val}$	$\Delta^{13}C_{Lys}$	$\Delta^{13}C_{Phe}$	$\Delta^{13}C_{Asx}$	$\Delta^{13}C_{Hyp}$	$\Delta^{13}C_{Glx}$	$\Delta^{13}C_{Gly}$	$\Delta^{13}C_{Ala}$	$\Delta^{13}C_{Pro}$	$\Delta^{13}C_{Phe}$
UCT 5200/ SAM AP 4292	C_3	1.0	0.5	0.6	0.3	2.9	0.6	-0.3	-0.7	-0.2	-0.2	-0.6	-3.6	-1.1	1.7	3.0	-5.8
UCT 1691/ SAM-AP 4637	C_3	1.7	0.7	-0.4	1.4	2.9	1.2	-	0.7	-0.4	-0.6	-3.1	-2.9	5.3	1.5	0.3	-4.8
UCT 1683/ SAM-AP 5041	C_3	1.9	2.1	2.2	2.1	2.6	1.4	0.6	1.4	-0.3	-1.9	-2.5	-1.6	4.5	1.7	-0.2	-3.5
UCT 5234/	C_4	2.1	1.7	2.2	2.3	2.7	1.7	0.5	0.5	-0.5	-1.2	-2.8	-2.4	6.2	1.9	0.1	-5.9

NMB 1704																	
UCT 5181/ SAM-AP 1163(B)	C_4	0.9	0.8	-0.3	-0.7	2.1	-0.1	-0.6	-1.0	0.5	-4.1	-3.6	-4.9	2.9	0.5	-1.8	-4.8
UCT 5217/ UCT 67	C_4	4.2	2.5	3.0	2.8	5.6	1.2	-	0.9	0.4	-1.4	-2.6	-1.4	7.0	3.4	0.4	-5.1
UCT 5213/ SAM-AP 1879	HMP	1.4	1.3	1.1	0.9	2.3	0.8	-0.3	-0.8	-0.7	-2.9	-3.0	-3.3	2.7	1.3	0.1	-4.1
UCT 5214/ SAM-AP 1889	HMP	0.7	0.4	2.5	0.5	1.9	0.9	-0.1	0.2	-1.6	-2.9	-3.4	-2.4	3.0	0.3	-0.2	-3.9
UCT 1747A/ SAM-AP 4304(A)	HMP	1.9	-0.1	2.2	-0.2	2.4	-0.1	0.5	-1.3	-1.4	-6.7	-1.3	-1.4	-0.6	2.4	1.4	-6.2
UCT 1750/ SAM-AP 4308	HMP	2.0	1.1	0.9	0.7	2.6	0.6	0.9	-0.5	-0.7	-0.3	-1.9	-1.6	4.5	2.9	0.8	-4.7
Correction factor[1]		**1.8**	**1.1**	**1.4**	**1.0**	**2.8**	**0.8**	**0.2**	**-0.1**	**-0.5**	**-2.2**	**-2.5**	**-2.6**	**3.4**	**1.8**	**0.4**	**-4.9**

[1] Correction factor was calculated for each amino acid by averaging the difference of that amino acid using all 10 samples. Correction factors were only calculated for the nine amino acids used in the PCA. Correction factors were not calculated for Val and Lys for GC-C-IRMS with TFA-IP esters because $\delta^{13}C_{Val}$ and $\delta^{13}C_{Lys}$ were not measured in Corr et al. (2005).

Table 4.5. $\delta^{13}C_{AA}$ values of archaeological humans with benchmark diets used in PCA. Data was published in Dunn et al. (2011), Honch et al. (2012), Raghavan et al. (2010), and Webb et al. (2018). Correction factors from Table 4.3 were applied to Honch et al. (2012), Raghavan et al. (2010), and Webb et al. (2018) as these studies used LC-C-IRMS.

Sample ID	**Diet**	**Site Location**	**Bulk $\delta^{13}C$**	**Bulk $\delta^{15}N$**	**$\delta^{13}C_{AA}$ values**								
					Ala	**Gly**	**Asx**	**Glx**	**Pro**	**Hyp**	**Phe**	**Val**	**Lys**
V11	C3 consumers	Bulgaria	-19.3	10.4	-19.1	-12.4	-18.6	-17.9	-20.2	-19.6	-27.6	-25.9	-21.9
V32	C3 consumers	Bulgaria	-19.0	10.2	-18.1	-11.2	-18.6	-16.7	-20.6	-19.8	-27.1	-25.5	-21.3
V43	C3 consumers	Bulgaria	-18.5	11.0	-17.5	-11.5	-17.5	-17.9	-19.6	-19.1	-26.4	-24.7	-20.2
D596	C3 consumers	Bulgaria	-19.3	10.0	-18.5	-12.6	-18.5	-16.6	-20.1	-19.5	-27.2	-26.1	-21.8
D772	C3 consumers	Bulgaria	-18.9	8.8	-19.1	-11.6	-19.2	-17.0	-20.3	-19.7	-27.6	-26.2	-22.4
D898	C3 consumers	Bulgaria	-19.1	11.2	-18.3	-12.1	-18.8	-16.0	-20.1	-19.2	-27.0	-26.3	-22.1
IG11	C3 consumers	Serbia	-19.8	10.9	-19.4	-12.6	-19.7	-17.7	-21.3	-20.9	-28.6	-27.0	-24.2
IG12	C3 consumers	Serbia	-19.9	11.1	-19.7	-11.7	-18.7	-16.9	-21.5	-20.6	-28.3	-27.1	-24.5
IG13	C3 consumers	Serbia	-19.7	10.4	-18.3	-12.4	-20.2	-17.6	-23.1	-22.0	-28.8	-27.4	-24.4

IG14	C3 consumers	Serbia	-19.5	9.5	-19.0	-12.4	-18.6	-16.6	-20.9	-20.0	-28.0	-26.9	-23.6
IG15	C3 consumers	Serbia	-18.6	10.2	-20.3	-10.8	-18.6	-16.5	-20.5	-19.7	-28.2	-26.1	-23.3
ROSS08	C3 consumers	Serbia	-20.1	9.9	-20.2	-12.5	-19.8	-16.7	-21.1	-22.1	-26.8	-26.3	-21.7
ROSS09	C3 consumers	Sweden	-20.6	8.8	-19.2	-12.9	-19.4	-17.4	-22.3	-21.3	-28.2	-27.7	-23.3
ROSS10	C3 consumers	Sweden	-20.8	9.1	-18.9	-13.5	-19.6	-17.9	-22.3	-21.0	-28.3	-27.9	-23.1
ROSS13	C3 consumers	Sweden	-20.6	9.2	-19.4	-13.9	-20.1	-16.1	-22.5	-22.9	-26.6	-26.7	-22.9
ROSS15	C3 consumers	Sweden	-20.6	8.7	-19.8	-13.6	-20.0	-17.8	-26.7	-21.0	-28.0	-27.3	-22.4
ROSS16	C3 consumers	Sweden	-20.7	8.2	-19.5	-14.4	-19.7	-17.0	-22.6	-22.5	-27.2	-27.6	-22.8
ROSS18	C3 consumers	Sweden	-21.1	8.4	-19.4	-14.0	-19	-19.4	-23.1	-25.5	-27.2	-27.2	-23.8
M1	C4 consumers	Belize	-13.4	8.5	-13.2	-10.0	-14.0	-11.7	-13.3	-12.1	-21.7	-21.6	-18.7
M2	C4 consumers	Belize	-11.0	8.2	-9.8	-7.1	-10.5	-8.6	-10.8	-9.5	-20.1	-19.4	-17.1
M3	C4 consumers	Belize	-13.0	8.3	-11.6	-8.5	-15.3	-9.9	-12.2	-10.1	-21.6	-21.3	-17.2
M4	C4 consumers	Belize	-12.6	8.3	-11.6	-8.4	-16.8	-9.8	-11.5	-10.3	-21.6	-21.2	-17.6
M5	C4 consumers	Belize	-9.1	11.5	-7.7	-4.1	-9.0	-6.3	-9.2	-7.6	-17.8	-16.9	-14.9
M6	C4 consumers	Belize	-13.4	8.2	-13.4	-9.2	-14.2	-12.4	-13.6	-12.4	-21.6	-21.0	-18.8
M7	C4 consumers	Belize	-8.2	9.5	-6.9	-4.0	-8.1	-5.4	-8.5	-7.3	-17.5	-16.6	-14.8
M8	C4 consumers	Belize	-8.9	8.9	-8.2	-4.2	-8.8	-5.6	-7.8	-7.3	-17.5	-16.6	-14.7
M9	C4 consumers	Belize	-13.9	8.3	-14.2	-9.8	-14.4	-11.5	-12.2	-11.7	-21.5	-21.0	-18.2
M10	C4 consumers	Belize	-8.9	9.8	-10.2	-5.4	-9.2	-6.5	-8.9	-7.2	-18.5	-16.0	-15.2
M11	C4 consumers	Belize	-12.4	8.7	-11.4	-9.5	-12.1	-9.8	-12.3	-10.4	-20.5	-20.0	-17.6
M12	C4 consumers	Belize	-13.1	9.3	-12.6	-9.2	-13.5	-11.6	-13.0	-11.6	-21.2	-20.4	-18.1
M14	C4 consumers	Guatemala	-7.9	8.3	-5.2	-3.1	-10.4	-5.3	-6.9	-6.4	-16.8	-15.4	-14.1
M15	C4 consumers	Guatemala	-8.8	7.7	-5.5	-4.5	-10.3	-5.9	-7.8	-7.6	-17.9	-16.8	-15.4
IG1	HFP consumers	Serbia	-18.9	13.0	-22.8	-10.3	-20.6	-17.9	-19.6	-18.7	-29.7	-23.4	-22.7
IG2	HFP consumers	Serbia	-19.0	13.7	-21.7	-9.4	-21.3	-19.0	-20.0	-19.1	-30.7	-23.3	-23.2
IG3	HFP consumers	Serbia	-18.9	14.1	-22.9	-9.5	-20.7	-17.9	-19.9	-18.8	-30.9	-22.9	-22.6
IG4	HFP consumers	Serbia	-18.0	16.1	-22.4	-9.0	-20.6	-17.0	-18.7	-17.4	-30.1	-22.5	-22.7
IG5	HFP consumers	Serbia	-18.6	15.6	-22.5	-9.0	-20.7	-19.4	-19.5	-18.4	-30.5	-23.0	-22.8
IG6	HFP consumers	Serbia	-17.3	15.8	-22.2	-8.2	-20.1	-16.6	-18.0	-17.1	-30.0	-22.5	-22.6

IG7	HFP consumers	Serbia	-18.6	16.0	-22.7	-9.3	-20.9	-17.2	-19.3	-18.1	-30.4	-23.0	-22.8
IG17	HFP consumers	Serbia	-18.2	16.3	-22.4	-9.5	-21.0	-17.6	-19.4	-18.1	-30.5	-22.9	-23.2
IG18	HFP consumers	Serbia	-17.7	17.0	-23.3	-8.1	-19.5	-17.1	-18.2	-17.4	-30.1	-22.3	-21.5
J1	HMP consumers	Japan	-14.2	17.8	-17.7	-5.2	-15.5	-14.4	-12.6	-13.5	-24.5	-19.2	-16.2
J4	HMP consumers	Japan	-13.5	17.5	-15.2	-5.1	-14.8	-11.2	-12.8	-13.0	-23.9	-18.4	-15.4
J5	HMP consumers	Japan	-14.4	17.5	-16.0	-8.2	-15.8	-12.0	-13.1	-13.8	-24.5	-19.6	-15.6
UCT 5213	HMP consumers	South Africa	-11.1	17.5	-13.4	-1.7	-13.0	-9.9	-11.5	-12.3	-22.0	-17.3	-13.9
UCT 5214	HMP consumers	South Africa	-11.5	17.5	-14.1	-2.3	-13.6	-9.8	-11.6	-13.1	-22.4	-16.9	-12.7
UCT 1747A	HMP consumers	South Africa	-12.3	17.3	-17.4	-4.0	-13.9	-12.5	-13.0	-13.9	-22.7	-16.7	-14.4
UCT 1750	HMP consumers	South Africa	-11.8	16.4	-15.6	-3.0	-13.1	-12.0	-12.5	-13.1	-21.6	-16.2	-13.2
Individual 1	HMP consumers	Greenland	-13.1	21.9	-14.1	-2.5	-13.2	-12.4	-13.0	-10.8	-23.9	-16.6	-15.2
Individual 2	HMP consumers	Greenland	-12.8	22.6	-13.4	-2.1	-12.1	-11.3	-12.3	-11.0	-23.8	-16.6	-15.2
Individual 3	HMP consumers	Greenland	-12.6	20.5	-13.6	-1.2	-13.4	-11.3	-12.7	-11.2	-23.1	-17.4	-14.7
Individual 4	HMP consumers	Greenland	-12.8	22.2	-13.2	-3.2	-13.0	-13.0	-12.0	-10.8	-23.6	-16.8	-14.9
Individual 5	HMP consumers	Greenland	-13.9	20.0	-14.2	-3.1	-13.9	-12.2	-13.1	-12.0	-25.0	-17.7	-16.3
Individual 6	HMP consumers	Greenland	-13.6	20.9	-14.4	-4.0	-13.9	-12.3	-12.9	-11.8	-24.7	-17.2	-15.3

Table 4.6. Bone collagen and amino acid quality data for NGA soldiers from the mass gravesite Šiaurės miestelis.

Sample ID	**Carbon (%)**	**Nitrogen (%)**	**Atomic C/N**	**Collagen Yield (%)**	**$\delta^{13}C_{Pro/Hyp}$**	**$\delta^{15}N_{Pro/Hyp}$**
NAP-K006*	**48.0**	**18.0**	3.1	10.0	1.00	0.99
NAP-K007	45.1	16.2	3.2	19.4	1.00	1.00
NAP-K023	44.3	15.9	3.2	13.1	0.97	0.99
NAP-K025	44.5	16.0	3.2	18.2	1.00	0.98
NAP-K037	**47.4**	**17.6**	3.1	18.4	0.97	0.99
NAP-K046	43.3	16.0	3.2	14.9	1.00	0.98
NAP-K050	**47.9**	**17.7**	3.1	17.8	0.99	0.97
NAP-K062	46.3	16.5	3.3	6.5	1.01	1.00
NAP-K063	43.2	15.9	3.2	15.3	1.01	1.00

NAP-K065	43.8	15.6	3.3	8.6	0.97	0.99
NAP-K069	46.2	17.1	3.1	20.0	0.97	0.99
NAP-K075	46.9	**17.4**	3.1	19.7	0.98	1.00
NAP-K091*	47.0	**17.6**	3.1	15.2	1.03	1.00
NAP-K107	43.4	16.0	3.2	14.5	0.99	1.00
NAP-K113	43.0	15.4	3.3	11.8	0.99	0.99
NAP-K121	47.0	16.9	3.3	18.6	1.01	0.97
NAP-K142	**49.5**	**17.4**	3.3	6.6	1.00	0.96
NAP-K143	43.6	16.0	3.2	4.3	0.99	0.95
NAP-K164	44.2	16.1	3.2	14.6	1.01	0.97
NAP-K182*	**47.5**	17.1	3.2	-	1.04	0.97

*Samples run in duplicate for bulk analysis. Quality indicators for duplicates reported as means.
Bolded figures above acceptable range for given quality indicator.

Table 4.7. Amino acid (AA) loadings for principal components 1 and 2 (PC 1 and PC 2).

	Loadings	
$\delta^{13}C_{AA}$	**PC 1**	**PC 2**
Ala	12.78	24.70
Gly	7.15	30.32
Asx	9.24	2.34
Glx	10.71	4.40
Pro	16.36	1.22
Hyp	16.28	0.50
Phe	9.47	14.54
Val	9.67	17.97
Lys	8.34	4.00

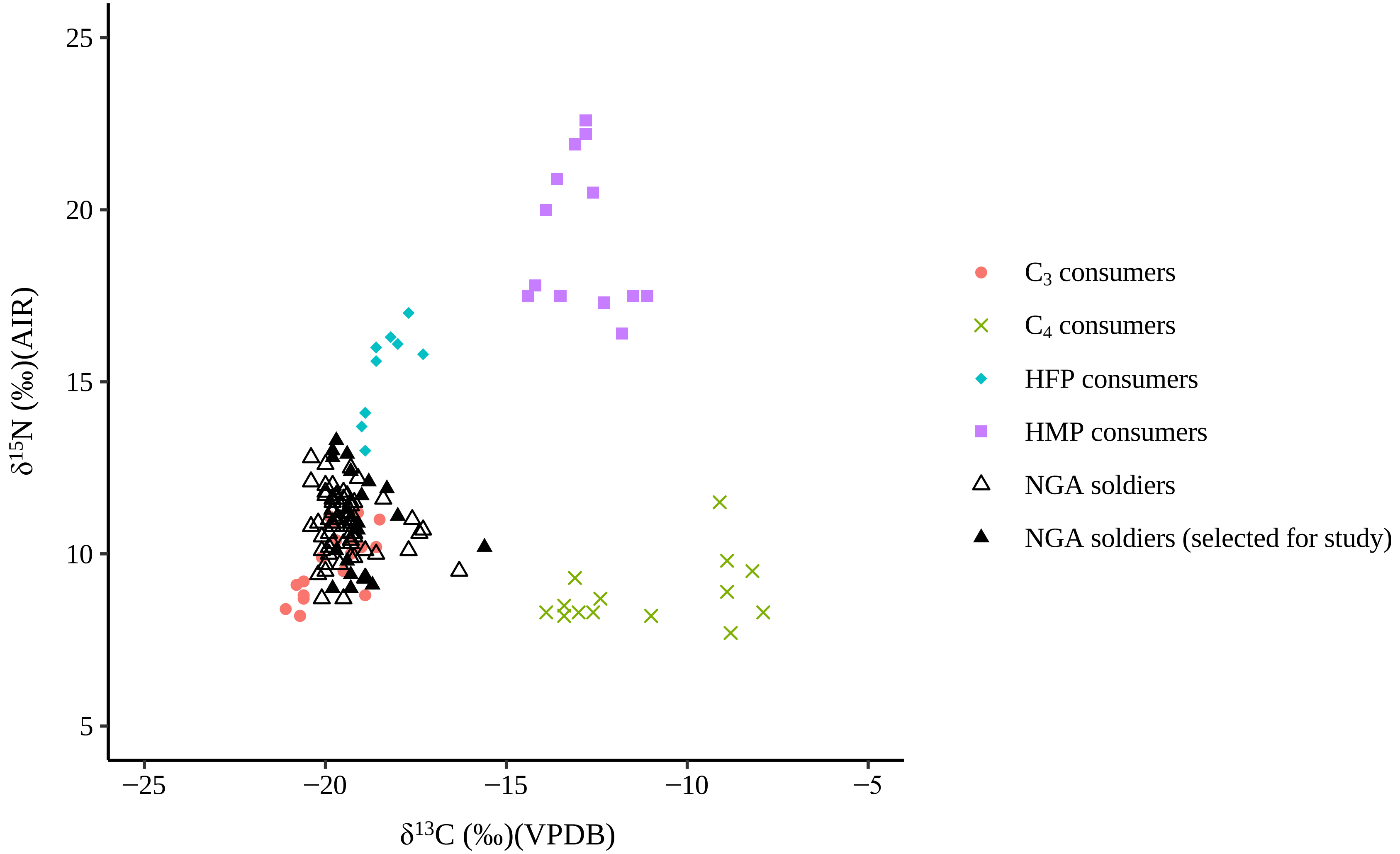

Figure 4.1. NGA soldiers rib bulk collagen stable carbon and nitrogen isotope values from the mass gravesite of Šiaurės miestelis plotted against archaeological humans with benchmark diets: C_3 consumers, C_4 consumers, high freshwater protein (HFP) consumers, and high marine protein (HMP) consumers. Benchmark diet data comes from Dunn et al., (2011), Honch, McCullagh, & Hedges (2012), Raghavan et al. (2010), and Webb et al. (2018). NGA soldiers values overlap with C_3 and HFP consumers and some NGA soldier values are between C_3 and C_4 consumers.

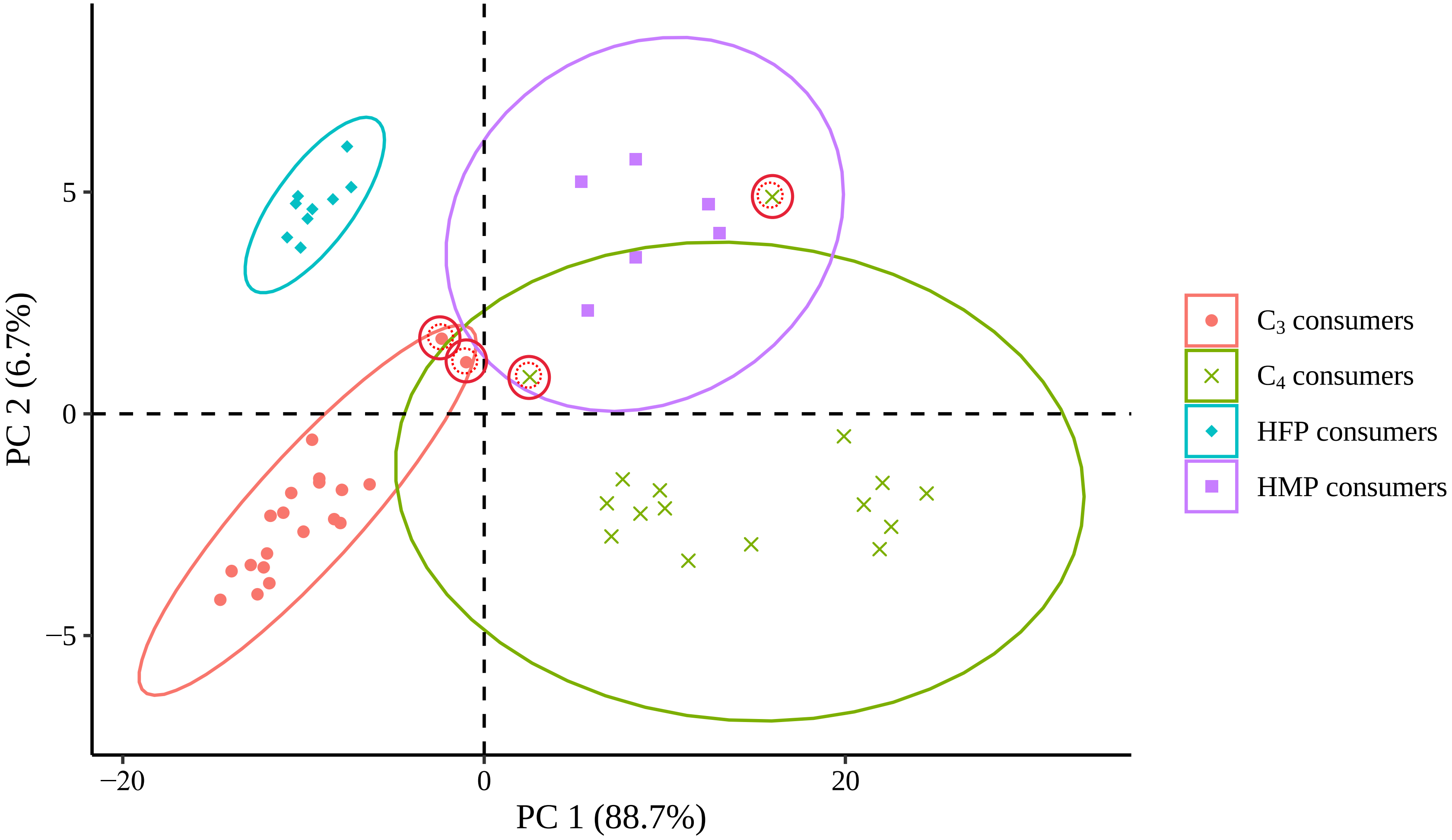

Figure 4.2. Initial principal components analysis (PCA) of archaeological humans with benchmark diets: C_3 consumers, C_4 consumers, high freshwater protein (HFP) consumers, and high marine protein (HMP) consumers. The PCA was run on $\delta^{13}C$ values of the following AAs: alanine (Ala), aspartic acid (Asx), glutamic acid (Glx), glycine (Gly), hydroxyproline (Hyp), lysine (Lys), phenylalanine (Phe), proline (Pro), and valine (Val). Benchmark diet data comes from Dunn et al., (2011), Honch, McCullagh, & Hedges (2012), Raghavan et al. (2010), and Webb et al. (2018). Four outliers were detected (red dotted circles). These individuals were removed before running final PCA.

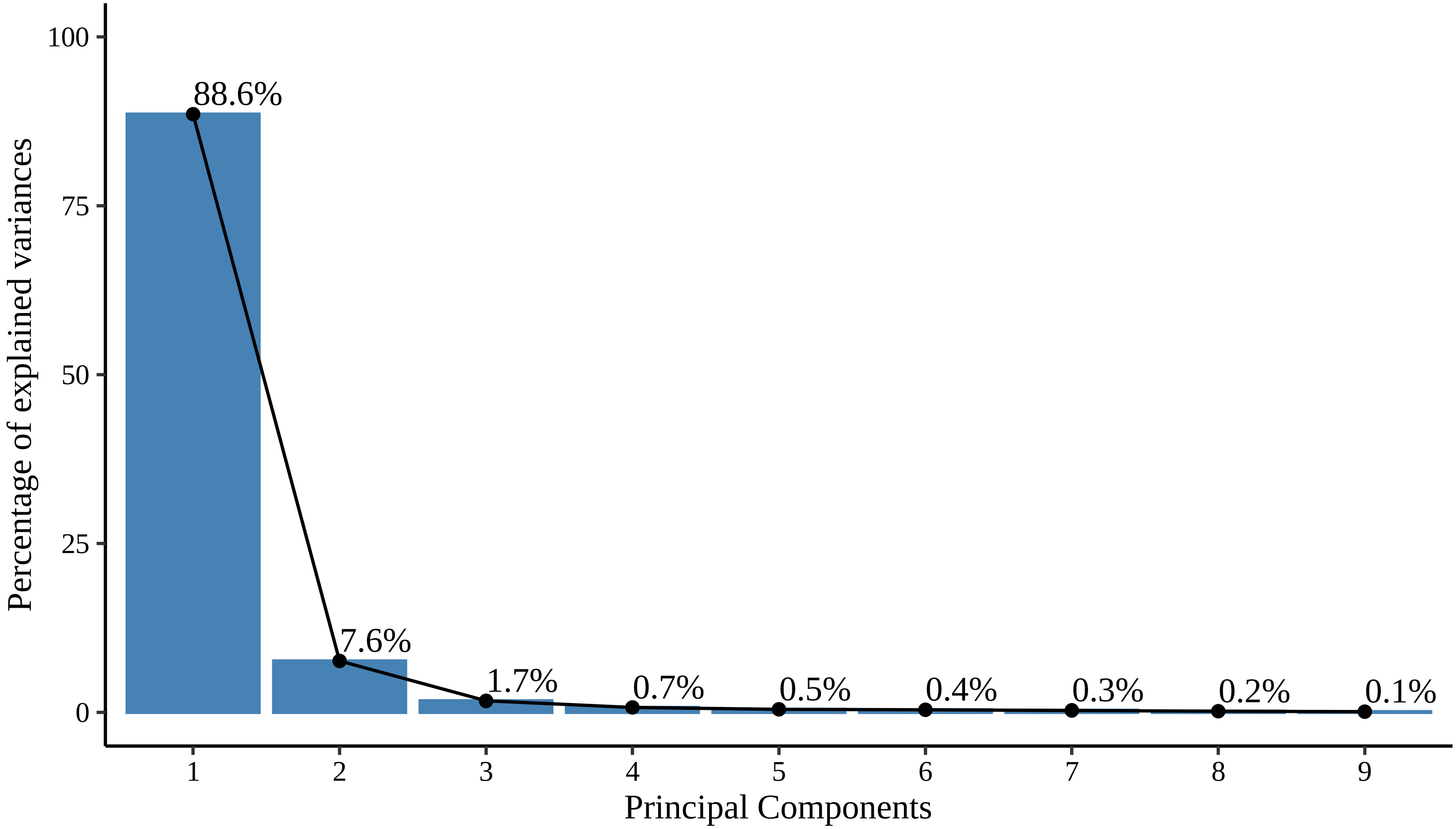

Figure 4.3. Scree plot showing how much variance in $\delta^{13}C_{AA}$ values each principal component (PC) captures. Only the first two PCs were retained as they explain more than 95% of the variance in the data.

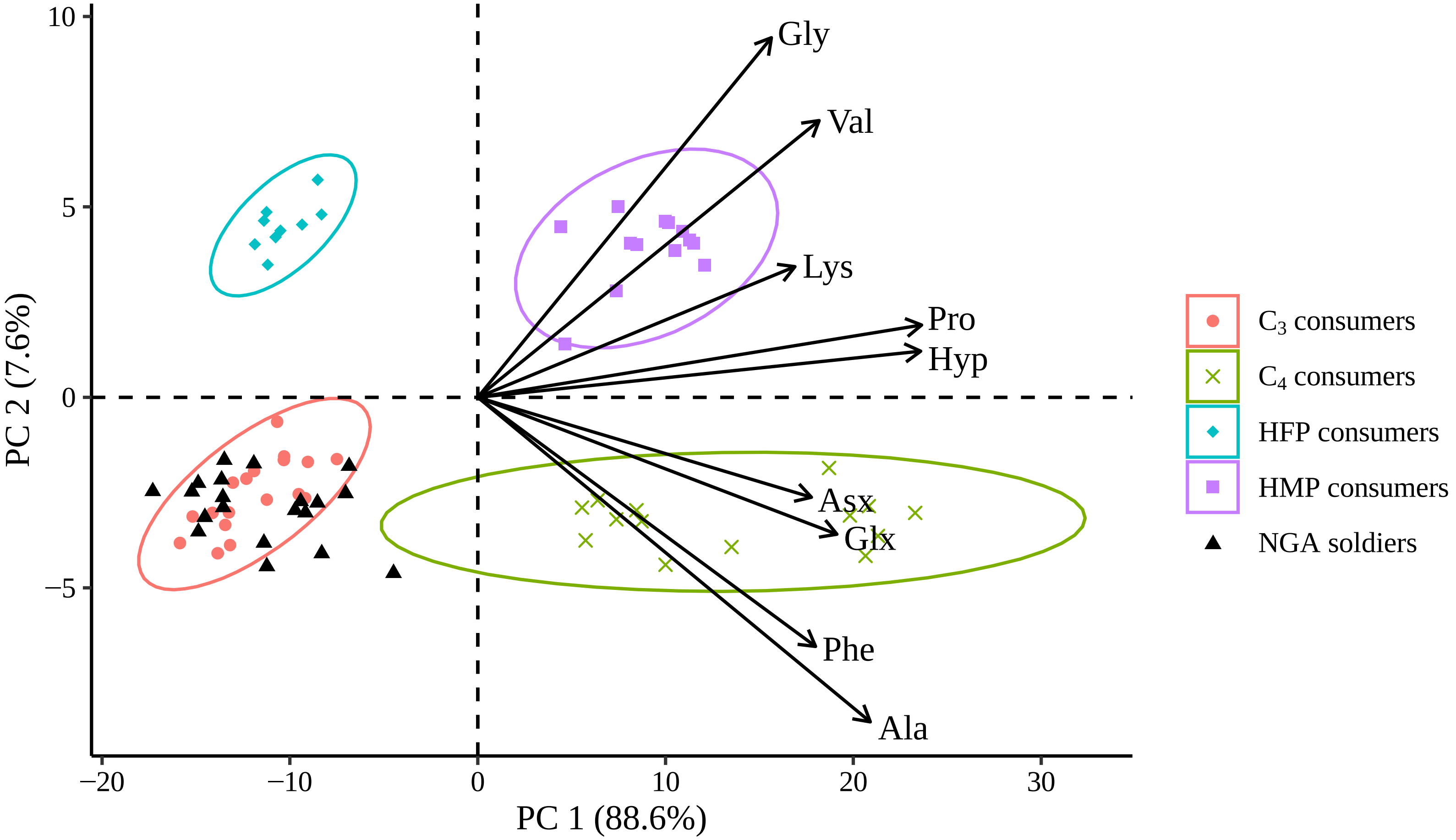

Figure 4.4. Biplot of archaeological humans with benchmark diets (C_3 consumers, C_4 consumers, high freshwater protein (HFP) consumers, and high marine protein (HMP) consumers) and NGA soldier principal component scores with lines representing the nine variables used in the PCA: $\delta^{13}C_{AA}$ values for alanine (Ala), aspartic acid (Asx), glutamic acid (Glx), glycine (Gly), hydroxyproline (Hyp), lysine (Lys), phenylalanine (Phe), proline (Pro), and valine (Val). Line direction indicates principal component scores for each variable (AAs with positive scores for PCs 1 and 2 have lines moving in an upper right direction, AAs with positive scores for PC 1 and negative scores for PC 2 have lines moving in a lower right direction) and line length indicates loadings for PC 1 and PC 2 for each variable. Benchmark diet data comes from Dunn et al., (2011), Honch, McCullagh, & Hedges (2012), Raghavan et al. (2010), and Webb et al. (2018).

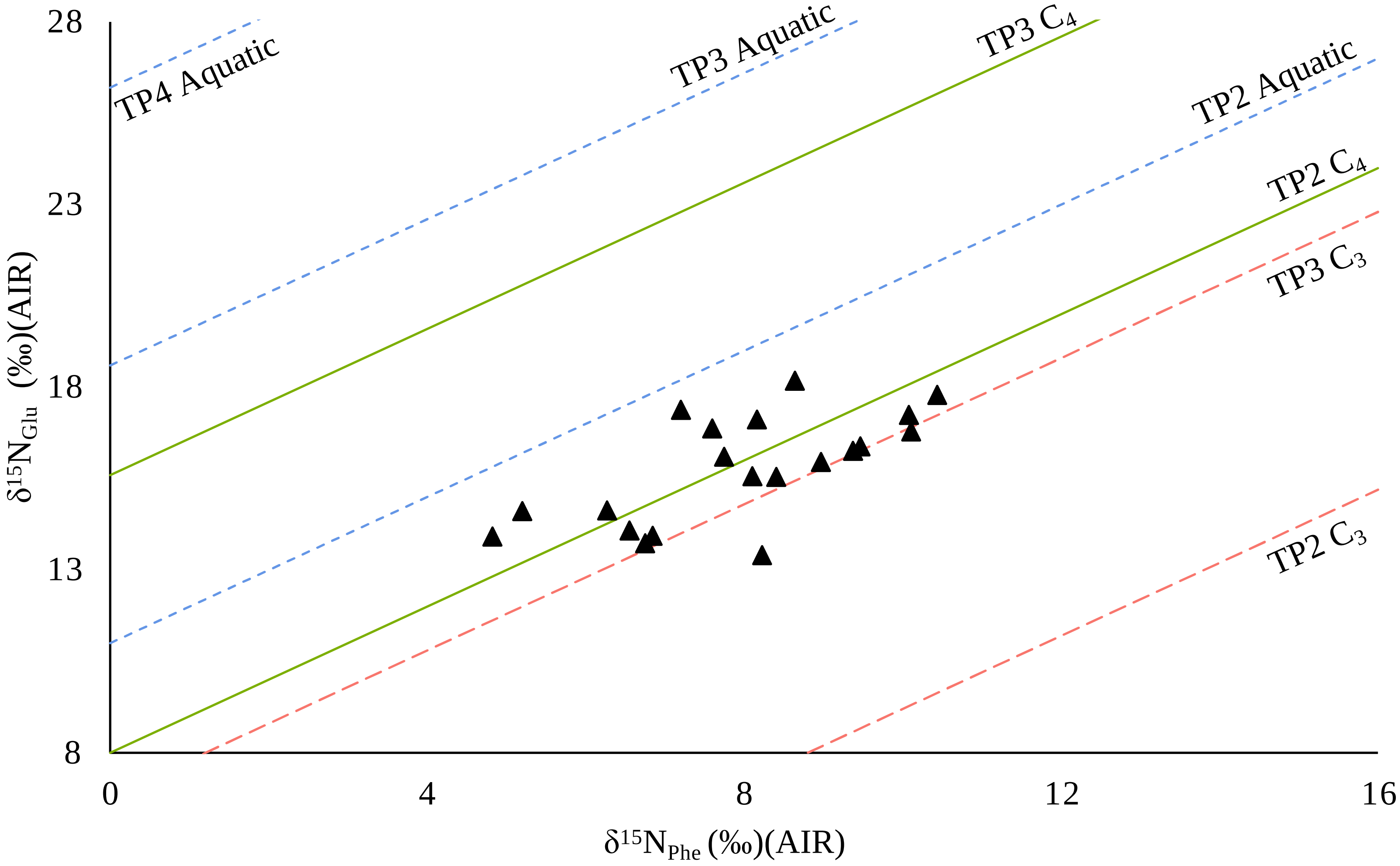

Figure 4.5. Bone collagen $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values for Napoleonic soldiers plotted against trophic lines from Chikaraishi et al. (2009, 2010). TP2 refers to primary consumers (herbivores), TP3 to secondary consumers (omnivores and carnivores), and TP4 to tertiary consumers (carnivores+).

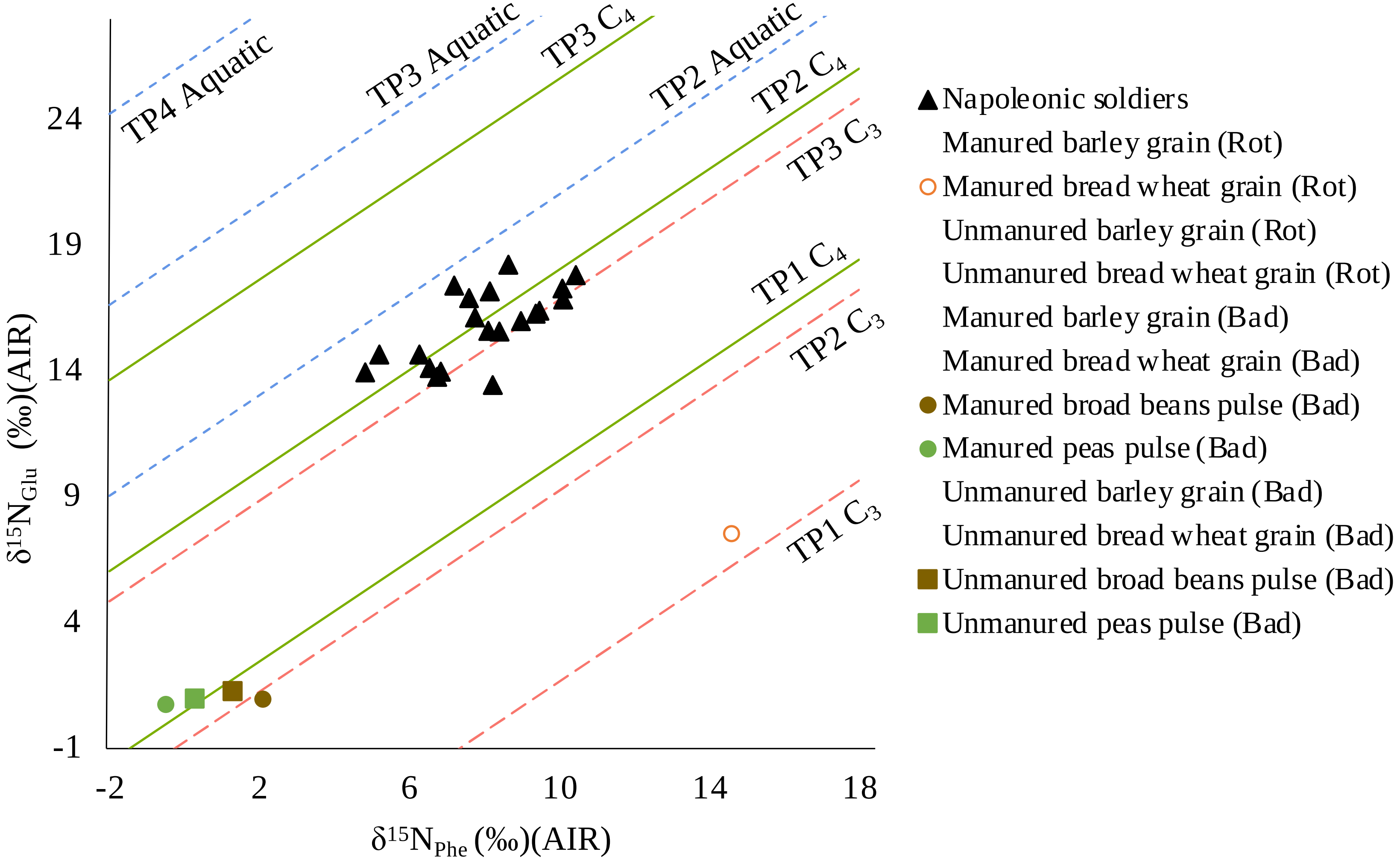

Figure 4.6. Manured and unmanured plant $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values published in Styring et al. (2014b) and NGA soldier $\delta^{15}N_{Phe}$ and $\delta^{15}N_{Glu}$ values plotted against trophic lines from Chikaraishi et al. (2009, 2010). TP1 refers to primary producers (plants), TP2 refers to primary consumers (herbivores), TP3 to secondary consumers (omnivores and carnivores), and TP4 to tertiary consumers (carnivores). Manured plants are represented by circles and squares. Barley symbols are blue, bread wheat orange, broad beans brown, and peas green. Plants grown at the site of Rothamsted (Rot) have no fill, while those grown at Bad Lauchstädt are filled with color. For parts of the plant analyzed, grain is 50% transparent, whereas pulses are not. Grains fall on the on the TP1 C_3 line for both manured and unmanured plants as expected, but pulses fall on the TP2 C_3 line.

CHAPTER 5

RECONSTRUCTING CHANGES IN DIET WITH MILITARY SERVICE AMONG RUSSIAN SOLDIERS USING STABLE CARBON AND NITROGEN ISOTOPE ANALYSIS[3]

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[3] Holder, S., Reitsema, L., Dupras, T., Piličiauskienė, G., & Jankauskas, R. To be submitted to *Journal of Anthropological Archaeology*.

ABSTRACT

Embodiment theory provides a useful framework to examine how the imperialism shaped soldier biology through mechanism of diet. In this study, I reconstruct diet to examine how Russian imperial maintenance shaped the dietary practices of its soldiers. I reconstruct changes in diet over the life course of 19th century Imperial Russian soldiers from a cemetery located at Midaugo Gatvėje, Vilnius, Lithuania (n=41) through stable carbon and nitrogen isotope ratio analysis of femur and rib bone collagen. Soldiers exhibit a mean femoral δ^{13}C value of -20.1 ± 0.5‰ and a mean femoral δ^{15}N value of 10.9 ± 0.9‰. Similarly, they exhibit a mean rib δ^{13}C value of -20.2 ± 0.4‰ and a mean rib δ^{15}N value of 11.1 ± 0.7‰. Results indicate that C_3 plants and terrestrial animals were the primary foods consumed prior to and during military service with potential consumption of freshwater fish. Although diet changed little with military service among Russian soldiers, comparison with nearly contemporaneous Napoleonic soldiers and British sailors shows that there was variation in the ways that 19th century European imperialism shaped the diets of servicemen.

INTRODUCTION

Human diet provides insight into an individual person’s life as what a person eats reflects a combination of nutritional needs, environmental constraints, individual preference, identity, and sociopolitical and economic structures (Anderson, 2014). Diet can be particularly useful for studying power in hierarchically organized societies. In control hierarchies, where individuals at higher levels make decisions that shape the lives and experiences at lower levels (Crumley, 1995), power is reflected in control over food production, access, and distribution (Hastorf, 2017). Empires can be described as control hierarchies; not only are they states with expansive geographic territory, but they are characterized by dominance over distinct cultural and political groups, where a sovereign rules not only the central state but the broader empire and rulers within it (Subrahmanyam, 2001). Imperialism reshapes the foodways of those under imperial control by restructuring food economies, controlling labor practices, and limiting access to food resources (Amin, 1977; Wolf, 1982).

Bioarchaeology is well-positioned to examine the impact of imperialism on foodways as data from the human skeleton is direct and provides insight into individual experiences, not just those recorded in historical accounts. Bioarchaeologists studying the impact of imperialism on foodways have found evidence of changes in diet among some groups under imperial rule (Daverman, 2011; Kellner & Schoeninger, 2008; Somerville et al., 2015), maintenance of diet among other groups under imperial rule (Buzon, Conlee, Simonetti, & Bowen, 2012; Toyne, Church, Tello, & Gamarra, 2017; Tung & Knudson, 2018), and variation among sites within an empire (Crowe et al., 2010; Killgrove & Tykot, 2013). These studies of the impact of imperialism on diet contribute to understanding the ways human groups incorporate and resist imperial rule through the transformation or maintenance of traditional dietary practices.

One group, however, is largely absent from the literature on imperialism and diet, especially in the absence of warfare: imperial soldiers. Soldiers are key actors in the establishment, expansion, and maintenance of empires. The purpose of this research is to evaluate the extent to which military service shapes soldier diets, via rations and shared lifestyles of soldiers, and uses diet as a proxy indicator of broader controls that an empire can have on shaping the bodies of soldiers. Specifically, I reconstruct the long-term and later life diets of Imperial Russian Army (IRA) soldiers from the site of Mindaugo Gatvėje located in Vilnius, Lithuania, that died during the cholera outbreak of 1830-1831 using stable carbon and nitrogen ratio analysis of femur and rib collagen.

Historical context

Russia established and expanded its empire by conquering neighboring territories (Said, 1994). Imperial annexations in the 18th and early 19th centuries included territory in present-day Estonia, Ukraine, Belarus, Lithuania, Poland, Finland, Georgia, and Moldova (Miller, 2015; Natalizi, 2002). Following the Congress of Vienna (1814-1815), Russia imperial expansion and warfare largely ceased until the Crimean War began in 1853 (Wirtschafter, 1990).

Imperial expansion and maintenance required a large military. Twenty-eight conscription levies, which supplied nearly two million men for service in the army and navy, were held in the first quarter of the 19th century (Beskrovny, 1996). Conscription disproportionately affected peasants and townspeople in Russia proper (Beskrovny, 1996; Keep, 1985). Additionally, several annexed territories and ethnic groups received exemptions or could pay money in place of providing men for military service (Wirtschafter, 1990). The age requirements of conscripts typically effected men around 18-20 and 35 years of age (Wirtschafter, 1990). Conscription levy policies targeted at Jewish recruits, which began in 1827, were particularly harsh with age at conscription being as low as 12 years and higher numbers of recruits from this community required to serve (Wirtschafter, 1990). Conscripted soldiers were expected to serve for a period of 20-25 years (Beskrovny, 1996; Wirtschafter, 1990).

During military service, IRA soldier diet varied based on whether they were garrisoned in barracks or quartered with civilians, soldier self-sufficiency, and dietary restrictions based on religion. Most soldiers were quartered with civilians in small towns or villages or garrisoned in barracks in cities for nine months out of the year (Wirtschafter, 1990). When garrisoned in barracks, soldiers were generally provided rations. Imperial Russian soldier rations typically included grains such wheat, barley, and rye in the form of bread, rusks, and groats along with meat, salt, and alcohol (Beskrovny, 1996; Wirtschafter, 1990). Supplies for soldier rations were often locally purchased (Beskrovny, 1996). Soldiers stationed in barracks typically had a more stable diet than those quartered with civilians as supplies were widely available in local markets (Wirtschafter, 1990). When quartered with civilians, civilians were responsible for feeding the soldiers. Civilians were expected to provide foods similar to soldier rations. For peasants who could barely afford to feed themselves, there was little meat or fish to be served, maize was substituted for rye bread, and soldiers often went hungry (Keep, 1985; Wirtschafter, 1990).

Soldier self-sufficiency (or more accurately group-sufficiency) was a mainstay in the Imperial Russian Army. When the state could not provide adequate supplies, soldiers were paid money directly in lieu of rations to purchase their own food (Keep, 1985). Additionally, less mobile troops such as Guard units would grow food in gardens to supplement their rations (Wirtschafter, 1990).

Lastly, although a majority of soldiers were Orthodox Christian, Jewish soldiers also served in the Imperial Russian Army (Hartley, 2008; Petrovsky-Shtern, 2009), and each religion had their own set of diet restrictions. For those who practiced Russian Orthodox Christianity, approximately 200 calendar days were considered *govenie* (i.e., fasting), which require abstinence from animal products (meat, eggs, and dairy) and sometimes fish (Matalas, Tourlouki, & Lazarou, 2001; Voronina, 2006). Although they varied by location and socioeconomic status, fast day staples included bread (usually rye), porridge and pies made of cereals, and vegetables (often carrots, potatoes, mushrooms, cabbage, turnips). Judaism prescribes a kosher diet, which prohibits consumption of particular animals including pigs, hare, wild birds, and several types of fish and shellfish (Regenstein, Chaudry, & Regenstein, 2003). It is unclear the degree to which Russian Orthodox soldiers followed fasting restrictions, and the role of religion on soldier daily life more broadly (Keep, 1985).

Theoretical framework and research goals

Embodiment theory provides a useful framework to examine the impact of imperialism on soldier bodies through the mechanism of diet. Embodiment refers to how the environment in which an individual lives, comprising both the social and the ecological, literally become incorporated into an individual’s biology (Krieger, 2005). In bioarchaeology, embodiment serves as a means to explore how the social world in which a body exists and interacts effects human skeletal biology (Zuckerman, Kamnikar, & Mathena, 2014). Key to embodiment theory are the concepts of skeletal plasticity and the life course (Schrader & Torres-Rouff, 2021). Skeletal plasticity refers to the ability of the skeleton to respond to external stressors or strains such as traumatic injury, arduous labor, malnutrition, and chronic disease (Ruff, Holt, & Trinkaus, 2006). Skeletal plasticity occurs through bone remodeling; together, these are the mechanisms that allows an individual’s social environment to become incorporated into skeleton. Much of the bioarchaeological research on embodiment has focused on the embodiment of aspects of social identity (e.g., Blom, 2005; Heathcote, Diego, Ishida, & Sava, 2012; Tiesler, 2014; White, Longstaffe, Pendergast, & Maxwell, 2009).

In this research, embodiment theory provides an explanatory framework to track how the process of imperial maintenance shaped soldier biology through the mechanism of diet. My first goal is to test the hypothesis that human diet changed later in life. Diets may have changed later in life if military rations differed isotopically from pre-military diet. Most soldiers were from Russia proper (i.e., the imperial core) but served in the peripheries of the empire (Wirtschafter, 1990), making the foods locally available potentially different isotopically. If there was a change in diet, I expect to see a difference in rib and femur stable isotope values of individual Russian soldiers. On the other hand, soldiers may have consumed isotopically indistinguishable diets prior to and during military service. Most conscripts were peasants and both soldier and peasant diet consisted primarily of terrestrial grains, vegetables, and livestock (Hoch, 1982; Wirtschafter, 1990), with peasants sometimes consuming fish (R. E. F. Smith & Christian, 1984). Additionally, Russia differed from other European countries in that it established and expanded its empire by conquering neighboring, rather than distant territories (Said, 1994). Thus, the foods locally available in the imperial periphery where soldiers served may not differed isotopically from the foods soldiers consumed prior to military service while living in the imperial core. If there was not a change in diet, I expect to see no difference in rib and femur stable isotope values of individual Russian soldiers.

My second goal is to test the hypothesis that diet became more homogenous isotopically later in life at the group level. Soldiers were prescribed rations during military service that may have resulted in them consuming more isotopically similar diets later in life. If diet became more homogenous later in life, I expect there to be greater isotopic heterogeneity in femora than ribs. Conversely, diet may have been equally heterogenous earlier and later in life or more heterogenous later in life. Although soldiers were prescribed rations, there was flexibility in what those rations were and how soldiers supplemented rations (see below). If diet was equally heterogenous or more heterogenous later in life, I expect similar heterogeneity in femora and ribs or greater heterogeneity in ribs.

My third goal is to test the hypothesis that IRA soldier diet heterogeneity differed from two contemporaneous military populations: early 19th century Napoleon's Grand Army (NGA) soldiers from the mass gravesite of Šiaurės miestelis, Vilnius, Lithuania (Chapter 3), late 18th-early 19th century British Royal Navy (BRN) sailors from the Royal Naval Hospital cemetery at Haslar, Gosport, UK (Roberts et al., 2012), and early 19th century BRN sailors from the Royal Navy Hospital cemetery at Stray Park in

Plymouth, UK (Roberts et al., 2012). Unlike IRA soldiers, NGA soldiers and BRN sailors were recruited from and served in more distant geographic landscapes. Additionally, while Russia was focused on maintaining its empire during the period of study, France and Britain were actively expanding their empires through warfare. These circumstances may lead to differences in diet heterogeneity. If diet heterogeneity differed between IRA soldiers and NGA soldiers and BRN sailors, then I expect greater isotopic heterogeneity in the ribs of NGA soldiers and BRN sailors than IRA soldiers. However, historical evidence indicates that all three of these military groups were prescribed rations that consisted primarily of C_3 grains in the form of bread, porridge, and alcohol and vegetables and meat from terrestrial animals (Filippini, 1965; Rodger, 1986; Wirtschafter, 1990). Thus, diet heterogeneity may be similar between IRA soldiers and NGA soldiers and BRN sailors. If diet heterogeneity was similar, I expect isotopic heterogeneity in the ribs of IRA and NGA soldiers and BRN sailors to be the same.

An assumption of this research is that IRA soldier ribs primarily reflect diet during the period of military service. Remodeling rates in ribs vary considerably with age, and thus the ribs of younger individuals may reflect different periods in their life (including time prior to military service) than older individuals. For older soldiers, I do expect that ribs primarily reflect military service as the period of military service in this time-period in Russia was 20-25 years (Beskrovny, 1996; Wirtschafter, 1990). For younger soldiers, ribs may capture a combination of military and pre-military diet. To investigate this assumption, I compare $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$ across age categories.

Stable isotope principles and diet reconstruction in Eastern Europe

Isotopes are atoms of the same element that have the name number of protons but different numbers of neutrons; stable isotopes do not decay over time (as radioactive isotopes do). Analysis of stable isotopes of carbon and nitrogen in bone collagen is an established method of reconstructing the source of protein in the diets of past humans (DeNiro & Epstein, 1978, 1981; van der Merwe & Vogel, 1978; Vogel & van Der Merwe, 1977), making it well-suited to characterize individual Imperial Russian soldier diet. Stable carbon isotope values vary systematically between classes of plants with different photosynthetic pathways and across ecosystems. For example, C_3 plants (e.g., wheat, barley, rye, most fruits and vegetables) exhibit $\delta^{13}C$ values that are lower than C_4 plants (e.g., millet, maize, sorghum, sugar) and CAM plants (e.g., Spanish moss, pineapple, agave) (Bender, 1971; DeNiro, 1987; B. N. Smith & Epstein, 1971). Marine plants and fish have $\delta^{13}C$ values that are higher than terrestrial C_3 plants and most freshwater fish and terrestrial animals, but that overlap with terrestrial C_4 and CAM plants (Fuller, Müldner, Van Neer, Ervynck, & Richards, 2012; Park & Epstein, 1961; Schoeninger & DeNiro, 1984). Stable nitrogen isotope values increase systematically with trophic level (Minagawa & Wada, 1984), providing insight into plant versus animal protein consumption. The latter can also be useful in distinguishing consumer diets between ecosystems as marine ecosystems tend to have more trophic levels and there are source differences in nitrogen in waters (Schoeninger & DeNiro, 1984; Sigman, Karsh, & Casciotti, 2009).

Differences in stable carbon and nitrogen isotope values of dietary resources are passed on to consumers with an offset caused by stable isotope fractionation (Chisholm, Nelson, & Schwarcz, 1982; Schoeninger, DeNiro, & Tauber, 1983; Tauber, 1981). Thus, the diet to consumer tissue space for bone collagen for nitrogen is approximately 3-5‰ (Schoeninger & DeNiro, 1984). The diet to bone collagen space for carbon is approximately 5‰ and tissue to tissue space (i.e., bone collagen of primary consumer/herbivore to bone collagen of secondary consumer/omnivore or carnivore) of about 1‰ (Schoeninger, 1989).

Stable isotope analysis of different mineralized tissues (e.g., teeth, bones) that form or remodel at different times or at different rates can be used to compare diet in a single individual during different periods of time such as childhood, early adulthood, and later life (Reitsema, 2013). Changes in aspects of identity or position in society that occur over an individual’s lifetime and impact diet can be detected by comparing stable isotope values of bones with different turnover times. Bone turnover, defined as the volume of replacement per unit of time (e.g., percentage per year), occurs through remodeling and differs between bones based on factors such as surface area to volume ratio and mechanical loading (Parfitt, 2002). As bone remodels, the isotopic composition of a consumer’s diet is incorporated into the newly remodeled bone. Thus, bones that turnover slower reflect longer-term diet than those that turn over faster.

For example, femoral bone collagen has a turnover time of 10 to 30+ years, depending on age, activity, and other factors (Hedges, Clement, Thomas, & O'Connell, 2007), whereas ribs turnover anywhere from four to 25 years (Stout & Paine, 1994). Previous studies have compared isotope values in femora and ribs to track to changes in diet and mobility later in life (e.g., Lamb, Evans, Buckley, & Appleby, 2014; Pollard et al., 2012; Roberts et al., 2012; Schroeder, O'Connell, Evans, Shuler, & Hedges, 2009; Sealy, Armstrong, & Schrire, 1995).

Stable isotope data is increasingly utilized to characterize the diets of Medieval and post-Medieval populations in Eastern Europe (Aguraiuja-Lätti & Lõugas, 2019; Petersone-Gordina, Roberts, Millard, Montgomery, & Gerhards, 2018; Poshekhonova, Razhev, Slepchenko, Marchenko, & Adaev, 2020; Reitsema, Kozłowski, Jankauskas, Drążkowska, & Krajewska, 2015; Simčenka, Jakulis, Kozakaitė, Piličiauskienė, & Lideén, 2020; Skipitytė et al., 2020; Tomczyk et al., 2020; Whitmore et al., 2019). These studies demonstrate that Eastern European food webs are complex, as far as stable isotope analysis is concerned. On one hand, most wild and domesticated plants are C_3 plants that stable isotope analysis alone cannot differentiate among. On the other hand, Eastern European diets comprised a complex mix of foods including C_3 plants, fewer C_4 plants, both marine and freshwater fish, and herbivore and omnivore terrestrial animal protein. These complex diets were shaped by a number of sociopolitical and historical factors that affected access or imposed dietary restrictions including urbanization, religion, socioeconomic status, sex, and age. Addressing this complexity benefits from the analysis of faunal remains to establish baseline isotope values of different animals occupying different niches, and historical information about the types of plants eaten.

MATERIALS AND METHODS

Mindaugo Gatvėje

Mindaugo Gatvėje cemetery is located in Naujamiestis ("New Town"), Vilnius, Lithuania, west of the city center (Figure 5.1). It was discovered in 2000 in preparation of construction of a residential house. Forty-four tombs with individual skeletons buried in coffins and an additional 26 individuals buried in common pits, some without coffins were discovered in the 1360 m^2 study area (Daminaitis, 2000). All individuals in this cemetery are estimated to be male and age at death estimates ranges from 15-17 years to 45-50 years (following Buikstra & Ubelaker, 1994). The presence of lime on most of the skeletal remains indicates these individuals likely died during the cholera outbreak of 1831, lime being believed to prevent the spread of the disease from corpses (Baldwin, 1999). Based on cemetery demography, location, and the discovery of orthodox crosses in five burials and medallions in two others, archaeologists determined the historic cemetery to be that of Imperial Russian soldiers sent from the southern region of the Russian Empire to Lithuania during 1830-1831 uprising (Daminaitis, 2000). Forty-one individuals were selected for the present study, based on presence of both ribs and femora.

Sample preparation and analysis

Bone collagen was extracted following a modified version of Longin (1971), where samples are demineralized in HCl (hydrochloric acid), soaked in NaOH (sodium hydroxide) to remove humic and fulvic contaminants, and gelatinized and centrifugated to isolate water-soluble collagen and remove impurities. A hand-held Dremel® tool was used to cut femur and rib into small chunks totaling 0.5-1.0 g and a rotary attachment was used to remove trabecular bone and the outer surface of cortical bone. Samples were cleaned using tap water and toothbrush, followed by five-minute rounds of ultrasonication using reverse osmosed (RO) water until water was clear. Although lipids in archaeological samples is rare, cleaned and dried bone pieces were soaked in 2:1 $CHCl_3$:CH_3OH (chloroform:methanol) three times for 20 minutes each given the recent origin and perceived level of preservation of samples. Next, samples were soaked in 0.5 M hydrochloric acid until demineralized, anywhere from two days to several weeks. Samples were then rinsed three times with RO water. Humic and fulvic acid contaminants were removed using 20-minute rinses of 0.1 M sodium hydroxide. Samples were continually rinsed until solution was clear, usually two to five rinses. Samples were then rinsed again with RO water a total of six times, followed by a rinse in 0.25 M hydrochloric acid, and finally replaced with RO water. The extracted water-soluble collagen was placed in the oven at 90° C for 16-24 hours. Samples were then spun in a centrifuge at 2400 rpm for 10 minutes, collagen containing liquid transferred to dram vials via pipette, frozen at -80° C for 10 minutes, freeze-dried for 24-48 hours, and homogenized in vial using a glass stirring rod.

Approximately 0.600-0.800 mg of sample collagen was weighed into a tin capsule and sent for analysis at the Stable Isotope Ecology Laboratory at the Center for Applied Isotope Studies at the University of Georgia.

Stable carbon and nitrogen stable isotope and elemental compositions were determined using a Thermo Scientific Flash 2000 organic elemental analyzer coupled to a Thermo Scientific Delta V Advantage continuous flow isotope ratio mass spectrometer via a Thermo Scientific Conflo IV open split interface and Carlo Erba NA1500 Nitrogen/Carbon/Sulfur elemental analyzer coupled to Thermo Scientific Delta V Advantage continuous flow isotope ratio mass spectrometer via a Thermo Finnigan Conflo III open split interface over four analytical sessions (Table S1). Stable carbon and nitrogen isotopic compositions were calibrated relative to VPDB and AIR scales using NIST1577c and elemental compositions were calibrated using NIST1570a. Precision was determined to be ± 0.13‰ for $\delta^{13}C$ and ± 0.11‰ for $\delta^{15}N$ based on repeated measurements of calibration standards, check standards, and sample replicates (Tables S2-S3). Precision was calculated following a modified version of Appendix G from Szpak, Metcalfe, and Macdonald (2017).

Quantitative data analysis

Statistical comparisons were performed in R (R Core Team, 2020) and are considered statistically significant when $p \leq 0.05$. I used parametric tests for comparisons within the IRA as sample size was sufficiently large and Shapiro Wilks tests of $\delta^{13}C_{fem}$ ($W = 0.968$, $p = 0.289$), $\delta^{13}C_{rib}$ ($W = 0.986$, $p = 0.895$), $\delta^{15}N_{fem}$ ($W = 0.984$, $p = 0.824$), and $\delta^{15}N_{rib}$ ($W = 0.983$, $p = 0.801$) demonstrate that there is no significant departure from normality.

For my first goal, a change in diet at the individual level is detected by a difference between rib and femur stable isotope values (Δ = rib - femur) is defined as a change in the proportion of isotopically distinguishable foods (i.e., marine, freshwater, terrestrial C_3, and terrestrial C_4). However, investigating change in diet using stable isotope values of different skeletal elements is not a straightforward process as differences in stable isotope values between different skeletal elements of the same individual may not simply reflect changes in the isotope composition of foods consumed. Physiological differences

(Reitsema, 2013), environmental differences and cultural practices (Szpak, 2014; van Klinken, Richards, & Hedges, 2000), and differences in sample preparation and analysis across laboratories can contribute to stable isotope variation in bone collagen (Chesson, Chau, & Edwards, early view; Chisholm, Nelson, Hobson, Schwarcz, & Knyf, 1983; Jørkov, Heinemeier, & Lynnerup, 2007; Pestle, Crowley, & Weirauch, 2014). I use minimal meaningful difference (MMD), developed by Pestle, Crowley, and Weirauch's (2014), to establish a more conservative threshold for meaningful difference between femur and rib stable isotope ratios. I interpret values beyond the MMD as evidence of changes in diet but return to the issue of non-dietary factors (physiological, environmental, and cultural) that may lead to differences in stable isotope values in the femur and rib bones of a single individual in the interpretive challenges section. MMD was developed as a threshold for what constitutes meaningful differences in stable isotope values measured at different laboratories and across studies. The MMD established by Pestle, Crowley, and Weirauch (2014) is 0.6‰ for $\delta^{13}C$ and 0.9‰ for $\delta^{15}N$.

For my second goal, a change in diet heterogeneity is detected by a statistically significant difference between femur and rib stable isotope value variance. I used an F-test to compare sample variance. For my third goal, differences in diet heterogeneity are detected by a statistically significant difference in rib stable isotope value variance between groups. I used an F-test to compare IRA and NGA $\delta^{15}N_{rib}$ variance as there is no significant departure from normality for NGA soldier $\delta^{15}N_{rib}$ values ($W = 0.973$, $p = 0.27$), but used an Ansari-Bradley test for $\delta^{13}C_{rib}$ variance as there is a significant departure from normality for NGA soldiers for $\delta^{13}C_{rib}$ values ($W = 0.730$, $p = 1.53e-08$). I used an F-test to compare IRA and BRN sample variance as there is no significant departure from normality for BRN sailors for $\delta^{13}C_{rib}$ (Haslar: $W = 0.971$, $p = 0.77$; Plymouth: $W = 0.975$, $p = 0.38$) or $\delta^{15}N_{rib}$ (Haslar: $W = 0.937$, $p = 0.38$; Plymouth: $W = 0.973$, $p = 0.30$).

Given that the soldiers in this study likely recently arrived in Vilnius and were buried in a cemetery without animal remains present, a site-specific faunal baseline could not be established. Instead, I used isotopic data from terrestrial animal samples analyzed in this study that come from 18th and 19th century sites around Vilnius and previously published terrestrial animal, freshwater fish, and marine fish stable isotope values from Medieval and post-Medieval sites located within the Russian Empire (Table S4). I used the minimum and maximum values from the faunal samples analyzed in this study and from Table S4 to develop estimates for terrestrial animal, freshwater fish, and marine fish consumers where soldiers were likely recruited from and/or served. One trophic-level enrichment was added to minimum and maximum faunal values to produce consumer estimates (+1‰ for carbon, +4‰ for nitrogen).

RESULTS

Evaluation of collagen preservation

The following criteria were used to evaluate collagen quality: collagen yield between 1% and 22% (van Klinken, 1999), carbon content (%C) between 13% and 47%, nitrogen content (%N) between 4.8% and 17.3% (Ambrose, 1990), and atomic C:N between 2.9 and 3.6 (DeNiro, 1985) (Tables 5.1 and 5.2). Collagen yield was calculated by dividing collagen weight by dry sample weight (after cleaning but prior to chemical treatments) and multiplying by 100. All faunal samples and human femur samples fall with accepted ranges for quality control criteria. All human rib samples have atomic C:N and %N within the ranges outlined above. Four human individuals have rib collagen %C above 47% and seven have a collagen yield above 22%. High carbon content can indicate the addition of organic carbon (van Klinken, 1999). However, all sample carbon content is within 0.5% of the upper limit. Additionally, there is not a strong linear relationship between %C and $\delta^{13}C$ for ribs ($r^2 = 0.03$). Thus, all samples are considered to have well-preserved collagen and were included in this study.

Stable carbon and nitrogen isotope data

Terrestrial faunal $\delta^{13}C$ values range from -22.3‰ to -19.9‰ with a mean of -21.3 ± 0.5‰ and $\delta^{15}N$ values range from 5.6‰ to 10.4‰ with a mean of 8.0 ± 1.5‰ (see Table 5.1 and Figure 5.2). Dogs have the highest $\delta^{13}C$ and $\delta^{15}N$ values ($\delta^{13}C$: -20.5 ± 0.2‰; $\delta^{15}N$: 10.3 ± 0.1‰), followed by pigs ($\delta^{15}N$ =9.1 ± 0.8‰) and goats ($\delta^{15}N$ =7.8 ± 1.4‰), and cattle and sheep have the lowest $\delta^{15}N$ values (cattle: 6.8 ± 0.9‰; sheep: 6.7 ± 1.1‰).

IRA soldier femur $\delta^{13}C$ values range from -21.0‰ to -19.1‰ with a mean of -20.1 ± 0.5‰ and IRA soldier femur $\delta^{15}N$ values range from 8.5‰ to 12.9‰ with a mean of 10.9 ± 0.9‰ (see Table 5.2 and

Figure 5.2). IRA soldier rib $\delta^{13}C$ values range from -21.1‰ to -19.1‰ with a mean of -20.2 ± 0.4‰ and rib $\delta^{15}N$ values range from 9.4‰ to 12.9‰ with a mean of 11.1 ± 0.7‰.

$\Delta^{13}C_{rib\text{-}femur}$ for individual IRA soldiers range from -0.8‰ to 0.9‰ with a mean of 0.0 ± 0.2‰ and $\Delta^{15}N_{rib\text{-}femur}$ range from -0.6‰ to 2.0‰ with a mean of 0.2 ± 0.5‰ (see Figure 5.3). Seventeen individuals have a $\Delta^{13}C_{rib\text{-}femur}$ of 0, 10 have a positive difference (i.e., femora have lower values), and fourteen a negative difference (i.e., ribs have lower values). Three individuals have a $\Delta^{15}N_{rib\text{-}femur}$ of 0, 30 have a positive difference, and eight have a negative difference. Four individuals have an $\Delta^{13}C_{rib\text{-}femur}$ (n=2), $\Delta^{15}N_{rib\text{-}femur}$ (n=3), or both (n=1) on or past the MMD threshold. All three individuals with $\Delta^{15}N_{rib\text{-}femur}$ and one individual with $\Delta^{13}C_{rib\text{-}femur}$ past the MMD threshold fall in the 20-25 years at death age range (Table 5.3).

The variance in $\delta^{13}C$ and $\delta^{15}N$ values of ribs and femora of IRA soldiers are not statistically significantly different ($\delta^{13}C$: F = 1.253, df = 40, p = 0.48; $\delta^{15}N$: F = 1.746, df = 40, p = 0.08).

There are statistically significant differences between IRA and NGA soldiers for $\delta^{15}N$ value variance (F = 0.434, num df = 40, denom df = 52, p = 0.007), but not $\delta^{13}C$ value variance (AB = 918.5, p = 0.319) (see Figure 5.4). There are not statistically significant differences between IRA soldiers and BRN sailors at Haslar for $\delta^{13}C$ value variance (F = 0.581, num df = 40, denom df = 19, p = 0.15) or $\delta^{15}N$ value variance (F = 2.106, num df = 40, denom df = 19, p = 0.08) (see Figure 5.4). There are statistically significant differences between IRA soldiers and BRN sailors at Plymouth for $\delta^{13}C$ value variance (F = 0.202, num df = 40, denom df = 49, p = 9.18e-07) and $\delta^{15}N$ value variance (F = 0.271, num df = 40, denom df = 49, p = 4.6e-05) (see Figure 5.4).

DISCUSSION

Faunal diet reconstruction

Faunal stable isotope results from 18th-19th century sites in Vilnius, Lithuania analyzed in this study indicate that these domestic animals were foddered on C_3 plants (see Figure 5.2). Sheep, horses, cattle, and two of the goats were likely fed exclusively C_3 grasses. Pigs, dogs, and one goat have higher $\delta^{15}N$ values than other domestic animals and overlap with human values. It is likely that scraps of meat from other animals were also dietary staple for these species, especially dogs. It is also possible that these animals subsisted on scraps of vegetables grown in manured soils as manuring has been shown to increase $\delta^{15}N$ values in plants and up the food chain (Bogaard et al., 2013; Bogaard, Heaton, Poulton, & Merbach, 2007; Commisso & Nelson, 2010; Fraser et al., 2011). Manuring of soils to increase crop production was practiced in Eastern Europe and Russia during the 19th century (Bohac, 2014; Molnar, 2003).

Reconstructing individual-level changes in IRA soldier diet

Human femur and rib stable isotope results indicate that Russian soldiers likely consumed primarily C_3 grains and vegetables, meat and other products from terrestrial animals foddered on C_3 grains, and/or freshwater fish, longer term and later in life (see Figure 5.5). Staple C_3 grains and vegetables for the Russian peasantry included rye, barley, buckwheat, and wheat for those who lived in wheat-growing regions, cabbages, onions, beetroot, cucumber, peas, and radishes (R. E. F. Smith & Christian, 1984). Meat, eggs, and milk products were considered luxury items in Russia at this time; peasants typically only consumed these foods on special occasion (R. E. F. Smith & Christian, 1984). Meat was supposed to be a dietary staple for IRA soldiers, but access was often limited when quartered with civilian peasants (Wirtschafter, 1990). Freshwater and anadromous fish such as beluga and common sturgeon, sterlet, zander, trout, common carp, tench, pike, and perch were rarely eaten by peasants, except for those living near rivers (R. E. F. Smith & Christian, 1984). Additionally, although fish were not formally a part of soldier rations, they may still have been consumed regularly when soldiers were quartered with civilians or through soldier supplementation either by purchasing at local markets or fishing when they were located near rivers. There is considerable overlap between freshwater and terrestrial C_3 ecosystems, confounding dietary interpretations. Isotopic evidence does not support that marine fish were consumed regularly either in the longer term or later in life (see Figure 5.5). Historical evidence indicates that while commoners living in cities such as St. Petersburg regularly consumed pickled or salted herring, those living in rural areas rarely had access (R. E. F. Smith & Christian, 1984).

Despite historical evidence of possible marine fish consumption, stable isotope evidence does not support that marine fish were a regular part of soldier diet prior to or during military service.

There were only individual-level diet changes in diet for four out of the 41 soldiers included in this study (see Figure 5.3). RUS-K003 has a $\Delta^{13}C_{\text{rib-femur}}$ value of +0.9. This shift to a higher $\delta^{13}C$ value indicates the possibility of C_4 plant foods in the diet during military service. Sorghum and maize are two C_4 plant foods that were commonly grown in different parts of Russia proper and the Russian empire during this time period (Molnar, 2003). As noted above, maize was sometimes substituted for rye bread for soldiers quartered in some parts of the Russian empire such as Bessarabia in peasant households (Wirtschafter, 1990). RUS-K018 has a $\Delta^{13}C_{\text{rib-femur}}$ of -0.8 and $\Delta^{15}N_{\text{rib-femur}}$ value of +2.0. The shift to a lower $\delta^{13}C$ value and higher $\delta^{15}N$ value may indicate increased input of freshwater fish during military service, which typically exhibit lower $\delta^{13}C$ values and higher $\delta^{15}N$ values than terrestrial fauna although freshwater fish values can vary considerably (Fuller et al., 2012; Guiry, 2019). RUS-K015 and RUS-K043 have $\Delta^{15}N_{\text{rib-femur}}$ values of +1.3 and +1.2. Higher $\delta^{15}N$ values are indicative of greater terrestrial meat protein intake during military service. For some peasants with limited access to meat protein, protein quality and quantity may have improved during military service (Wirtschafter, 1990). It is also possible that that differences in $\delta^{15}N$ values reflect differences in plant growing strategies, where the lower $\delta^{15}N$ values reflect consumption of plants not grown using manure and higher $\delta^{15}N$ values do. The consumption of mushrooms, which are a historically documented food source in Russia (A. K. Smith, 2008), could also explain relatively higher $\delta^{15}N$ values (O'Regan, Lamb, & Wilkinson, 2016).

Reconstructing changes in diet heterogeneity among IRA soldiers

Variance in stable isotope ratios, a proxy for diet heterogeneity among soldiers in the IRA, also did not change significantly later in life (see Figure 5.2). Thus, it appears that soldier rationing and shared lifestyles during military service did not lead to greater diet homogeneity later in life. There are several explanations for why diet did not shift or become more homogenous with service in the Imperial Russian Army. First, a lack of change may be the result of conscription policies that targeted a relatively homogenous group, which is reflected in dietary practices. Conscription practices disproportionately impacted the lower classes from Russia proper, most of whom were Orthodox Christian (Beskrovny, 1996; Keep, 1985). Although specific foods and preparation likely varied within and across different regions of Russia, C_3 grains and vegetables, terrestrial animals, and freshwater fish were commonly consumed by peasants across Russia (Hoch, 1982; R. E. F. Smith & Christian, 1984). Second, 34 of the 41 soldiers included in this study had an age at death of 15-30 years. It is possible that these individuals were new conscripts and did not serve long enough for any diet change to be captured rib collagen stable isotope values (see Figure 5.3). However, only one of the 7 soldiers between 35-50 years showed a shift from femoral to rib values above MMD indicating maintenance in diet with military service was typical. Additionally, three of the four individuals with evidence of diet change were in the 20-25 years at death age range. Thus, it appears that even those were likely conscripted in their last few years of life had the potential to experience diet change that could be detected isotopically. Third, the geographic origin of individual soldiers is currently unknown. Thus, it is possible that most or all of the soldiers excavated from Mindaugo Gatvėje are from the same region and thus considered isotopically indistinguishable diets. Strontium isotope or stable oxygen isotope analysis of tooth enamel could clarify interpretation of pre-military diet by determining geographic origin and is an intended future direction of this research (e.g., Bentley, 2006; Lightfoot & O'Connell, 2016; Mitchell & Millard, 2009).

Russian imperialism and soldier diet

Russia's approach to imperialism differed from other European empires as it established and expanded its empire by conquering neighboring territories, rather than more distant territories (Said, 1994). Thus, while soldiers were typically recruited from the imperial core and served in the periphery of the Russian Empire, the distance between the imperial core and periphery was comparatively short/small. This has two potential implications for the maintenance and homogeneity of diet later in life. First, it is possible that strong imperial control over the daily life of soldiers including over what they ate was maintained as they served within the boundaries of empire. As noted above, the IRA was disproportionally made up of Russian peasants. Access to foods was typically based on what they could purchase if they lived in cities and what they could grow and catch in rural areas, particularly for peasants who had little opportunity to supplement their diets by purchasing food at markets (Hoch, 1982; R. E. F. Smith & Christian, 1984). IRA soldiers, many of whom were garrisoned with peasant families, were limited by the same major barrier to access high protein quality foods: socioeconomic status. Thus, Russia's approach to imperialism and this period of imperial maintenance in the from 1815 to 1850, may have facilitated maintaining imperial oversight of its subjects, both peasant civilians and imperial soldiers.

A second possible explanation for how Russia's approach to overtaking neighbors impacted soldier diet is that the local environments, and thus foods available, were similar at the imperial core and periphery. While Eastern Europe is far from homogenous, local diets among post-Medieval populations across the Russian empire are predominantly C_3 vegetable and grains and terrestrial animal products, with potential freshwater fish consumption (see Figure 5.6). The isotopically homogenous diet among Eastern Europeans including IRA soldiers may simply be that C_3 plants (wild and domesticated) and terrestrial animals dominated the landscape, with those located near rivers having access to freshwater food resources. In this case, the impact of Russian imperialism on the maintenance of longer-term diet was the result of similar environmental conditions in where soldiers were from and where they served. These two explanations, imperial control and environmental similarities, are not mutually exclusive.

While both expansion and maintenance required a large army, this could be achieved by conscripting soldiers from within the empire through the long service requirement (i.e., 20-25 years). Imperial maintenance in particular allowed for the large IRA to be split into smaller units and be stationed with civilians or in barrack for most of the year. Whether through structures of imperial control or local environmental conditions or both, this approach shaped soldier diet during military service, which was detected through maintenance in longer term diet later in life.

Diet comparison with Napoleonic soldiers and British sailors

To examine whether differing strategies to expand and maintain the empires resulted in differences in diet heterogeneity among servicemen, I compared Russian soldier rib $\delta^{13}C$ and $\delta^{15}N$ values with those of NGA soldiers, BRN sailors from Haslar, and BRN sailors from Plymouth (see Figure 5.4). Historical evidence indicates that all three of these military groups were prescribed rations that consisted primarily of C_3 grains in the form of bread, porridge, and alcohol and vegetables and meat from terrestrial animals (Filippini, 1965; Rodger, 1986; Wirtschafter, 1990). There is also evidence that individuals in all three groups supplemented their rations by purchasing, foraging, and/or stealing foods from local populations and markets (Austin, 2000; Beskrovny, 1996; Forrest, 2002; Lavery, 1998). One major difference that exists between the IRA and NGA and BRN is that the former was in a period of imperial maintenance during the period of study, whereas the latter two groups were in periods of imperial expansion through warfare. A second major difference is that while it appears that the BRN required rations to be carried on ships with sailors, NGA and IRA relied much more heavily on purchasing rations from local suppliers and markets (Beskrovny, 1996; Riehn, 1990; Rodger, 1986).

I carried out a diet reconstruction of soldiers that served in Napoleon's Grand Army (NGA) during the Russian Campaign of 1812 and died of hypothermia, starvation, and louse-transmitted diseases in Vilnius, Lithuania during the retreat (see Chapter 3). NGA soldiers came from across Europe including France, Germany, Poland, Lithuania, Italy, Spain, and Portugal (Riehn, 1990; Riley, 2007). They also represent a range of different ranks from conscripts to Imperial Guardsmen to officers, and many individuals likely served in military campaigns across prior to the Russian Campaign of 1812.

Isotope results indicate that Napoleonic soldiers consumed a more heterogeneous diet than Russian soldiers. This is reflected in greater dispersal of $\delta^{15}N$ values among NGA soldiers. Conscription in Napoleon's Grand Army targeted recruits from a variety of socioeconomic statuses (Rothenberg, 1981; Tozzi, 2016), whereas Imperial Russian Army conscription disproportionately affected lower class families (Wirtschafter, 1990). Thus prior to and during military service, higher classes soldiers likely had greater access to meat protein than their lower-class counterparts (Knapp, 1988). Additionally, NGA rations varied by corps and some groups such as Imperial guardsmen had more consistent rations (Rothenberg, 1981), meaning that some groups within the army had greater amounts of meat in their prescribed rations and were much more likely to receive their prescribed rations during periods of supply difficulties, which were frequent throughout the Napoleonic Wars. Thus, there was likely greater variation in access to meat and animal products of NGA soldiers prior to and during military service than IRA soldiers.

Roberts and colleagues (2012) carried out a diet reconstruction of British sailors from two cemeteries associated with British Royal Navy hospitals: Haslar, Gosport and Plymouth. BRN sailors represented both the upper and lower decks, with positions ranging from seaman and marines to cooks and carpenters. British sailors were recruited by conscription or volunteered, with some seamen recruited from ships and ports across the globe (Lambert, 2000, 2004 via Roberts et al., 2012). During the time these cemeteries were in use, the BRN deployed sailors to North America, the Caribbean, India, Australia and New Zealand, and South Africa (Chamberlain, 2000).

Stable isotope results also indicate that there was greater heterogeneity in diet among BRN sailors at Plymouth compared to IRA soldiers, but diet heterogeneity was similar for IRA soldiers and BRN sailors at Haslar. Greater dispersal of $\delta^{13}C$ values may be the result of C_4 plant consumption by some BRN sailors. Roberts and colleagues (2012) suggest that C_4 input may be because those interred at Plymouth sailed to or originated from North America, where corn was a diet staple. Like NGA soldiers, the greater dispersal of BRN sailor $\delta^{15}N$ values at Plymouth compared to IRA soldiers may be related to differential access to meat prior to and during military service.

Isotopic comparisons between IRA soldiers and NGA soldiers and BRN sailors provides valuable insight into how late 18th to early 19th century imperial expansion and maintenance differentially impacted servicemen diets. Although all four groups (Haslar and Plymouth treated separately) were prescribed isotopically similar food rations, Napoleonic soldiers and British sailors at Plymouth also had considerable input from C_4 plant foods and some individuals in the latter group may have consumed marine fish as well. It could be that C_4 plant foods and marine fish were diet staples prior to military service. It could also be that these foods were consumed during military service and reflect variation in food consumed whether as a result of locally purchased food for rations or supplementation of rations by servicemen. While British Royal Navy ships carried barrels of preserved foods and live animals, local foods could be substituted for rations but were tightly controlled by the Victualling Board and would require the captain to purchase foods and be reimbursed (Lavery, 1998; Rodger, 2004 via Roberts et al., 2012). While historical records indicate that servicemen in all three military groups supplemented their rations by purchasing, foraging, or stealing food, Napoleonic soldiers and British sailors (at Plymouth) in this study may have served in regions where more isotopically diverse foods were readily accessible.

Interpretive challenges

While I interpreted $\Delta^{13}C_{\text{rib-femur}}$ and $\Delta^{15}N_{\text{rib-femur}}$ values equal to or past the MMD threshold established by Pestle, Crowley, and Weirauch (2014) as indicative of diet change, there are physiological, environmental, and cultural factors that may account for isotopic differences in rib and femur isotope values of the same individual. First, differences in stable isotope fractionation and uptake caused physiological differences such as disease and stress can cause non-diet related stable isotope variation (see review by Reitsema, 2013). Second, environmental differences such as climate, salinity, aridity can cause variation in both carbon and nitrogen stable isotope values (Szpak, 2014; van Klinken, Richards, & Hedges, 2000). Lastly, cultural practices such as the manuring of arable land can contribute to variation in stable nitrogen isotope values, mimicking meat consumption (Bogaard et al., 2013, 2007). Thus, it is possible that what I interpreted as changes in diet of four individuals in this study, may be the result of changes in an individual's physiological status, differences in environmental conditions prior to and during military service, or differences in land management practices.

CONCLUSION

I examined whether and to what degree the diets of 19th Imperial Russian soldiers changed with military service in the context of imperial maintenance. While the military structures organizing the daily lives of these men changed with military service, there was not a significant shift in the diets of the group or most individuals, nor did diet become more isotopically homogenous later in life. Instead, longer-term diet and later life diet consisted of C_3 grains and vegetables, terrestrial animals, and possibly freshwater fish. Whether through imperial control over their daily lives and access to foods or to similar foods available on the local landscape in the imperial core and periphery, Russia's strategy of conquering neighboring territories and the period of imperial maintenance that followed led to maintenance of IRA soldier diet from longer-term to later life.

Comparison with two contemporary military groups sheds further light on how 19th century European imperial shaped servicemen diet. British sailors from Plymouth and Napoleonic soldiers showed greater diet heterogeneity than IRA soldiers. These differences likely stem from differences in diet prior to and during military service. Because Britain and France were actively expanding their empires through warfare, their servicemen came from a wider variety of geographic origins and socioeconomic backgrounds than soldiers that served in the IRA. Additionally, the former served in campaigns across Europe during the period of study, whereas Russia was focused on imperial maintenance within its borders. Taken together, this research shows that imperial strategies to imperial expansion and maintenance resulted in differing recruiting and provisioning strategies, which had different impacts on the diets of soldiers serving in imperial militaries.

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Table 5.1. Isotopic and bone quality data for faunal remains from 18th-19th century sites in Vilnius, Lithuania.

Sample ID	**Site**	**Time period**	**Species**	**Bone**	**Carbon (%)**	**Nitrogen (%)**	**Atomic C/N**	**Collagen Yield (%)**	**δ^{13}C (‰) VPDB**	**δ^{15}N (‰) AIR**
10	Reformatai square	late 18th-19th c.	Sheep (*Ovis aries)*	cranium	43.5	15.8	3.2	21.2	-22.3	5.6
11	Reformatai square	late 18th-19th c.	Goat (*Capra hircus)*	cranium	43.4	15.6	3.2	12.8	-20.8	6.7
12	Reformatai square	late 18th-19th c.	Goat (*Capra hircus)*	cranium	43.4	15.7	3.2	15.9	-19.9	9.4
13	Reformatai square	late 18th-19th c.	Goat (*Capra hircus)*	cranium	42.2	15.3	3.2	8.8	-21.2	7.4
14	Reformatai square	late 18th-19th c.	Pig (*Sus scrofa domesticus)*	femur	44.3	15.9	3.3	17.1	-21.4	9.4
15	Lower castle territory	19th c.	Pig (*Sus scrofa domesticus)*	humerus	44.4	15.9	3.3	15.6	-21.9	7.7
16	Lower castle territory	19th c.	Pig (*Sus scrofa domesticus)*	cranium	43.9	15.5	3.3	7.9	-21.2	9.9
17	Reformatai square	late 18th-19th c.	Dog (*Canis l. familiaris)*	mandible	43.1	15.4	3.3	13.5	-20.3	10.2
18	Reformatai square	late 18th-19th c.	Dog (*Canis l. familiaris)*	vertebra	43.3	15.7	3.2	17.5	-20.6	10.4
19+	Reformatai square	late 18th-19th c.	Horse (*Equus ferus caballus)*	mandible	44.3	15.9	3.2	19.0	-21.2	7.3
20	Reformatai square	late 18th-19th c.	Horse (*Equus ferus caballus)*	mandible	44.2	15.9	3.2	20.3	-21.6	6.6
21	Reformatai square	late 18th-19th c.	Horse (*Equus ferus caballus)*	mandible	43.0	15.5	3.2	23.7	-21.6	7.0
22	Vilniaus str. 24	19th c.	Cattle (*Bos taurus)*	metacarpus	43.5	15.7	3.2	19.4	-21.8	7.3
23	Vilniaus str. 24	19th c.	Cattle (*Bos taurus)*	radius	44.0	15.7	3.3	6.9	-21.6	7.5
24	Vilniaus str. 24	19th c.	Cattle (*Bos taurus)*	radius	43.5	15.7	3.2	20.4	-21.6	5.8
25	Vilniaus str. 24	19th c.	Sheep (*Ovis aries)*	cranium	42.7	15.2	3.3	17.9	-21.0	7.8
26	Vilniaus str. 24	19th c.	Sheep (*Ovis aries)*	cranium	44.8	15.9	3.3	20.4	-21.3	6.0
27	Vilniaus str. 24	19th c.	Sheep (*Ovis aries)*	cranium	39.7	14.2	3.3	6.0	-21.3	7.4
28	Vilniaus str. 24	19th c.	Pig (*Sus scrofa domesticus)*	tibia	42.5	15.1	3.3	9.1	-21.1	9.4
29+	Vilniaus str. 24	19th c.	Pig (*Sus scrofa domesticus)*	humerus	42.7	15.2	3.3	10.2	-21.1	9.7
30	Vilniaus str. 24	19th c.	Pig (*Sus scrofa domesticus)*	tibia	43.0	15.5	3.2	19.5	-21.5	8.7

+samples run in duplicate

Table 5.2. Demographic, isotopic, and bone quality data for Imperial Russian soldiers from Mindaugo Gatvėje.

			Femur Collagen Data						**Rib Collagen Data**							
Sample ID	**Sex**	**Age (Years)**	**C (%)**	**N (%)**	**C/N**	**Collagen Yield (%)**	**δ^{13}C (‰) VPDB**	**δ^{15}N (‰) AIR**	**C (%)**	**N (%)**	**C/N**	**Collagen Yield (%)**	**δ^{13}C (‰) VPDB**	**δ^{15}N (‰) AIR**	**Δ^{13}C**	**Δ^{15}N**
RUS-K002	M	40-45	43.1	15.6	3.2	13.9	-20.3	10.4	45.7	16.6	3.2	24.1	-20.4	10.6	0.0	0.1
RUS-K003	M	45-50	42.6	15.3	3.2	9.2	-20.1	10.7	42.8	15.4	3.2	11.2	-19.3	11.0	0.9	0.3
RUS-K004a	M	30-35	41.0	14.7	3.2	3.8	-19.6	11.9	43.7	15.8	3.2	22.4	-19.5	11.8	0.1	-0.1
RUS-K004b	M	20-25	43.1	15.6	3.2	14.9	-19.6	11.9	43.4	15.7	3.2	18.8	-20.0	11.5	-0.4	-0.4
RUS-K007	M	20-25	43.7	15.8	3.2	14.0	-20.3	10.8	43.4	15.8	3.2	19.1	-20.3	11.2	0.1	0.5
RUS-K008	M	25-30	42.7	15.4	3.2	12.9	-19.6	12.9	44.5	16.1	3.2	19.1	-19.6	12.9	0.0	0.0
RUS-K009	M	25-30	43.1	15.6	3.2	16.9	-19.7	11.8	47.4	17.3	3.2	22.3	-19.7	11.7	0.0	-0.1
RUS-K010	M	20-25	43.0	15.5	3.2	12.1	-20.5	10.4	46.4	16.8	3.2	23.5	-20.6	10.5	-0.1	0.1
RUS-K012	M	20-25	43.3	15.6	3.2	11.8	-20.7	10.6	42.1	15.1	3.3	9.0	-20.7	11.0	0.0	0.3
RUS-K013+	M	15-17	42.0	15.3	3.2	11.4	-20.6	10.3	44.0	15.9	3.2	15.7	-20.5	10.6	0.1	0.3
RUS-K014	M	20-25	42.9	15.4	3.3	12.6	-20.3	11.7	43.2	15.6	3.2	11.3	-20.2	11.4	0.1	-0.4
RUS-K015	M	20-25	43.3	15.6	3.2	13.6	-19.5	9.6	47.3	17.1	3.2	16.9	-20.0	11.0	-0.5	1.3
RUS-K016	M	20-25	43.4	15.8	3.2	13.1	-19.8	11.5	42.7	15.4	3.2	8.5	-20.3	11.9	-0.5	0.4
RUS-K017	M	16-17	43.4	15.7	3.2	11.9	-20.7	10.3	43.2	15.6	3.2	14.3	-20.7	10.4	0.0	0.1
RUS-K018*	M	20-25	42.9	15.6	3.2	14.5	-19.1	8.5	43.9	15.8	3.2	15.5	-19.9	10.6	-0.8	2.0
RUS-K019	M	18-20	41.4	14.9	3.2	9.1	-21.0	9.2	43.7	15.8	3.2	19.7	-20.8	9.7	0.2	0.6
RUS-K020	M	20-25	43.7	15.8	3.2	14.4	-20.5	10.4	42.8	15.4	3.2	10.6	-20.4	11.1	0.1	0.7
RUS-K021	M	20-25	43.5	15.8	3.2	13.5	-20.5	10.8	43.2	15.5	3.2	13.4	-20.4	11.1	0.1	0.4
RUS-K022	M	25-30	43.7	15.8	3.2	13.2	-20.6	10.5	42.8	15.5	3.2	16.5	-20.6	10.5	0.0	0.1
RUS-K023	M	~20	42.8	15.5	3.2	6.7	-20.5	11.6	42.8	15.5	3.2	15.4	-20.6	11.7	-0.1	0.2
RUS-K024	M	20-25	42.9	15.5	3.2	10.3	-20.6	10.2	43.1	15.6	3.2	16.2	-20.6	10.3	0.0	0.1
RUS-K025+*	M	20-25	43.0	15.5	3.2	13.1	-19.7	10.0	44.2	15.9	3.2	18.1	-19.7	10.8	0.0	0.8
RUS-K026	M	20-25	43.0	15.5	3.2	9.7	-19.8	12.1	46.2	16.6	3.2	8.6	-20.0	12.3	-0.2	0.2
RUS-K027	M	20-25	42.6	15.5	3.2	10.7	-20.7	10.1	42.7	15.4	3.2	19.9	-20.6	10.3	0.0	0.2

RUS-K028	M	~20	42.9	15.5	3.2	17.7	-21.0	10.3	43.1	15.6	3.2	16.3	-21.0	10.5	0.0	0.2
RUS-K029	M	15-17	42.4	15.3	3.2	9.5	-20.2	11.5	47.3	17.2	3.2	18.5	-20.2	11.7	0.0	0.1
RUS-K030	M	18-20	43.0	15.6	3.2	16.3	-20.4	11.1	47.3	17.3	3.2	15.7	-20.3	11.3	0.0	0.2
RUS-K031	M	20-25	42.1	15.1	3.2	9.9	-20.1	11.3	42.7	15.5	3.2	18.3	-20.0	11.3	0.0	0.0
RUS-K032*	M	20-25	43.8	15.9	3.2	13.6	-20.2	11.5	47.0	17.1	3.2	21.0	-20.2	11.3	0.0	-0.2
RUS-K033	M	20-25	44.0	16.0	3.2	19.9	-20.7	10.8	42.5	15.4	3.2	9.4	-20.7	10.9	0.0	0.1
RUS-K034+	M	20-25	44.0	16.0	3.2	19.4	-19.9	12.2	44.1	16.0	3.2	21.1	-20.0	11.6	-0.2	-0.6
RUS-K035	M	20-25	44.2	16.0	3.2	18.2	-19.8	11.6	42.6	15.5	3.2	12.6	-19.8	11.5	0.0	-0.1
RUS-K036	M	35-40	42.8	15.5	3.2	14.5	-19.8	12.4	43.2	15.6	3.2	19.9	-19.7	12.7	0.1	0.3
RUS-K037	M	50-55	43.4	15.7	3.2	17.9	-19.5	11.9	44.4	15.9	3.3	20.6	-19.8	12.1	-0.3	0.1
RUS-K038	M	45-50	43.0	15.6	3.2	16.6	-20.2	11.3	43.2	15.5	3.2	22.4	-20.3	11.3	-0.1	0.0
RUS-K039	M	20-25	42.9	15.6	3.2	18.6	-21.0	9.3	42.3	15.3	3.2	22.1	-21.1	9.4	-0.1	0.1
RUS-K040	M	25-30	43.2	15.7	3.2	10.9	-20.0	11.1	41.6	15.0	3.2	10.3	-20.1	11.3	-0.1	0.2
RUS-K041	M	40-45	44.5	16.2	3.2	21.0	-19.1	10.6	43.2	15.7	3.2	21.4	-19.1	10.8	0.0	0.3
RUS-K042	M	20-25	44.1	16.0	3.2	19.7	-20.2	10.7	46.6	16.9	3.2	22.6	-20.1	10.8	0.1	0.1
RUS-K043*	M	20-25	42.2	15.2	3.2	8.0	-19.5	9.7	44.0	15.9	3.2	14.0	-19.9	10.9	-0.4	1.2
RUS-K044+	M	20-25	42.9	15.6	3.2	16.4	-20.0	11.8	42.5	15.4	3.2	21.8	-20.0	11.7	-0.1	-0.1

+femoral samples run in duplicate, *rib samples run in duplicate

Table 5.3. Percentage of soldiers for each age category showing a change in diet as evidenced by $\Delta^{13}C_{rib\text{-}femur}$ and $\Delta^{15}N_{rib\text{-}femur}$ values.

	Age ranges							
	15-20 years	**20-25 years**	**25-30 years**	**30-35 years**	**35-40 years**	**40-45 year**	**45-50 years**	**50-55 years**
$\Delta^{13}C_{rib\text{-}femur}$	0% (0/7)	4% (1/23)	0% (0/4)	0% (0/1)	0% (0/1)	0% (0/2)	50% (1/2)	0% (0/1)
$\Delta^{15}N_{rib\text{-}femur}$	0% (0/7)	13% (3/23)	0% (0/4)	0% (0/1)	0% (0/1)	0% (0/2)	0% (0/2)	0% (0/1)

Figure 5.1. Map showing location Mindaugo Gatvėje in Vilnius, Lithuania.

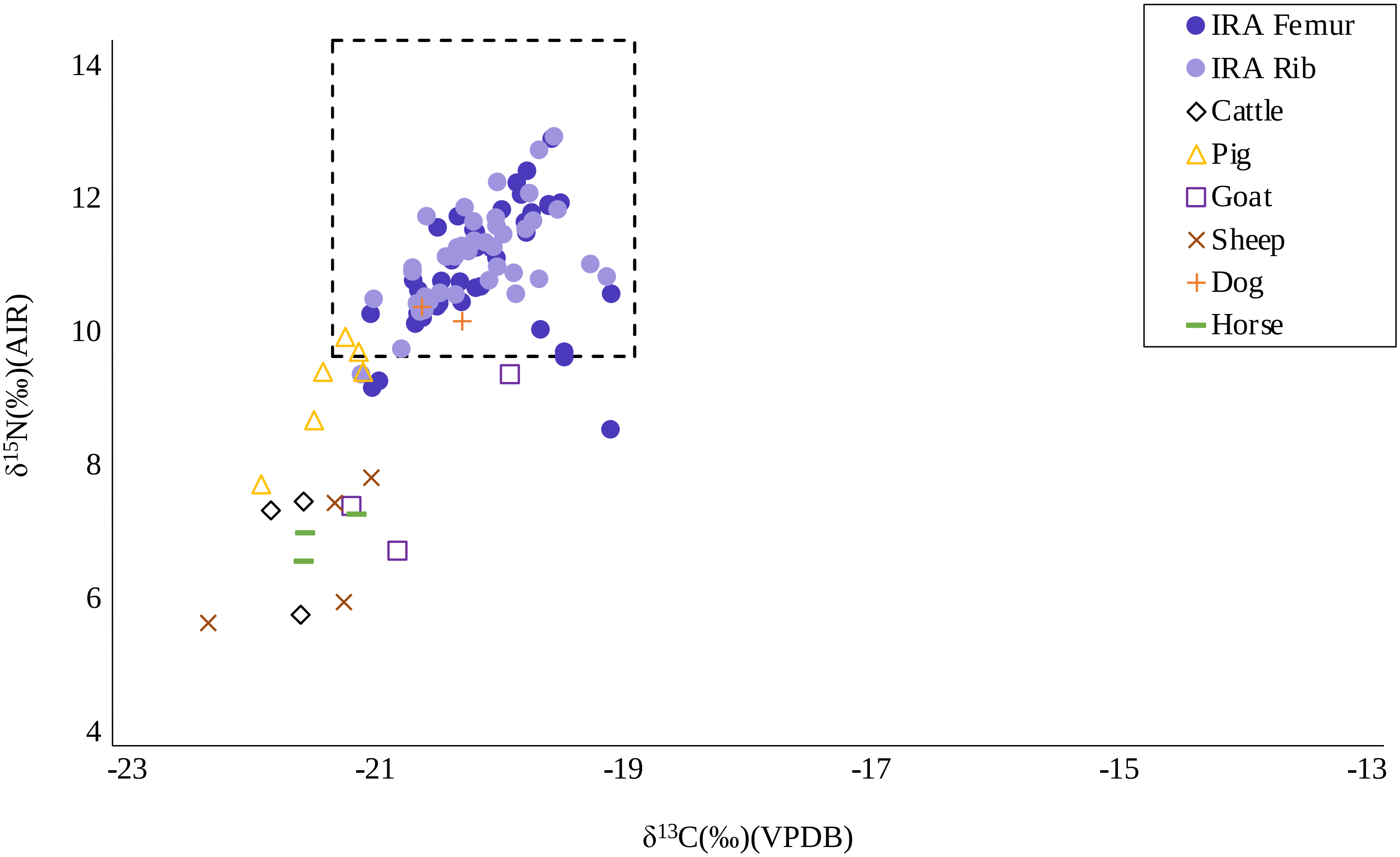

Figure 5.2. Stable carbon and nitrogen isotope data of individual Imperial Russian Army (IRA) soldier rib and femur and terrestrial animal bone collagen samples analyzed in this study. The dashed rectangle indicates the range of δ^{13}C and δ^{15}N values of faunal samples with one trophic-level enrichment (+1‰ for carbon, +4‰ for nitrogen).

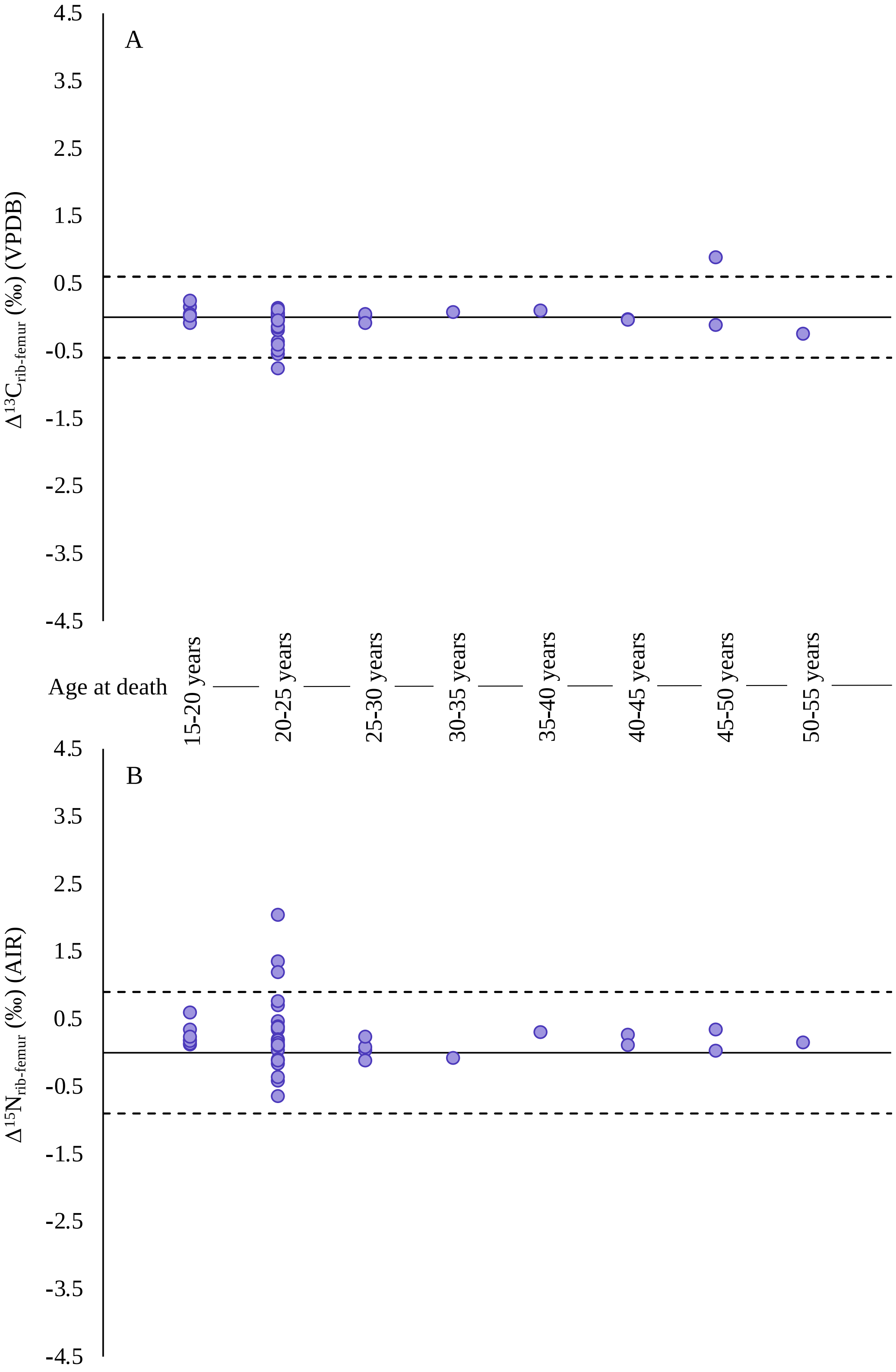

Figure 5.3. Differences in stable carbon (A) and nitrogen (B) isotope values between femur and rib collagen samples for Imperial Russian Army (IRA) soldiers by age. Solid line represents a difference of 0 and dotted lines represent MMD (0.6‰ for carbon and 0.9‰ for nitrogen).

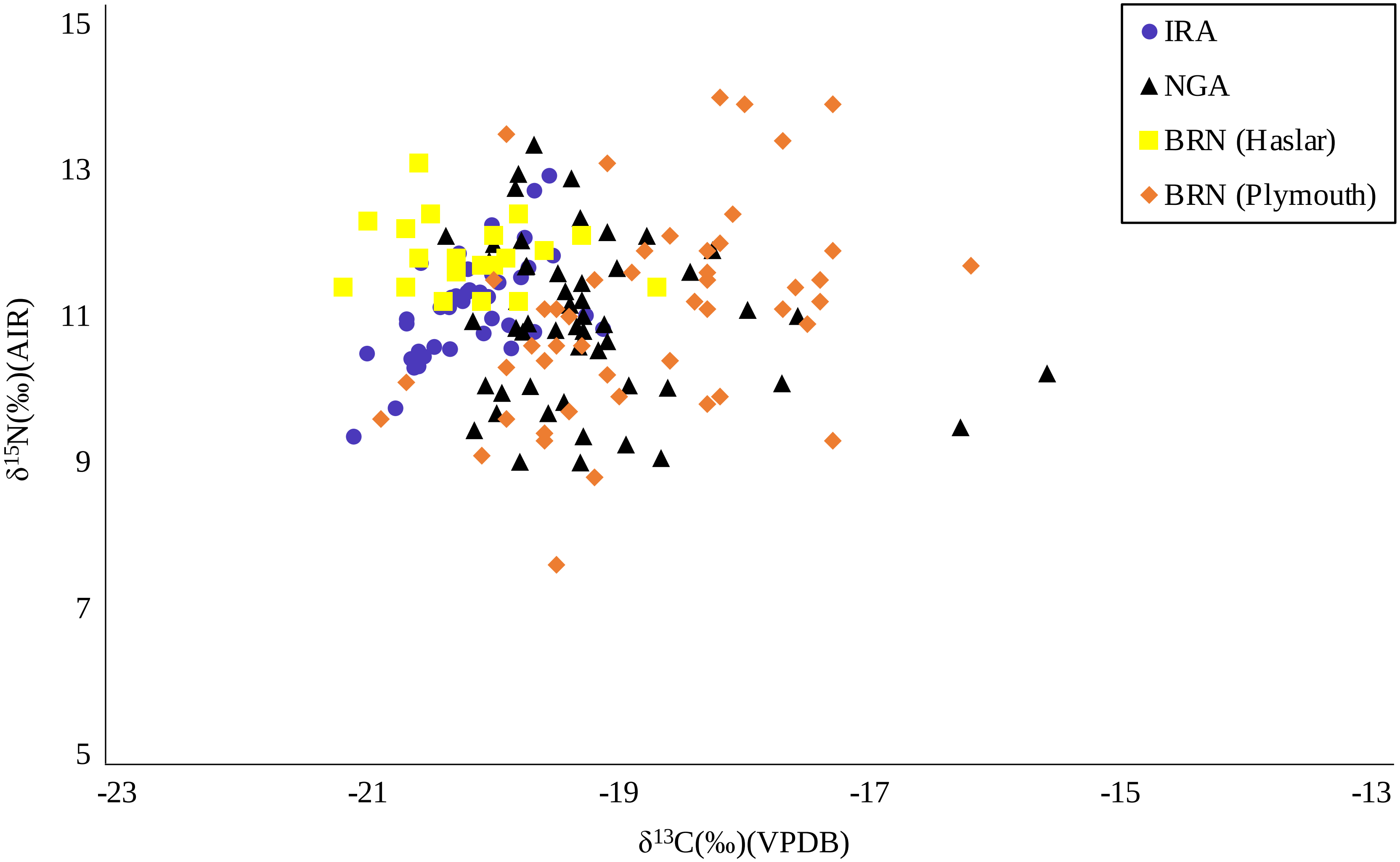

Figure 5.4. Stable carbon and nitrogen isotope data of the rib collagen of Imperial Russian Army (IRA) soldiers, Napoleon's Grand Army (NGA) soldiers (Holder et al. in prep), and British Royal Navy (BRN) sailors at Haslar and Plymouth, UK (Roberts et al., 2012).

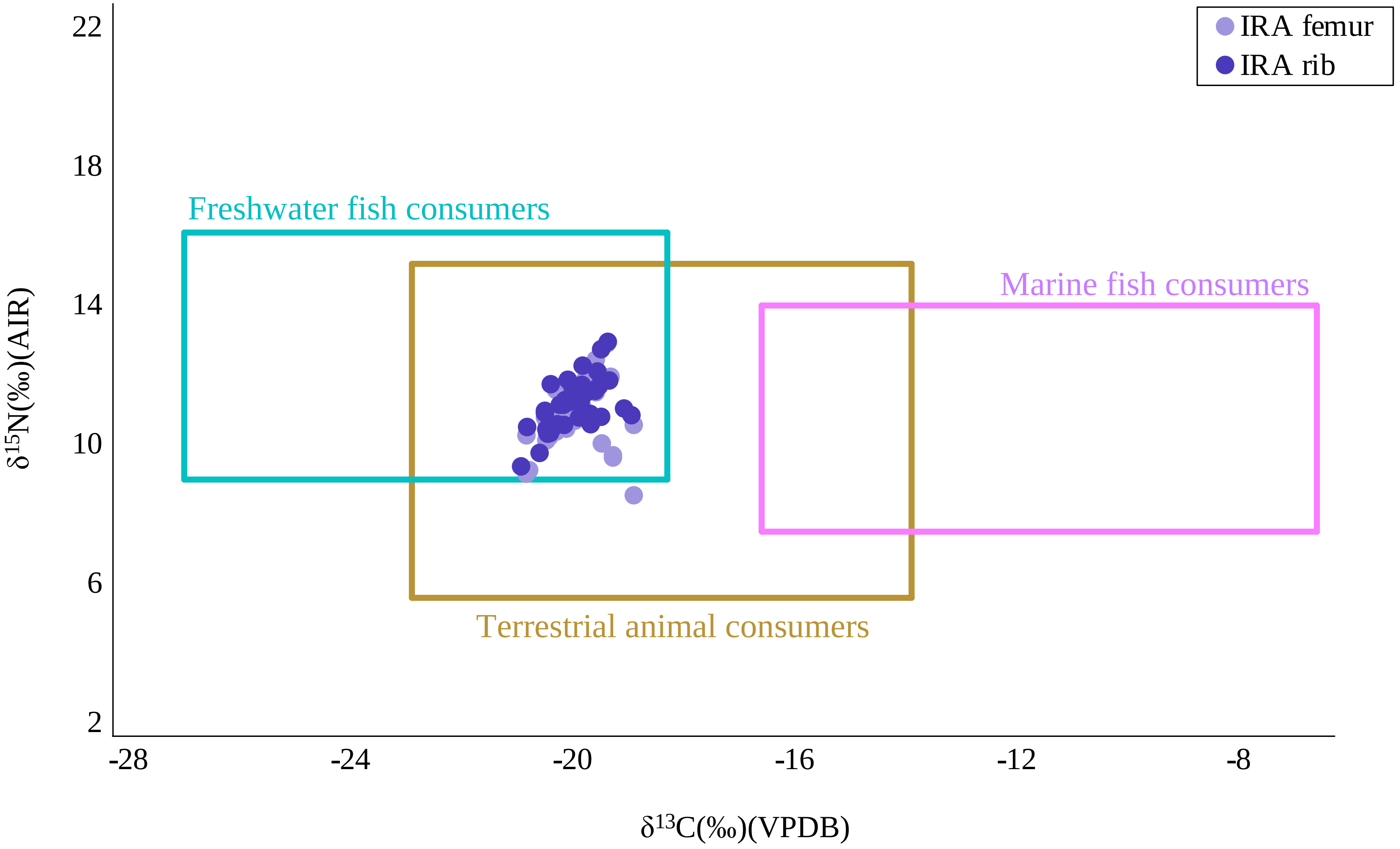

Figure 5.5. Stable carbon and nitrogen isotope data of individual Imperial Russian Army (IRA) soldier rib and femur compared to estimates of terrestrial (tan box), freshwater (light blue box), and marine (light purple box) protein consumers. Consumer estimates are based on the minimum and maximum values from published data of terrestrial animals (this study; Bläuer et al., 2016; Hollund et al., 2020; Hanks et al., 2018; Iacumin et al., 2004; Lahtinen and Salmi, 2019; Meadows et al., 2020; Reitsema et al., 2017; Simčenka et al., 2020; Skipitytė et al., 2020; Tomczyk et al., 2020), freshwater fish (Meadows et al., 2020; Reitsema et al., 2017; Simčenka et al., 2020), and marine fish (Barrett et al., 2011; Robson et al., 2016), plus one trophic-level enrichment (+1‰ for carbon, +4‰ for nitrogen). (Add refs to Mendeley)

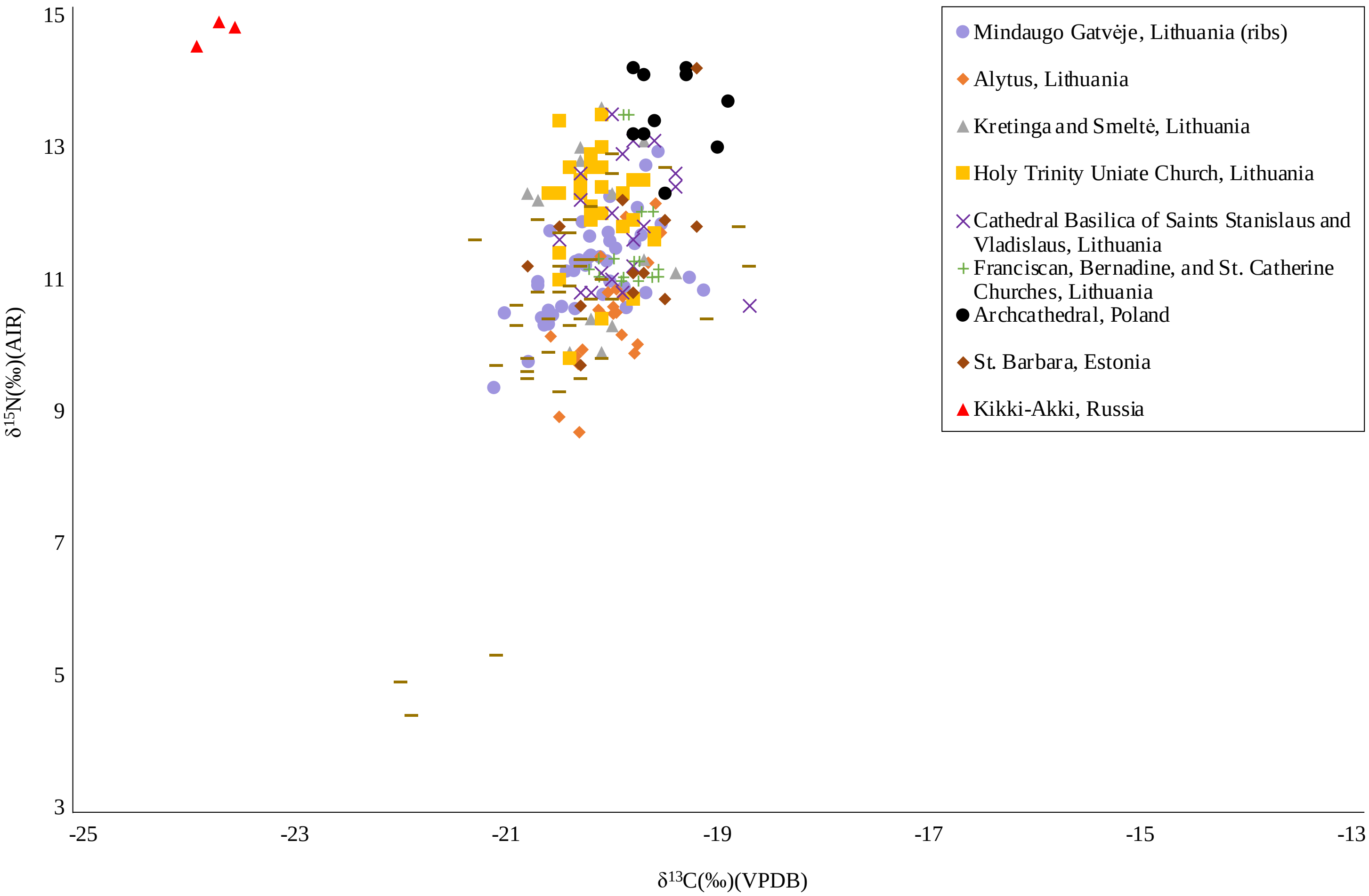

Figure 5.6. Stable carbon and nitrogen isotope data of the rib collagen of Imperial Russian Army soldiers from Mindaugo Gatvėje, Lithuania compared with civilians from the 14th-18th century site of Alytus, Lithuania (Whitmore et al., 2019), 16th-18th century site of Kretinga and Smeltė, Lithuania (Skipitytė et al., 2020), 17th-18th century site of Holy Trinity Uniate Church, Lithuania (Simčenka et al., 2020), 16th-18th century site of Cathedral Basilica of Saints Stanislaus and Vladislaus, Lithuania (Schotten, 2015), 15th-18th century Franciscan Church of Our Lady of the Assumption, Bernadine Church of St. Francis and St. Bernard, and Church of St. Catherine, Lithuania (Reitsema et al., 2015), 15th-18th century Archcathedrals of Przemyśl and Warszawa, Poland (Reitsema et al., 2015), 14th-18th century site of St. Barbara, Estonia, 18th-19th century site of Kikki-Akki, Russia (Poshekhonova et al., 2020), and 16th-19th century sites throughout Yakut, Russia (Romanova et al., 2019).

SUPPLEMENTARY MATERIALS

Appendix A – Instrumentation, Calibration, and Precision for Isotopic Measurements

This Appendix is modeled after the recommendations of Szpak, Metcalfe, and Madonald (2017) in Appendix E for reporting calibration and analytical uncertainty in stable isotope measurements. Only precision is calculated here as the Stable Isotope Ecology Laboratory (SIEL) does not calculate known delta values for check standards, thus accuracy and total analytical uncertainty cannot be estimated.

Carbon and nitrogen isotopic and elemental compositions were determined using elemental analyzers coupled to continuous flow mass spectrometers via open split interface at SIEL at the Center for Applied Isotope Studies at the University of Georgia. Instrumentation for each analytical session is presented in Table S5.1.

Table S5.1. Instrumentation for individual analytical sessions.

Session	Mass spectrometer	Elemental analyzer	Interface
1, 2, 4	Thermo Scientific Delta V Advantage	Thermo Scientific Flash2000	Thermo Conflow IV
3	Thermo Scientific Delta V Advantage	Carlo Erba NA1500	Thermo Finnigan Conflow III

Table S5.2 presents the standard deviations for $\delta^{13}C$ and $\delta^{15}N$ values for the check and calibration standards along with the number of standards included in each analytical session. As NIST1570a (spinach leaves) was used to calibrate stable elemental but not isotopic composition, it was treated as a check standard to calculate internal precision for $\delta^{13}C$ and $\delta^{15}N$ values. Using check and calibration standards, measurement precision (the pooled standard deviation of the check and calibration standards) was ±0.12‰ for $\delta^{13}C$ and ±0.10‰ for $\delta^{15}N$ (df=24).

Table S5.2. Mean and standard deviation of all check and calibration standards for all analytical sessions containing data presented in this paper.

Session ID	Standard	n	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Session 1	NIST1577c	2	± 0.03	± 0.05
Session 2	NIST1577c	5	± 0.01	± 0.07
Session 3	NIST1577c	5	± 0.06	± 0.14
Session 4	NIST1577c	4	± 0.03	± 0.09
Session 1	NIST1570a	2	± 0.17	± 0.07
Session 2	NIST1570a	5	± 0.05	± 0.08
Session 3	NIST1570a	5	± 0.26	± 0.08
Session 4	NIST1570a	4	± 0.09	± 0.13

Ten percent of the samples were analyzed in duplicate (10/103), the results of which are presented in Table S5.3. The measurement precision specific to the samples (the pooled standard deviation of all samples analyzed in duplicate) was ±0.07‰ for $\delta^{13}C$ and ±0.05‰ $\delta^{15}N$ (df=10).

Table S5.3. Stable carbon and nitrogen isotopic compositions for all samples analyzed in duplicate. “A” corresponds to first measurement and “B” corresponds to second measurement.

Sample ID	**Session**	**Element**	**$\delta^{13}C_A$**	**$\delta^{13}C_B$**	**$\delta^{15}N_A$**	**$\delta^{15}N_B$**
RUS-K032	1	Rib	-20.19	-20.24	11.34	11.34
RUS-K018	2	Rib	-19.80	-19.93	10.61	10.53
RUS-K025	2	Rib	-19.66	-19.70	10.80	10.79
RUS-K043	2	Rib	-19.88	-19.89	10.84	10.93
RUS-K013	2	Femur	-20.65	-20.61	10.21	10.29
RUS-K025	3	Femur	-19.65	-19.70	10.11	9.95
RUS-K034	3	Femur	-19.96	-19.77	12.24	12.22
RUS-K044	3	Femur	-20.06	-19.90	11.85	11.82
19	4	Mandible	-21.16	-21.14	7.23	7.29
29P	4	Humerus	-21.08	-21.19	9.69	9.72

Precision ($u(R_w)$) reported in-text was calculated using Equations 2-3 of Appendix F and calculated in Appendix G of Szpak, Metcalfe, and Macdonald (2017).

Appendix B – Supplementary Data

Table S5.4. Isotopic data used to establish faunal isotope baseline in this study.

Sample ID	Species		Ecosystem	$\delta^{13}C$ (‰) VPDB	$\delta^{15}N$ (‰) AIR	Place	Time period	Reference
10	Sheep	*Ovis aries*	Terrestrial	-22.3	5.6	Lithuania	late 18th-19th c.	This study
11	Goat	*Capra hircus*	Terrestrial	-20.8	6.7	Lithuania	late 18th-19th c.	This study
12	Goat	*Capra hircus*	Terrestrial	-19.9	9.4	Lithuania	late 18th-19th c.	This study
13	Goat	*Capra hircus*	Terrestrial	-21.2	7.4	Lithuania	late 18th-19th c.	This study
14	Pig	*Sus scrofa domesticus*	Terrestrial	-21.4	9.4	Lithuania	late 18th-19th c.	This study
15	Pig	*Sus scrofa domesticus*	Terrestrial	-21.9	7.7	Lithuania	19th c.	This study
16	Pig	*Sus scrofa domesticus*	Terrestrial	-21.2	9.9	Lithuania	19th c.	This study
22	Cattle	*Bos taurus*	Terrestrial	-21.8	7.3	Lithuania	19th c.	This study
23	Cattle	*Bos taurus*	Terrestrial	-21.6	7.5	Lithuania	19th c.	This study
24	Cattle	*Bos taurus*	Terrestrial	-21.6	5.8	Lithuania	19th c.	This study
25	Sheep	*Ovis aries*	Terrestrial	-21.0	7.8	Lithuania	19th c.	This study
26	Sheep	*Ovis aries*	Terrestrial	-21.3	6.0	Lithuania	19th c.	This study
27	Sheep	*Ovis aries*	Terrestrial	-21.3	7.4	Lithuania	19th c.	This study
28	Pig	*Sus scrofa domesticus*	Terrestrial	-21.1	9.4	Lithuania	19th c.	This study
29	Pig	*Sus scrofa domesticus*	Terrestrial	-21.1	9.7	Lithuania	19th c.	This study
30	Pig	*Sus scrofa domesticus*	Terrestrial	-21.5	8.7	Lithuania	19th c.	This study
Z 44	Elk		Terrestrial	-21.3	6.3	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 45	Elk		Terrestrial	-21.6	6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 46	Elk		Terrestrial	-21.3	6.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

Z 47	Elk	Terrestrial	-21.6	6.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 48	Elk	Terrestrial	-22	5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 49	Elk	Terrestrial	-21.7	5.5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 50	Elk	Terrestrial	-22	6.7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 51	Elk	Terrestrial	-21.5	5.9	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 52	Elk	Terrestrial	-22	6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 53	Elk	Terrestrial	-22.3	6.9	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Zam-Elk-01	Elk	Terrestrial	-21.6	6.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Zam-Elk-02	Elk	Terrestrial	-21.2	5.5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-1	Elk	Terrestrial	-21.4	4.6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

ZMS-6	Elk		Terrestrial	-21.2	6.3	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-7	Elk		Terrestrial	-21.7	4.3	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-8	Elk		Terrestrial	-21.4	5.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-10	Reindeer	*Rangifer tarandus*	Terrestrial	-19.4	7.5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
1597	Beaver		Terrestrial	-22.1	5.6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
1600	Beaver		Terrestrial	-21.7	6.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
1601	Beaver		Terrestrial	-21.8	7.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
1602	Beaver		Terrestrial	-22.2	5.3	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
568	Beaver		Terrestrial	-22.2	3.7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
577	Beaver		Terrestrial	-22.2	6.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

846	Beaver	Terrestrial	-22.7	4.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
71	Beaver	Terrestrial	-22.2	6.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
74	Beaver	Terrestrial	-22.4	5.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
76	Beaver	Terrestrial	-22.5	4.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 1	Beaver	Terrestrial	-21.8	6.9	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 2	Beaver	Terrestrial	-22.1	4	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 3	Beaver	Terrestrial	-22.8	3.9	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 4	Beaver	Terrestrial	-22.6	6.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 5	Beaver	Terrestrial	-22.5	5.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-2	Beaver	Terrestrial	-22.3	3.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

ZMS-3	Beaver		Terrestrial	-21.3	5.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-4	Beaver		Terrestrial	-22.4	3.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ZMS-5	Beaver		Terrestrial	-21.1	5.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Ayg-2/22/9	Sheep/Goat	*Ovis*	Terrestrial	-16.4	9.5	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg-2/22/16	Sheep	*Ovis aries*	Terrestrial	-17.4	8.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg-2/22/16	Sheep	*Ovis aries*	Terrestrial	-19.0	9.9	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg 2/22/16	Sheep	*Ovis aries*	Terrestrial	-18.6	9.4	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg 2/22/16	Sheep/Goat	*Ovis*	Terrestrial	-18.2	8.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg 2/22/16	Sheep/Goat	*Ovis*	Terrestrial	-15.9	9.5	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg 2/22/16	Sheep/Goat	*Ovis*	Terrestrial	-15.1	9.5	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ayg 2/22/16	Sheep	*Ovis aries*	Terrestrial	-19.1	7.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Gor 2/3/5	Pig	*Sus d.*	Terrestrial	-19.5	5.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Gor 2/3/6	Sheep	*Ovis aries*	Terrestrial	-20.0	5.1	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ino 1/3/8	Sheep	*Ovis aries*	Terrestrial	-19.0	5.5	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
Ino 1/3/26	Sheep/Goat	*Ovis*	Terrestrial	-19.3	5.9	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA1/V/2	Cattle	*Bos*	Terrestrial	-20.6	7.1	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA2/III/11	Sheep/Goat	*Ovis*	Terrestrial	-20.1	7.4	North Caucasus, Russia	Bronze Age	Hollund et al. 2010

VeA3/III/11	Cattle	*Bos*	Terrestrial	-18.6	6.1	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA4/III/11	Cattle	*Bos*	Terrestrial	-19.8	6.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA5/III/11	Cattle	*Bos*	Terrestrial	-19.5	7.3	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA6/III/11	Cattle	*Bos*	Terrestrial	-18.3	8.0	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA7/III/11	Cattle	*Bos*	Terrestrial	-19.9	7.0	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA8/II	Cattle	*Bos*	Terrestrial	-21.1	7.0	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA10/II	Cattle	*Bos*	Terrestrial	-19.1	8.6	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA11/II	Cattle	*Bos*	Terrestrial	-20.0	5.9	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA13/II	Cattle	*Bos*	Terrestrial	-19.2	9.3	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA14/III	Cattle	*Bos*	Terrestrial	-19.8	7.6	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA16/III	Cattle	*Bos*	Terrestrial	-19.2	6.3	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA17/III	Cattle	*Bos*	Terrestrial	-20.2	6.9	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA18/II	Sheep/Goat	*Ovis*	Terrestrial	-19.7	4.6	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA20/II	Cattle	*Bos t.*	Terrestrial	-20.1	7.8	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA22/II	Cattle	*Bos t.*	Terrestrial	-20.3	9.0	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
VeA23/II	Pig	*Sus d.*	Terrestrial	-19.1	9.5	North Caucasus, Russia	Bronze Age	Hollund et al. 2010
9/14	Sheep		Terrestrial	-18.5	8.1	Southern Russia	1800-1700 BP	Iacumin et al. 2004
9/15	Sheep		Terrestrial	-19.9	7.2	Southern Russia	1800-1700 BP	Iacumin et al. 2004
R-9	Sheep		Terrestrial	-18.8	7.7	Southern Russia	2150-2050 BP	Iacumin et al. 2004
R-4	Sheep		Terrestrial	-18.3	9.4	Southern Russia	3450-3250 BP	Iacumin et al. 2004
R-17	Sheep		Terrestrial	-18.3	7.9	Southern Russia	3650 BP	Iacumin et al. 2004
R-18	Sheep		Terrestrial	-17.8	9.6	Southern Russia	3650 BP	Iacumin et al. 2004

R-13	Sheep		Terrestrial	-20.3	7.0	Southern Russia	3750-3650 BP	Iacumin et al. 2004
R-19	Cattle		Terrestrial	-19.2	8.2	Southern Russia	3750-3650 BP	Iacumin et al. 2004
R-11	Cattle		Terrestrial	-19.8	5.6	Southern Russia	3950-3750 BP	Iacumin et al. 2004
8/5	Cattle		Terrestrial	-20.6	4.1	Southern Russia	6000 BP	Iacumin et al. 2004
8/6	Cattle		Terrestrial	-20.7	4.2	Southern Russia	6000 BP	Iacumin et al. 2004
8/7	Deer		Terrestrial	-19.7	5.8	Southern Russia	6000 BP	Iacumin et al. 2004
2/3	Sheep		Terrestrial	-19.4	5.8	Urals	2400-2200 BP	Iacumin et al. 2004
2/2	Sheep		Terrestrial	-16.3	11.2	Urals	2400-2200 BP	Iacumin et al. 2004
KA-5001		*Bos taurus*	Terrestrial	-19.7	6.2	Urals	Bronze Age	Hanks et al. 2018
KA-5002		*Ovis aries*	Terrestrial	-18.2	7.8	Urals	Bronze Age	Hanks et al. 2018
KA-5003		*Bos taurus*	Terrestrial	-18.6	8.7	Urals	Bronze Age	Hanks et al. 2018
KA-5004		*Sus scrofa*	Terrestrial	-21.1	10.1	Urals	Bronze Age	Hanks et al. 2018
KA-5005		*Ovis aries*	Terrestrial	-18.4	9.8	Urals	Bronze Age	Hanks et al. 2018
KA-5007		*Ovis aries*	Terrestrial	-18.5	6.1	Urals	Bronze Age	Hanks et al. 2018
KA-5008		*Bos taurus*	Terrestrial	-19.5	6.5	Urals	Bronze Age	Hanks et al. 2018
KA-5012		*Sus scrofa*	Terrestrial	-20.8	5.8	Urals	Bronze Age	Hanks et al. 2018
BES 3		*Bos taurus*	Terrestrial	-18.5	8.4	Urals	Bronze Age	Hanks et al. 2018
BES 2		*Ovis aries*	Terrestrial	-17.7	7.8	Urals	Bronze Age	Hanks et al. 2018
BKAR 16		*Bos taurus*	Terrestrial	-19	6.9	Urals	Bronze Age	Hanks et al. 2018
BKAR 17		*Ovis aries*	Terrestrial	-18.5	6.4	Urals	Bronze Age	Hanks et al. 2018
BKAR 18		*Sus scrofa (ferus)*	Terrestrial	-21.2	6.4	Urals	Bronze Age	Hanks et al. 2018
CHA 17		*Alces alces*	Terrestrial	-20.4	3.1	Urals	Bronze Age	Hanks et al. 2018
CHA 6		*Alces alces*	Terrestrial	-20.3	2.7	Urals	Bronze Age	Hanks et al. 2018
CHA 10		*Bos taurus*	Terrestrial	-20.1	7.3	Urals	Bronze Age	Hanks et al. 2018
CHA 12		*Bos taurus*	Terrestrial	-19.8	9.2	Urals	Bronze Age	Hanks et al. 2018
CHA 4		*Bos taurus*	Terrestrial	-20.3	4.5	Urals	Bronze Age	Hanks et al. 2018
CHA 43		*Bos taurus*	Terrestrial	-19	7.0	Urals	Bronze Age	Hanks et al. 2018
CHA 5		*Ovis aries*	Terrestrial	-19.4	5.7	Urals	Bronze Age	Hanks et al. 2018
CHA 49		*Sus scrofa*	Terrestrial	-20.1	6.9	Urals	Bronze Age	Hanks et al. 2018

CHA 49		*Sus scrofa*	Terrestrial	-20.1	6.9	Urals	Bronze Age	Hanks et al. 2018
CHA 50		*Sus scrofa*	Terrestrial	-21.5	6.6	Urals	Bronze Age	Hanks et al. 2018
CHA 50		*Sus scrofa*	Terrestrial	-21.5	6.6	Urals	Bronze Age	Hanks et al. 2018
KAM 14		*Bos taurus*	Terrestrial	-18.2	7.1	Urals	Bronze Age	Hanks et al. 2018
KAM 15		*Bos taurus*	Terrestrial	-19	5.5	Urals	Bronze Age	Hanks et al. 2018
KAM 16		*Bos taurus*	Terrestrial	-18.4	9.4	Urals	Bronze Age	Hanks et al. 2018
KAM 17		*Bos taurus*	Terrestrial	-19.1	5.4	Urals	Bronze Age	Hanks et al. 2018
KAM 18		*Bos taurus*	Terrestrial	-18.6	6.1	Urals	Bronze Age	Hanks et al. 2018
KAM 10		ovicaprid	Terrestrial	-17.9	8.1	Urals	Bronze Age	Hanks et al. 2018
KAM 11		ovicaprid	Terrestrial	-17.3	8.8	Urals	Bronze Age	Hanks et al. 2018
KAM 12		ovicaprid	Terrestrial	-18.4	7.1	Urals	Bronze Age	Hanks et al. 2018
KAM 13		ovicaprid	Terrestrial	-18.2	8.4	Urals	Bronze Age	Hanks et al. 2018
KAM 8		ovicaprid	Terrestrial	-19	4.3	Urals	Bronze Age	Hanks et al. 2018
KAM 9		ovicaprid	Terrestrial	-17.1	9.4	Urals	Bronze Age	Hanks et al. 2018
24.1T	Cattle	*Bos taurus*	Terrestrial	-19.1	5.6	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
21.2T	Cattle	*Bos taurus*	Terrestrial	-20.9	6.9	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
7.1T	Cattle	*Bos taurus*	Terrestrial	-21.5	5.1	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
19.1T	Cattle	*Bos taurus*	Terrestrial	-21.9	4.9	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
16.1T	Cattle	*Bos taurus*	Terrestrial	-20.5	5.2	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
4.1T	Brown bear	*Ursus arctos*	Terrestrial	-20.6	6.2	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
1.1T	Brown bear	*Ursus arctos*	Terrestrial	-19.6	7.2	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020

23.1T	Sheep	*Ovis aries*	Terrestrial	-21.1	5	Poland	Early Medieval Period (11th-12th c.)	Tomczyk et al. 2020
9.1T	Pig	*Sus domestica*	Terrestrial	-21.7	6.7	Poland	Late Medieval/early Modern (11th-17th c.)	Tomczyk et al. 2020
12.1T	Pig	*Sus domestica*	Terrestrial	-20.4	8.2	Poland	Late Medieval/early Modern (11th-17th c.)	Tomczyk et al. 2020
20.2T	Pig	*Sus domestica*	Terrestrial	-20.9	8	Poland	Late Medieval/early Modern (11th-17th c.)	Tomczyk et al. 2020
14.1T	Cattle	*Bos taurus*	Terrestrial	-21.9	4.9	Poland	Late Medieval/early Modern (11th-17th c.)	Tomczyk et al. 2020
18.2T	Cattle	*Bos taurus*	Terrestrial	-21.3	8.5	Poland	Modern Period (18th-19th c.)	Tomczyk et al. 2020
13.1T	Goat	*Capra hircus*	Terrestrial	-21.3	7.5	Poland	Modern Period (18th-19th c.)	Tomczyk et al. 2020
ANI 1	Goat	*Capra hircus*	Terrestrial	-21.7	5.9	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 2	Goat	*Capra hircus*	Terrestrial	-21.3	4.5	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 3	Goat	*Capra hircus*	Terrestrial	-22.2	6.0	Lithuania	18th c.	Skipitytė et al. 2020
ANI 4	Sheep	*Ovis aries*	Terrestrial	-22.1	8.2	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 5	Sheep	*Ovis aries*	Terrestrial	-22.2	4.4	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 6	Sheep	*Ovis aries*	Terrestrial	-21.8	7.4	Lithuania	18th c.	Skipitytė et al. 2020
ANI 9	Pig	*Sus scrofa domesticus*	Terrestrial	-22.8	5.8	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 10	Pig	*Sus scrofa domesticus*	Terrestrial	-21.1	9.0	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 11	Pig	*Sus scrofa domesticus*	Terrestrial	-22.0	7.0	Lithuania	18th c.	Skipitytė et al. 2020
ANI 12	Hare	*Lepus timidus/Lepus europaeus*	Terrestrial	-23.9	1.9	Lithuania	18th c.	Skipitytė et al. 2020
ANI 14	Hare	*Lepus timidus/Lepus europaeus*	Terrestrial	-23.5	2.9	Lithuania	18th c.	Skipitytė et al. 2020

ANI 15	Cattle	*Bos taurus*	Terrestrial	-22.4	5.6	Lithuania	16th-17th c.	Skipitytė et al. 2020
ANI 16	Cattle	*Bos taurus*	Terrestrial	-21.9	6.0	Lithuania	18th c.	Skipitytė et al. 2020
ŽPVR 19	Grey partridge	*Perdix perdix*	Terrestrial	-20.8	7.3	Lithuania	15th c.	Simčenka et al. 2020
ŽPVR 20	Grey partridge	*Perdix perdix*	Terrestrial	-21.5	6.5	Lithuania	15th c.	Simčenka et al. 2020
ŽPVR 21	Greylag geese	*Anser anser*	Terrestrial	-22.9	5.0	Lithuania	15th c.	Simčenka et al. 2020
ŽPVR 22	Greylag geese	*Anser anser*	Terrestrial	-23.0	9.4	Lithuania	15th c.	Simčenka et al. 2020
ŽPVR 25	Elk	*Alces alces*	Terrestrial	-22.1	4.3	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 26	Elk	*Alces alces*	Terrestrial	-22.2	2.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 27	Bison	*Bison bonasus bonasus*	Terrestrial	-23.8	3.7	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 28	Wisent	*Bison bonasus bonasus*	Terrestrial	-22.9	5.4	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 31	Cattle	*Bos taurus*	Terrestrial	-21.6	7.3	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 32	Pig	*Sus scrofa domesticus*	Terrestrial	-21.3	8.5	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 33	Sheep	*Ovis aries*	Terrestrial	-22.2	9.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 34	Boar	*Sus scrofa*	Terrestrial	-21.7	5.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 35	Wisent	*Bison bonasus bonasus*	Terrestrial	-24.1	4.5	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 36	Red deer	*Cervus elaphus*	Terrestrial	-22.3	3.6	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 37	Elk	*Alces alces*	Terrestrial	-22.4	3.4	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 38	Chicken	*Gallus gallus domesticus*	Terrestrial	-21.0	8.1	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 47	Cattle	*Bos taurus*	Terrestrial	-22.1	6.6	Lithuania	17th c.	Simčenka et al. 2020
ŽPVR 48	Cattle	*Bos taurus*	Terrestrial	-21.9	7.9	Lithuania	17th c.	Simčenka et al. 2020
Hela-2322	Sheep		Terrestrial	-21.6	3.1	Finland	Post-medieval	Bläuer et al. 2016

Hela-2323	Sheep		Terrestrial	-21.9	5.1	Finland	Medieval	Bläuer et al. 2016
Hela-2352	Sheep		Terrestrial	-21.6	6.6	Finland	Medieval	Bläuer et al. 2016
Hela-2353	Sheep		Terrestrial	-21.6	6.8	Finland	Medieval	Bläuer et al. 2016
Hela-2354	Sheep		Terrestrial	-21.7	5.5	Finland	Medieval	Bläuer et al. 2016
Hela-2355	Sheep		Terrestrial	-21.9	7	Finland	Medieval	Bläuer et al. 2016
Hela-2356	Sheep		Terrestrial	-21.7	5.7	Finland	Medieval	Bläuer et al. 2016
Hela-2552	Sheep/goat		Terrestrial	-21.2	7.5	Finland	Medieval	Bläuer et al. 2016
Hela-2553	Sheep		Terrestrial	-21.8	7	Finland	Medieval	Bläuer et al. 2016
Hela-2584	Sheep		Terrestrial	-21.4	5.8	Finland	Medieval	Bläuer et al. 2016
Hela-2593	Sheep		Terrestrial	-22.1	7.3	Finland	Medieval	Bläuer et al. 2016
Hela-2594	Sheep		Terrestrial	-20.8	5.2	Finland	Post-medieval	Bläuer et al. 2016
Hela-2528	Cattle		Terrestrial	-21.8	4	Finland	Post-medieval	Bläuer et al. 2016
Hela-2549	Cattle		Terrestrial	-21.8	6.1	Finland	Medieval	Bläuer et al. 2016
Hela-2550	Cattle		Terrestrial	-21.7	7.2	Finland	Medieval	Bläuer et al. 2016
Hela-2551	Cattle		Terrestrial	-21.7	4	Finland	Medieval	Bläuer et al. 2016
Hela-2579	Cattle		Terrestrial	-21.6	4.2	Finland	Post-medieval	Bläuer et al. 2016
Hela-2580	Cattle		Terrestrial	-21.8	4.2	Finland	Medieval	Bläuer et al. 2016
Hela-2581	Cattle		Terrestrial	-22	3.3	Finland	Post-medieval	Bläuer et al. 2016
Hela-2583	Cattle		Terrestrial	-21.7	2.9	Finland	Post-medieval	Bläuer et al. 2016
Hela-2585	Cattle		Terrestrial	-22.1	4.6	Finland	Post-medieval	Bläuer et al. 2016
Hela-2590	Cattle		Terrestrial	-22.2	3.2	Finland	Medieval	Bläuer et al. 2016
Hela-2592	Cattle		Terrestrial	-21.6	5.1	Finland	Post-medieval	Bläuer et al. 2016
Hela-2691	Cattle		Terrestrial	-22.5	5.9	Finland	Post-medieval	Bläuer et al. 2016
OKAJA-1-C	Cattle	*Bos taurus*	Terrestrial	-23.1	2.8	Finland	17th-19th c.	Lahtinen and Salmi 2019
OPIK-1-C	Cattle	*Bos taurus*	Terrestrial	-22.3	4.8	Finland	18th-19th c.	Lahtinen and Salmi 2019
OKAJA-2-S		*Ovis aries/Capra hircus*	Terrestrial	-22	5	Finland	17th-19th c.	Lahtinen and Salmi 2019
OPIK-2-S		*Ovis aries/Capra hircus*	Terrestrial	-21.7	7.4	Finland	18th-19th c.	Lahtinen and Salmi 2019

OKAJA-3-P	Pig	*Sus scrofa domesticus*	Terrestrial	-22.3	5.5	Finland	17th-19th c.	Lahtinen and Salmi 2019
OPIK-3-P	Pig	*Sus scrofa domesticus*	Terrestrial	-21.7	9.9	Finland	18th-19th c.	Lahtinen and Salmi 2019
OKAJA-4-H	Hare	*Lepus timidus*	Terrestrial	-22.4	1.6	Finland	17th-19th c.	Lahtinen and Salmi 2019
OPIK-4-H	Hare	*Lepus timidus*	Terrestrial	-22.8	3	Finland	18th-19th c.	Lahtinen and Salmi 2019
OFRA-2-G	black grouse	*Tetrao tetrix*	Terrestrial	-21.6	2.3	Finland	17th-19th c.	Lahtinen and Salmi 2019
OPIK-7-M	The western capercaillie	*Tetrao urogallus*	Terrestrial	-22.4	1.7	Finland	18th-19th c.	Lahtinen and Salmi 2019
OPIK-8-A	Bird	*Anas* sp.	Terrestrial	-23.4	8.2	Finland	18th-19th c.	Lahtinen and Salmi 2019
OFRA-1-D	Reindeer	*Rangifer tarandus*	Terrestrial	-19.6	5.5	Finland	17th-19th c.	Lahtinen and Salmi 2019
ROTI-1458	Reindeer	*Rangifer tarandus*	Terrestrial	-20.1	3.9	Finland	11th-17th c.	Lahtinen and Salmi 2019
TOKE-SY22P	Reindeer	*Rangifer tarandus*	Terrestrial	-19	4.1	Finland	17th-18th c.	Lahtinen and Salmi 2019
TOKE-4023	Reindeer	*Rangifer tarandus*	Terrestrial	-21.2	3	Finland	17th-18th c.	Lahtinen and Salmi 2019
TOKE-SY39	Seal	Phocidae	Terrestrial	-23	11.2	Finland	17th-18th c.	Lahtinen and Salmi 2019
81-05	Elk	*Cervus* sp.	Terrestrial	-22.8	3.8	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
207-98	Hare	*Lepus europeaus*	Terrestrial	-21.7	5.0	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
140-050A	Aurochs	*Bos primigenius*	Terrestrial	-22.2	4.0	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
781-02	Deer	*Cervus* sp.	Terrestrial	-21.5	4.4	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
810-02	Deer	*Cervus* sp.	Terrestrial	-21.8	4.2	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
40-05	Chicken	*Gallus gallus*	Terrestrial	-18.2	9.1	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
639	Chicken	*Gallus gallus*	Terrestrial	-19.0	9.1	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
816-02	Cow	*Bos taurus*	Terrestrial	-20.7	7.8	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017

834-02	Cow	*Bos taurus*	Terrestrial	-21.0	7.9	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
839-02	Cow	*Bos taurus*	Terrestrial	-21.5	7.6	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
200	Cow	*Bos taurus*	Terrestrial	-21.0	6.4	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
810-02	Cow	*Bos taurus*	Terrestrial	-21.3	6.4	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
100	Pig	*Sus scrofa*	Terrestrial	-21.6	7.9	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
119-05	Pig	*Sus scrofa*	Terrestrial	-21.6	5.9	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
816-02	Pig	*Sus scrofa*	Terrestrial	-19.8	6.8	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
841-02	Sheep*	*Ovis* sp.	Terrestrial	-21.5	7.1	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
Min				**-24.1**	**1.6**			
Max				**-15.1**	**11.2**			
Z 31	Cyprinid	Cyprinidae	Freshwater	-24.2	5.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 32	Cyprinid	Cyprinidae	Freshwater	-24.4	5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 33	Cyprinid	Cyprinidae	Freshwater	-24.8	5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 35	Cyprinid	Cyprinidae	Freshwater	-23.7	6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 36	Cyprinid	Cyprinidae	Freshwater	-26.3	6.7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

Z 37	Cyprinid	Cyprinidae	Freshwater	-25.1	5.8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 38	Cyprinid	Cyprinidae	Freshwater	-27	6	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 39	Cyprinid	Cyprinidae	Freshwater	-26.5	8	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 40	Cyprinid	Cyprinidae	Freshwater	-27.3	6.5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 21	Pike	*Esox lucius*	Freshwater	-23	8.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 22	Pike	*Esox lucius*	Freshwater	-21.8	6.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 23	Pike	*Esox lucius*	Freshwater	-20.1	6.1	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 24	Pike	*Esox lucius*	Freshwater	-22.3	7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 25	Pike	*Esox lucius*	Freshwater	-20	6.7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 26	Pike	*Esox lucius*	Freshwater	-20.6	7.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020

Z 28	Pike	*Esox lucius*	Freshwater	-23.3	7.2	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 29	Pike	*Esox lucius*	Freshwater	-20.4	6.7	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
Z 30	Pike	*Esox lucius*	Freshwater	-19.5	6.5	Central Russia	Late Mesolithic-Middle Neolithic (c. 6500-4000 cal BC)	Meadows et al. 2020
ŽPVR 10	Bream	*Abramis brama*	Freshwater	-26.3	7.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 11	Zander	*Sander lucioperca*	Freshwater	-27.5	7.8	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 12	Zander	*Sander lucioperca*	Freshwater	-23.4	11.0	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 13	Pike	*Esox lucius*	Freshwater	-25.0	6.8	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 14	Pike	*Esox lucius*	Freshwater	-25.4	12.1	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 41	Bream	*Abramis brama*	Freshwater	-27.8	8.6	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 42	Zander	*Sander lucioperca*	Freshwater	-27.3	11.9	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 43	Pike	*Esox lucius*	Freshwater	-24.9	9.3	Lithuania	16th-17th c.	Simčenka et al. 2020
ŽPVR 45	Perch	*Perca fluviatilis*	Freshwater	-21.4	7.9	Lithuania	16th c.	Simčenka et al. 2020
ŽPVR 46	Perch	*Perca fluviatilis*	Freshwater	-25.4	12.1	Lithuania	17th c.	Simčenka et al. 2020
75-08	Catfish	*Siluris glanis*	Freshwater	-24.1	11.8	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
547-03	Catfish	*Siluris glanis*	Freshwater	-25.1	12.1	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
114-08A	Catfish	*Siluris glanis*	Freshwater	-21.6	9.2	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
274-03	Carp-bream	*Abramis brama*	Freshwater	-23.0	9.4	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017

64-07	Carp-bream	*Abramis brama*	Freshwater	-27.1	8.6	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
408-03	Tench	*Tinca tinca*	Freshwater	-28.2	8.9	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
71-04	Aspe	*Aspius aspius*	Freshwater	-24.0	6.6	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
161-05	Pike	*Esox lucius*	Freshwater	-23.9	7.3	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
50-98	Pike	*Esox lucius*	Freshwater	-25.6	11.4	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
100-04	Pike	*Esox lucius*	Freshwater	-25.3	8.9	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
630-03	Pike-perch	*Sander lucioperca*	Freshwater	-22.3	10.1	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
4-02	Pike-perch	*Sander lucioperca*	Freshwater	-25.2	12.0	Poland	Medieval period (10th-13th c.)	Reitsema et al. 2017
Min				**-28.2**	**5.0**			
Max				**-19.5**	**12.1**			
1136	cod		Marine	-16	13	Poland	15-16th	Barrett et al. 2011
1139	cod		Marine	-17.8	11.8	Poland	15-16th	Barrett et al. 2011
1142	cod		Marine	-16.6	11.5	Poland	15-16th	Barrett et al. 2011
1145	cod		Marine	-16.9	10.6	Poland	15-16th	Barrett et al. 2011
1152	cod		Marine	-17.7	10.6	Poland	16th	Barrett et al. 2011
AHC3a + b		Gadidae	Marine	-12.7	11.5	Denmark	4300-4100 cal BC	Robson et al. 2016
AHC6a + b		Gadidae	Marine	-14.2	11.6	Denmark	4300-4100 cal BC	Robson et al. 2016
AMC1a + b		*Scomber scombrus*	Marine	-15.8	11.3	Denmark	4300-4100 cal BC	Robson et al. 2016
AHM2a + b		*Scomber scombrus*	Marine	-15.3	11.2	Denmark	4300-4100 cal BC	Robson et al. 2016
AHP2a + b		Pleuronectidae	Marine	-15.5	8.5	Denmark	4300-4100 cal BC	Robson et al. 2016
DS3a +b		*Squalus acanthias*	Marine	-12.7	10.2	Denmark	5000-3500 cal BC	Robson et al. 2016
DS6a +b		*Squalus acanthias*	Marine	-14	11.7	Denmark	5000-3500 cal BC	Robson et al. 2016

DM1a +b	*Scomber scombrus*	Marine	-15.4	12.3	Denmark	5000-3500 cal BC	Robson et al. 2016
DM2a +b	*Scomber scombrus*	Marine	-15.4	9.6	Denmark	5000-3500 cal BC	Robson et al. 2016
DP3a +b	Pleuronectidae	Marine	-11.8	7.1	Denmark	5000-3500 cal BC	Robson et al. 2016
DP5a +b	Pleuronectidae	Marine	-16.6	7.2	Denmark	5000-3500 cal BC	Robson et al. 2016
NSIG3a + b	Gadidae	Marine	-11.4	11.3	Denmark	5400-3950 cal BP	Robson et al. 2016
NSIG5a + b	Gadidae	Marine	-7.8	9.7	Denmark	5400-3950 cal BP	Robson et al. 2016
NSIP4	Pleuronectidae	Marine	-8.1	6.5	Denmark	5400-3950 cal BP	Robson et al. 2016
NSIP5a + b	Pleuronectidae	Marine	-10.4	7.5	Denmark	5400-3950 cal BP	Robson et al. 2016
DC1a +b	Gadidae	Marine	-11.5	10.3	Denmark	5000-3500 cal BC	Robson et al. 2016
DC4a +b	Gadidae	Marine	-11.8	10.2	Denmark	5000-3500 cal BC	Robson et al. 2016
Min			**-17.8**	**6.5**			
Max			**-7.8**	**13**			

CHAPTER 6

CONCLUSION

INTRODUCTION

The purpose of this research was to investigate the invisible ways that early to mid-19th century imperial expansion and maintenance shaped imperial soldier biology through the mechanism of diet. My first goal was to investigate whether individual soldier diet changed with military service. My second goal was to examine whether diet became more homogenous among soldiers with military service through rationing of foods and shared soldier lifestyles. My third goal was to compare diet heterogeneity among three contemporaneous military populations to explore how strategies to imperialism (establishing distant colonies versus overtaking neighbors) and whether an empire was experiencing a period of expansion through warfare differentially shaped soldier diet. This research focused on Napoleon's Grand Army (NGA) soldiers that died during the Russian Campaign of 1812 retreat in Vilnius, Lithuania and were buried in mass grave at the site of Šiaurės miestelis and Imperial Russian Army (IRA) soldiers that died during the 1830-1831 cholera epidemic in Vilnius, Lithuania and were buried at the site of Mindaugo Gatvėje. I also used published data on British Royal Navy (BRN) sailors that died at two BRN hospitals and were buried in associated cemeteries (Haslar, Gosport and Plymouth, both in the UK). I investigated changes in diet and diet heterogeneity using stable carbon and nitrogen isotope ratio analysis of NGA and IRA soldier bulk rib and femur bone collagen and compound specific stable carbon and nitrogen isotope analysis of individual amino acids (AA-CSIA) of the rib collagen of a subset of NGA soldiers. The results show that stable isotope analysis of bulk collagen and AA-CSIA are successful in characterizing diet at various stages in life. Results indicate that a large proportion of NGA soldiers experienced a change in diet with military service, but that longer-term diet heterogeneity among soldiers was maintained during military service. Diet heterogeneity during military service was linked to variability the consumption of terrestrial plants and animals among soldiers and differences in local environmental conditions, not related to consumption of freshwater or marine fish. Results also indicate that very few IRA soldiers experienced a change in diet with military service and that diet was relatively homogenous prior to and during military service. Isotopic comparisons between military groups indicate NGA soldiers and BRN sailors from Plymouth consumed more heterogenous diets during military service than IRA soldiers and BRN sailors at Haslar. *Embodied imperialization of life* links soldier biology to broader systems of imperial power and control, implicating imperial expansion and maintenance strategies in the precarity of soldier life, focusing on foodways. The results of this study indicate that whether imperial servicemen experienced a change diet and whether there was diet heterogeneity among servicemen in early to mid-19th century European militaries is a product of how and where European states were expanding or maintaining their empires, which are reflected in recruiting and provisioning practices.

SUMMARY OF FINDINGS

NGA soldiers experienced changes in diet but no change in diet heterogeneity

I reconstructed the diets of NGA soldiers to investigate whether the prescribing of rations and shared lifestyles during military service resulted in changes in individual soldier diet and homogenizing of diet among soldiers. To do this, I employed stable carbon and nitrogen isotope analysis of bulk rib and femur collagen of 53 soldiers that died during the Russian Campaign retreat of 1812 and were buried in a mass grave at Šiaurės miestelis, Vilnius, Lithuania. Twenty-one of 53 (40%) NGA soldiers had shifts in diet later in life. For those NGA soldiers who consumed C_4 grains such as maize, millet, and sorghum and those who consumed less animal products, there was a shift toward greater consumption of C_3 grains and vegetables such as wheat and rye and animal products. However, consumption of freshwater fish could not be ruled out. Although individuals experienced changes in diet, diet heterogeneity among soldiers was maintained during military service. The maintenance of diet heterogeneity with military service may be due to flexibility in provisioning strategies, differences in rations within the army, and soldier supplementation. NGA conscription and recruiting practices led to a diverse army of soldiers from across Europe and representing an array of socioeconomic backgrounds. These practices are reflected in longer-term diet heterogeneity. While the provisioning of rations led to a shift in diet of some soldiers, flexibility in provisioning strategies and soldiers “living off the land” maintained diet heterogeneity at the group level. Napoleon’s emphasis on a large and efficient army resulted in flexible strategies that served his imperial purposes of a swift overtaking of geographically distant territories. This flexibility is reflected not only in soldier biology through the mechanism of diet but also in the loss of thousands of soldiers’ lives during the devasting retreat of the Russian Campaign of 1812.

NGA soldier diet heterogeneity linked to terrestrial plant and animal consumption

The diverse backgrounds of NGA soldiers, high mobility during military service, and flexibility in provisioning practices makes reconstructing the diets of this heterogenous group a challenge when using traditional methods of stable isotope analysis of bulk tissues such as bone collagen. Here, I used AA-CSIA on a subset of NGA soldier rib collagen (n=20) to address uncertainties regarding the interpretation of diets of NGA soldiers that were unresolved at the bulk collagen level. I ran a principal components analysis (PCA) on NGA soldier $\delta^{13}C_{AA}$ values against data published in Honch, McCullagh, and Hedges (2012) of humans with established diets from to examine whether soldiers may have consumed freshwater, marine, or terrestrial foods. Additionally, I used equations established by Chikaraishi and colleagues (2009; 2010) to the estimate trophic position of NGA soldiers from $\delta^{15}N_{Glx}$ and $\delta^{15}N_{Phe}$ values, and plotted those with published plant values from Styring, Fraser, Bogaard, and Evershed (2014) to examine whether manuring was confounding trophic level interpretations. Results indicate that 19 of 20 soldiers consumed primarily terrestrial diet consisting of C_3 plants and animal protein. One soldier’s diet had a considerable C_4 input. Results also indicate that C_3 consumers were secondary consumers, meaning that their bone collagen amino acids came from animals foddered on C_3 plants, and the singular C_4 consumer was a primary consumer. Manuring does not impact trophic interpretations based on the relationship between $\delta^{15}N_{Glx}$ and $\delta^{15}N_{Phe}$ values, but whether the plants consumed were N_2-fixers, such as legumes, does. This latter finding has implications for estimating trophic position for both bulk and compound-specific methods among populations where the consumption of legumes is high, especially because some legumes are high in dietary protein. Despite the heterogeneity in bulk collagen and compound-specific stable isotope values among NGA soldiers, PCA and trophic estimate results indicate that diets were relatively homogenous in that most soldiers consumed terrestrial animal products foddered on C_3 plants. Thus, heterogeneity detected at the bulk and compound-specific levels may not be the result of consuming different types of plant foods or foods from different ecosystems, but rather isotopic variation among terrestrial C_3 plants at the base of food chain resulting from differences in local environmental conditions. This finding has implications for reconstructing the diets of heterogenous groups using traditional bulk isotope methods, especially in the absence of a site-specific faunal baseline. In these situations, AA-CSIA is a more appropriate, albeit costly method, for accurate diet reconstruction of past populations.

IRA soldiers did not experience changes in diet or change in diet heterogeneity

I reconstructed the diets of IRA soldiers to investigate whether the prescribing of rations and shared lifestyles during military service resulted in changes in individual soldier diet and homogenizing of diet among soldiers. To do this, I employed stable carbon and nitrogen isotope analysis of bulk rib and femur collagen of 41 soldiers that died during the cholera epidemic of 1830-1831 and were buried at Mindaugo Gatvėje, Vilnius, Lithuania. Only four of 41 IRA soldiers experienced changes in diet later in life. Two of the four showed changes in types of plant grains and vegetables consumed and three of the four showed evidence of increased consumption of animal products. Diet was relatively homogenous longer-term and during military service. Whether through the mechanism of strict control or as a result of similarities in foods available in the local environment prior to and during military service, Russia's approach to conquering neighboring territories resulted in the maintenance of longer-term diet with military service.

NGA soldiers and BRN sailors consumed more heterogenous diets than IRA soldiers

Lastly, I compared later life diet heterogeneity among NGA soldiers, IRA soldiers, and BRN sailors to investigate the relationship between strategies to imperial expansion and maintenance, conscription and recruiting practices, and flexibility in provisioning of food rations. For this analysis, I compared stable carbon and nitrogen isotope ratios of bulk rib collagen. Data from BRN sailors comes from two different sites published in (Roberts et al., 2012): Stray Park, Plymouth, UK (n=50) and Haslar, Gosport, UK (n=20). Results indicate that IRA soldiers and BRN sailors at Haslar consumed isotopically homogenous diets, whereas NGA soldiers and BRN sailors at Plymouth consumed isotopically heterogenous diets.

Differences in diet heterogeneity among these three groups (treating Haslar and Plymouth together) can be linked to broader strategies for imperial expansion and maintenance. Whereas Britain and France expanded their empires globally by establishing distant colonies, Russia expanded its empire by conquering territories directly adjacent. Additionally, during the period(s) under study, the BRN and NGA were actively engaged in imperial expansion through warfare, while Russia was experiencing a period of relative peace and focusing on imperial maintenance. Thus, while servicemen in NGA and BRN were serving in campaigns across Europe and beyond (North America in the case of BRN and Egypt in the case of NGA), IRA soldiers served primarily within the Russian Empire in eastern Europe. Additionally, the BRN and NGA were multi-national militaries that represented an array of socioeconomic statues, whereas the IRA was largely made up of peasants from the imperial core of Russia. These conditions impacted what foods soldiers were provisioned and how they were able to supplement rations. Whether through the mechanism of imperial control, local environment, or a holdover of pre-military diet, degree of heterogeneity in the stable isotope ratios of the ribs of these servicemen speak to broader differences in approaches to early 19th European imperialism and its differential impact on soldier biology.

TOWARD AN EMBODIED IMPERIALIZATION OF LIFE

The results of this dissertation speak to an *embodied imperialization of life*, a concept I developed to frame and interpret how imperialism reshaped the biology of soldiers in 19th century France and Russia. The *embodied imperialization of life* begins with the ideologies of imperialism. Imperialism is concerned with the accumulation of lands, labor, and resources, which achieved through the establishment, expansion, and maintenance of empires. A major difference between the French and Russian empires is that France during the period of study was actively expanding its empire on across the continent of Europe through warfare, whereas Russia focused on overtaking neighboring territory and was focused on maintaining its borders during the period of study.

The expansion and maintenance of empires required a large army so the next step in the *embodied imperialization of life* is soldier recruitment. Soldier recruitment took a variety of forms in France and Russia, with conscription being a primary mode. A second major difference between these two empires is that while Russia primarily conscripted young men from with the imperial core, France conscripted young men from across its empire including from annexed and allied territories.

Supporting large armies of literally hundreds of thousands of men required imperial infrastructures that organized the purchasing and distribution of food resources. This is the third step in the *embodied imperialization of life*. The provisioning of rations by both armies differed across contexts (i.e., on campaign versus quartered in barracks or with civilians) and within armies in the same context (i.e., officers versus conscripts). Additionally, NGA and IRA came to rely on soldier living off the land practices that included foraging, stealing, buying, and growing foods. Thus, soldier diet encompassed foods provisioned to soldiers and those acquired through living off the land practices. The differential impact of food provisioning and supplementation practices literally become incorporated into the tissues of soldier bodies, including bone, and can be used to track changes in diet over time.

The results of this dissertation indicate that differences in French and Russian imperialism and recruitment had differential impacts on individual diet change and changes in diet heterogeneity among soldiers. NGA recruited a diverse army of soldiers with varying geographic origins and social backgrounds (including economic status, religion, and ethnicity). This diversity is reflected in longer-term diet heterogeneity discovered in a previous study (Holder, Dupras, Jankauskas, Williams, & Schultz, 2017). Military service re-shaped the diets of many soldiers but maintained diet heterogeneity as most soldiers likely served in numerous campaigns across the European landscape, where foods available for rations and living off the land differed (less because of differences in the consumption of isotopically distinguishable foods and more because of environmentally induced isotope variation). Additionally, differences in how rations were provisioned within the army may have contributed to diet heterogeneity.

On the other hand, the IRA recruited primarily peasants from the Russian imperial core. Few soldiers showed evidence of diet change and diet was isotopically homogenous prior to and during military service. Although IRA provisioning strategies were flexible and rations locally purchased, soldiers primarily served within the borders of the Russian Empire in Eastern Europe. Whether because of similarities in environmental conditions or fewer logistical challenges in feeding soldiers within the empire, serving within the imperial borders shaped the maintenance of diet homogeneity among IRA soldiers. Thus, it is through these mechanisms of imperial accumulation, soldier recruitment and provisioning, and their impacts on soldier biology that I am came to understand 19th century French and Russian soldier experiences as the *embodied imperialization of life*.

CONTRIBUTIONS TO BIOARCHAEOLOGY

This research contributes to bioarchaeological knowledge in three areas: 1) a comparative approach speaks to variation in and patterns across broader social processes, 2) adds to the growing applications of critical social theory in bioarchaeology, and 3) has methodological implications for reconstructing the diets of heterogenous and mobile populations.

First, through a comparative approach, this research goes beyond a bioarchaeological case study and speaks to broader patterns of 19th century European imperialism and its impact on soldier biology. Case studies and regional approaches have been the bread and butter of bioarchaeological research for decades (see for example Stojanowski & Duncan, 2015). These studies are important as they track human behavioral and biological responses to broader social and ecological processes at the local level by investigating changes in population diet, disease, and demography. More recently, bioarchaeologists are making comparisons within and across regions and time-periods to explore variation in these responses within and across communities. The present study explores variation in approaches to imperialism by European states in the 19th century and its differential impact on soldier biology by not only comparing different sites but sites of different military groups in different regions of Europe.

Second, this research contributes to the growing body of bioarchaeological literature that employs critical social theory. The application of theoretical frameworks, particularly critical social theory, are increasingly commonplace in bioarchaeology in recent decades (see C. M. Cheverko et al., 2020). The increasing application of critical social theory in bioarchaeology to studying violence and warfare have moved the field beyond identification of instances of interpersonal violence and warfare to situating these instances within their broader political economic contexts to better understand how violence is used to maintain power and control (e.g., Martin, Harrod, & Pérez, 2012; Tung, 2012). This research draws from critical social theory in science and technology studies (STS) to examine the invisible ways that imperial maintenance and expansion through violence and warfare shaped the biology of imperial soldiers, implicating imperial strategies and practices in the precarity of soldier life.

Third, this research has methodological implications for reconstructing diets of past populations, particularly for heterogenous and mobile groups. Stable carbon and nitrogen isotope analysis of the bulk rib collagen of NGA soldiers revealed wide dispersal of both $\delta^{13}C$ and $\delta^{15}N$ values, which were initially interpreted as differences in types of foods consumed. However, results of PCA run on $\delta^{13}C_{AA}$ values and trophic estimates from $\delta^{15}N_{Glx}$ and $\delta^{15}N_{Phe}$ values revealed that most NGA soldiers consumed the same types of foods (i.e., terrestrial animals foddered on C_3 plants). Thus, dispersal of bulk and amino acid $\delta^{13}C$ values in particular among NGA soldiers was likely caused by something other than diet. I argue that climatic differences may account for these differences. Climatic differences have been shown to account for up to 2 to 4‰ variability in $\delta^{13}C$ values across Europe (van Klinken, van der Plicht, & Hedges, 1994). Therefore, when reconstructing the diets of groups such as soldiers that emanate from and serve in distant regions, environmental factors such as climate must be factored into interpretations. In these instances, AA-CSIA provides an alternative that can overcome such challenges.

CONTRIBUTIONS TO STUDIES OF IMPERIALISM AND MILITARY SCIENCE

This dissertation brings together two bodies of research and contributes to each: imperialism and military science. As discussed in Chapter 2, imperialism is near ubiquitous across time and space in the last 5,000 years of human history. Empires are established and maintained through the acquisition of territory and dominance of people in those territories, which reshapes local economies, cultures, and biologies. Much of the literature on imperialism focuses on those under imperial rule or compares the imperial core versus periphery (Amin, 1977; Said, 1994). This work is important as it demonstrates the harms done by imperialism and counters imperial logics used by dominant groups to justify imperialism and settler colonialism. The present study contributes to this body of knowledge by focusing on a group typically overlooked in studies of imperialism: soldiers. This research provides a more holistic view of imperial strategies and practices, and the differential impact those had on human biology.

Moreover, in this dissertation I developed a theoretical framework that can be applied beyond the diets of 19th century European soldiers. Diet is only one of many mechanisms through which the *embodied imperialization of life* can occur. Imperialism can and does reshape labor practices, exposure to disease, experience of interpersonal and other forms of violence, and growth and development. Each of these can impact the skeletal remains of imperial subjects beyond soldiers. Given the focus on differential valuation and impacts, this framework facilitates a comparative approach to study imperialism. Comparisons could be made within populations such by sex, age, or status. Comparisons could also be made between or across populations such as between the imperial core versus periphery or between sites experiencing different levels of imperial domination (i.e., those under strict control versus those with relative autonomy). It is my hope that bioarchaeologists and researchers interested in imperialism and bodies more broadly take up this framework, re-work it, and apply it in new and exciting beyond what I have theorized here.

The second body of research this dissertation contributes to is military science. Research on the impact of warfare on contemporary soldier bodies has focused on mental health and psychological stress, chemical and biological weapons, infectious disease, and non-battle injuries (Joellenbeck, Russell, & Guze, 1999). Research by medical anthropologists and human biologists have contributed to a greater understanding of the complex impact of violence, including organized warfare, on human lives by integrating human biology and sociocultural context (e.g., Panter-Brick, 2010; Rodney & Mulligan, 2014; Singer & Hodge, 2010). Bioarchaeological studies provide temporal depth to our understanding of warfare's adverse impacts on the health of soldiers and civilians by documenting and interpreting changes in skeletal trauma, pathological conditions, diet, and demography. This study provides insight into the ultimate (i.e., imperialism and warfare) and proximate (i.e., diet) factors that reshaped soldier biology in seemingly mundane, and yet profound ways. Whether studying soldier bodies in the present or the past, this research demonstrates how a critical social theory lens implicates the structural mechanisms responsible for differential experiences and outcomes of soldiers as a results of their military service.

STUDY LIMITATIONS AND FUTURE DIRECTIONS

Several issues present challenges for interpreting stable isotope results from bulk tissues in these samples. First is the nature of the samples. Because of mobility during life and burial context, establishing an appropriate faunal baseline was not possible for any of the three militaries included in this study. Instead, I used a combination of faunal remains from where or near where NGA and IRA soldiers were buried and published data from an array of archaeological contexts encompassing where soldiers came from and where these armies campaigned previously. This created considerable overlap between diet groups and uncertainties when characterizing soldier diet.

Second is the averaging effect of bone as a result of bone remodeling and turnover and uncertainty regarding the time periods captured in femur and rib collagen. Few studies exist that examine how long it takes for different bones to remodel and how different factors such as age, sex, and health status impact these. Most bioarchaeologists that compare different bones (particularly femora and ribs) make one of two claims, myself included (Holder et al., 2020): the ambiguous claim that ribs reflect the last "few" years of life or the unsupported claim that ribs reflect the final 2-5 years of life. We cite a foundational study by Sealy et al. (1995) to support these claims. However, nowhere in the article do the authors claim a specific range of time. While I think the assumption that ribs capture a shorter period of time than femora is correct, a study by Stout and Payne (1994) demonstrates that like femora, they can take a decade plus to completely turnover. More research is needed into turnover times in different skeletal elements and individual factors affecting them.

Lastly is the challenge of isotope equifinality. Isotopic equifinality refers to the problem where multiple dietary, physiological, or environmental factors can result in the same isotopic “signature” in consumer tissues (Reitsema & Holder, 2018), thus confounding interpretation. This challenge is exacerbated by the other limitations discussed above. AA-CSIA can help resolve many of the challenges of isotope equifinality but is an expensive alternative to traditional bulk tissue methods.

Future research will address some of the limitations discussed above. While access to NGA soldier teeth is currently not possible, analysis of IRA soldier teeth is possible. Stable carbon, nitrogen, and oxygen isotope analysis of teeth can be used to reconstruct earlier life diet and geographic origin (Katzenberg, 2008), which will provide greater insight into IRA recruiting practices. Additionally, stable carbon isotope analysis of bone apatite can be used to reconstruct whole diet (Ambrose and Norr, 1993; Tieszen and Fagre, 1993). When combined with statistical modeling (e.g., Froehle et al., 2012), this method can help further discriminate between different diet contributions.

CONCLUDING REMARKS

In this study, I investigated the invisible ways that early to mid-19th century imperial expansion and maintenance shaped imperial soldier biology through the mechanism of diet. I integrated multi-scalar, diachronic, and synchronic approaches by tracking individual-level diet changes among NGA and IRA soldiers, changes in diet heterogeneity in NGA and the IRA, and compared later life diet heterogeneity among NGA soldiers, IRA soldiers, and BRN sailors. Results indicate that several NGA soldiers experienced individual-level diet shifts, but pre-military diet heterogeneity was maintained with military service. Conversely, few IRA soldiers experienced individual level shifts and pre-military diet homogeneity was maintained during military service. Later life diet, likely capturing both pre-military and military diets, varied across military groups. NGA soldiers and BRN sailors from Plymouth consumed more heterogenous diets during military service than IRA soldiers and BRN sailors at Haslar. Individual-level diet shifts or maintenance, maintenance of diet homogeneity or heterogeneity within groups, and comparisons of later life diet homogeneity and heterogeneity across groups are the result of how servicemen were recruited (i.e., who and from where) and where servicemen served. These practices speak to broader strategies of early to mid-19th century European imperial states, both how they expanded and whether they were engaged in imperial expansion or maintenance during the period(s) of study. States actively engaged in imperial expansion through warfare campaigns that took place at a great distance from the imperial core had greater longer-term diet heterogeneity that was maintained later in life and many individuals in their militaries experienced diet shifts, whereas those who were focused on imperial maintenance in regions not far from the imperial core showed evidence of diet homogeneity longer-term and later in life with few individuals experiencing diet shifts. Thus, strategies to imperial expansion and maintenance impacted recruiting and provisioning practices, which differentially impacted soldier biology through the mechanism diet. This study provides insight into how large-scale social processes differentially impact human biology within and across groups.

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