Looking to the North Sea:
Isotopic and osteological evidence for medieval diet, mobility, and health at Stoke Quay, Ipswich

Volume I of II

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To my parents, Dan and Dianne Farber. I am incredibly lucky and thankful to be your daughter.

Hail Bopp!

Abstract

The North Sea trading *emporia* of the early medieval period were instrumental in the redevelopment of overseas exchange networks in post-Roman Britain, southern Scandinavia, and Western Europe. These trade centres catalysed the process of urbanisation that intensified throughout the subsequent centuries, giving rise to the social and economic landscape of pre-modern England and Europe. Studying the *emporia* and their evolution into towns can provide insights into the factors that fuelled urbanisation, and can demonstrate the effect of this phenomenon on human diet, health, and mobility in the medieval period.

This thesis approaches issues of medieval urbanisation and its effects through chemical and osteological analyses of skeletal remains from 363 humans and 99 animals from the recently excavated site of Stoke Quay, Ipswich (late 6th-late 15th centuries AD). Through stable carbon, nitrogen, oxygen, and radiogenic strontium isotope analysis, paired with osteological and palaeopathological observations, this research characterises the degree and timing of urbanisation at Ipswich, and its impact on the population buried at Stoke Quay. Specific research questions address the timing and extent of the 'fish event horizon' in England, the effects of urbanisation on health, and the extent of mobility and treatment of foreigners in medieval English towns.

The paired isotopic and osteological findings challenge the current view that men were the only early consumers of marine fish, but support the hypothesis that intense marine fish consumption was linked to maritime trades. The results indicate that foreigners were subject to higher rates of violence than locals, and that this violence increased over time along with nonspecific stressors and infectious disease. This thesis demonstrates that Ipswich was an exceptional location from the outset, with significantly higher and more widespread consumption of marine resources than contemporary sites across England and around the North Sea, and with a more diverse and dynamic population than was previously imagined.

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Part 1: Introduction and Background

Chapter 1: Introduction to Stoke Quay and its historical context

1.1 Overview

Following a decline in urban centres and international trade in England after the collapse of the Roman Empire, the early medieval period saw a rise in trade networks stretching across the North Sea basin and into northwest Europe, laying the groundwork for the powerful merchant groups of the later medieval period such as the Hanseatic League. The great trading *emporia* of England and northwest Europe played a major role in the development of this economic activity. Studying these *emporia* and their evolution into towns can provide a view of European trade expansion over time, and insights into the exchange of people and ideas over long distances. More specifically, human remains from these sites provide direct evidence of medieval diet and health, while material culture, structures, and waste deposits give indications of trade networks, food sources, and standards of living.

This thesis investigates long-term medieval dietary trends and evidence for mobility at the site of Stoke Quay, Ipswich (Figure 1.1). As one of the primary English *emporia*, Ipswich (or *Gippeswic*) was an important Anglo-Saxon trading location that became one of the earliest urban centres in England and retained a presence in international trade throughout the Middle Ages. The site of Stoke Quay provides much needed evidence for the development of Ipswich from a Mid Saxon *emporium*, or *wic*, to a busy medieval port town. It can also be seen as a microcosm of broader trends central to the development of Britain and the strengthening of trade networks in the North Sea region.



Figure 1.1 The location of Stoke Quay, Ipswich, in Suffolk, England. Due to a Victorian-era canal the site is closer to the River Orwell than it was during the medieval period.

The archaeological evidence from Stoke Quay includes a Mid Saxon burial landscape, Mid and Late Saxon habitation sites, an Ipswich Ware kiln, craftworking remains, imported and locally made pottery, medieval rubbish pits, and a medieval parish cemetery (Brown, in press). It is one of the largest medieval skeletal assemblages yet excavated in England, comprising a total of 1,162 human burials and over 70,000 animal bones. The site represents a near-continuous record of burial practice for nearly 900 years, providing an ideal population through which to study long-term developments in diet, mobility, and standards of living in England.

This thesis uses materials excavated from Stoke Quay to focus on three primary themes: diet and the consumption of marine fish, urbanisation and its effect on health, and the changing demographics and treatment of 'nonlocal' people in the medieval period. These themes are explored through stable carbon and nitrogen isotope analysis and osteological observations on the skeletal remains of 363 humans and 99 animals, spanning the late 6th- late 15th centuries, and $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of 45 humans and 6 pigs from the same group. The samples and results are divided into roughly 200-year periods according to site phasing, and contextualised through comparisons with contemporary sites.

This chapter provides a description of the site of Stoke Quay, followed by a brief introduction to the three central themes explored in this thesis. The research questions and objectives are outlined, as well as the hypotheses that guided the research and the way in which they are tested in this thesis. Finally, the chapter ends with an overview of the thesis structure.

1.2 Stoke Quay site background

1.2.1 Discovery and excavation

The site of Stoke Quay, Ipswich, was excavated in 2012 by Oxford Archaeology and Pre-Construct Archaeology (OA-PCA), in advance of a housing development by ISG plc. on behalf of Genesis Housing Association (Brown, in press). The 1.2 ha site is situated on glaciofluvial sand and gravel drift deposits on the southern edge of the River Orwell (Figure 1.2) (British Geological Survey 1:50,000 series, England and Wales Sheet 207, Ipswich).

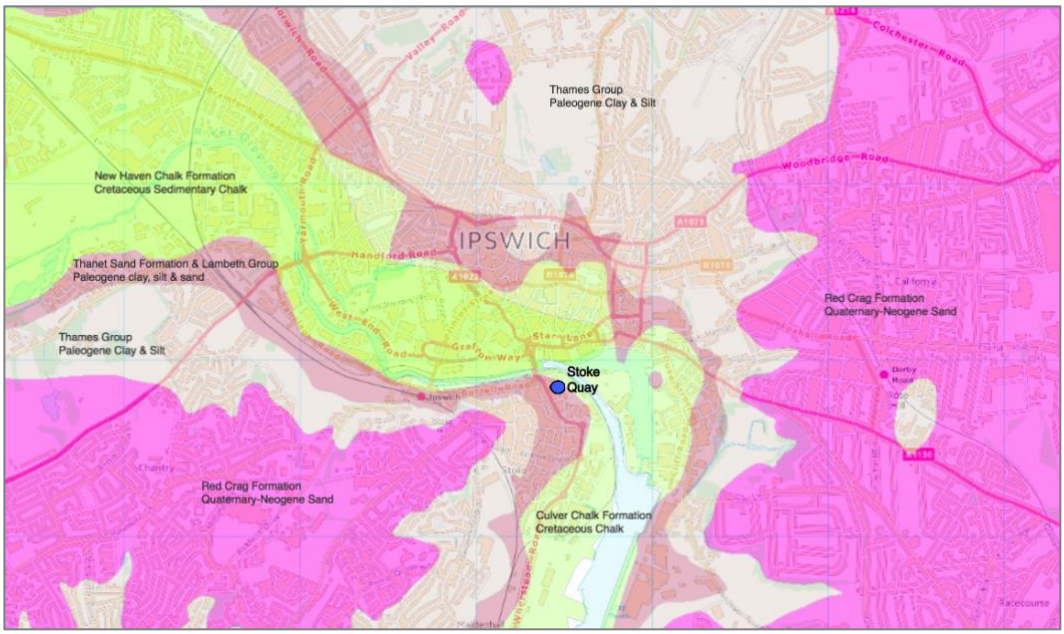


Figure 1.2. Geological map of the Ipswich area, showing Stoke Quay's location on glaciofluvial sand and gravel drift deposits next to Cretaceous chalk (adapted from British Geological Survey 1:50,000 series, England and Wales Sheet 207, Ipswich).

In the past the ground in this area rose by several metres from the river towards the southwest, but it was flattened by the construction of malt houses in the early 20th century. Additional changes occurred in the Victorian period, when canalisation of a portion of the Orwell altered the river's path. The site is now adjacent to the shoreline, but in the medieval period the river would have been located approximately 40m north of the site. Despite its previous distance from the river, Stoke Quay is located in an area historically designated as marshland, so the eastern area of the site would have been seasonally wet (Brown, in press).

The 2012 excavations uncovered a Mid Saxon burial landscape with 20 individuals and up to nine barrows, as well as evidence of habitation and craft sites including building post-holes, a well-preserved Ipswich Ware kiln, boundary ditches, rubbish pits, wells, probable latrines, and thousands of animal remains (Figure 1.3). Perhaps the most surprising discovery was a medieval parish church cemetery containing 1142 discrete burials, which appear to belong to the church of St. Augustine, the location of which was unknown for nearly 500

years before its rediscovery during the excavation (Brown, in press; Breen, in press).

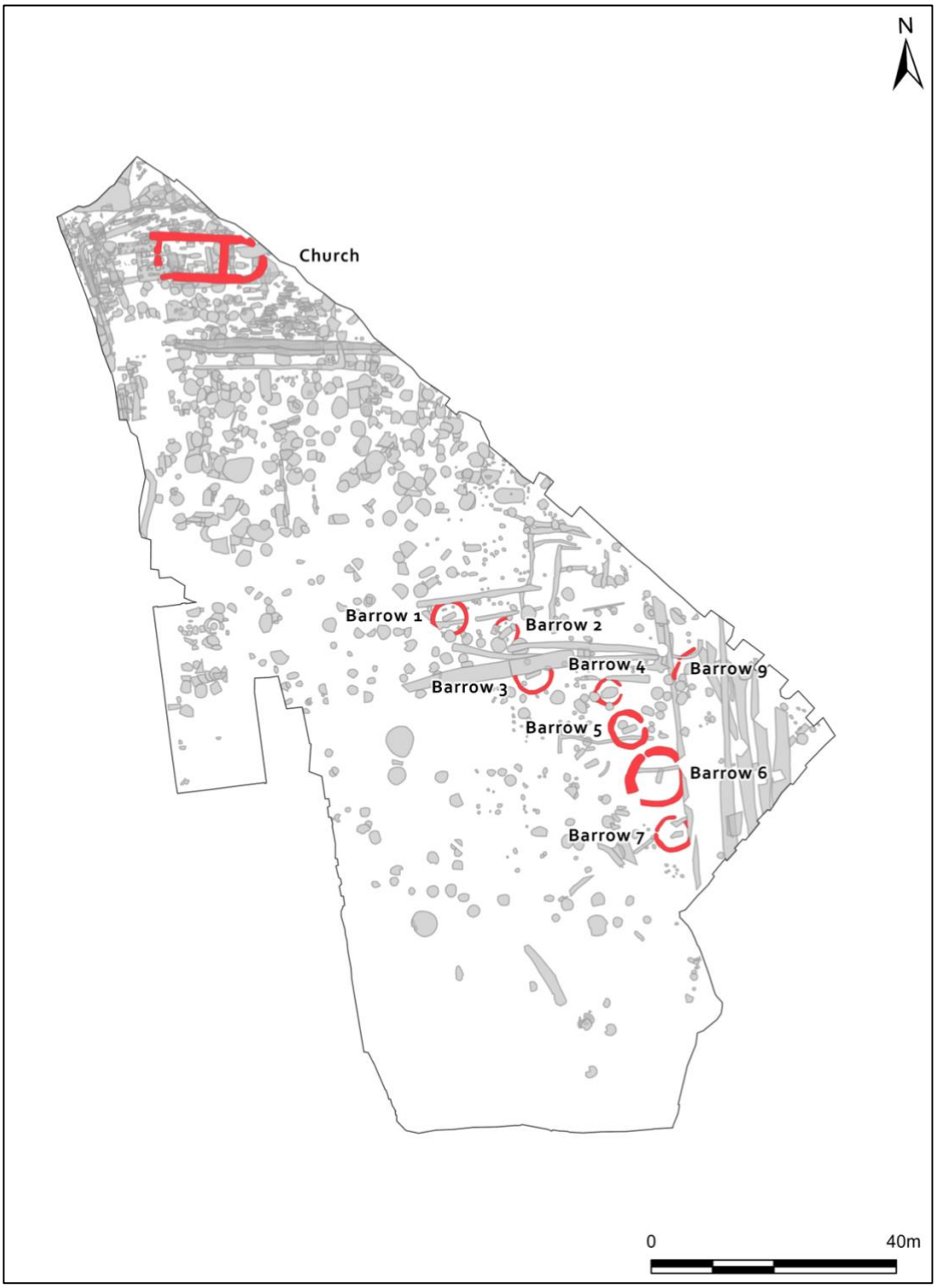


Figure 1.3. Stoke Quay, Ipswich site plan, with major features shown in red. The Late Saxon-Medieval church is located in the northwest corner of the site, and Mid Saxon barrows are located in the southeastern portion of the site.

1.2.2 Site phasing

Contexts were spot-dated on site in order to aid in the selection of environmental sample locations and to establish a working stratigraphic sequence. All contexts were provisionally assigned to a Phase during excavation, then re-evaluated and modified during the post-excavation analysis. Phasing was based on both relative and absolute dating techniques, including spatial and stratigraphic relationships, artefactual dating, radiocarbon dating, and documentary evidence (Brown, in press). The Phases relevant to this thesis are shown in Table 1.1. In the text of this thesis, the phase numbers have been replaced with named time periods for easier reading and to situate the Stoke Quay assemblage within a broader historical context.

Phase		Period Name	Description	Date	Burials
2		(Early) Mid Saxon	Early Middle Saxon burials & settlement	Late 6th – early 8th c.	20
3		(Later) Mid Saxon	Middle Saxon settlement	Early 8th – mid/late 9th c.	0
4	4.1	Late Saxon	Late Saxon settlement	Mid 9th – 10th c.	0
	4.2	Late Saxon	Late Saxon (pre-Church) burials	Late 9th/10th – late 11th c.	316
5		Anglo-Norman	Early Medieval cemetery	Late 11th – late 12th c.	558
6		Medieval	Medieval cemetery	Late 12th – late 15th c.	259

Table 1.1. Stoke Quay site Phases assigned by excavators with the equivalent time periods used in this thesis, and associated descriptions, dates, and numbers of burials (adapted from Brown et al., in press: Tables 1.1, 3.7, 3.10).

To better establish spatial and temporal relationships, all burials were also assigned to Cemetery Groups within each Phase. These groupings were based on stratigraphic relationships, location, burial patterns, and orientation. Nine burials could not be reliably phased, but the other 1153 burials are allocated into 24 Cemetery Groups (Brown, in press). The Cemetery Groups are

listed in Table 1.2, and maps with the Cemetery Group distributions for each period are shown in Chapters 4-7.

Phase	Dating	Cemetery Group	Burials	Location
4.2 (Late Saxon)	Late 9th – 11th c.	CG 1	137	North of later church
		CG 2B	20	Beneath inner footprint of later church
		CG 2C	53	Beneath inner footprint of later church
		CG 5	63	South of later church
		CG 9	5	Cist burials (south of later church)
		CG 9A	7	Subset of CG 9
		CG 10	25	Stone 'pillow' burials (mostly south/west of later church)
		CG 10A	7	Subset of CG 10
5 (Anglo-Norman)	Late 11th – late 12th c. (some burials may date to 13th c.)	CG 3	51	North of church
		CG 6	13	West of church
		CG 7A	84	Just south of church (north of possible path)
		CG 7B	141	South of path and CG 7A (central area)
		CG 7C	100	South of path and CG 7A (western area)
		CG 7D	63	Graves clustered along earliest southern cemetery boundary (southern part of northern side of boundary)
		CG 7E	100	South of path and CG 7A (eastern area)
		CG 8A	5	Graves predating remodelling of chancel
6 (Medieval)	13th – 15th c.	CG 2A	18	Burials within church
	13th – 15th c.	CG 4	156	Main cemetery, mostly to south of church
	mid 13th(?) – 15th c.	CG 8	29	East of church, contemporary with remodelling?
	12th – 14th c. (?)	CG 11	37	Graves later than the first south cemetery ditch
	14th c. (?)	CG 12	9	Graves later than the second south cemetery ditch
	14th – 15th c. (?)	CG 13	10	Graves later than the third (latest) south cemetery ditch
4-6	No specific date	No group	9	Unallocated burials

Table 1.2. Cemetery Group names and descriptions by site Phase (adapted from Brown, in press: Tables 3.7, 3.9).

Radiocarbon dating was conducted on 19 skeletons, distributed broadly across the site. Selection for dating was largely based on osteological factors and funerary practices such as unusual pathologies, trauma, burial type, and the presence of certain grave goods, though several skeletons were included to develop a relative chronology for the Cemetery Groups (Brown, in press). The radiocarbon dates were instrumental in developing the phasing for the site, but these direct dates only represent 1.6% of the total number of burials. The density of burials and intercutting of graves at this site further complicate the dating (Brown 2017).

Though care was taken to be as accurate as possible in assigning dates to phases, it is also important to note that any periods assigned by modern archaeologists and historians create an oversimplification of burial chronology. Burial at Stoke Quay would have proceeded according to the waxing and waning of settlement numbers, not adhering strictly to the time periods imposed by modern archaeologists and historians. Keeping these factors in mind, any conclusions based on temporal relationships between the burials must be taken with a degree of caution.

1.2.3 Skeletal recording and demographics

Following recovery, the human skeletal remains were cleaned and placed in individual acid-free cardboard boxes, then assessed by osteologists at Oxford Archaeology. To properly catalogue the large number of skeletons, Oxford Archaeology developed a database containing all pertinent osteological and contextual evidence for each burial (Loe et al., in press). The author was granted access to the database to select samples for isotopic analysis and to gather

osteological data for each sampled skeleton (see Chapter 2, Section 2.2.2). Total estimated age and sex distributions for the cemetery are shown in Table 1.3.

Phase	Age/sex	Total no. Individuals
Phase 2 (Mid Saxon)	Male	5
	Female	6
	Unsexed	7
	Adult Total	**18**
	Juvenile Total	**2**
	Total	**20**
Phase 4 (Late Saxon)	Male	74
	Female	81
	Unsexed	18
	Adult Total	173
	Juvenile Total	143
	Total	**316**
Phase 5 (Anglo-Norman)	Male	124
	Female	123
	Unsexed	57
	Adult Total	304
	Juvenile Total	254
	Total	**558**
Phase 6 (Medieval)	Male	85
	Female	91
	Unsexed	9
	Adult Total	185
	Juvenile Total	74
	Total	**259**
Unphased	Male	0
	Female	6
	Unsexed	1
	Adult Total	7
	Juvenile Total	2
	Total	**9**
Totals	Male	283
	Female	301
	Adult	**669**
	Juvenile	**473**
	Combined Total	**1142**

Table 1.3. Overall estimated age and sex for the Stoke Quay cemetery skeletal assemblage. Adapted from Gibson et al. (in press), Tables A5.4 and A5.50.

1.2.3 Site history and use

The excavations at Stoke Quay revealed little evidence of human occupation prior to the Mid Saxon period, aside from a small number of

redeposited Roman finds and late Palaeolithic worked flint blades that may have eroded from the riverbank. In the early Mid Saxon period (c. late 6th to mid 7th centuries), the southeastern portion of the site was used as a barrow cemetery, with at least seven but possibly nine barrows, along with two clusters of inhumations that may extend in date to the early 8th century, and several isolated burials. Preservation was generally poor for the Mid Saxon skeletons due to their location on an area of the site subject to seasonal wetting and drying (Brown, in press; Teague, in press).

A settlement arose on the site in the later Mid Saxon period (late 7th or early 8th centuries), as evidenced by post-holes, ditches, and a large number of pits, cesspits, and wells that were mainly focused in the southern area of the site. There is some evidence for property boundaries in the form of fence lines represented by linear arrangements of postholes. Contemporaneously, an Ipswich Ware kiln was constructed in an area possibly sheltered by remnants of the earlier barrows. This kiln is the first evidence for the Ipswich Ware pottery industry south of the River Orwell in Ipswich (Sudds, in press). This period also produced the first evidence for a road along the western edge of the site that was later known as *Losegateweye*, the predecessor of the modern Great Whip Street (Teague, in press).

In the Late Saxon period (mid/late 9th- late 11th centuries), activity at the site primarily shifted to the northern area, though settlement continued on a reduced scale in the southern area. Several buildings from this period have been identified in the northern area, including sunken-featured buildings that appear to pre-date the cemetery of St. Augustine. The presence of an enclosed cemetery with 316 burials is evident from the late 9th/early 10th centuries and clearly pre-

dates the construction of the later stone church. A timber structure or cross may have been present at the site before the stone church was constructed, but no evidence for this was found during the excavation (Teague, in press).

The Late Saxon cemetery included a number of different burial types, including stone-lined graves and burials with head supports, or 'ear muffs' (see Chapter 5 for further information on this practice). Evidence for wooden coffins was found in 75 burials, of which four included clench bolts, which are used in the construction of clinker-built boats and have links to Scandinavian shipbuilding traditions (Brookes 2007). One burial also included an iron sintel, associated with Frisian boat building (Teague, in press; Gaimster, in press).

Sometime in the mid to late 11th century a stone church was built in the pre-existing cemetery, overlaying some of the earlier burials. The precise construction date is unknown, but the stone structure or an earlier timber structure was in place by 1086 when the parish church was recorded in Domesday Book. The foundations of the stone church were almost completely robbed at some point after use of the church ceased, but the footprint of the robber trenches shows that the structure was two-celled and on an east-west alignment. After the church was constructed, activity was focused on the northern area of the site, though some continued use of the southern area is evident from pits and a possible stock enclosure, suggesting that this area may have been used for pasture (Teague, in press).

The Anglo-Norman assemblage (late 11th to late 12th centuries) is comprised of 558 individuals, of which 117 were buried in coffins and 13 of these included clench bolts. The Medieval cemetery (13th-late 15th centuries) included 259 burials, which were laid out in a more orderly fashion than the

burials in the preceding periods. In the Medieval assemblage, 18 individuals were buried within the church and only 73 individuals were buried in coffins, with 7 including clench bolts (Teague, in press).

During the Medieval period the chancel of the church was rebuilt and altered from apsidal to square-shaped. There is also evidence for an addition to the nave, and for a rectangular stone structure to the immediate west of the church, tentatively identified as a priest's house. The church of St. Augustine went out of use sometime after 1482, which is the last recorded date of its use. The area appears to have been given over to pasture until the 17th century, when the northern part of the site was used for various industrial activities including a cooperage, a shipyard, and a malthouse (Teague, in press; Breen, in press).

St. Augustine's was not amongst the poorest parishes listed in the 1227 Ipswich tallage roll, but by 1254 the fortunes of the parish appear to have declined. Many of the wealthier parish churches in Ipswich were remodelled several times through donations from wealthy parishioners, while St. Augustine's seems to have only undergone one phase of renovations. In the later medieval period, wills and charters indicate that several wealthy Ipswich residents owned land in St. Augustine's parish, but they all appear to have rented out their tenements in the parish while they themselves lived in wealthier areas. This evidence suggests that the population buried at St. Augustine's cemetery were generally of low to middling socioeconomic status, and the burials likely represent an average parish population from this port town (Loe et al., in press; Brown et al., in press).

The long duration of Stoke Quay's use as a settlement and burial site, and the likely average to low socioeconomic status of its burial population, makes it a

prime case study to investigate questions of urbanisation and its effect on health and quality of life at the developing medieval town of Ipswich. These questions and the overarching themes of this thesis are explored in the following sections.

1.3 Central themes

The research questions addressed in this thesis are drawn from an interest in the overarching themes of diet and the transition to increased marine fish consumption, the impact of medieval urbanisation on health, and changes in mobility and the treatment of 'foreigners' over time. This section introduces each of these three themes, laying the foundation for the research questions and hypotheses described in section 1.4.

1.3.1 Medieval diet and the exploitation of marine fish

The 'fish event horizon'

In Roman Britain, fish in preserved form such as *garum* sauce comprised a standard component of diet for many people, but fish may have had greater impact on elite diets (Locker 2010; Richards et al. 1998). After the retreat of Roman forces from Britain, the early medieval period saw a return to predominantly terrestrial food consumption dominated by cereals and the three major domesticate species of cattle, sheep/goats, and pigs (O'Connor 2012; Crabtree 1996; Hamerow 2007). There is relatively scarce evidence for fish consumption in the Early and early Mid Saxon periods, but analyses of those fish bone assemblages that have been excavated from slightly later English sites (7th to 10th centuries) show that they are largely comprised of migratory and freshwater species (Barrett et al. 2004a,b; Ortner et al. 2016).

The most important of the migratory species was eel (*Anguilla anguilla*), a catadromous fish that predominantly lives in fresh or brackish water but spawns in the ocean (Robson et al. 2012; Wheeler & Jones 2009). Eel and freshwater species, especially those of the cyprinid family (carp, minnows), were caught in fish traps and weirs in rivers and estuaries. Minor quantities of inshore marine fish as well as herring are also evident in the fish bone evidence, but these do not appear to have been important food sources at this early date (Serjeantson & Woolgar 2006).

Though individual researchers had independently noted an increase in fish bone remains around the 10th and 11th centuries, James Barrett and colleagues were the first to compile and summarise the evidence in a convincing argument for a shift in dietary resource procurement around the turn of the millennium. In their seminal *Antiquity* paper, they compared fish bone assemblages at 127 English sites, and demonstrated a dramatic change from predominantly riverine species before 1000 AD, to increasing numbers of marine species such as herring and cod after the turn of the millennium, which they termed the 'fish event horizon' (Barrett et al. 2004a).

Subsequent studies have further explored this phenomenon through a number of different methods, including isotope analyses of archaeological cod and herring (Barrett et al. 2008; Orton et al. 2011), detailed zooarchaeological analyses of fish bone assemblages from sites such as York and London (Orton et al. 2014; Orton et al. 2016), and explorations of the documentary evidence for this shift in England and elsewhere (Kowaleski 2003, 2016; Holm 2016). These studies have further bolstered Barrett and colleagues' initial observations

regarding the rapid shift to dominance of herring and cod in the period after 1000 AD, with a concomitant decline in eel (Barrett 2018).

There are a number of proposed explanations for the shift in patterns of fish consumption around the 11th century, including technological, ecological, and cultural changes (Barrett et al. 2004a). However, the most convincing argument put forth for the rapid shift to marine fish consumption is that the growing urban populations of England and Europe created increased demand for this commodity (Barrett et al. 2004a; Van Neer & Ervynck 2003; Kowaleski 2016). This argument is supported by the presence of herring and cod in almost exclusively urban settings prior to the 11th century, making their first appearance in *wics* and coastal towns before later spreading to rural and inland areas (Barrett et al. 2004a).

Another contributor to this shift may have been technological. Advances in shipbuilding technologies had made it possible to sail to deeper waters than had previously been possible, and larger ship sizes increased the cargo capacity from *c*. 20 tonnes in 1000 to up to 60 tonnes in 1025 (Crumlin-Pedersen 1999; Barrett 2004a). The carrying capacity of ships continued to increase over the course of the medieval period, with important implications for the ability to sail long distances and trade large quantities of goods (Greenhill 1988).

The growing trade in fish required the use of numerous preservation methods, especially drying and salting, because fish spoils very quickly after it is caught. These preservation methods work best on low fat fish varieties such as gadids (fish of the cod family including haddock and whiting), which can be air-dried without salt at high latitudes with low temperatures. Dried, unsalted gadids were sold as 'stockfish' during the medieval period, and were a particular

specialty of northern areas such as Norway. In lower latitudes including England, cod and other gadids were often salted and air-dried. Herring is more fatty than cod, and requires smoking, salting, or pickling for longer-term preservation. Pickling wasn't developed as a herring cure until the 12th-13th centuries, and prior to this, all herring cures involved salt (Barrett 2016; Kowaleski 2003).

The availability of salt proved instrumental to the development of the successful herring fisheries in medieval England. In the cool and damp British climate, salt was produced by heating salt pans to high temperatures, requiring large amounts of fuel. The peat-rich Norfolk Broads were located in close proximity to the salt pans in coastal Norfolk and Suffolk, and the migratory route of North Sea herring passed by these areas in the early autumn (Kowaleski 2016; Campbell 2002). The timing of major medieval fairs also coincided with the herring migratory route, beginning with the first appearance of the herring shoals off the coast of northern England and continuing southward until mid November, with the Great Yarmouth fair coinciding with the shoals' arrival off the coast of Norfolk and Suffolk (Kowaleski 2008).

Zooarchaeological evidence for fish consumption at Stoke Quay

The 'fish event horizon' is of primary importance to the research undertaken in this thesis, as the Stoke Quay skeletal assemblage spans the period before, during, and after this major shift in the exploitation of marine fish. With its location on the Orwell estuary and proximity to the productive herring fisheries off the Norfolk and Suffolk coasts, as well as its close association with overseas trade, Ipswich would be a likely location for the early exploitation of

marine fish. In St. Augustine's parish, historical records from the later medieval period attest to mariners living in the area at that time (Breen, in press).

The zooarchaeological evidence from Stoke Quay supports the consumption of fish in St. Augustine's parish, with over 11,000 fish bones excavated from pits and other features. The fish bone evidence also indicates that fish were being consumed at Stoke Quay from the later Mid Saxon period, with over 6,000 of the total fish bone assemblage coming from the Mid Saxon settlement deposits at the site (Nicholson, in press). In keeping with other sites, these Mid Saxon assemblages are dominated by eel, which comprise nearly 5,000 of the total fish bones from the period (Barrett et al. 2004a; Nicholson, in press). However, the Mid Saxon deposits also include several hundred flatfish bones, 300 herring bones, and over 100 cod bones. As a comparison, late 7th-mid 9th century deposits at Blue Bridge Lane, York, yielded c. 3,000 eel, c. 500 herring, and 3 cod bones, while roughly contemporary deposits at Fishergate, York yielded 3,140 eel, 567 herring, and 10 cod bones (Harland et al. 2016). In London, cod bones are virtually absent from deposits dating to the same period (Orton et al. 2016).

The fairly sizable quantities of fish remains at Stoke Quay, particularly with regards to the cod bones, suggest that the 'fish event horizon' may have occurred earlier at Stoke Quay than at contemporary sites, but it is unclear from the bones alone whether fish played an important role in Mid Saxon and Late Saxon diet at Stoke Quay.

At York, Gundula Müldner has used carbon and nitrogen stable isotope analysis to study changes in diet over time, and found evidence for marine fish consumption by males at the mid 11th-12th century parish church cemetery of St.

Andrew, Fishergate (Müldner 2009, 2016). Müldner suggests that the first regular consumers of marine fish in relatively low-status parishes such as St. Andrew's were those who were directly involved in the fish trade (Müldner 2016; Kemp & Graves 1996). This is a reasonable hypothesis, but until now, no human isotopic studies of the timing of the 'fish event' have been conducted in Ipswich or in southeastern England, despite the known size and importance of the medieval herring fisheries off the east coast of England.

Understanding how the consumption of marine fish and other foods might have changed over time at Stoke Quay can add depth to our understanding of how this dietary and economic shift came about, and who was involved. It can also shed light on how Ipswich participated in the procurement and trade of fish and other products throughout the medieval period, and provide better context for studies on medieval health and urbanisation.

1.3.2 Urbanisation and health

Ipswich as an early urban centre

As one of the primary *emporia* of early medieval England, Ipswich was an early centre for regional and international trade, with evidence for contacts with Frisia, the Rhineland, and Gaul from the 6th-7th centuries (Brodt 2000). Ipswich was one of the first locations in England to develop 'urban' characteristics such as industrial and craft-working activities and non-agricultural specialist occupations in the late 6th-7th centuries (Dyer 2000; Holt 2000; Crabtree 2012).

The most well known industrial activity at Ipswich was the production of Ipswich Ware, the first industrially produced wheel-thrown pottery in England since the Roman period, which was made in Ipswich in the 8th-9th centuries. As

the settlement expanded in the 8th century, the northeastern area of the settlement became an important focus for the large-scale production of these ceramics (Blinkhorn 1999; Dalwood 2018; Sudds, in press). The discovery of an Ipswich Ware kiln at Stoke Quay now expands the range of this industrial activity across the river from the main settlement (Teague, in press).

By the late 8th and 9th centuries, with the rise of a coin-based economy, towns further evolved into markets for the purchase of locally and internationally sourced products and foods (Hodges 2012; Scull 2013). Some of the *emporia* declined during the mid-9th century as this process was taking place, while others, such as Ipswich, developed and thrived as regional market towns (Crabtree 2014). During this period Ipswich continued to engage in considerable overseas trade, particularly with Dorestad (Malster 2000; Wade 2014).

By the 11th century England had many towns, and by the writing of Domesday Book in 1086, an estimated 1 in 12 Englishmen were town-dwellers, translating to an urban population of over 100,000 people (Dyer 2000). Ipswich appears to have undergone some sort of crisis during this period, as evidenced from excavations of burned buildings in the town centre (Wade 2014). Domesday Book also records a marked reduction in the number of burgesses in 1086 from their numbers in 1066 (Malster 2000). Urban growth across England appears to have accelerated after around 1180 and it intensified in the following centuries (Schofield & Vince 2009).

Despite major crises such as the famines of the early 14th century and the Black Death in the mid-14th century, towns continued to be populated by mobility from the countryside. Ipswich remained an important regional capital and port throughout the medieval period though its importance decreased as

other towns such as Norwich continued to rise in power and wealth (Dyer 2000; Kowaleski 2008).

The process of urbanisation was a major development of the medieval period, setting the stage for population distributions and trade networks that ushered in the modern age. Urbanisation can also have negative effects, and in the medieval period these included poorly ventilated and crowded dwellings, unsanitary waste disposal, and contaminated water sources (Dyer 1989; Roberts & Manchester 2010; Roberts & Cox 2003; Schofield & Vince 2009).

Impacts of urban living on health

Towns in the medieval period offered numerous commercial opportunities, and townspeople generally exercised a degree of freedom not found in rural settlements (Postles 2000; Dyer 2000). However, the high population density in medieval urban areas also created ample opportunities for disease transmission. Issues with waste disposal and clean water supplies, for example, would have increased the incidence of certain gastrointestinal diseases and parasites, spreading illnesses such as cholera, typhoid, and infantile gastroenteritis, which may have been fatal to children and infants (Roberts & Manchester 2010; Buckley 1994).

In addition to polluted water, airborne pollutants could be a major health issue in medieval urban environments. Poor air quality in urban areas was a concern for medieval townspeople, with complaints about the problem documented from at least the 13th century, and the commission of four investigations of the issue from 1285 to 1310 (Lewis 1995; Brimblecombe 1975). Atmospheric pollution is a frequent cause of chronic sinusitis, and

skeletal evidence of sinusitis has been found in higher frequencies in medieval urban versus rural assemblages, particularly amongst males. Higher urban prevalence of the condition may have been partly due to poor air quality encountered through occupations in the tanning, smithing, pottery, and textile industries (Lewis et al. 1995; Summer 1971; Lancaster 1990; Roberts & Manchester 2010; Waldron 2009; Boocock 1995).

Polluted air and water were not the only health hazards associated with urban living environments in medieval England. Particularly among the urban poor, higher population levels and the often-crowded living conditions facilitated the transmission of infectious diseases such as tuberculosis (TB). In humans, TB can be contracted through consumption of cow milk and meat infected with the bacteria *Mycobacterium bovis*, but in urban environments it is more often contracted through inhalation of *M. tuberculosis* bacilli, which become airborne when an infected person coughs (Roberts & Manchester 2010).

Often associated with poverty and malnutrition, TB transmission rates increase with population density, making it essentially an urban disease. Only about 2-7% of TB infections affect the skeleton, so prevalence rates from archaeological assemblages likely underestimate the true impact of this disease in the past (Roberts & Cox 2003; Roberts & Manchester 2010; Waldron 2009; Aufderheide & Rodriguez-Martin 1998).

Diet has a strong influence on the immune system's ability to fight infection, but a poor diet during childhood and adolescence can also affect skeletal and dental development and result in reduced adult stature (Roberts & Manchester 2010). Because of this correlation between diet and stature, stature has been used to evaluate inequality between and among groups, and

correlations have been found between low stature and characteristics such as dental enamel defects and younger age-at-death (Ribot & Roberts 1996; Gunnell et al. 2001). An association has been made between stature and urbanisation, but the evidence is not conclusive: adolescent growth was found to be hindered in post-Medieval London, but not in late Medieval York (Lewis 2002).

Along with crowded and unsanitary living conditions, medieval townspeople were at risk for injuries caused by accidents and interpersonal violence. Interpersonal violence appears to have generally increased during the medieval period, but it was especially prevalent in urban environments (Walker 2012; Lewis 2002). A particular increase in violence after the Black Death has been shown in several areas, especially in London, and this evidence for violence more frequently affected men (Krakowka 2017; Walker 2012; Lewis 2002).

At Ipswich, violence is attested to in the osteological record at the site of Blackfriars, where high rates of skeletal trauma were recorded (Mays 1991). Violence can also be seen in the documentary record. In 1447, violence was apparently widespread enough that the local government ordered the town's inhabitants to come to the assistance of anyone being assaulted, or risk disenfranchisement (Malster 2000). As discussed in the following section, some of this violence may have been directed against foreigners.

1.3.3 Mobility and demographics

From its earliest beginnings, Ipswich was connected with trade, which was facilitated by its location on the major north-south road from London to Colchester, and its position on the banks of the River Orwell in close proximity to the North Sea coast. This trade was both regional and international in scale.

The role of Ipswich in regional trade can be seen in the distribution of Ipswich Ware, which was extensively traded in the English hinterlands in the 8th-9th centuries, likely through riverine and coastal routes (Blinkwood 1999; Dalwood 2018; Sudds, in press). Ipswich Ware has been found at nearly all rural Mid Saxon sites in the kingdom of East Anglia, often in large numbers. Outside of the East Anglia, these ceramics have been found at high-status secular and religious sites as distant as Kent and Yorkshire (Wade 1988).

Trade at Ipswich was not limited to the regional hinterland, as shown by archaeological evidence from the Mid Saxon town. Large quantities of imported pottery have been excavated from the Mid Saxon deposits at Ipswich, with 14% of the ceramic assemblage of this period coming from the Continent (Scull 2013). The imported wares appear to have originated in the Rhineland (in the Vorgebirge and near Mayen), Flanders (Meuse Valley), and northern France, further supporting the continued trade between Ipswich and its Continental counterparts (Wade 1988; Hodges 1978).

Trading patterns appear to have shifted over time. In the 7th century, trade and social affiliations were focused on Merovingian northern France and Flanders, while in the 8th and 9th centuries this focus shifted toward the Rhineland, through increasing contacts with the *emporia* at Domburg and then Dorestad (Wade 1988; Scull 2013). Much of this trade may have come through Frisian merchants, who were likely the main exporters of agricultural and craft products from the Rhineland to eastern England as well as Jutland, though the scale of such importation is difficult to measure (Lebecq 1992).

During the Viking invasions in the 9th and 10th centuries, Ipswich was raided several times before falling under the control of the Danelaw, which

lasted from 869-917 (Malster 2000). At this time, there is less evidence for craft industries or international trade, though it is unclear if this was caused by the Danish presence or merely coincidental (Wade 2014; Malster 2000).

Trade picked up again after the Conquest in 1066, and Ipswich continued to play a role in international trade, though regional competition arose from centres such as Norwich and Lynn. Some trade was likely tied to the thriving fisheries off the coast, with a permanent settlement of fishermen at Yarmouth from the early 11th century, where by the early 12th century fleets of foreign fishermen were visiting in order to take part in the profitable herring fishery (Kowaleski 2003). Evidence for inhabitants in Ipswich of nonlocal origin can be seen in the record of town officers from the 13th century, which included surnames suggesting origins in other parts of Suffolk and Norfolk, Essex, and Flanders (Malster 2000). After the Black Death, migration within England also increased, as rural men, women, and adolescents sought employment in the growing urban labour forces (Dyer 2000; Lewis 2002). It is likely that some would have come to Ipswich.

From 1324-1329, overseas 'aliens' at Ipswich held 4.6% of the total foreign trade in England, making Ipswich the 6th most important English port for foreign traders, after London, Boston, Hull, Southampton, and Lynn (Kowaleski 2008, Table 19.4). Some of these traders would have merely been visitors to the town, while others appear to have settled in Ipswich. Indeed, from 1300-1485, over 200 'aliens' were recorded as resident in Ipswich, including Brabanters, Flemings, Zeelanders, Gelderlanders, Hollanders/Dutch, Germans, and more (Brown et al., in press; England's Immigrants Database).

It therefore appears that foreigners played a part in everyday life at Ipswich, particularly in terms of trade and fishing. Less clear is how these 'aliens' were treated, and how their quality of life compared to that of locals. It should be noted that, from a modern perspective, it is unclear at what distance medieval people would consider someone to be 'nonlocal' or 'alien', but in some cases at least, those coming from overseas appear to have been seen as different.

As the medieval period progressed, the superior trade privileges afforded to foreign merchants, particularly those in the Hanseatic League, contributed to a wave of hostility to foreigners. In some towns, 'alien' hosting regulations required foreigners to lodge with an English host and report their daily business dealings. Parliament passed a national version of this legislation in 1439, along with the first of many taxes on aliens. In London, anti-foreigner sentiment, long an issue, turned violent by the mid 15th century, leading many Italian merchants to leave the city and trade instead with other towns perceived as friendlier to nonlocals, such as Southampton (Kowaleski 2008).

At Ipswich, violence against foreigners was not unheard of, and was recorded in the coroners rolls from at least the mid 1300s, with accounts of enquiries into the violent deaths of several foreigners including a death from a tavern brawl and several murders (Malster 2000). Historical records are scarce prior to the 13th century, so alternative methods are required to determine whether this anti-alien sentiment and violence were developments of the later Middle Ages, or whether they were long-term characteristics of urban life.

1.4 Research questions and hypotheses

Based on the three main themes discussed in the previous section, a number of overarching research questions and hypotheses were developed to guide the research in this thesis. The research questions are addressed first, followed by the hypotheses.

1.4.1 Research questions

The first overarching question is when, and to what extent, the 'fish event horizon' occurred at Stoke Quay. Barrett (2004) hypothesised based on fish bone evidence that marine fish exploitation first began to intensify in coastal areas and among men, before spreading inland and to other demographic groups. Does this hold true at Stoke Quay? How may fish consumption have varied within the community over time? Would the assumed low socioeconomic status of the residents of St. Augustine's parish lead to greater or lesser fish consumption, and how might this relate to types of employment? Did females and children also consume marine fish, and if so, was it of the same kind?

The second question is how urbanisation affected life in the parish of St Augustine's, particularly with regard to the disease indicators highlighted in Section 1.3.2. With their apparently low socioeconomic status, would the individuals buried at Stoke Quay have greater evidence for chronic poor health, or would they have died of acute causes that would leave no trace on their skeletons? How did diet affect health? Are there associations between indicators of health such as stature, and evidence for changes in diet?

Thirdly, can the mobility attested to in the historical and archaeological record of Ipswich also be seen at Stoke Quay? If so, who were these incomers—

males, females, children? Were they coming primarily from the surrounding countryside or from further afield? Finally, how were 'foreigners' treated? Were they more or less susceptible to disease, or to involvement in interpersonal violence?

1.4.2 Hypotheses

Several hypotheses were formulated in response to the overarching research questions listed above. They are given below, along with the methods utilised in this thesis to test these hypotheses.

1) The timing of the 'fish event horizon' likely occurred earliest at coastal sites (Barrett et al. 2004), and with the location of Stoke Quay near the River Orwell, the burial of some individuals with clench bolts, and the history of shipbuilding at Ipswich, it is hypothesised here that marine fish exploitation began earlier at Stoke Quay than at inland sites. While this may seem intuitive, it has not been tested in an urban, coastal setting. This hypothesis is tested through bone collagen stable carbon and nitrogen isotope analysis of 363 individuals from the Mid Saxon to Medieval periods, including age groups from infants to the elderly. Dietary baselines are modelled from carbon and nitrogen isotope analysis of 99 animal bones excavated from refuse pits and wells from the Mid Saxon through Medieval periods at the site.

2) With the association between urbanisation and negative health outcomes, and the evidence for increasing urbanisation at Ipswich over time, it is hypothesised here that health at Stoke Quay declined over time. This is tested through analysis of osteological assessments for the sample group, gathered from data recorded in the Oxford Archaeology online database. Comparisons are

made between palaeopathological indicators for the entire assemblage, obtained from the forthcoming Stoke Quay monograph, and prevalence rates for skeletal markers of stress and disease from early and late medieval sites across Britain, obtained from the literature (Roberts and Cox 2003). Disease prevalence rates are also compared with carbon and nitrogen stable isotope results to examine potential relationships between health and diet.

3) Given Ipswich's history of overseas trade and shipbuilding, and the presence of imported pottery in the Mid Saxon deposits and clench-bolt burials in the Late Saxon and Anglo-Norman cemetery, it is hypothesised that the population buried at Stoke Quay included individuals of nonlocal origin, and that these individuals may have been subject to differential treatment and greater disease burdens. This is tested through radiogenic strontium and stable oxygen isotope analysis of tooth enamel carbonate from 45 individuals from the Mid Saxon through Medieval periods. Teeth from 6 pigs are also sampled to help establish a baseline for local bioavailable strontium ratios.

1.5 Overview of thesis structure

Due to the number of samples analysed and the long duration of burial practice at Stoke Quay, much of this thesis is structured as a series of case studies, each focused on a particular phase of the site's use. Chapter 2 provides an overview of the materials and methods used to analyse the human samples and the principles behind those methods, while Chapter 3 describes the materials and methods used to establish baseline values for the interpretation of human diet and mobility.

Chapters 4-7 focus on specific periods at Stoke Quay. Each chapter begins with an overview of some of the relevant historical and archaeological background for the associated time period at Ipswich, set within the broader context of events in England and the North Sea world. Research questions and hypotheses are outlined that are tailored to each chapter but align with the overarching research questions of the thesis. Each chapter describes the materials and analytical results for the assemblage from that period, with a discussion and interpretation of the results and chapter-specific conclusions.

Chapter 4 focuses on the Mid Saxon (Phase 2) period, beginning with the evidence for craftworking and trade at the site and discussing the isotopic and osteological evidence for diet, mobility and health at the *emporium* from the late 6th-early 8th centuries. Chapter 5 addresses the Late Saxon (Phase 4) assemblage, beginning with an overview of the Viking conflicts and their potential effect on trade at Ipswich, followed by a discussion of the isotopic evidence for marine fish consumption, mobility, and health. Chapter 6 focuses on the late 11th- late 12th century Anglo-Norman (Phase 5) period, examining evidence for diet, mobility and health during this period of intensified urbanisation. Chapter 7 focuses on the Medieval period (Phase 6), the final phase of burial at Stoke Quay dating to the 13th-late 15th centuries, addressing impacts of increased urbanisation and the crises of the 14th century on diet, health, and mobility at the site.

In Chapter 8, the results from all four periods are brought together and compared, in order to address the overarching hypotheses of this thesis. Finally, Chapter 9 summarises the main findings from this study, and highlights the implications of these results for our understanding of the development of Ipswich and its place in England and the North Sea world.

Chapter 2: Materials and methods for evaluating human diet and mobility

2.1 Introduction

This chapter outlines the materials and methods used in this thesis to evaluate temporal changes in human diet and mobility at medieval Stoke Quay, Ipswich, through analysis of $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in human bones and teeth. The focus of this chapter is on the human samples, while Chapter 3 focuses on the faunal materials and published isoscapes used to establish baselines for interpreting the human isotopic results.

Section 2.2 includes a brief summary of the basic principles behind $\delta^{13}C$ and $\delta^{15}N$ analysis and their application to human palaeodietary studies, followed by a description of the sampling strategy for the human skeletal material analysed for $\delta^{13}C$ and $\delta^{15}N$, along with demographic information for the sample as a whole. More detailed demographic data are given for each period in Chapters 4-7. Section 2.2 concludes with the methods used for bone collagen extraction and $\delta^{13}C$ and $\delta^{15}N$ analysis. Section 2.4 presents a summary of the principles of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis in human mobility studies, followed by the sampling strategy for the human teeth analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, and the methods used for analysis.

2.2 Assessing human diet at Stoke Quay

2.2.1 Carbon and nitrogen stable isotopes in bone collagen

The following section outlines the principles behind the application of stable carbon and nitrogen isotope analysis of bone collagen in palaeodietary studies, centred on the issues that are most applicable to the study of diet in

medieval England. Given that one of the main research objectives of this thesis is to evaluate the timing and extent of the transition to intense marine fish exploitation in the medieval period, the focus is on the detection of marine versus terrestrial resources, and physiological and environmental factors that can affect $\delta^{13}C$ and $\delta^{15}N$ in human tissues.

The principles of $\delta^{13}C$ and $\delta^{15}N$ analysis

The ratios of stable isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotopes in animal tissues are passed from dietary sources to the body tissues of consumers, and in the process they undergo fractionation, defined as "the measurable difference in the isotopic ratio of two associated substances, e.g., a reaction product and its substrate" (Schwarcz & Schoeninger 1991). The differences in ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ in biological tissues are minute, but they are measurable through mass spectrometry and reported as units per thousand, or per mil (‰). Rather than reporting the absolute differences in isotope ratios, the differences are expressed relative to an international standard through the δ notation using the following equation:

$$\delta \text{ E (x)} = \left(\frac{Rx}{Rs} - 1\right) \text{ x } 1000$$

where R is the isotope ratio in the sample (x) or standard (s) for an element (E) (Ehleringer & Rundel 1988; Schwarzc & Schoeninger 1991). The international standard for carbon stable isotope values ($\delta^{13}C$) is Vienna Pee Dee Belemnite carbonate (VPDB), and for nitrogen stable isotope values ($\delta^{15}N$) the standard is Ambient Inhalable Reservoir (AIR) (Hoefs 1987).

Factors affecting $\delta^{13}C$ and $\delta^{15}N$ variation in terrestrial and marine systems

Variations in carbon isotopes in terrestrial ecosystems primarily reflect the photosynthetic pathways used by plants at the base of ecosystems, which can be divided into three categories: C_3, C_4, and CAM (Crassulacean acid metabolism). The names of the first two pathways refer to the number of carbon atoms used by the plants in the first stage of CO_2 fixation during photosynthesis (Smith & Epstein 1971; Bender 1968, 1971; Hatch et al. 1970).

Most plants in temperate and/or high latitude or altitude regions follow the C_3 pathway, including all trees, most shrubs, herbs, temperate-climate grasses and hence cereals such as wheat, barley, and rye. The $\delta^{13}C$ for these plants can vary widely based on temperature, humidity, light conditions, moisture levels, and the degree of CO2 recycling, with $\delta^{13}C$ values from around -24‰ to -36‰ and a global mean around -26.5‰ (Farquhar et al. 1989; Smith & Epstein 1971; Bender 1968; van der Merwe & Medina 1991; Ehleringer & Rundel 1988). The C_4 pathway is used by plants adapted to warm conditions in the growing (rainy) season, including maize, sugarcane, millet, and tropical grasses. The $\delta^{13}C$ for C_4 plants cluster more tightly, between around -9‰ to -14‰, and average around -12.5‰ (Smith & Epstein 1971; Bender 1968; Ehleringer & Rundel 1988).

In contexts such as that of medieval England, in which diet was based on C_3 plants and animals grazing on those plants, $\delta^{13}C$ is primarily used to differentiate between marine and terrestrial dietary inputs, as the primary producers in marine ecosystems are isotopically enriched compared to terrestrial plants (Tauber 1981; Chisholm et al. 1982; Schoeninger & DeNiro 1984; Lee-Thorp et al. 1989). This is because the source of marine carbon is

mainly dissolved bicarbonate, which is relatively high in $\delta^{13}C$ compared to atmospheric carbon (Farquhar et al. 1989).

The primary producers in marine environments, including phytoplankton, algae, diatoms and radiolaria, have varying $\delta^{13}C$ but a mean around -20‰ (Smith & Epstein 1971; Lee-Thorp 2008). A small trophic level shift of approximately 1-2‰ has also been observed with $\delta^{13}C$, which is useful for modelling expected $\delta^{13}C$ values from baseline faunal $\delta^{13}C$ ranges (Bocherens & Drucker 2003; see Chapter 3). These isotopic differences are particularly useful for this thesis, as the human bone collagen $\delta^{13}C$ will therefore reflect the $\delta^{13}C$ from terrestrial or marine dietary sources (or more likely, a combination of both).

While differences in the $\delta^{13}C$ of animal tissues are fundamentally a result of differences in the carbon sources and photosynthetic pathways of plants at the base of the ecosystem, differences in $\delta^{15}N$ at the base of the food chain are dependent on soil composition and plant physiology. The source of nitrogen for terrestrial ecosystems is atmospheric N_2, which has a globally uniform $\delta^{15}N$ of 0‰. Depending on moisture levels, salinity, erosion from local geological features, recycled plant and animal matter, and soil microbial activity, soil and plant $\delta^{15}N$ is typically 1-4‰ above atmospheric N_2 (Finlay & Kendall 2008; Shearer et al. 1978; Heaton 1987).

Most plants rely on mycorrhizal activity in their root systems to fix nitrogen from soil nitrates and ammonia, and will have higher $\delta^{15}N$ at around 3‰ (Kronzucker et al. 1997; Wada et al. 1975; Craine 2015). In contrast, nitrogen-fixing plants such as legumes have $\delta^{15}N$ close to that of atmospheric N_2, at around 0‰ (Handley 2002; Craine et al. 2015). Marine plants rely primarily

on recycled NO_3 in seawater, with average $\delta^{15}N$ around 5-6‰ in the upwelling centres around the ocean margins (Liu & Kaplan 1989; Raven et al. 2002).

Stable nitrogen isotope ratios ($\delta^{15}N$) also show trophic level shifts, but these are more pronounced than with $\delta^{13}C$, with $\delta^{15}N$ rising between approximately 3-5‰ per trophic level (DeNiro & Epstein 1971; Schoeninger & DeNiro 1984). This is due to the preferential excretion of ^{14}N over ^{15}N in animals, which leads to higher $\delta^{15}N$ values in animal tissues compared to those in the diet (Minagawa & Wada 1984). Because marine food chains are much longer than those on land, most marine foods and consumers of those foods have high $\delta^{15}N$, which can be used to differentiate between consumers of marine versus terrestrial foods (Minagawa & Wada 1984; Schoeninger & DeNiro 1984).

Analyses of $\delta^{13}C$ and $\delta^{15}N$ can provide useful information on dietary inputs, including marine resource consumption, but these isotopes are particularly effective at identifying marine food inputs when they are combined.

Factors affecting the interpretation of human and animal $\delta^{13}C$ and $\delta^{15}N$ in medieval England

In addition to the fundamental principles influencing $\delta^{13}C$ and $\delta^{15}N$ variation in biological and ecological systems, a number of other factors can also affect the ratios of these isotopes in human tissues. Several of these factors are of particular importance for interpreting human and animal $\delta^{13}C$ and $\delta^{15}N$ from medieval English contexts.

Animal husbandry and agricultural practices can have a marked effect on the $\delta^{13}C$ and $\delta^{15}N$ of associated humans. One example of this is the practice of manuring fields to add nutrients to the soil and improve agricultural

productivity, which became a frequently used method in Anglo-Saxon England (Hamerow 2007). Animal manure preferentially loses ^{14}N, mainly through volatile gaseous ammonia, which leaves the remaining ammonium relatively enriched in ^{15}N. When this ammonium is converted to soil nitrate it is therefore enriched in ^{15}N, which is taken up by plants that grow on these soils and consequently raises plant $\delta^{15}N$ (Bogaard et al. 2007; Kendall 1998; Kreitler & Jones 1975). These higher $\delta^{15}N$ values will be passed up the food chain to animals and humans (Bogaard et al. 2007). When interpreting human $\delta^{15}N$ for potential consumption of marine foods, it is therefore important to consider manuring as an alternative explanation for elevated $\delta^{15}N$ values.

Another human farming practice that can affect both $\delta^{13}C$ and $\delta^{15}N$ is the grazing of animals such as sheep and cattle on salt-marshes. Salt-marsh plants such as halophytes have been shown to have higher $\delta^{15}N$ than terrestrial or freshwater species, and high $\delta^{15}N$ have also been found in other plants growing in coastal areas or inland salt-pans (Cloern et al. 2002; Virginia & Delwiche 1982; Heaton 1987). Salinity can also affect plant $\delta^{13}C$, reducing discrimination against ^{13}C during photosynthesis and therefore elevating the plant $\delta^{13}C$ (Guy et al. 1986a,b; van Groeningen & van Kessel 2002). Additionally, coastal environments support the only wild C_4 plants in northwest Europe, which in the past would have primarily been a cordgrass species named *Spartina maritima*, now largely extinct (McGrail 1981; Castillo et al. 2008; Müldner et al. 2014).

Recent studies on archaeological cattle and sheep from England and the Netherlands have shown, in some cases, elevated $\delta^{15}N$ in coastal areas compared to those found inland, with salt-marsh grazing posed as the most likely explanation for these differences (Britton et al. 2008; Müldner et al. 2014). The

higher $\delta^{13}C$ and $\delta^{15}N$ for these animals may be due to salinity affecting the $\delta^{13}C$ and $\delta^{15}N$ of the plants, but the higher salinity of the plants can also induce water stress in animals and cause them to excrete more ^{15}N-depleted urea, thus raising their $\delta^{15}N$ (Britton et al. 2008; Ambrose & DeNiro 1986; Sponheimer et al. 2003). The higher $\delta^{13}C$ in these animals could also be influenced by grazing on coastal wild C_4 plants such as *Spartina maritima*, or consumption of ^{13}C-enriched floating seaweed, which can drift onto beaches (Müldner et al. 2014). Given the location of Stoke Quay near marshland and close to the North Sea coast, these factors bear consideration when interpreting the human isotopic values, and speak to the importance of $\delta^{13}C$ and $\delta^{15}N$ sampling of local archaeological fauna.

Along with these external factors that can influence human $\delta^{13}C$ and $\delta^{15}N$ through diet, a number of physiological factors can also exert an influence on bone collagen values. Nitrogen balance can affect $\delta^{15}N$ in body tissues, with decreased $\delta^{15}N$ associated with anabolic states such as pregnancy (Fuller et al. 2004, 2005), and increased $\delta^{15}N$ associated with catabolic states such as nutritional stress, prolonged illnesses, and fracture healing (Fuller et al. 2004; Katzenberg & Lovell 1999; Beaumont et al. 2015; D'Ortenzio et al. 2015). Physiological factors can also alter $\delta^{13}C$; for example, $\delta^{13}C$ can decrease during starvation due to the breakdown of body fat deposits, which have a lower $\delta^{13}C$ than other tissues such as muscle (Beaumont & Montgomery 2016; Neuberger et al. 2013; Tieszen & Fagre 1993).

These physiological factors may have affected individuals buried at Stoke Quay, as the assemblage includes women of childbearing age, evidence for prolonged infections in the form of periostitis and diseases such as tuberculosis, and high numbers of bone fractures (Loe et al, in press). The period of use for the

cemetery at Stoke Quay also overlaps with times of known food shortages and crises, including, for instance the famines of the early 14th century (Dyer 2000).

Applying $\delta^{15}N$ and $\delta^{13}C$ in palaeodietary studies

Because $\delta^{13}C$ and $\delta^{15}N$ vary predictably across biological and ecological systems, analysing these isotopes in human and animal tissues can potentially inform us about proportions of different foods in the diet, including marine versus terrestrial resources and whether a diet is plant based or rich in animal proteins.

The most commonly used tissue in palaeodietary studies is bone collagen, the primary source of protein in bone, which consists of fibrils composed of 3 helical peptide chains with a poorly crystalline mineral matrix (Brock 2013; Lee-Thorp 2008). Experimental studies indicate that 51.3% to 75% of the carbon isotopes in bone collagen are derived from amino acids, while the remainder appear to come from lipids and carbohydrates (Fernandes et al 2012; Jim et al. 2006; Ambrose & Norr 1993). Nitrogen forms an important component of many amino acids, and in biological tissues, nitrogen isotopes primarily reflect the protein component of the diet (Ambrose & Norr 1993; Tieszen & Fagre 1993).

Bone tissue continuously remodels during life, but the rate of turnover varies with an individual's age, turning over rapidly in infancy and childhood and slowing after reaching adulthood (Hedges et al. 2007). This means that bone collagen $\delta^{13}C$ and $\delta^{15}N$ will reflect average values from bone remodelled over a number of years before death, depending on the age of the individual and the bone sampled. Bone collagen often preserves well in temperate environments, so analysing the $\delta^{13}C$ and $\delta^{15}N$ of archaeological human bones allows us to compare

dietary trends between individuals, age groups, sexes, and periods (e.g. Richards et al. 2006; Müldner & Richards 2007; Kancle et al. 2018; Hannah et al. 2018).

The analysis of $\delta^{13}C$ and $\delta^{15}N$ from bone collagen is particularly useful for directly evaluating dietary inputs in contexts where other dietary evidence may be poorly preserved or lacking, as is often the case with archaeological materials. For instance, small species and juvenile animals are susceptible to degradation in the soil, and easily biodegradable foods such as fruits, vegetables, and uncharred cereals often disappear from the burial environment. Even when small bones or plant materials are preserved, they may not be collected during archaeological excavations; this was particularly true prior to the 1970s, when soil sieving and flotation became routine practice (Crabtree 1996; Payne 1975; Reitz & Wing 2010). Secondary animal products such as cheese or milk, or meats preserved off the bone such as salt pork or dried fish, will often leave no direct trace in archaeological contexts (Reitz & Wing 2010).

Bone collagen $\delta^{13}C$ and $\delta^{15}N$ is used in this thesis to address questions about the timing and extent of the 'fish event horizon' at Stoke Quay, and to identify potential dietary differences between demographic groups. The human sample selection and analysis are discussed in the following section.

2.2.2 Materials: Sampling strategy and bone selection

The sampling strategy for the human assemblage was developed with several aims, designed to fit within the overarching themes of marine fish exploitation and urbanisation that are explored in this thesis (see Chapter 1). The first aim was to obtain a broad idea of how diet may have changed at Stoke Quay throughout the medieval period, while the second aim was to test for the

presence and timing of the 'fish event horizon' (Barrett et al. 2004a) at Stoke Quay. The third aim was to evaluate differences between males and females, age groups, and individuals of higher versus lower status as indicated by grave location and type, which showed some variation by period (Teague, in press). The fourth objective was to investigate potential correlations between dietary isotope values and skeletal indicators of stress and pathology. In order to achieve these aims, a sampling strategy was developed which sampled individuals from all age groups, all time periods, and both sexes. The sampling strategy was developed in two stages.

Stage 1: Sampling for the pilot study

The first stage of sample selection and analysis was conducted in 2015 in collaboration with Oxford Archaeology (OA) under the guidance of Dr Louise Loe, Head of Burials at OA. Bone samples from a total of 50 individuals were analysed for $\delta^{13}C$ and $\delta^{15}N$ as part of a pilot study on overall dietary patterns at Stoke Quay for publication in the forthcoming site monograph (Brown et al., in press). Rib bones were preferentially used, but in several cases poor preservation necessitated the use of cranial and limb bones.

The individuals selected by Dr Loe and her colleagues for this study were chosen for a number of reasons, including age, sex, burial location, pathology, trauma, and whether the individual had been selected for other isotopic studies including $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ or ^{14}C analysis (Loe et al., in press; Farber & Lee-Thorp, in press). Additionally, one individual, Sk 5909, had been previously analysed by Peter Ditchfield in a small pilot study during the assessment phase of the project, and these results were included in the interpretations for the

larger pilot. This brought the total number of individuals to 51 (see Appendix 2 for individual demographics including age, sex, and time period).

The pilot study results suggested that human isotopic compositions may have changed over time, and were possibly correlated by time period or spatial locations, but precise relationships were not yet clear. The results also hinted that the 'fish event horizon' might have begun earlier at Stoke Quay than at some contemporary sites, so this was highlighted as an area to explore further in the thesis. A wide range of isotopic values was observed in the pilot study results, leading to the conclusion that a large sample size was needed to capture the potential isotopic variability in the population (Farber & Lee-Thorp, in press).

Though the pilot study samples were selected with a different strategy than those in the main thesis study, they are incorporated with the rest of the assemblage in the materials, results, and discussions in this thesis (Chapters 4-8). In Appendix 2, the pilot study sample IDs are marked with an asterisk.

Stage 2: Sampling for the thesis study

Based on observations from the pilot study results, a sampling strategy was developed to select individuals for the main $\delta^{13}C$ and $\delta^{15}N$ study in this thesis. To obtain samples large enough to enable statistical comparisons between age groups and sexes, the strategy was to obtain 20 individuals (10 males and 10 females) from each age adult age group (18-25, 26-35, 36-45, 45+), from each period of the main cemetery's use: the Late Saxon, Anglo-Norman, and Medieval periods.

To enable analysis of potential spatial patterning in isotopic results, individuals were selected from all Cemetery Groups in proportions roughly

following those in the assemblage. In other words, if more Late Saxon females aged 25-36 were buried in Cemetery Group 1 than in 2C, the final sample would include higher numbers from Cemetery Group 1. As discussed in Chapter 1, the Cemetery Groups are subcategories within each Phase relating to grave groupings or other shared burial characteristics. Each Phase thus contained different numbers of Cemetery Groups, with varying numbers of individuals.

Although adults were the primary focus for the research questions, it was considered important to also capture some of the potential variability in diet experienced by the youngest age groups. To this effect, 10 individuals were to be sampled from each subadult age group (1-5, 6-12, 13-17) for each period. As with the adults, these subadults were also distributed across Cemetery Groups according to the proportion of burials in each group.

The strategy detailed above resulted in unequal sample sizes from each Cemetery Group, but it was it was deemed more important to obtain equal numbers of males and females from each age group than to limit samples to only those sexes and age groups that were represented across all Cemetery Groups. This strategy was seen as the best way to approach the research aims outlined above, and to highlight avenues for potential future research.

Finally, all individuals from Phase 2 (n = 20) with some preserved bone were sampled (n = 18). It was anticipated from the outset that many of these individuals might not yield collagen suitable for analysis, due to the poor state of preservation for many of these early burials (see Chapter 4 for further details), but they were included in the interest of obtaining the maximum amount of information from this important period in the development of Ipswich. In total, 348 individuals were to be included in the second batch of samples.

Combined sample for $\delta^{13}C$ and $\delta^{15}N$ analyses

Basic age and sex distributions for the final sample (including the pilot study samples) are given in Table 2.1 and shown in Figures 2.1-2.3. The final sample demographics did not exactly match what was planned, for several reasons. For example, samples for the Medieval 1-5 year age group could not be located, so they were not included. Additionally, some age groups, such as the 18-25 year-olds, had fewer than 10 well-preserved individuals of each sex, so this group contains fewer individuals than planned. Nevertheless, the final sample includes all age groups and both sexes. Combined with the pilot study samples, the total sample size is 363.

	Age group								
Sex	**1-5**	**6-12**	**13-17**	**18-25**	**18+**	**26-35**	**36-45**	**45+**	**60+**
Unknown (?)	20	30	42	1	2	4	0	0	0
Female (F, ?F, ??F)	0	0	0	28	1	34	34	31	1
Male (M, ?M, ??M)	0	0	4	25	0	32	42	30	2
Total	20	30	46	54	3	70	76	61	3

Table 2.1. Total count for the Stoke Quay human $\delta^{13}C$ and $\delta^{15}N$ samples, tabulated by age group and estimated biological sex (n = 363).

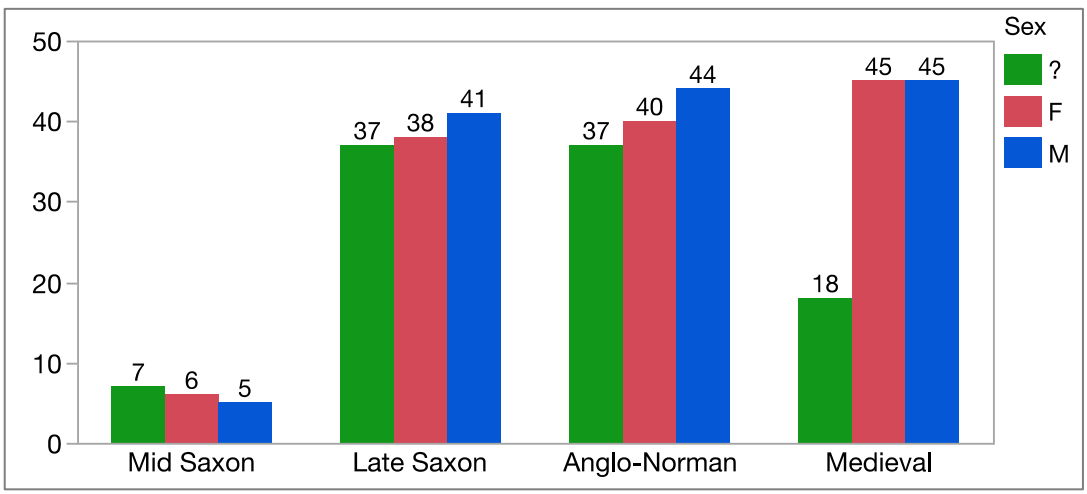


Figure 2.1 Sex distribution by period for Stoke Quay human $\delta^{13}C$ and $\delta^{15}N$ samples (n = 363).

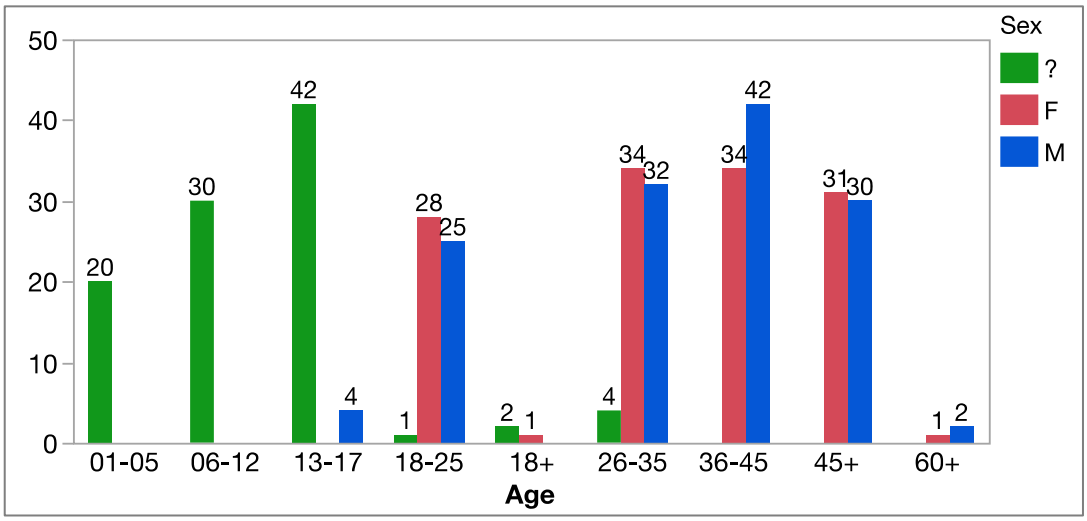


Figure 2.2. Age and sex distribution for Stoke Quay human $\delta^{13}C$ and $\delta^{15}N$ samples (n = 363).

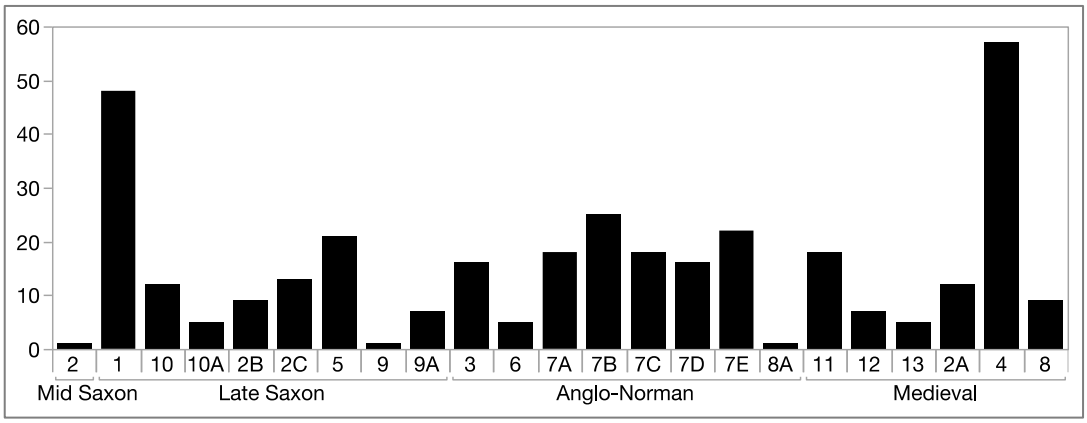


Figure 2.3 Cemetery group distributions by period for the Stoke Quay human skeletons sampled for $\delta^{13}C$ and $\delta^{15}N$ (n = 363).

Bone selection

To ensure the maximum amount of comparability across time periods and between individuals, samples were chosen from skeletons that had preserved ribs. Right ribs were the preferred element, followed by left ribs if no right ribs were present. Mid-thoracic ribs were selected whenever possible, and to minimise destruction to intact bones, samples were taken from the mid-shaft portion, preferably on bones that were already broken. In a few cases, individuals who were deemed particularly interesting, and therefore desirable for inclusion in the sample, did not have any preserved ribs. In these cases, leg

bones were chosen. This occurred most frequently with the poorly preserved Phase 2 assemblage.

After excavation, the skeletons were cleaned and recorded by Oxford Archaeology, and had been entered into a database by the time physical sample selection took place. The bones were stored in individual boxes in the OA storehouse, where the author located each skeleton, identified bones to element and side, and selected bones for analysis. The bones were brought to the Research Laboratory for Archaeology and the History of Art at the School of Archaeology, Oxford, for processing and analysis.

2.2.3 Methods for collagen extraction and $\delta^{13}C$ and $\delta^{15}N$ analyses

This section describes the methods used for bone collagen extraction and $\delta^{13}C$ and $\delta^{15}N$ analysis, as well as the statistical methods used to evaluate the results.

Sample preparation and collagen extraction

Bone surfaces were cleaned using an air-abrasive system with 5μm aluminium oxide powder. Using a diamond-tipped circular saw bit on a hand-held drill, between 0.5g and 1g of bone was removed and then crushed with an agate mortar and pestle. Bone samples were removed from the least conspicuous location, on a case-by-case basis, taking care to avoid any areas with visible periostitis or other pathological lesions, and to preserve the structural integrity of the bones. For rib bones, sternal and vertebral ends were avoided in order to preserve these features, as they are useful for identifying the rib number, so samples were preferentially removed from broken mid-shaft fragments. The drill

was cleaned between each sample with a copper bristle brush, compressed air, and methanol. Samples were drilled over aluminium foil, which was replaced with each sample, and the worktop surface was cleaned with methanol after drilling each sample.

Collagen was extracted from the bone samples following the methods of O'Connell & Hedges (1999): crushed bone samples were demineralized in 5ml aliquots of 0.5M HCl solution, then refrigerated at 4° C. The acid was changed every 24 hours until no further reaction was observed. Samples were rinsed twice with distilled milli-µ ultra pure H_2O, and refrigerated at 4° C to remove the HCl solution. The distilled H_2O was replaced every 24 hours for up to 4 days. Next, the H_2O was removed and replaced with 5ml aliquots of pH3 H_2O, then heated at 70° C for 48 hours. The supernatant liquid was removed with Eezee™ filters, and then decanted into Nalgene™ transport tubes with temporary parafilm covers. Samples were placed in a freezer for at least 24 hours until fully frozen, then freeze-dried in a Zirbus VaCo5 freeze drier fitted with an oil free vacuum system for 48-72 hours, or until no further weight loss was observed.

Instrumental analysis

After collagen extraction, subsamples of 0.85-1.15mg were weighed out for analysis into pre-cleaned tin capsules. Samples were combusted in a Sercon GSL sample conversion system using helium carrier gas. A 2% split of the evolved gasses was analysed for carbon and nitrogen stable isotopic composition, using a Sercon Geo-20-22 gas source mass-spectrometer operating in continuous flow mode. Isotopic values, elemental abundances, and carbon-to-nitrogen ratios were calibrated against an in-house alanine standard and in-

house cow and modern seal collagen standards, which are traceable back to the V-PDB standard via USGS 40 and 41. Further aliquots of the alanine standard were used to monitor and correct for instrumental drift.

Bone collagen samples were run in duplicate and an average value is reported in delta notation relative to V-PDB for carbon and AIR for nitrogen. In the few cases where duplicates differed by > 1‰, samples were analysed a third time. Replicate analysis of the alanine in-house standard suggests that the individual values obtained during these analyses are precise to ± 0.1‰ for $\delta^{13}C$ and ± 0.1‰ for $\delta^{15}N$. Summary statistics for the mean values from replicate analyses and their standard deviations, along with expected values, are given in Table 2.2. All samples reported in this thesis met requirements for collagen preservation, with C:N ratios of 2.9-3.6, and collagen survival over 1% (DeNiro 1985; van Klinken 1999).

		$\delta^{13}C$			$\delta^{15}N$		
Standard	**n**	**Expected**	**Measured mean**	**±1σ**	**Expected**	**Measured mean**	**±1σ**
Alanine	132	-27.1	-27.1	0.1	-1.6	-1.5	0.1
Cow	112	-24.3	-24.5	0.1	7.8	7.6	0.1
Seal 1	104	-12.0	-12.4	0.1	16.6	16.1	0.2
Seal 2	8	-13.3	-13.5	0.1	17.3	16.9	0.3

Table 2.2. Summary statistics for $\delta^{13}C$ and $\delta^{15}N$ standards, with expected values, mean measured values, and standard deviations.

Statistical analysis

The $\delta^{13}C$ and $\delta^{15}N$ results for duplicate runs were averaged and bivariate plots were produced on JMP 14 statistical software for each phase. Regression lines were generated, and r^2 values were assessed for correlations between $\delta^{13}C$ and $\delta^{15}N$. Sample distributions were tested for normality using a Shapiro-Wilks

test, which is more powerful than the Kolmogorov-Smirnov or the Lilliefors corrected Kolmogorov-Smirnov tests (Ghasemi & Zahediasi 2012).

When datasets followed the Normal distribution, one-way ANOVA were performed to test for significant differences between groups. When significant differences were observed, the post-hoc parametric Tukey-Kramer Honestly Significant Difference (Tukey-Kramer HSD) test was run. This test is similar to the Student's t-test but makes adjustments for multiple analyses, making it a more conservative test for differences among groups. Datasets not following the Normal distribution were assessed using nonparametric tests: Kruskal-Wallis, followed by the post-hoc Steel-Dwass, the nonparametric equivalent of the Tukey HSD test (Agresti & Finlay 2014).

2.3 Assessing human mobility at Stoke Quay

The location of Ipswich near the North Sea coast and its important role in overseas trade during the medieval period would have facilitated the movement of people along with the goods coming in to port. As discussed in Chapter 1, the patterns of humans coming into Ipswich may have changed throughout the medieval period, as trading relationships evolved along with economic and political pressures. With its long duration of use and large number of individuals, the Stoke Quay cemetery provides a skeletal assemblage well suited to addressing questions of medieval mobility in Ipswich through $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of human tooth enamel carbonate.

This section addresses the fundamental principles behind the use of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis in palaeomobility studies, as well as factors that can impact interpretations of human $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values. Next, the materials

used to evaluate mobility at Stoke Quay are described, followed by the methods used in these analyses.

2.3.1 Strontium and oxygen isotopes in tooth enamel

Oxygen and strontium isotope compositions in skeletal tissues reflect the environmental conditions in which an individual was living when a particular tissue formed, and thus both are indicators of geographical location. These isotopic systems are commonly used in archaeological research to distinguish between individuals who spent their early lives in the area near a site and individuals who may have migrated from elsewhere.

The principles of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

Strontium is a trace element whose isotopic composition and abundance vary in different rocks and soils. Strontium isotopic values are expressed as the ratio of the radiogenic ^{87}Sr isotope (the stable product of ^{87}Rb radioactive decay) to ^{86}Sr ($^{87}Sr/^{86}Sr$) (Faure & Powell 1972). Measurement via modern thermal ionisation mass spectrometry (TIMS) is typically precise to 6 decimal places, or to 5 decimal places for multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS)(Copeland et al. 2010). Despite this analytical precision, when $^{87}Sr/^{86}Sr$ ratios are applied in human and animal mobility studies they are usually only considered as meaningful to 4 or 5 decimal places because of the natural variability in biological systems.

Oxygen is an abundant element whose isotopic composition varies around the globe. Oxygen isotopes are reported in parts per mil (‰) in the delta notation as the ratio of $^{18}O/^{16}O$ ($\delta^{18}O$), and are expressed relative to an

international standard, usually Vienna Pee Dee Belemnite (VPDB) or Vienna Standard Mean Ocean Water (VSMOW)(Dansgaard 1964).

Factors affecting $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ variation in geological and hydrological systems

Tectonic movements and other geological processes have resulted in a range of rock types and ages across geographical space, with varying proportions of strontium and rubidium. Rocks with higher initial rubidium levels contain more ^{87}Sr than rocks with lower initial rubidium, and as these rocks erode, their composite minerals may weather at different rates (Ericson 1985; Faure 1977; Aberg 1995). The strontium sources in a given area combine as rocks erode into soil and strontium leaches into water sources, forming an $^{87}Sr/^{86}Sr$ composition that can be used as a characteristic tracer for the area. Due to the large atomic mass of strontium, it does not measurably fractionate as it passes from the soil into biologically available solutions, so the 'local' $^{87}Sr/^{86}Sr$ signal is preserved as it passes on to plants, animals, and humans (Ericson 1985; Flockhart et al. 2015).

Unlike strontium isotopes, oxygen isotopes are subject to strong fractionation in all processes involving transformation of water. These include exchange reactions and phase changes in the hydrological cycle. Phase changes such as evaporation, condensation, and precipitation are largely dependent on temperature, which varies based on factors including seasonal changes, altitude and latitude (Dansgaard 1964; Gat 1996).

Additional factors that influence the isotopic composition of precipitation in a given area include distance from the coast and the amount of seasonal rainfall. This combination of factors is reflected in a wide range of $\delta^{18}O$ values

from around the world; for example, meteoric waters can have $\delta^{18}O$ values ranging from about -40‰ to +6‰ (Figure 2.4), though for Europe the range is much narrower, averaging annually from around -5‰ in the west to -11‰ in the northeast (Ehleringer & Rundel 1988)(Figure 2.5).

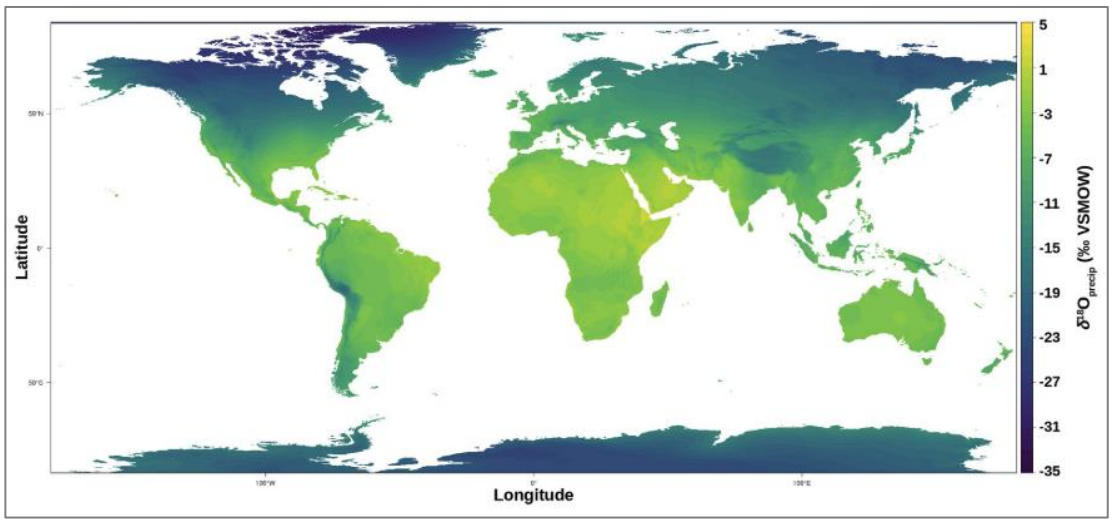


Figure 2.4. Isoscape of global $\delta^{18}O$ patterns modelled from GNIP isoscape date, from Pederzani & Britton 2019, Figure 2).

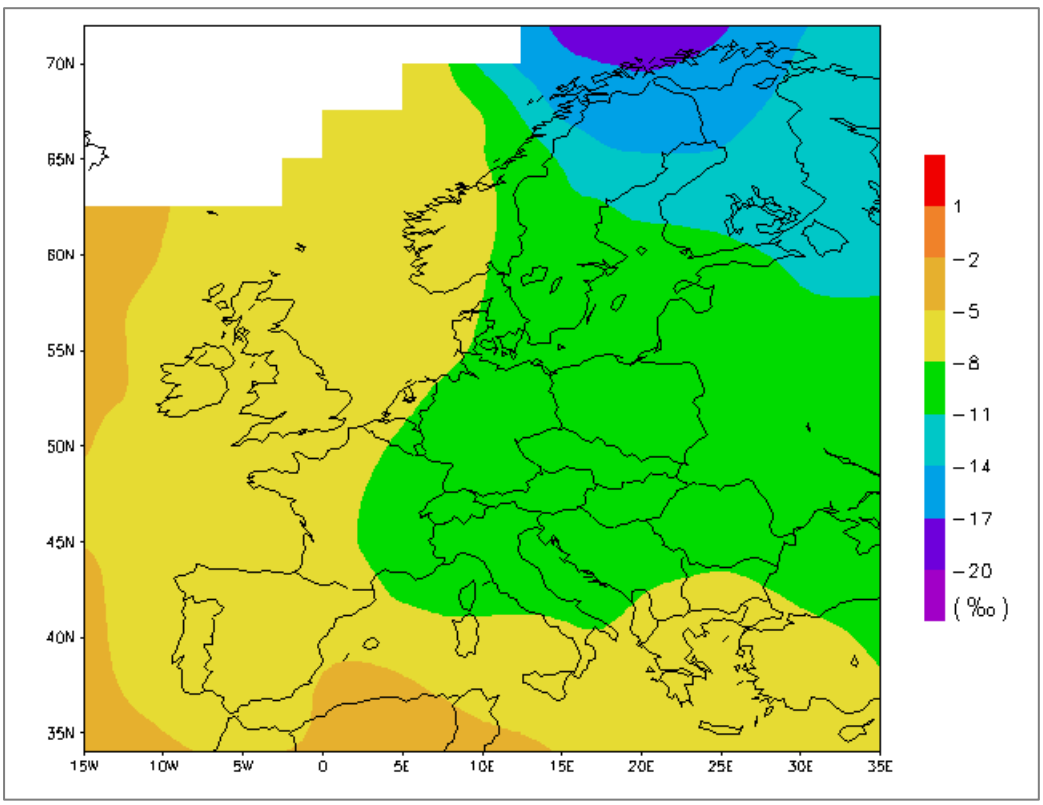


Figure 2.5. Map of weighted annual $\delta^{18}O$ in Europe (IAEA 2001, GNIP Maps and Animations, International Atomic Energy Agency, Vienna. Accessible at http://isohis.iaea.org).

Factors affecting the interpretation of human $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in palaeomobility studies

The $^{87}Sr/^{86}Sr$ ratios from ingested food and water are incorporated into skeletal tissues when strontium substitutes for calcium in biological apatite, a major component of the mineral phase of mammalian teeth and bones (Ezzo 1994; Hoppe et al. 2003). Oxygen is also present in biological apatite, in both phosphate and carbonate groups, both of which form in equilibrium with body water with a temperature-dependent fractionation effect (Bryant & Froelich 1996; Longinelli 1984; Daux et al. 2008; Iacumin et al. 1996). The oxygen in body tissues is derived primarily from ingested fluids, but can also be structurally bound in food (Bryant & Froelich 1995; Kohn 1996; Podlesak et al. 2008; Pederzani & Britton 2019).

Though both oxygen and strontium are present in bones, enamel is more commonly analysed in archaeological studies due to its resistance to diagenetic changes and contamination (Budd et al. 2000; Hoppe et al. 2003; Lee-Thorp & Sponheimer 2003; Zazzo et al. 2004). Human tooth enamel develops during childhood and does not remodel during the lifetime, so isotope values obtained from this tissue indicate geographical region during infancy or childhood (Hillson 1996).

The $^{87}Sr/^{86}Sr$ ratios measured from human tissues reflect the provenience of inputs to an individual's diet, and to a lesser degree, drink. If the $^{87}Sr/^{86}Sr$ ratios of an individual do not match the range in the area of their burial, this is interpreted as an indication that the individual was raised elsewhere (Ericson 1989; Sealy et al. 1991; Bentley 2006; Evans et al. 2012). Because many different regions may have similar underlying bedrock geology, $^{87}Sr/^{86}Sr$ ratios are most

useful when interpreted in conjunction with other isotopes, particularly oxygen isotopes (Pederzani & Britton 2019; Evans et al. 2012; Chenery et al. 2010).

Different geographical areas have predictable mean precipitation $\delta^{18}O$ values, though there is variation by year and by season. The $\delta^{18}O$ values in mammalian tissues primarily reflect the dominant source of ingested water (see above), so by analysing $\delta^{18}O$ in biological tissues and comparing these values to expected values for a given area, one can theoretically detect the individual's general location during tissue development (Ehleringer et al. 2008; Pellegrini et al. 2016). In principle, is therefore possible to detect migration from one isotopically distinct region to another (Budd et al. 2001).

However, in practice this is much more complicated, due to the many fractionation effects between $\delta^{18}O$ in meteoric waters and mammalian body water, and from body water into bone phosphate and carbonate (Longinelli 1984; Luz et al. 1984; Makarewicz & Sealy 2015). The source of consumed oxygen can also have an effect on $\delta^{18}O$, depending on the proportions of oxygen ingested from meteoric water, groundwater, and food sources (Lee-Thorp 2008; Luz & Kolodny 1985; Sponheimer & Lee-Thorp 2001).

Furthermore, additional fractionation can occur in the process of food and drink preparations, as demonstrated by Brettell and colleagues (2012), in a study evaluating the effects of culturally mediated behaviour on ingested $\delta^{18}O$. Practices such as cooking stews, brewing teas and beer, and producing wine, were all shown to significantly raise $\delta^{18}O$ values in those liquids, and if these products were consumed with regularity, they could result in higher $\delta^{18}O$ values than might otherwise be expected (Brettell et al. 2012).

Finally, determining how to define 'local' $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ ranges is a source of much debate (see Pederzani & Britton 2019; Lightfoot & O'Connell 2016). These issues are explored in further detail in Chapter 3, Section 3.4. The following section describes the sample selection strategy for human tooth enamel samples for the study of mobility at Stoke Quay.

2.3.2 Materials: Sampling strategy and tooth selection

As discussed in Chapter 1, one of the three central themes explored in this thesis is mobility in the medieval period, and the treatment of 'foreigners' in Ipswich and other medieval English towns. The goal of this part of the thesis was therefore to use $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of tooth enamel to identify potential 'Nonlocals' as well as some likely 'Locals', and to compare the skeletal characteristics of these two groups along with any differences in pathological conditions. The methods used to interpret the isotopic results are discussed in Section 3.4 of the following chapter.

As with the sampling strategy for human bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis (Section 2.2.2), the sampling strategy for tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis took place in two stages. This section describes the two stages of sample selection, and highlights the difficulty in attempting to predict origins in a cemetery assemblage with few grave goods and relatively uniform burial rites.

Stage 1: Sampling for the pilot study

The strategy for selecting individuals for tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was developed based on the results of a small pilot study conducted under the guidance of Dr Louise Loe at Oxford Archaeology. The pilot study

provided a useful testing ground for tooth enamel sample selection, whereby characteristics correlated with either 'local' or 'nonlocal' interpretations in the pilot could be used to select samples for inclusion in the main thesis study. As with the dietary pilot study, the mobility pilot study results are published in the forthcoming Stoke Quay site monograph (Farber & Lee-Thorp, in press). Dr Loe selected 15 individuals for inclusion in the mobility pilot study for a variety of reasons, shown in Table 2.3).

Sk #	Reason for testing	Age	Sex	Interpretation
5909	Clench bolt burial; evidence of leprosy	45+	F	Nonlocal
5931	Radiocarbon dated	19-20	?M	Nonlocal
7599	Evidence for syphilis; ancestry	26-35	M	Local
8104	Radiocarbon dated; burial inside church	36-45	?M	Local
8532	Evidence for tuberculosis; ancestry	26-35	F	Local
20109	Seax burial	36-45	?M	Nonlocal
20292	Perimortem neck trauma	13-17	?M	Nonlocal
20748	Burial inside church; pillow stones	26-35	F	Local
20808	Barrow burial; ancestry; sharp-force trauma	36-45	M	Nonlocal
21217	Ancestry	36-45	M	Local
21289	Burial in church; perimortem sharp-force spine trauma; Paget's disease	60+	M	Local
21348	"Normal W-E" burial; sacro-iliac ankylosis	18+	F	Local
22114	"Normal W-E" burial; severe periostitis; rib trauma	26-35	M	Local
22739	Elbow trauma	45+	M	Nonlocal
22989	Evidence for tuberculosis; ancestry	26-35	?F	Nonlocal

Table 2.3. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ pilot study sample selection rationale, demographic information, and interpretation (n = 15). Data from Farber & Lee-Thorp, in press.

An analysis of the tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results from the 15 individuals in the pilot study revealed that 'unusual' skeletal or burial characteristics were not necessarily correlated with interpretations of mobility. For example, several individuals sampled for the pilot study because of their "mixed" ancestry assessments or interesting pathologies yielded $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results interpreted as 'local' (Table 2.3). This group included Sk 21217 (mixed ancestry), Sk 7599 (probable syphilis), and Sk 8532 (mixed ancestry and

likely tuberculosis). In contrast, Sk 22989, also of mixed ancestry with likely tuberculosis, did in fact yield 'nonlocal' $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ interpretations (Farber & Lee-Thorp, in press).

That there was no clear-cut pattern for 'local' or 'nonlocal' status based on skeletal characteristics or pathologies is not entirely surprising because of the complexity of human behaviour and physiology, but it did increase the difficulty of designing a sampling strategy for further $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis. However, one useful finding was that individuals interpreted as 'nonlocal' tended to have $\delta^{13}C$ or $\delta^{15}N$ values near the outer margins of the group distribution (Figure 2.6).

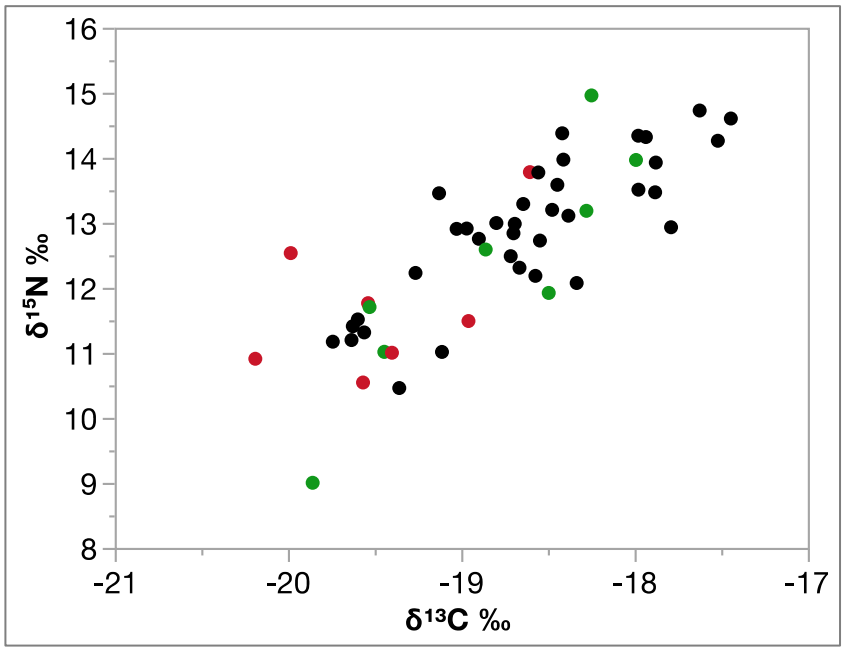


Figure 2.6. Stoke Quay pilot $\delta^{13}C$ and $\delta^{15}N$ results (n = 51), with $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results (n = 15) coloured by interpretations of mobility (green is 'local', red is 'nonlocal'). Data from Farber & Lee-Thorp, in press.

The potential link between diet and mobility did not hold for every individual interpreted as 'nonlocal', but five out of seven individuals interpreted as 'nonlocal' did show this pattern. The 'nonlocals' also included individuals with evidence for skeletal trauma or infectious disease. The possible correlation

between diet and mobility formed the basis for the main study sampling strategy, supplemented by other characteristics such as trauma and disease.

Stage 2: Sampling for the thesis study

Based on the lessons learned from the pilot study, sample selection for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis took place once the majority of the dietary isotope analysis had been completed. The $\delta^{15}N$ and $\delta^{13}C$ results were plotted, and 20 individuals yielding $\delta^{15}N$ and $\delta^{13}C$ results outside a 95% density ellipse were selected for analysis, to test the hypothesis that dietary differences would be a reflection of other differences, including potential nonlocal origins.

Several other individuals were also included because of unusual trauma or pathologies, again following the results of the pilot study. Pathologies of interest included tuberculosis and syphilis, while evidence for trauma included injuries likely resulting from interpersonal violence, as well as trauma possibly resulting from occupational hazards associated with sailing (Boston 2014). The potential sailors were selected for inclusion because, as a port, the population of medieval Ipswich would have included local mariners as well as sailors or fishermen from overseas (Kowaleski 2008; Breen, in press).

As stated above, the goal of the main study was to identify 'nonlocals' among the skeletal assemblage at Stoke Quay and to draw comparisons between the treatment of locals versus 'foreigners', so it was important to include some potential 'locals' for comparison. Therefore, in addition to the 20 individuals selected for their potential to be 'nonlocal,' 10 individuals with average dietary isotope results and no other distinguishing skeletal characteristics were sampled, with the hypothesis that these individuals were more likely to be born

and raised locally. The sample selection criteria and sex distributions for the combined studies are shown in Figure 2.7, overall age and sex distributions are given in Table 2.4, and sex distributions by period are shown in Figure 2.8.

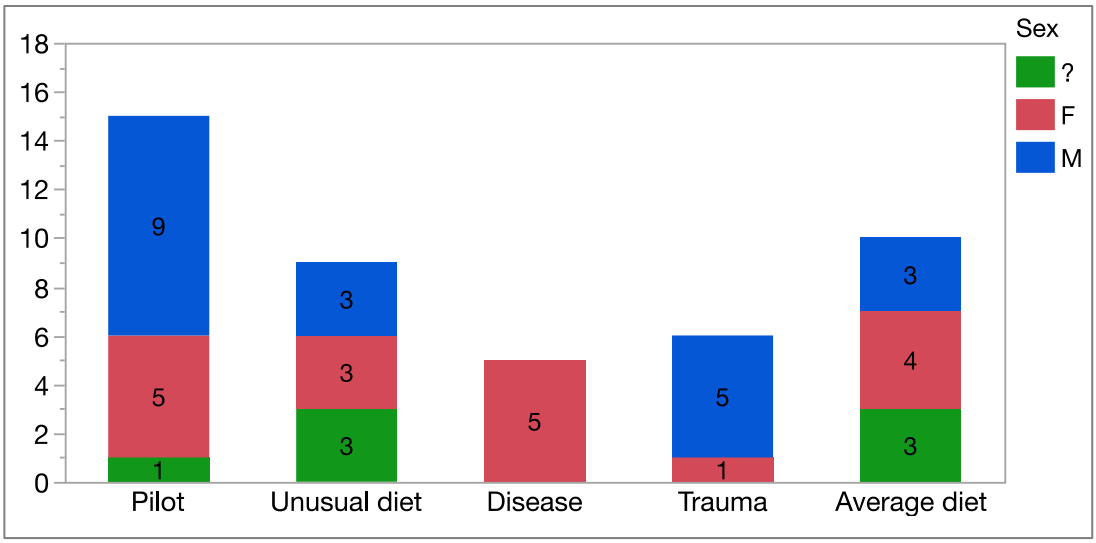


Figure 2.7. Sample selection criteria for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ enamel carbonate analysis, coloured by sex (n = 45).

	Age group							
Sex	**6-12**	**13-17**	**18-25**	**18+**	**26-35**	**36-45**	**45+**	**60+**
Unknown (?)	4	3	1	2	4	0	0	0
Female (F, ?F, ??F)	0	0	2	1	4	6	5	0
Male (M, ?M, ??M)	0	1	1	0	7	6	4	1
Total	4	4	4	3	15	12	9	1

Table 2.4. Age and sex distribution for combined pilot study and main study samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ enamel carbonate analysis, coloured by sex (n = 45).

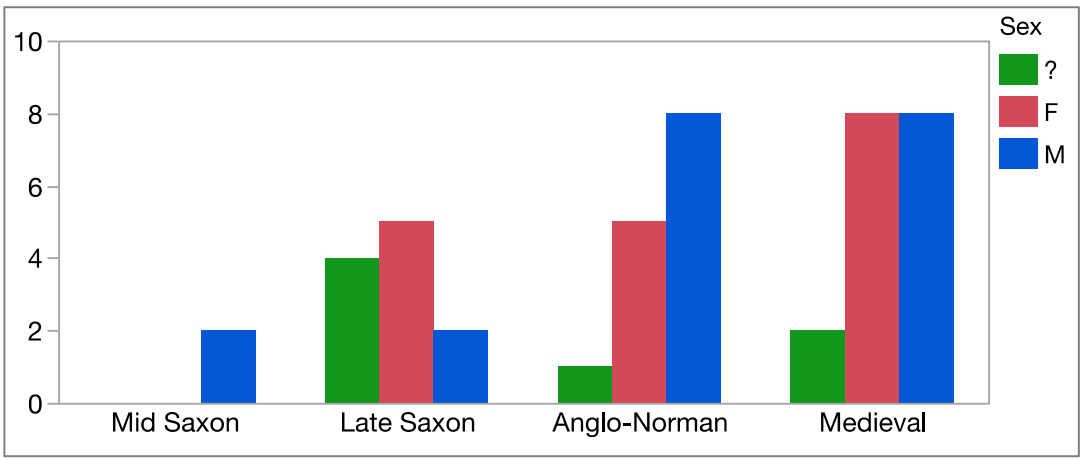


Figure 2.8. Sex distribution by period for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ enamel carbonate analysis, coloured by sex (n = 45).

Tooth selection

Individual dentitions were examined by the author for the presence of well-preserved, adult teeth without caries. To capture the childhood environment while avoiding the isotopic influence of breast-feeding, the second molar was sampled, which mineralizes between 2.5 and 7 years of age (Smith 1991; Hillson 1996). To ensure consistency and reduce destruction of dental enamel hypoplasia and calculus, the lingual surface of the tooth was sampled. If this surface was too thin to obtain enough enamel powder, the mesial or distal surfaces were used.

2.3.3. Methods for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

This section describes the methods used to prepare enamel powder samples, followed by pretreatment and analytical methods for $\delta^{18}O$ analysis of enamel carbonate. Next, methods for isolating strontium and $^{87}Sr/^{86}Sr$ analysis are detailed, followed by a description of the statistical methods used to analyse the data.

Sample preparation

Sample preparation took place at the Research Laboratory for Archaeology and the History of Art (RLAHA). Tooth surfaces were cleaned with an air abrasive system using 5μm aluminium oxide powder, in order to remove the outermost layer of enamel as well as any adhering sediment. Bulk samples of fine powder were then removed using a diamond-tipped dental burr, which was cleaned between samples with a copper wire brush, compressed air, and

methanol. Approximately 20mg of fine powder was set aside for $^{87}Sr/^{86}Sr$ analysis, and 6-10mg reserved for $\delta^{18}O$ analysis.

Pre-treatment for $\delta^{18}O$ analysis

Pre-treatment and analysis for $\delta^{18}O$ took place at RLAHA. Enamel powder designated for $\delta^{18}O$ analysis was loaded into 2ml microcentrifuge tubes, and pre-treated following methods described by Sponheimer and Lee-Thorp (1999). Briefly: 1ml aliquots of 1.5% sodium hypochlorite (NaClO) were added to the microcentrifuge tubes to remove organic contaminants such as humic acids. After 30 minutes, the samples were placed in a microcentrifuge for 3 minutes, and the supernatant liquid was removed with a Pasteurs pipette. Samples were rinsed 3 times with distilled milli-µ H_2O, and centrifuged between each rinse.

Next, 2ml aliquots of 0.1M acetic acid were added to remove inorganic contaminants such as carbonates and iron oxides. After 10 minutes, samples were centrifuged again, and rinsed 3 times with milli-µ H_2O. After the final rinse was removed, the microcentrifuge tubes were temporarily covered with parafilm and placed in a freezer for 5 hours. Samples were then freeze-dried until no further weight loss was observed, about 2 hours.

Instrumental $\delta^{18}O$ analysis

Pre-treated enamel powder was weighed out into 700-1000µg subsamples into pre-cleaned glass tubes. The samples were analysed in a SERCON CAPS device coupled with a SERCON 20/20 IRMS running in dual-inlet mode. Samples were reacted with purified phosphoric acid (H_3PO_4) at 90° C, and the evolved CO_2 were pre-concentrated with a cold finger apparatus before

admission to the mass-spectrometer. Calibration to the VPDB standard was made using the international marble standard IAEA CO1, and instrumental drift was monitored via in-house mammoth and wildebeest enamel standards. As is typical for this type of mass spectrometer, 12 measurements were recorded for each sample, and the average value was normalised using the measured and expected standard values. The expected values for the standards are presented in Table 2.5, along with measured mean values and standard deviations.

As shown in Table 2.5, for the pilot study analyses the mean measurements for standards were in good agreement with expected values, but for the main study analyses the means were slightly further from expected values due to issues with machine reference gas levels. Samples were run once for the pilot, but for the main study duplicate analyses were attempted. However, numerous instrumental problems were encountered during the main $\delta^{18}O$ analysis, resulting in a loss of samples as well as time. Ultimately these issues meant that a portion of the analyses could not be repeated, and some samples did not yield any usable results. Therefore, $\delta^{18}O$ values are only available for 18 of the 30 samples in the main study, or a total of 33 out of 45 individuals in the combined results.

Pilot				
Standard	**n**	**Expected $\delta^{18}O_{VPDB}$**	**Measured mean $\delta^{18}O_{VPDB}$**	**±1σ**
IAEA CO1	10	-2.4	-2.4	0.2
Mammoth	5	-6.7	-6.8	0.2
Main Study				
Standard	**n**	**Expected $\delta^{18}O_{VPDB}$**	**Measured mean $\delta^{18}O_{VPDB}$**	**±1σ**
IAEA CO1	34	-2.4	-2.6	0.6
Mammoth	9	-6.7	-6.7	0.2
Wildebeest	10	1.8	2.1	0.2

Table 2.5. Summary statistics for $\delta^{18}O$ standards, with expected values, mean measured values, and standard deviations for the pilot study and the main study.

Pre-treatment and separation for $^{87}Sr/^{86}Sr$ analysis

The other ~20mg of enamel powder was placed in microcentrifuge tubes and reserved for stable strontium isotopic analysis at the Department of Geological Sciences at the University of Cape Town, South Africa (Laboratory Manager: Dr. Petrus Le Roux). The 15 pilot study samples and six pig enamel samples were sent for analysis at the University of Cape Town laboratory, and I performed strontium separation chemistry for the remaining 30 human samples at the same laboratory, under the guidance of Ms. Kerryn Grey and Ms. Fayrooza Rawoot.

Powdered enamel samples were pre-treated following established laboratory procedures: enamel was dissolved in a HF:HNO_3 mixture in closed Teflon beakers on a hot plate for 48 hours at 140° C, then dried down and converted to nitrate through digestion in a HNO_3 bath. Strontium separation was performed following chemistry described by Miková and Denková (2007), developed from the methods of Pin et al. (1994), using Sr.Spec ion exchange resins (Eichrom Environment, Bruz, France).

Instrumental $^{87}Sr/^{86}Sr$ analyses

Samples were analysed as 200 ppb in 0.2% HNO_3 solution, using the NIST SRM987 reference standard with an $^{87}Sr/^{86}Sr$ normalizing value of 0.710255. All strontium isotope data were corrected for rubidium interference using the measured signal for ^{85}Rb and the natural $^{85}Rb/^{87}Rb$ ratio. Instrumental mass fractionation was corrected using the exponential law and an $^{86}Sr/^{88}Sr$ value of 0.1194. All strontium isotopic analyses were performed on a Nu Instruments

NuPlasma HR in the MC-ICP-MS facility in the Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa (PI: Petrus Le Roux).

The in-house standard NM95 run with the human enamel samples yielded $^{86}Sr/^{88}Sr$ ratios of 0.708890 ± 0.000036 (n = 4). Previous runs of the standard yielded a mean $^{86}Sr/^{88}Sr$ ratio of 0.708915 ± 0.000047 (n = 125).

Statistical analysis

To analyse $^{86}Sr/^{88}Sr$ and $\delta^{18}O$ results, bivariate plots were produced on JMP 14 statistical software. Distributions were tested for normality, following the methods described in Section 2.2.3. Comparisons between pathological indicators for individuals interpreted as 'local' and 'nonlocal' were performed using Chi-Square analysis.

2.4 Skeletal indicators of urban living environments

As described in Chapter 1 (Section 1.3.2), urban environments in the medieval period could be dangerous places to live, with hazards arising from such issues as water and air pollution, food contamination, infectious disease, and interpersonal violence. Studying the impacts of these issues on medieval skeletal remains can provide insight into the quality of life in the past, as well as changes in disease virulence and prevalence over time.

This section provides a brief overview of the palaeopathological indicators and measurements considered in this thesis, as well as the osteological methods used by Oxford Archaeology to evaluate the skeletons.

2.4.1 Palaeopathological indicators of urban living

One of the primary questions addressed in this thesis is how the process of urbanisation affected the inhabitants of Ipswich buried at Stoke Quay. The effects of urbanisation can be manifold, but for the purposes of this study consideration was limited to several pathological indicators, described below: *cribra orbitalia*, maxillary sinusitis, and periostitis, as well as evidence for tuberculosis and other infectious diseases, skeletal trauma, and stature.

Cribra orbitalia

Parasitic infections such as hookworm and gastrointestinal diseases can lead to anaemia, which, if chronic, can result in a condition known as *cribra orbitalia*: porous lesions in the roof of the eye orbits due to subperiosteal inflammation and bleeding or expansion of the diploë (the trabecular 'spongy' inner table of bone)(Ortner 2003; Wapler et al. 2004). This condition has been recorded in high frequencies in both prehistoric and historic archaeological collections worldwide (Reinhard 1992; Walker et al. 2009; Sullivan 2005; Roberts & Cox 2003).

The lesions characteristic of *cribra orbitalia* may have several potential causes, including iron-deficiency anaemia, haemolytic anaemia, and other metabolic diseases such as scurvy and rickets, but it is often found in archaeological contexts consistent with poor sanitation, nutrient-deficient diets, and infectious diseases (Walker et al. 2009; Walker 1986; Blom et al. 2005; Roberts & Cox 2003). Given the association between *cribra orbitalia* and indicators of crowded, unsanitary living conditions, it is considered in this thesis as an indicator of urban living in conjunction with other conditions.

Maxillary sinusitis

Another condition that can develop in urban areas is maxillary sinusitis, visible in skeletal remains as new bone formation on the floor of the maxillary sinuses, the air-filled spaces in the maxillary bones of the face. Sinusitis occurs when inflammation blocks the connection between the sinus and the nasal cavity, causing viral or bacterial infections within the sinus. In chronic cases the inflammation of the sinuses leads to new bone formation. Sinusitis can affect all of the paranasal sinuses, but the maxillary sinuses are often the most easily visible due to their location and the thinness of the anterior walls, which frequently break during or after excavation (Waldron 2009; Boocock 1995).

In modern populations, chronic sinusitis is associated with atmospheric pollution, and irritation of the sinuses can be caused by exposure to industrial air pollution, fossil fuel and wood smoke, pollen, and parasitic dust (Anand 2004; Lewis et al. 1995; Lewis 2002; Waldron 2009). As noted in Section 1.3.2, maxillary sinusitis has been found in higher frequencies in urban assemblages, particularly amongst males. Higher urban prevalence may be partly due to poor air quality conditions caused by the tanning, smithing, pottery, and textile industries (Lewis et al. 1995; Summer 1971; Lancaster 1990; Roberts & Manchester 2010). With this apparent relationship between urban living and maxillary sinusitis, the condition is used in this thesis as another indicator of urbanisation.

Periostitis

Chronic inflammation can lead to other pathological conditions such as periostitis, the formation of new bone on the membrane (periosteum) covering

the external surface of bone. It is often used as a nonspecific stress indicator in skeletal remains, as it may be caused by a number of pathological conditions including localised and systemic infections, haemorrhages from trauma or scurvy, rickets, soft-tissue lesions, tuberculosis, syphilis, leprosy and other conditions including anaemia and parasitic infections (Waldron 2009; Roberts & Cox 2003; Grauer 1993). The tibia is the most commonly affected bone in archaeological assemblages, possibly because it lies close to the surface of the skin and can be subject to frequent minor injuries (Roberts & Manchester 2010; Waldron 2009; Goodman et al. 1988).

As a non-specific indicator of stress, periostitis alone is not diagnostic of specific conditions, but in conjunction with other pathological conditions it is interpreted as an indication of living conditions (Roberts & Cox 2003; Grauer 1993). Further information can be gleaned by whether the periostitis is active or healed at the time of death: healed periostitis indicates that an individual has survived the cause of the inflammation, while active periostitis indicates that they were still fighting the infection when they died (Roberts & Manchester 2010; Loe et al., in press).

Stature

Diet has a strong influence on the immune system's ability to fight infection, and diets lacking essential nutrients can lead to metabolic diseases such as scurvy and iron-deficiency anaemia. A poor diet can affect skeletal and dental development, and insufficient nutrients in childhood and adolescence can result in reduced adult stature (Roberts & Manchester 2010). Reduced stature

may be associated with urbanisation, but this has not been fully explored (Lewis 2002).

In a survey of mean estimated stature across Britain, Roberts and Cox (2003) found an increase in mean stature for both males and females from the 5th-11th centuries, followed by a decline from the mid 11th century through the late Medieval period. The difference in stature between these time periods may be due to an influx of taller people during the earlier period, or it may be related to the increased population densities and poorer living environments common to the later Medieval period (Roberts & Manchester 2010; Lucy 2000; Steckel 1995). With the relationship between stature and diet, and the potential relationship between stature and urbanisation, patterns in mean estimated stature at Stoke Quay can provide valuable contextual information regarding the impact of diet and urbanisation during the medieval period.

Specific infectious diseases

Two main pathological categories are considered in this thesis in relation to specific infectious diseases: tuberculosis and treponemal disease. Tuberculosis in humans is usually caused by *Mycobacterium bovis*, a zoonosis transmitted from cows to humans primarily via the consumption of infected milk and meat, and *Mycobacterium tuberculosis*, transmitted between humans. *M. tuberculosis* spreads when an infected person coughs and expels bacilli, which are breathed in by another person, or through contact with bacilli in excreted fluids, where the bacilli survive for some time outside the body (Roberts & Manchester 2010). Because it spreads easily from person to person, transmission rates increase with population density, making this disease more

common in urban areas (Roberts & Manchester 2010; Roberts & Cox 2003; Waldron 2009).

Only about 2% (at most 7%) of tuberculosis infections affect the skeleton, so prevalence rates from archaeological assemblages likely grossly underestimate the true past prevalence rates for this disease (Roberts & Cox 2003; Waldron 2009; Aufderheide & Rodriguez-Martin 1998).

Like *Mycobacterium tuberculosis,* treponemal disease is also passed from human to human. Treponemal disease encompasses four infectious diseases caused by bacteria from the genus *Treponema*, which include venereal syphilis (and congenital syphilis), Yaws, Bejel (endemic syphilis), and Pinta. Venereal syphilis is passed through sexual contact and can also pass through the placenta to infect a foetus in utero (congenital syphilis), and Yaws is not sexually transmitted but is passed from person to person. Yaws and venereal syphilis are indistinguishable in the skeleton, and while venereal syphilis is known to affect populations worldwide, Yaws is primarily a tropical disease. Syphilis undergoes three stages, known as primary, secondary, and tertiary. The skeleton is usually only affected in tertiary syphilis, which occurs in about 1/3 of infected individuals, and can arise up to thirty years after the initial infection (Waldron 2009; Roberts & Cox 2003).

Skeletal changes used to identify treponemal disease include periosteal new bone formation, particularly to the frontal bone, ribs, sternum, and tibia. Tibial periostitis can be severe, and is often located on the anterior tibia, giving rise to the description of the condition as 'sabre tibia'. During the later stages of the disease, lytic lesions known as *caries sicca* form, most frequently on the

frontal bone but sometimes affecting large areas of the skull (Waldron 2009; Hackett 1976; Harper et al. 2011).

Trauma

Skeletal trauma can take the form of fractures and dislocations, and the types of trauma in a population can reveal much about lifestyle, including the living environment (rural or urban), occupations, and interpersonal violence. Trauma is among the most common conditions identified in the palaeopathological literature, and by studying the morphology, location on the body, and state of healing of traumatic injuries, we can learn about the cause of injuries and how they were treated in the past (Roberts & Manchester 2010).

In this thesis, discussions of trauma primarily relate to fractures, and differentiating between accidental versus interpersonal violence-related injuries. It can be difficult to distinguish between accidental and intentional trauma, but some patterns have been identified for injuries likely resulting from interpersonal violence. These include injuries to the cranium, particularly the face and skull vault above the hat brim line, as well as transverse rib fractures, defensive injuries to the hands and forearms, and 'parry fractures' on the distal ulna (Roberts & Manchester 2010; Jurmain 1999; Judd 2002b, 2008; Krakowka 2017a,b).

Sharp-force trauma is often consistent with interpersonal violence, particularly when lesions have distinctive characteristics for the type of weapon involved (Byers 2015). Violent assaults with sharp objects often result in sharp-force trauma to the ribs, palmer surface of the hand bones, and cervical vertebrae (Krakowka 2015). Along with these defensive injuries, interpersonal

violence can also be inferred from fractures to the fourth and fifth metacarpals, a common result of punching with a closed fist (Brickley 2006).

Interpersonal violence appears to have increased during the medieval period, particularly in urban areas such as London, where men were more frequently affected (Walker 2012; Lewis 2002; Krakowka 2017).

2.4.2 Osteological methods employed by Oxford Archaeology

The Heritage Burials team at Oxford Archaeology (OA) analysed each skeleton in the Stoke Quay collection for a broad suite of osteological measurements and palaeopathological indicators. Osteological analyses were performed following published guidelines (Brickley & McKinley 2004), and digitally recorded using forms created to capture all pertinent demographic and palaeopathological data. For each skeleton, osteologists recorded preservation status and inventories of bones, joint surfaces and teeth. When possible, estimations of sex, age, ancestry, metric measurements and stature calculations were recorded, as well as nonmetric traits and full descriptions of any pathological lesions (Gibson et al., in press).

Cribra orbitalia was scored following Stuart-Macadam (1991:101-113). If maxillary sinuses were preserved and observable, maxillary sinusitis was recorded on a presence/absence basis. Presence of the condition was recorded if new bone deposition was seen on the surfaces of the maxillary antra, following the guidelines of Boocock et al. (1995). Periostitis was recorded following standard texts (Aufderheide & Rodrigues-Martin 1998; Ortner 2003; Resnick 1995; Gibson et al., in press).

2.4.3 Acquisition and use of palaeopathological data in this thesis

Summary data tables from OA were used as a first step toward selecting skeletons for analysis in this thesis, considering age, sex, Cemetery Group, Phase, preservation level, presence of dentition, and ancestry assessments. The online database was used to gather detailed information on pathological lesions, trauma, and stature for each individual. The author then transformed the detailed osteological and palaeopathological information from the database into simple presence/absence categories.

In cases where dental pathology is referenced in this thesis, it is also on a presence/absence basis from observations made by OA osteologists following definitions given in Hillson (1996). The author used the OA database to determine if trauma was present or absent on each skeleton, and when it was present, it was interpreted by the author as consistent or not consistent with interpersonal violence, along with the timing of the trauma (antemortem or perimortem), according to information provided in the database and the author's own evaluation of the trauma patterns following Krakowka (2017a,b), Roberts & Manchester (2010); Jurmain (1999); Judd (2002b, 2008), and Galloway (1999).

The incidence of pathological lesions and skeletal trauma were reported as crude prevalence rates (CPR; the number of cases out of the total number of individuals in the sample population) rather than true prevalence rates (TPR; the number of cases relative to the number of skeletal elements present in which the condition could occur). Crude prevalence rates were used to allow comparisons with published sources, which frequently record CPR rather than TPR.

Chapter 3: Establishing baselines for human diet and mobility

3.1 Introduction

This chapter lays the foundation for the remainder of the thesis, by establishing baseline isotope ranges for interpreting human diet and mobility. Baselines for $\delta^{13}C$, $\delta^{15}N$, and $^{87}Sr/^{86}Sr$ interpretation are constructed through faunal analyses, while the $\delta^{18}O$ interpretation relies on published ranges.

To adequately discuss the faunal samples, this chapter is presented as miniature study of its own, beginning with an overview of medieval diet (Section 3.2). Section 3.3 focuses on the faunal samples analysed for $\delta^{13}C$ and $\delta^{15}N$, beginning with the sampling strategy and a description of materials and analytical methods, followed by a presentation of the results, discussed by time period. The section ends with a synthesis of the findings from the faunal $\delta^{13}C$ and $\delta^{15}N$ analyses and how they are used to inform interpretations of human diet.

The last section of this chapter (3.4), addresses the faunal materials and methods used to establish a baseline for 'local' bioavailable $^{87}Sr/^{86}Sr$, which are discussed in relation to expected values for southeast England from published isotope distributions. Finally, the methods used to establish a 'local' $\delta^{18}O$ range are discussed, including an unsuccessful attempt to sample local water sources.

3.2 Overview of medieval diet

Human diet during the medieval period was not static; rather, it evolved throughout the Mid Saxon to Medieval periods as agricultural methods developed and population pressures shifted. Food quantity and availability varied by region, and was impacted by factors such as soil type, rainfall,

temperature, and topography (Pearson 1997). Diet was further impacted by socioeconomic and demographic factors such as occupation, income, gender, population density, and cultural norms. In the Medieval period, changes in climate and labour shortages after the Black Death caused disruptions to the food supply that had a major impact on human diet and health (Dyer 2000; Roberts & Cox 2003). The consumption of fish was discussed in Chapter 1, while some of the other basic components of medieval diet are discussed below.

3.2.1 Grains

Grains typically formed the bulk of caloric intake, particularly in the earlier medieval period, with a focus on subsistence farming in many areas from at least the 6th century (Schofield 2006; Hagen 2006). Crop production became more specialised and intensified during the period from c. 600-900 AD, contemporary with the rise of the Anglo-Saxon kingdoms. The increased productivity of arable land in the Mid Saxon period was accomplished through several means, including the adoption of higher-yielding crops, technological innovations including the use of the mouldboard plough, and managed manuring of fields (Ooisthuzen 2011; Hamerow 2002).

The types of grains that could be most easily cultivated depended upon the soil type and climate of a given area, but bread wheat and barley were the dominant grain crops in the Mid Saxon period. Wheat was the preferred grain for bread, due to its superior, light consistency compared to bread made from other grains, but it was in most cases a luxury consumed primarily by the wealthier levels of society until later in the medieval period (Hagen 2006; Hooke 2011).

Historical documents such as manorial accounts of food rations for harvest workers demonstrate that bread was mainly baked from barley until the early 14th century, when the use of wheat and rye increased. Wheat bread was predominant after the mid 14th century (Dyer 2003). Some variations were possible depending on local soils and tastes; for example, archaeobotanical evidence from Ipswich indicates that rye may have been a major component of local breads (Maclaren 2001). Bread could also be made out of oats, an important secondary crop in many areas, and in times of need poor peasants would add ground peas, beans or acorns to their bread (Pearson 1997; Hammond 1995).

In addition to being baked in bread, grains were also consumed in fermented form. The fermentation process increased the nutritional value of the grain, and the resulting alcohol content made it safer to drink than many water sources (Hagen 2006; Brettell et al. 2012). The most common alcoholic beverage was ale, for which the preferred malting grain was barley, though wheat, oats and rye were also used. Ale was so important that it was usually included in rations for harvest workers and in daily monastic allowances (Bailey 2007; Dyer 2000; Brettell et al. 2012; Pearson 1997).

Pottage, a cereal-based porridge, was another common component of medieval diet, particularly among the lower classes (Dyer 2000; Pearson 1997). Pottage could also include legumes, vegetables, herbs, and meat. The poorest members of society likely subsisted mainly on bread and vegetables, which could have been supplemented seasonally by nuts, berries, and mushrooms (Brettell et al. 2012; Hagen 2006; Hammond 1995; Roberts & Cox 2003).

3.2.2 Animal products

Animal products constituted another important element of medieval diet. Meat was mainly provided by cattle, sheep, and pigs, though fowl including chickens and geese were also consumed (Sykes 2006; Serjeantson 2006). During the early medieval period, meat was mostly consumed by the wealthy, while less wealthy individuals could enjoy this luxury at feast times (Hagen 2006).

Throughout the medieval period, cattle were the most commonly consumed species (Hamerow 2007; Sykes 2006). Secondary species were sheep and pigs, whose relative abundance depended on regional landscapes and population density. Cattle and sheep could have been reared close to home in the earlier medieval period and later in rural areas. Because of the larger areas of land necessary to sustain cattle and sheep, towns would have been provisioned with these species brought in on the hoof from surrounding farmlands (Sykes 2006; Crabtree 1996; Hagen 2006). In addition to meat, cows and sheep provided the important secondary products of milk and wool, respectively. Milk could be drunk fresh in the summertime, and the rest of the year it could be consumed in preserved forms as cheese and butter (Dyer 2000; Sykes 2006).

Pig rearing efficiently transforms low-quality cereals and food waste into nutritious meat products. In earlier periods, pigs could be reared partially on pannage, or foraged acorns and other resources from wooded areas. This low-input husbandry was very effective, as most pigs could be slaughtered at the beginning of winter and their products preserved. Later, when population densities increased and towns developed, pigs were reared in back gardens, though in some areas they also roamed the streets consuming rubbish (Albarella 2006; O'Connor 2011).

Despite their importance, meat and milk products were not the only sources of dietary protein in the medieval period. Fish were also an important protein source. As discussed in Chapter 1, the exploitation of marine fish changed dramatically between the Mid Saxon and Medieval periods, shifting from a reliance on freshwater and migratory species in the Mid and early Late Saxon periods, to a predominance of fresh and preserved herring, cod, and other marine fish in the Anglo-Norman and Medieval periods. This shift had wide-ranging effects on diet, trade, and occupations throughout the North Sea region.

3.3 Establishing faunal $\delta^{13}C$ and $\delta^{15}N$ baselines

This section describes the sampling strategy for faunal samples selected to establish a $\delta^{13}C$ and $\delta^{15}N$ baseline for human diet at Stoke Quay, followed by a description of the materials and methods used for this analysis. The results are presented for each period in turn, and the section ends with a discussion of the application of the faunal data to human dietary interpretations.

3.3.1 Sampling strategy

With one of the primary research aims of this thesis focusing on the timing and extent of the 'fish event horizon' at Ipswich, analysing archaeological fish bones would be a logical first step for establishing human dietary baselines at Stoke Quay. Fish bones were found in considerable quantities at Stoke Quay, with over 11,000 bones recovered, primarily through bulk flotation (Nicholson, in press). However, fish bones could not be obtained in time for inclusion in this thesis, so the faunal sampling strategy instead focused on capturing the breadth of $\delta^{13}C$ and $\delta^{15}N$ values for the common domesticates.

The potential variability in animal husbandry methods across different landscapes, combined with shifting climate and environmental conditions through the long duration of Stoke Quay's use, required sampling a large number of animal bones from all time periods to construct a baseline for human diet. The faunal sampling strategy was established with a two-fold aim: 1) to characterise the range of dietary inputs available at Stoke Quay; and 2) to begin evaluating how food sources for Ipswich might have changed over time. A range of species was selected from each Phase, with the aim of achieving adequate sample sizes for several major species for statistical comparisons across time periods.

Faunal bones were recovered from all Phases at Stoke Quay, but were particularly numerous in the Mid Saxon period and scarcer in the Late Medieval period. In total, c. 71,250 bones were recovered by hand collection, and 60,172 were recorded. Cattle were by far the most numerous throughout all periods at Stoke Quay, followed by sheep/goat and pig (Figure 3.1). Within each period, species varied by size, age at death, and elements present (Rielly, in press).

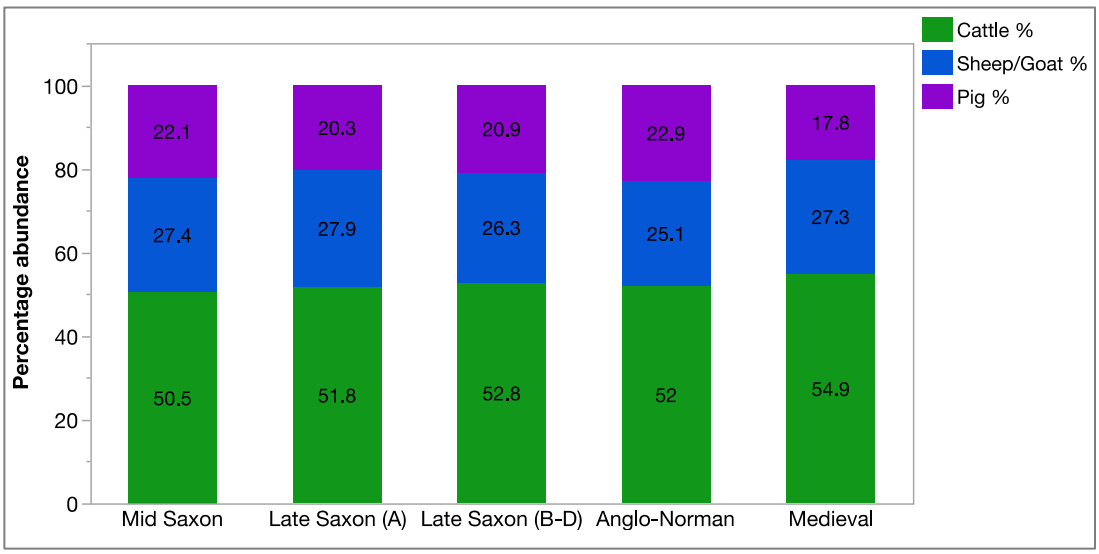


Figure 3.1. Percentage abundance for major domesticates by period based on total fragment counts. Late Saxon data are separated by site area (data from Rielly, in press: Table 7.5). Total fragment counts for each period: Mid Saxon: 12,349, Late Saxon (A): 798, Late Saxon (B): 3,539, Anglo-Norman: 3,892, Medieval: 2,433.

Many isotopic studies of medieval cemetery assemblages have included small numbers of faunal remains. Cemetery sites are often limited to human burials, so any faunal remains available will be from sites nearby or in the general region of interest. In other cases, faunal bones may be recovered from sites but these are often few in number. For example, Bownes and colleagues (2018) analysed 43 humans at the site of Box Lane, Pontefract, in West Yorkshire, and though they analysed every available animal bone in the collection, this only amounted to eight samples. As another example, in a study by Mays and colleagues (2012) of 76 humans from 18 Anglo-Saxon sites dating to the 5th-7th centuries, no food remains were available from any of the sites.

For this thesis, a very different problem was encountered: with such a large assemblage, the issue was not whether there would be enough animal bones to choose from, but rather, how to best choose a representative sample from such a large collection.

Species Selection

Fauna were selected from deposits dating to the Later Mid Saxon to Medieval periods (Phases 3-6). Fewer than 10 faunal bones were excavated from Early Mid Saxon deposits (late 6th-8th centuries AD), so to avoid destroying scarce material these bones were not sampled. The overall sampling strategy is outlined first, followed by information about animal ages and skeletal elements.

Samples were selected after reviewing the faunal database created by Kevin Rielly, zooarchaeologist at Pre-Construct Archaeology (PCA). To ensure, to the maximum degree possible, that the selected samples were from securely dated contexts with limited post-depositional disturbance, eligible contexts were

restricted to deposits from pits and wells containing over 500 animal bones, followed by those with over 100 bones (Figure 3.2). Bones from richer deposits were thought to have a higher chance of representing actual food waste.

Textual and zooarchaeological evidence indicate that the three major domesticates— cattle, sheep/goat, and pig—comprised the majority of the animal protein consumed by medieval townspeople (Sykes 2006; Dyer 2000). Several studies have found great variability in domesticate $\delta^{13}C$ and $\delta^{15}N$ depending on diet and location. For example, grazing cattle and sheep/goats on saltmarshes can raise both $\delta^{13}C$ and $\delta^{15}N$ values in these animals (Britton et al. 2008), while pig diets can include everything from forest pannage to human refuse (Albarella 2006).

Even at a single site, domesticates can yield a wide range of $\delta^{13}C$ and $\delta^{15}N$. Sheep/goats at Roman to Iron Age Yarnton yielded a $\delta^{15}N$ range of over 5‰, while the pig $\delta^{15}N$ range was approximately 3‰ (Lightfoot et al. 2009). Hamilton and Thomas (2012) found broad ranges in pig $\delta^{13}C$ and $\delta^{15}N$ in animals of varying ages and from different periods, with a $\delta^{13}C$ range up to 3‰ and a $\delta^{15}N$ range of nearly 10‰. Characterising such variation in values for these common food animals requires large sample numbers.

With this in mind, and the objective of making statistically meaningful comparisons between time periods and species, a sampling strategy was devised consisting of 10 cattle, 10 sheep/goats, and 10 pigs from each period. This would result in 40 total individuals for each species, considered sufficient to capture the potential variation in $\delta^{13}C$ and $\delta^{15}N$. Small numbers of additional species were also sought, with a goal of five chickens and four geese for each period, plus one horse and one dog to represent comparative herbivore and omnivore values.

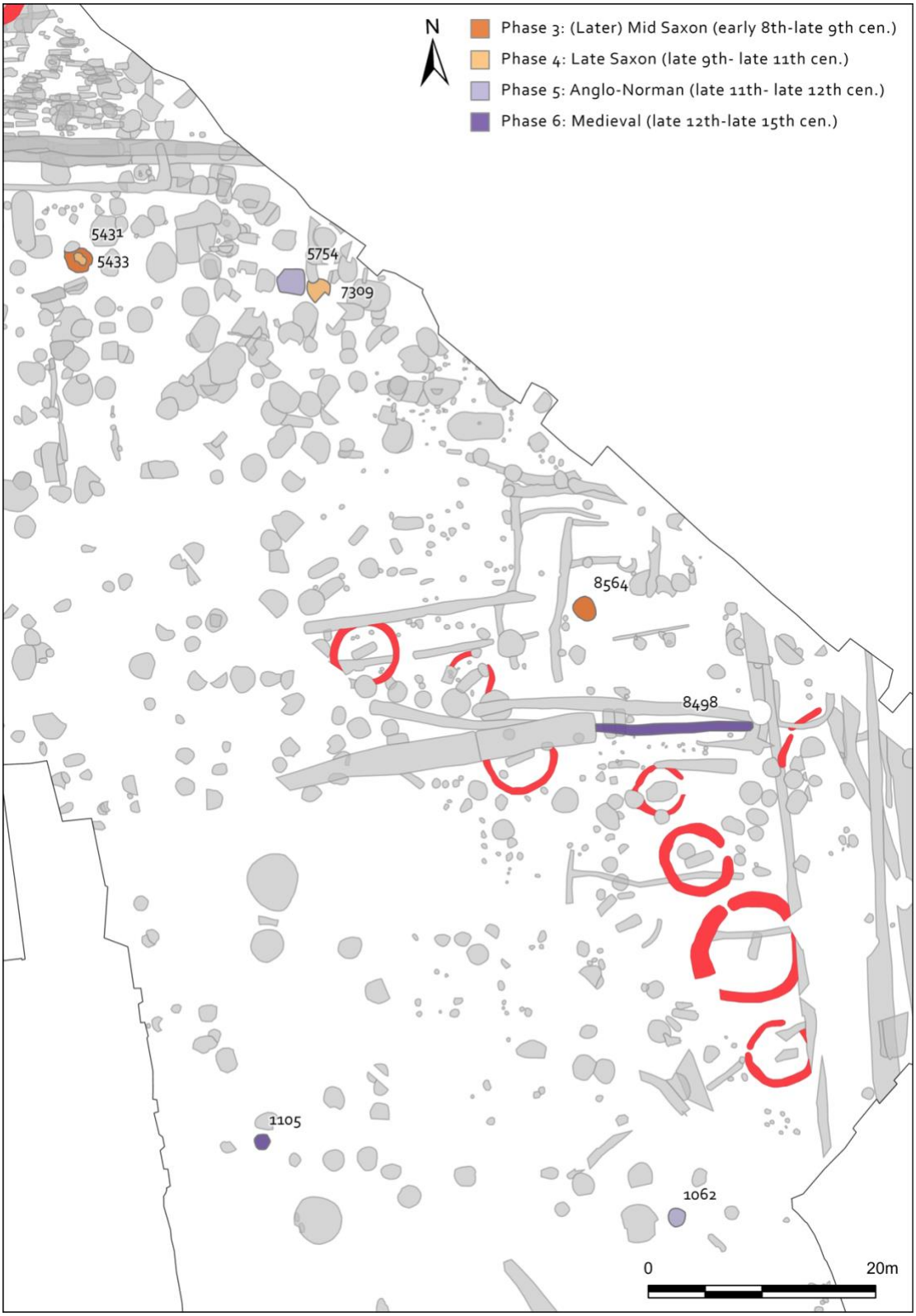


Figure 3.2. Archaeological features from the Mid Saxon through Medieval periods from which faunal samples were obtained for $\delta^{13}C$ and $\delta^{15}N$ analysis. Map produced from data provided by Oxford Archaeology/Pre-Construct Archaeology.

Table 3.1 shows the planned sampling strategy for each period and the actual sample numbers obtained. The disparities between these figures are due to the short amount of time available to obtain samples at the PCA storehouse, and discrepancies between how bones were listed in the database and how they were physically stored. The sample distribution is not equal between phases, but with 98 samples these fauna provide considerable comparative isotopic data for establishing a dietary baseline for humans at Stoke Quay.

Species	Planned (per period)	Actual			
		Mid Saxon	Late Saxon	Anglo-Norman	Medieval
Cattle	10	4	3	7	3
Pig	10	7	8	11	3
Sheep/goat	10	5	7	10	3
Horse	1	-	-	1	-
Dog	1	-	-	1	-
Goose	4	6	1	1	2
Chicken	5	6	2	5	-
Cat	-	-	-	1	-
Mallard	-	-	-	1	-
Phase Totals	41	28	21	38	11
Overall Total	164	98			

Table 3.1. Planned vs. actual species counts per period for faunal $\delta^{13}C$ and $\delta^{15}N$ analysis.

Bone selection

Given the extreme time constraints in the PCA storehouse and the author's level of proficiency in faunal identification, mandibles were selected to ensure that individual animals were not sampled twice, as they are easily identifiable to the three major domesticates. For each context, mandibles were selected from the same side except when there were clear age differences between specimens. Subadult to mature adult animals were selected to capture the greatest breadth of isotopic values for each species. Age was identified using tooth eruption and wear, following Grant (1982) and Schmid (1972).

Bones from additional animal species proved difficult to find and identify quickly. Horse cranial bones and dog humeri were easily identified, but bird and cat bones were removed from comingled bags and sent to Kevin Rielly for identification. As with the three major domesticates, bird bone selection aimed to avoid sampling the same individual twice. Humeri and tarsometatarsi were preferred, and for each context bones came from the same side unless they were clearly different individuals based on size and developmental stage (Table 3.2).

Period	Species	N	Bones sampled	Side	Total #
Mid Saxon	Cow	4	Mandible	L (x4)	28
	Sheep/goat	5	Mandible	L (x3), R (x2)	
	Pig	7	Mandible	L (x3), R (x4)	
	Chicken	6	Humerus	L (x1), R (x1)	
			Femur	L (x1)	
			Metatarsus	L (x1, F), R (x1, M)	
			Ulna	L (x1)	
	Goose	6	Humerus	L (x2), R (x2)	
			Tibia	R (x1)	
			Metacarpus	R (x1)	
Late Saxon	Cow	3	Mandible	R (x3)	21
	Sheep/goat	7	Mandible	L (x2), R (x5)	
	Pig	8	Mandible	L (x3), R (x5)	
	Chicken	2	Tibia	L (x1), R (x1)	
	Goose	1	Radius	?	
Anglo-Norman	Cow	7	Mandible	L (x1), R (x6)	38
	Sheep/goat	10	Mandible	L (x4), R (x6)	
	Pig	11	Mandible	L (x5), R (x6)	
	Chicken	5	Metatarsus	L (x2), R (x1)	
			Humerus	L (x1)	
			Femur	R	
	Goose	1	Scapula	R	
	Horse	1	Maxilla	R	
	Mallard	1	Tibia	R	
	Dog	1	Humerus	L	
	Cat	1	Ulna	R	
Medieval	Cow	2	Mandible	L (x2)	10
	Sheep/goat	3	Mandible	L (x3)	
	Pig	3	Mandible	L (x1), R (x2)	
	Goose	2	Femur	L (x1), R (x1)	
Total					98

Table 3.2. Faunal samples from Mid Saxon to Medieval Stoke Quay (n = 98).

3.3.2 Methods

Sample preparation and collagen extraction

Faunal bone surfaces were cleaned and samples were removed following the methods described previosuly (Section 2.2.3). Mandible samples were removed from the least conspicuous location on each bone, avoiding butchering evidence. Long bone samples were removed from broken ends when possible, to minimise damage to intact surfaces.

Collagen extraction followed the methods of O'Connell & Hedges (1999)(see Section 2.2.3), and was performed in two batches, starting with the cow, sheep/goat, pig, and horse bones. In the first round of extraction and analysis, several samples yielded collagen quality indicators outside the acceptable range (Section 2.2.3). Collagen was re-extracted from these bones in the second batch, with an additional step following the method of Szpak (2017).

Briefly, bone samples were demineralized in 0.5M HCl, then rinsed in milli-µ H_2O until they reached neutral pH. The H_2O was replaced with 5ml aliquots of room temperature 0.1M NaOH to remove humic contaminants. The NaOH was replaced every 20 minutes until no further colour change was observed, then the NaOH was replaced with milli-µ H_2O. The H_2O was replaced every 24 hours until samples reached pH neutral. The samples were then placed in pH3 H_2O and analysed as described above. The second batch included dog, cat, chicken, goose, and mallard bones, also treated with a precautionary base wash.

Instrumental Analysis

After collagen extraction, subsamples of 0.85-1.15mg were weighed into pre-cleaned tin capsules. Instrumental analysis proceeded as in Section 2.2.3.

Statistical analyses

Statistical analyses were performed following the methods described in Chapter 2, Section 2.2.3.

3.3.3 Results

This section presents the faunal $\delta^{13}C$ and $\delta^{15}N$ results separately by period, including summary statistics and data distributions for each assemblage, and plots of results. Individual values are given in Appendix 1.

Mid Saxon

Basic statistics for each species are summarised in Table 3.3a. Figure 3.3a presents the Mid Saxon $\delta^{13}C$ and $\delta^{15}N$, and a line of best fit shows a weak positive correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.17$, $p = 0.029$). As shown in Figure 3.3a, the Mid Saxon fauna include one $\delta^{13}C$ outlier, 5432-G3, identified as a goose but with isotopic results indicating it may be a migratory marine bird. The outlier was excluded and analyses were re-run.

The revised group $\delta^{13}C$ mean is -20.0‰ (±1.2, 1σ), and the data are normally distributed (Shapiro-Wilk W test, $W = 0.9745$, $p = 0.7245$). The revised $\delta^{15}N$ mean is 8.1‰ (±2.2, 1σ), and the data are not normally distributed (Shapiro-Wilk W test, $W = 0.9026$, $p = 0.0154$). The revised scatterplot is shown in Figure 3.3b, and revised summary statistics for the geese and combined samples are given in Table 3.3b.

Species	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Chicken	6	10.7	1.5	8.5	12.5	-19.8	0.6	-20.5	-18.9
Goose	6	9.4	2.3	6.6	12.1	-21.1	3.2	-23.6	-14.7
Cow	4	7.0	0.7	6.4	7.7	-22.0	0.2	-22.2	-21.8
Sheep/Goat	5	7.3	1.7	4.8	9.3	-20.4	1.5	-22.4	-18.5
Pig	7	6.5	0.6	5.4	7.4	-21.0	0.6	-21.7	-20.3
Combined	28	8.2	2.2	4.8	12.5	-20.8	1.6	-23.6	-14.7

Table 3.3a. $\delta^{15}N$ and $\delta^{13}C$ summary statistics for Stoke Quay Mid Saxon fauna (n = 28).

Species	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Goose	5	9.0	2.3	6.6	12.1	-22.4	0.7	-23.6	-21.8
Combined	27	8.1	2.2	4.8	12.5	-21.0	1.2	-23.6	-18.5

Table 3.3b. Revised $\delta^{15}N$ and $\delta^{13}C$ summary statistics for Stoke Quay Mid Saxon fauna (n = 27), with outlier 'goose' removed.

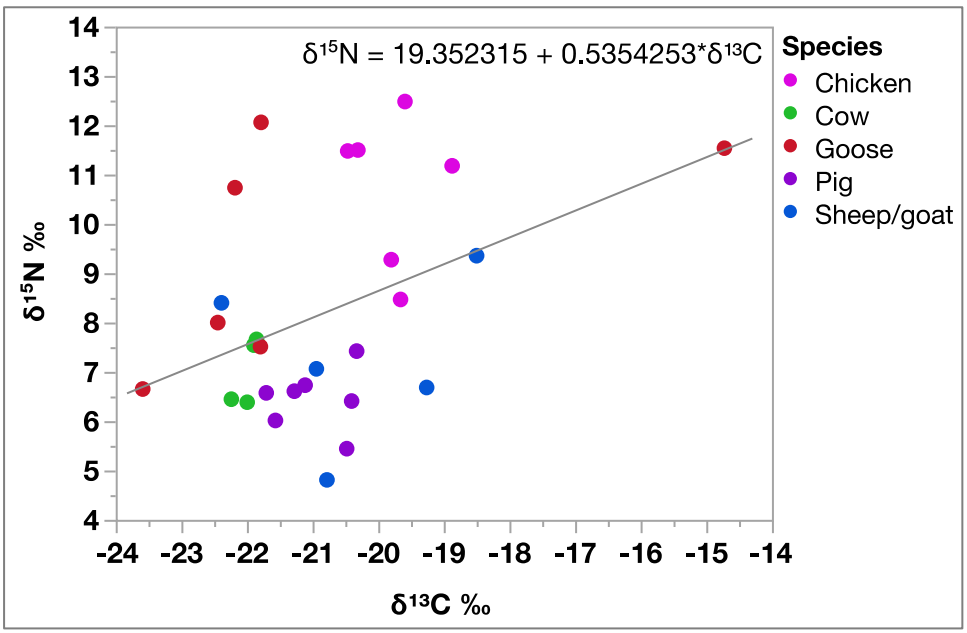


Figure 3.3a. $\delta^{13}C$ and $\delta^{15}N$ for Stoke Quay Mid Saxon fauna (n = 28). A line of best fit (in grey) shows a low correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.17$; $p = 0.029$).

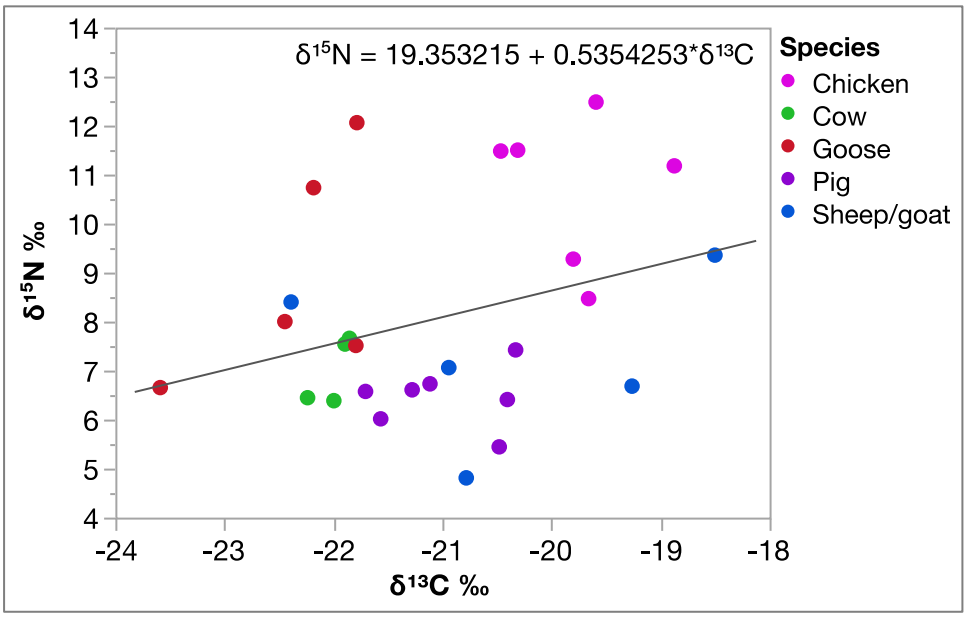


Figure 3.3b. $\delta^{13}C$ and $\delta^{15}N$ for Stoke Quay Mid Saxon fauna with goose outlier removed (n = 27). A line of best fit (in grey) shows very low correlation between $\delta^{13}C$ and $\delta^{15}N$ (r^2 = 0.09; p = 0.1222).

Late Saxon

Basic statistics for each species are summarised in Table 3.4. The $\delta^{13}C$ mean is -21.6‰ (±0.8, 1σ), and the data are normally distributed (Shapiro Wilk W test, W = 0.9156, p = 0.0708). The $\delta^{15}N$ mean is 7.3‰ (±1.8, 1σ), and the data are normally distributed (Shapiro-Wilk W test, W = 0.9301, p = 0.1382). Parametric tests are used to analyse both $\delta^{15}N$ and $\delta^{13}C$ for this period.

Figure 3.4 presents the Late Saxon $\delta^{13}C$ and $\delta^{15}N$, and a line of best fit shows a weak positive correlation between $\delta^{13}C$ and $\delta^{15}N$ (r^2 = 0.26, p = 0.0192).

Species	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Chicken	2	11.2	0.2	11.0	11.3	-20.0	0.2	-20.1	-19.8
Goose	1	9.9	-	-	-	-21.6	-	-	-
Cow	3	6.8	1.0	5.6	7.5	-22.4	0.2	-22.5	-22.2
Sheep/Goat	7	7.2	1.2	5.9	9.2	-21.9	0.5	-22.5	-21.3
Pig	8	6.4	1.2	4.7	8.2	-21.5	0.6	-22.4	-20.6
Total	21	7.3	1.8	4.7	11.3	-21.6	0.8	-22.5	-19.8

Table 3.4 $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Stoke Quay Late Saxon fauna (n = 21).

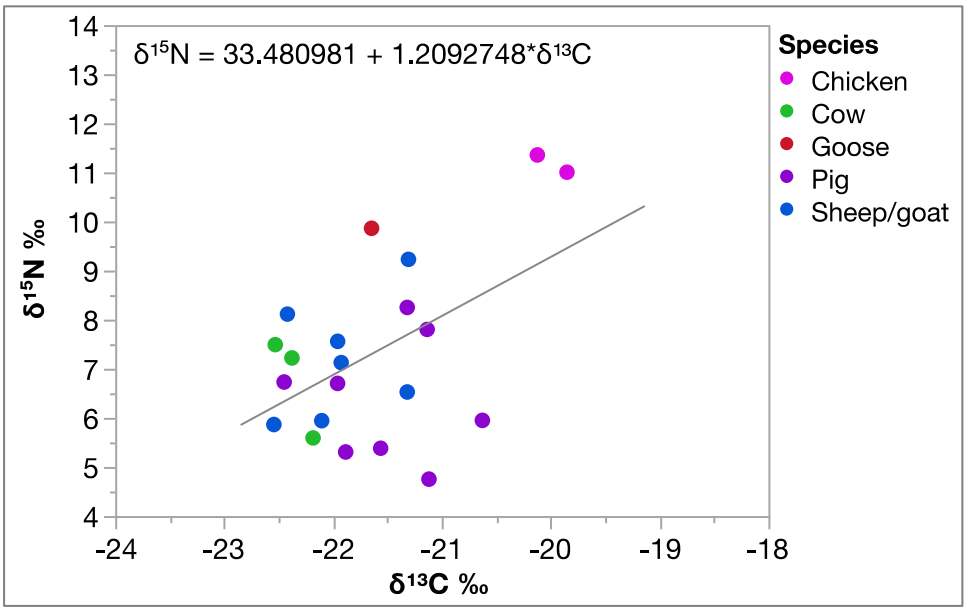


Figure 3.4. $\delta^{13}C$ and $\delta^{15}N$ for Stoke Quay Late Saxon fauna (n = 21). A line of best fit (grey line) shows low correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.26$, p = 0.0192).

Anglo-Norman

Summary statistics for each species are given in Table 3.5. The $\delta^{13}C$ mean is -21.3‰ (±0.9, 1σ), and the $\delta^{15}N$ mean is 7.3‰ (±1.9, 1σ). Both datasets are normally distributed, so parametric tests are used (Shapiro-Wilk W test, $\delta^{13}C$: W = 0.9453, p = 0.0625; $\delta^{15}N$: W = 0.9556, p = 0.1371).

Figure 3.5 shows the Anglo-Norman $\delta^{13}C$ and $\delta^{15}N$, with a weak positive correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.33$, p = 0.0001).

Species	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Chicken	5	9.3	0.5	8.6	9.8	-20.4	0.4	-20.8	-19.8
Goose	1	8.5	-	-	-	-22.3	-	-	-
Mallard	1	7.5	-	-	-	-22.6	-	-	-
Cow	7	6.9	0.6	6.3	7.7	-22.0	0.5	-22.7	-21.5
Sheep/Goat	10	5.9	1.6	4.1	8.1	-21.5	0.5	-22.2	-20.6
Pig	11	6.9	1.1	5.4	8.6	-21.3	0.4	-22.0	-20.5
Horse	1	6.3	-	-	-	-22.3	-	-	-
Dog	1	12.3	-	-	-	-19.2	-	-	-
Cat	1	12.0	-	-	-	-18.9	-	-	-
Total	38	7.3	1.9	4.1	12.3	-21.3	0.9	-22.7	-18.9

Table 3.5. $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Stoke Quay Anglo-Norman fauna (n = 38).

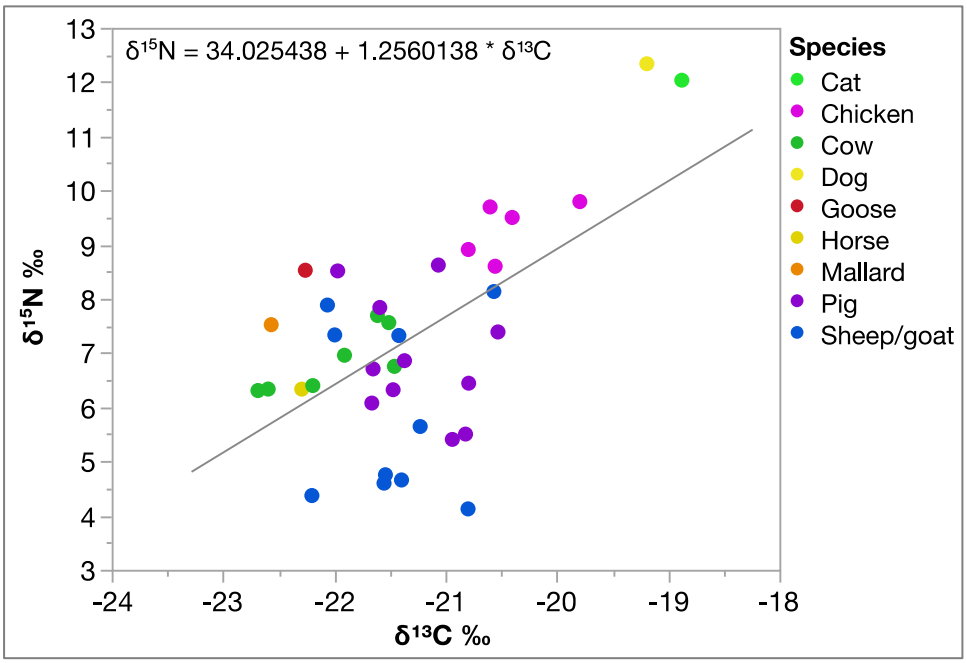


Figure 3.5. $\delta^{13}C$ and $\delta^{15}N$ for Stoke Quay Anglo-Norman fauna (n = 38). A line of best fit (grey line) shows a weak positive correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.33$, p = 0.0001).

Medieval

Summary statistics for each species are given in Table 3.6. The $\delta^{13}C$ mean is -21.9‰ (±0.5, 1σ), and the $\delta^{15}N$ mean is 7.2‰ (±1.8, 1σ). Both datasets are normally distributed so parametric tests are used (Shapiro-Wilk W test, $\delta^{13}C$: W = 0.8773, p = 0.1214; $\delta^{15}N$: W = 0.8455, p = 0.0514).

Figure 3.6 presents the Medieval $\delta^{13}C$ and $\delta^{15}N$, with a negative but statistically insignificant correlation between $\delta^{13}C$ and $\delta^{15}N$. The direction of the regression line is influenced by the goose values, which are lower for $\delta^{13}C$ and higher for $\delta^{15}N$ than the other species, and by the lack of chicken samples in this period ($r^2 = 0.15$, p = 0.2667).

Species	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Goose	2	10.0	0.9	9.4	10.6	-22.6	0.7	-23.1	-22.2
Cow	2	6.0	0.5	5.6	6.4	-22.2	0.1	-22.2	-22.1
Sheep/Goat	3	6.7	1.8	5.6	8.7	-21.7	0.2	-21.8	-21.5
Pig	3	6.5	0.7	5.8	7.0	-21.5	0.2	-21.7	-21.4
Total	10	7.2	1.8	5.6	10.6	-21.9	0.5	-23.1	-21.4

Table 3.6. $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Stoke Quay Medieval fauna (n = 10).

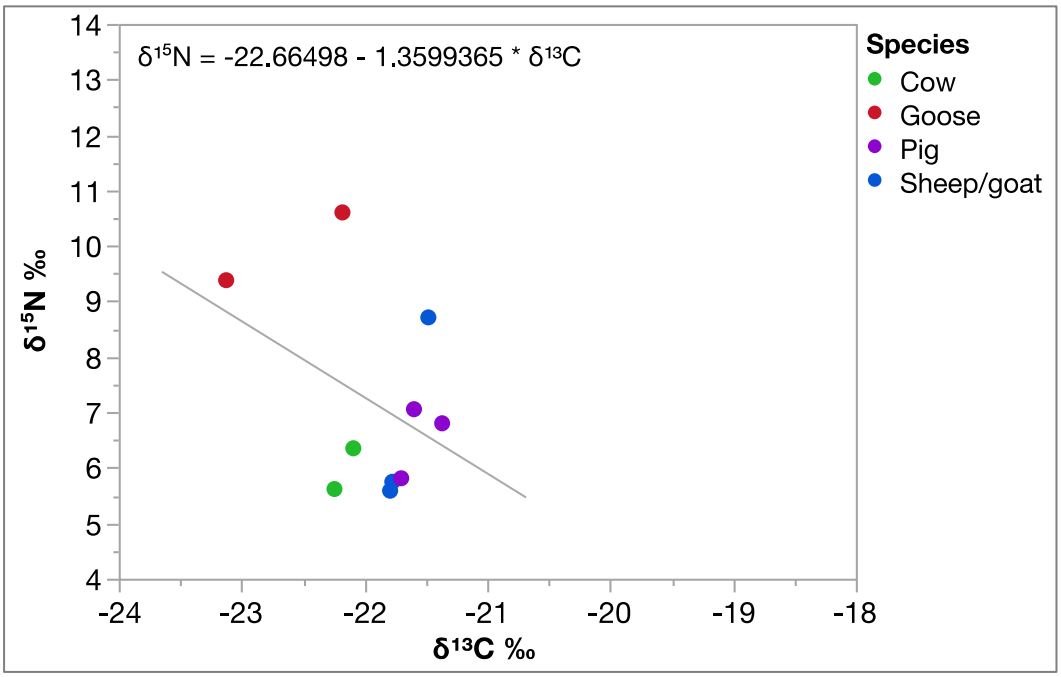


Figure 3.6. $\delta^{13}C$ and $\delta^{15}N$ for Stoke Quay Medieval fauna (n = 10). A line of best fit (grey line) shows a weak negative correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.15$, $p = 0.2267$).

3.3.4 Changes in faunal $\delta^{13}C$ and $\delta^{15}N$ over time

In this section, the overall $\delta^{13}C$ and $\delta^{15}N$ distributions for each period are compared and general interpretations are made regarding the data distributions. This is followed by a comparison of species by period, to evaluate potential differences in animal husbandry or food sourcing over time.

Overall $\delta^{13}C$ and $\delta^{15}N$ over time

To evaluate broad differences in the $\delta^{13}C$ and $\delta^{15}N$ of animals at Stoke Quay, the bivariate plots from Section 3.3.3 are fitted with 95% density ellipses grouped by species (Figure 3.7). The Mid Saxon $\delta^{13}C$ and $\delta^{15}N$ vary widely for each species, with the largest ellipses for geese, chickens, and sheep/goats. The Late Saxon and Anglo-Norman cow, sheep/goat and pig values are more tightly grouped with considerable overlap between species, while the smaller assemblages of Medieval domesticates have the least degree of overlap.

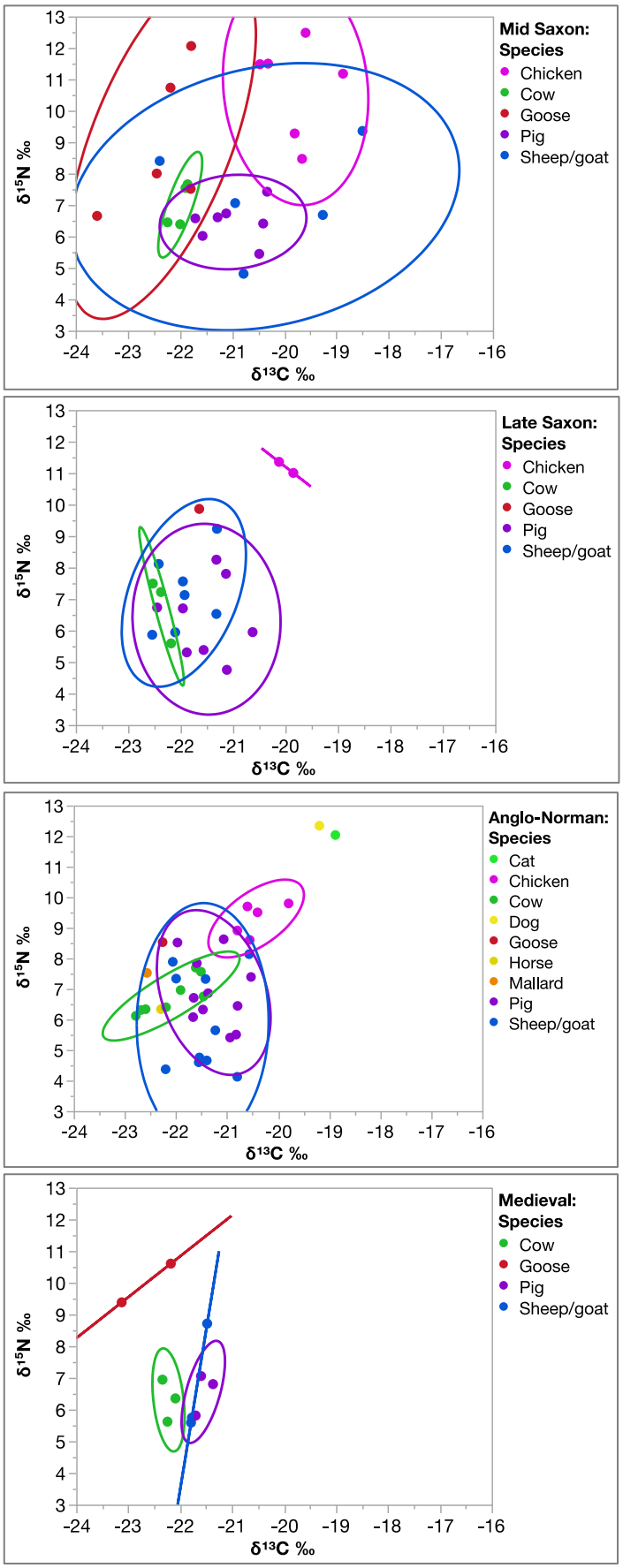


Figure 3.7. Bivariate plots of Stoke Quay faunal $\delta^{13}C$ and $\delta^{15}N$ by period with 95% density ellipses by species (see legends).

With the wide spread of Mid Saxon faunal values, even within a single species, it would appear that food sources and animal husbandry were not tightly controlled during this period. These results could indicate that at this time, food sources at Stoke Quay were not subject to the same constraints as those evidenced across the river in the centre of the Mid Saxon settlement, discussed in further detail below.

Zooarchaeological analyses of faunal remains from central Mid Saxon Ipswich have supported a 'redistributive' model for provisioning, meaning that food renders from surrounding estates may have been paid to the king and redistributed to the inhabitants of the *emporium*. This is supported by low observed frequencies of poultry, wild fowl, and pig bones at *Hamwic*, *Eoforwic*, and central *Gippeswic* (Hamerow 2007; O'Connor 2001; Crabtree 1996). Whether Stoke Quay was also part of this 'redistributive' provisioning model can be assessed using zooarchaeological information for the Mid Saxon assemblage.

The Mid Saxon faunal assemblage is by far the largest of any period at Stoke Quay, with over 12,000 bone fragments recovered from a variety of cut features. Based on total fragment counts, over 50% of the major domesticate bones were cattle, 27.5% were sheep/goats, and 22% were pigs. Other species formed a more minor component of the assemblage but comprised a fairly wide range of species, with notable quantities of poultry (chicken, goose and some duck), and smaller numbers of other game animals and birds. Some of the goose and duck bones may be from wild rather than domestic birds (Rielly, in press).

The majority of poultry bones were from adult animals, signifying a greater reliance on eggs than on meat, though the presence of juvenile chickens indicates some were culled for consumption early in life. The presence of a few

very young birds may suggest that some chickens were locally reared. Bones from several neonate calves and lambs likely represent infant mortalities from other locally reared animals. With the presence of neonate cattle and sheep as well as chicken, goose and pig, and the wide spread of $\delta^{13}C$ and $\delta^{15}N$ for fowl, it is possible that with a position across the River Orwell and in close proximity to marshland to the east, the inhabitants of Stoke Quay may have exercised more independence over their food sources than did their neighbours across the river.

However, despite the evidence for some local rearing of animals, the larger proportion of adult cattle and sheep, many in the older age categories, suggests that much of the meat supply was brought in from outside the settlement (Rielly, in press). This is also supported by the wide spread of isotopic values for the sheep, indicating that these animals may have been sourced from a variety of environments in the surrounding hinterland. If this were the case, it would support the idea of food rendering to the *emporia*.

A different pattern is visible for the later periods. From the Late Saxon period onward, the $\delta^{13}C$ and $\delta^{15}N$ for each species are much more tightly clustered. This could indicate that animal husbandry practices were more standardised by this time, or that the animals sold at Ipswich markets were sourced from the same agricultural areas and therefore grazed on similar soils. This requires further testing by comparing values from each species over time.

Species $\delta^{13}C$ and $\delta^{15}N$ over time

This section compares $\delta^{13}C$ and $\delta^{15}N$ over time for species represented in more than one period. Plots of $\delta^{13}C$ and $\delta^{15}N$ by period for each species are shown in Figures 3.8a-c. Despite variations in the range of values for chickens,

geese, cows and pigs over time, there are no statistically significant differences between periods for any of these four species (ANOVA; Figures 3.8a,b). The sheep/goat values show a different pattern, with statistically significant differences between periods for $\delta^{13}C$ (ANOVA, $p = 0.0213$; Figure 3.8c).

A comparison of $\delta^{13}C$ means for the sheep from each period shows a statistically significant difference between the Mid Saxon and Late Saxon groups ($p = 0.0145$, Tukey-Kramer HSD). Four of the five Mid Saxon sheep/goats have $\delta^{13}C$ above the group mean, and the two sheep/goats with the highest $\delta^{13}C$ have values above -19.5‰ (5432-OC5, 5432-OC3). Several possibilities could explain these high values. Firstly, the two animals could be juveniles and their high $\delta^{13}C$ could be reflecting a trophic level shift over maternal $\delta^{13}C$ values from suckling, but this would be expected to also raise $\delta^{15}N$, and while 5432-OC5 has relatively high $\delta^{15}N$, 5432-OC3 does not. Furthermore, based on dental eruption, 5432-OC5 is not a juvenile, so the suckling hypothesis is rejected.

Another explanation could be that these two animals were goats, rather than sheep, which would expand the likely range of food sources for these animals. This is possible but unlikely, because an analysis of the diagnostic elements used to distinguish sheep from goats revealed a roughly 2.5:1 ratio of sheep to goat horn cores, and a nearly 16:1 ratio of sheep to goat proximal radii (Rielly, in press). Based on this evidence, most sheep/goat bones from this period likely belong to sheep, while goats probably contributed very little to the meat diet and were instead used primarily for horn-working.

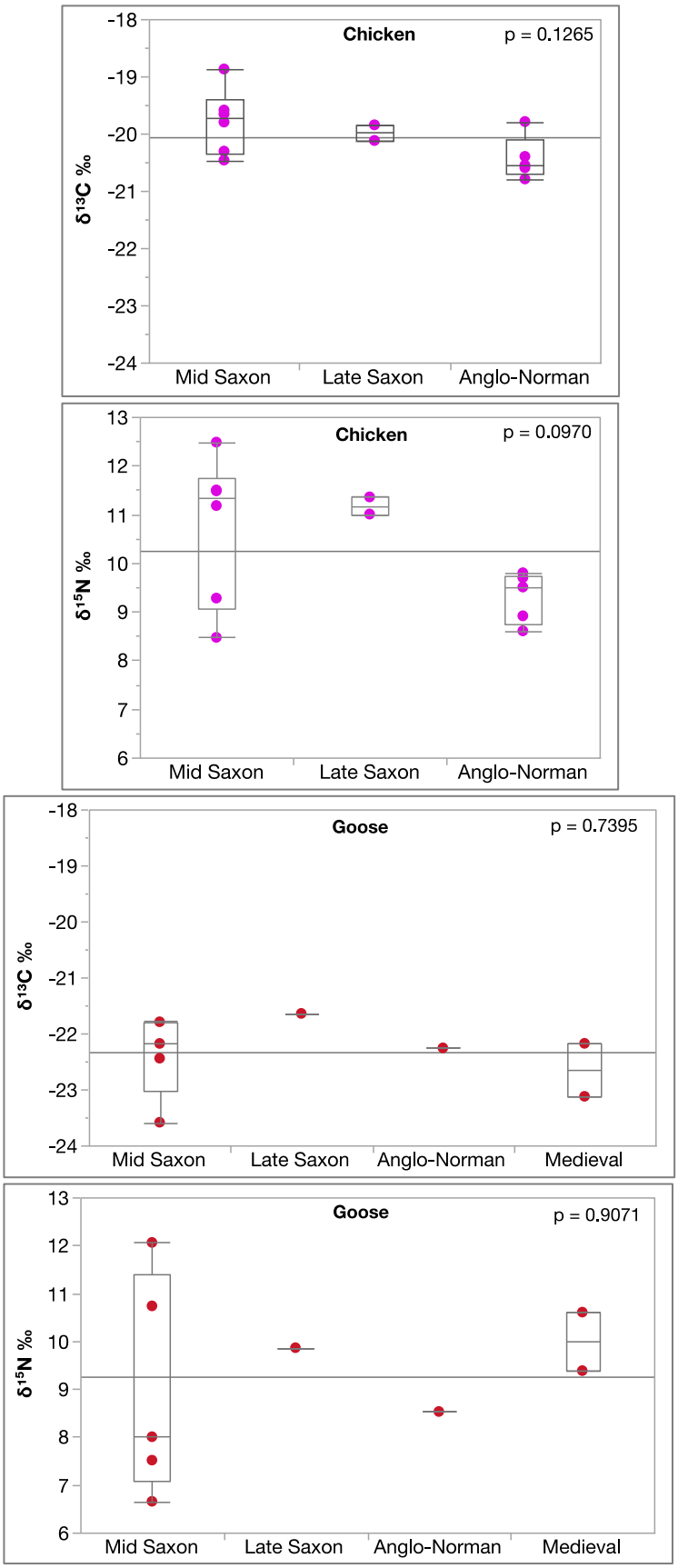


Figure 3.8a. $\delta^{13}C$ and $\delta^{15}N$ by period for Stoke Quay chickens (top) and geese (bottom, outlier removed), with no statistically significant differences by period. Horizontal grey l lines show group mean.

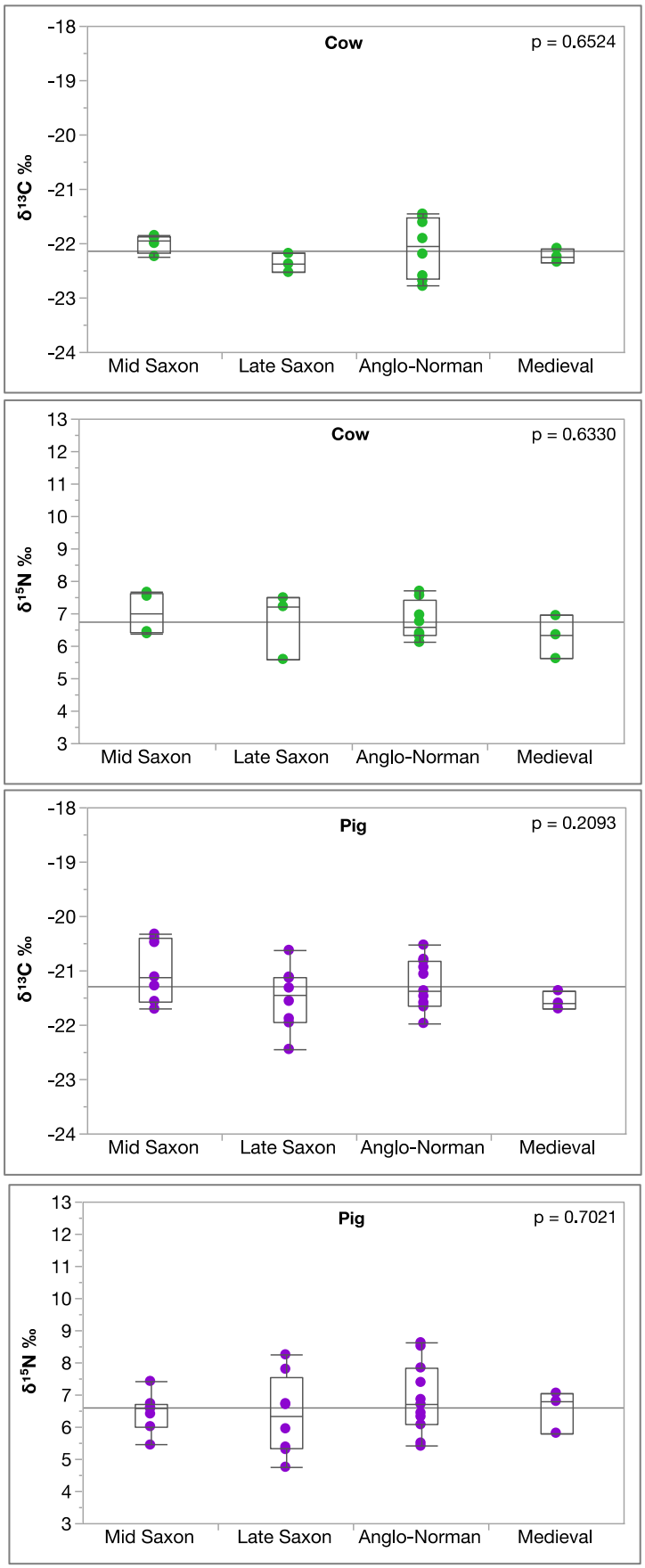


Figure 3.8b. $\delta^{13}C$ and $\delta^{15}N$ by period for Stoke Quay cows (top) and pigs (bottom), with no statistically significant differences by period. Horizontal grey lines show group mean.

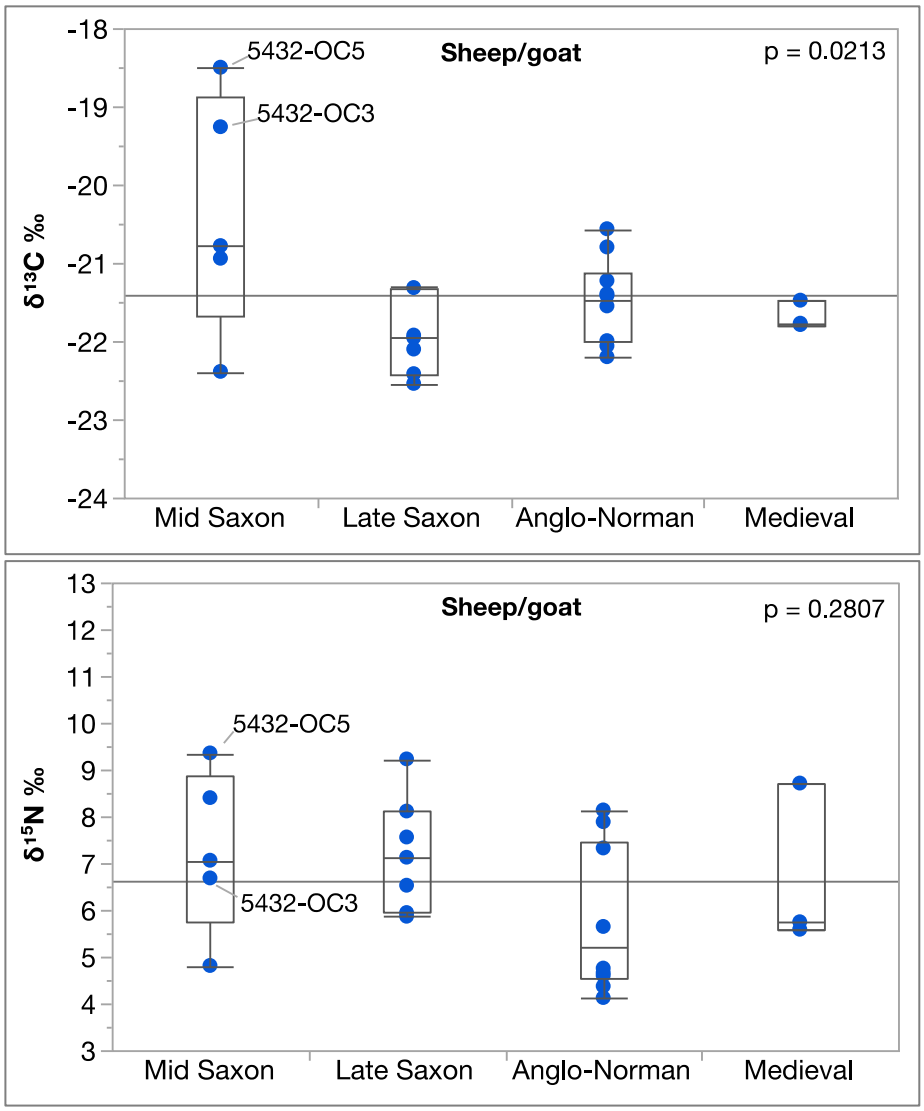


Figure 3.8c. $\delta^{13}C$ and $\delta^{15}N$ by period for Stoke Quay sheep/goats, with statistically significant differences by period (ANOVA, p = 0.0213). A means comparison shows statistically significant differences between Mid Saxon and Late Saxon groups (p = 0.0145, Tukey-Kramer HSD). Horizontal grey lines show group mean.

A third hypothesis, which appears to be more appropriate, is that these animals were grazing on saltmarshes, which has been shown to result in more positive $\delta^{13}C$ and $\delta^{15}N$ in animals grazing in such environments (Britton et al. 2008; Müldner et al. 2014). Indeed, the $\delta^{13}C$ and $\delta^{15}N$ of 5432-OC5 and 5432-OC3 overlap with the values of contemporary sheep from coastal environments at Uitkerke and Koksijde in the Netherlands (Müldner et al. 2014). With its location on the brackish Orwell estuary and proximity to the North Sea coast, the

inhabitants of Mid Saxon Stoke Quay could have either grazed their own sheep on saltmarshes or purchased meat from sheep grazed in that type of environment. If saltmarsh grazing were responsible for the unusually high values seen in the two Mid Saxon sheep, this practice appears to have gone out of use by the Late Saxon period, when sheep $\delta^{13}C$ and most $\delta^{15}N$ return to values more in keeping with typical grazing environments.

3.3.5 Modelling terrestrial food sources for interpreting human diet

As discussed at the beginning of this chapter, in the absence of direct fish bone $\delta^{13}C$ and $\delta^{15}N$ from Stoke Quay, human consumption of marine fish is modelled in this thesis by first establishing a baseline for terrestrial food values through $\delta^{13}C$ and $\delta^{15}N$ analysis of faunal remains from the site.

To determine whether separate models of terrestrial animal $\delta^{13}C$ and $\delta^{15}N$ would be needed for each period, the faunal data were grouped and compared by period. Carnivores (one dog and one cat from the Anglo-Norman period) were excluded from this analysis, as they were included not as potential food sources but rather as proxies for omnivorous/carnivorous diet at the site. The goose with very high $\delta^{13}C$ was also removed because it was an outlier.

When the carnivores and goose are removed, the faunal $\delta^{13}C$ show statistically significant differences by time period ($p = 0.0126$, ANOVA; Figure 3.9a). A means comparison shows statistically significant differences between the Mid Saxon and Medieval groups ($p = 0.0160$, Tukey-Kramer HSD; Figure 3.9b). The faunal $\delta^{15}N$ exhibit a different pattern, with no statistically significant differences in value distribution or means (Figure 3.10a, b). The ranges for both

isotopes also vary by period, with the Mid Saxon assemblage showing the largest range (Table 3.7).

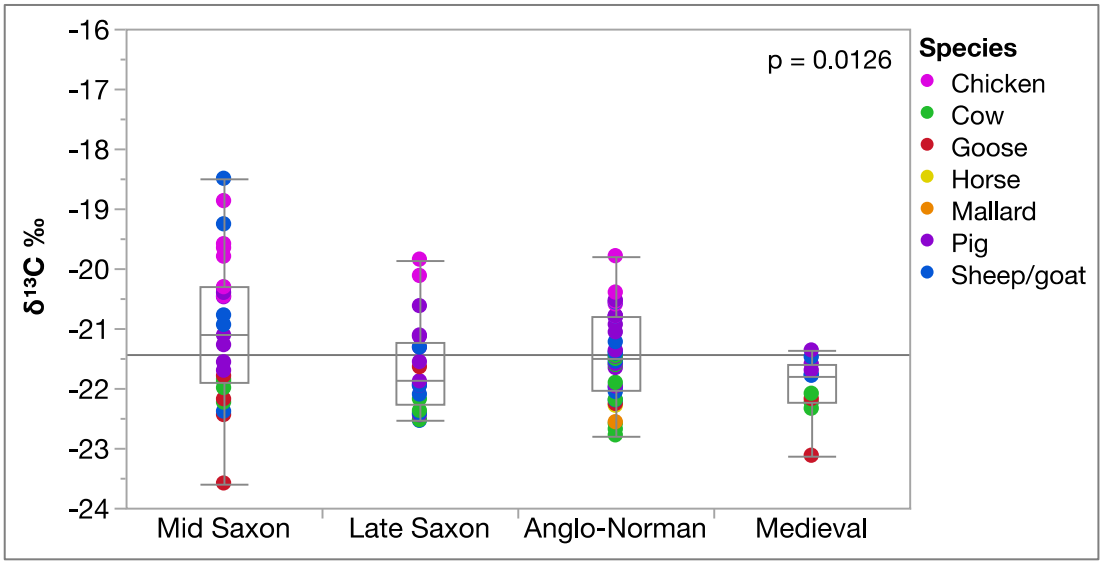


Figure 3.9a. Boxplots for Stoke Quay faunal $\delta^{13}C$ by time period, excluding carnivores and 1 goose (n = 96), with statistically significant differences by period (p = 0.0126, ANOVA). Horizontal grey line shows group mean.

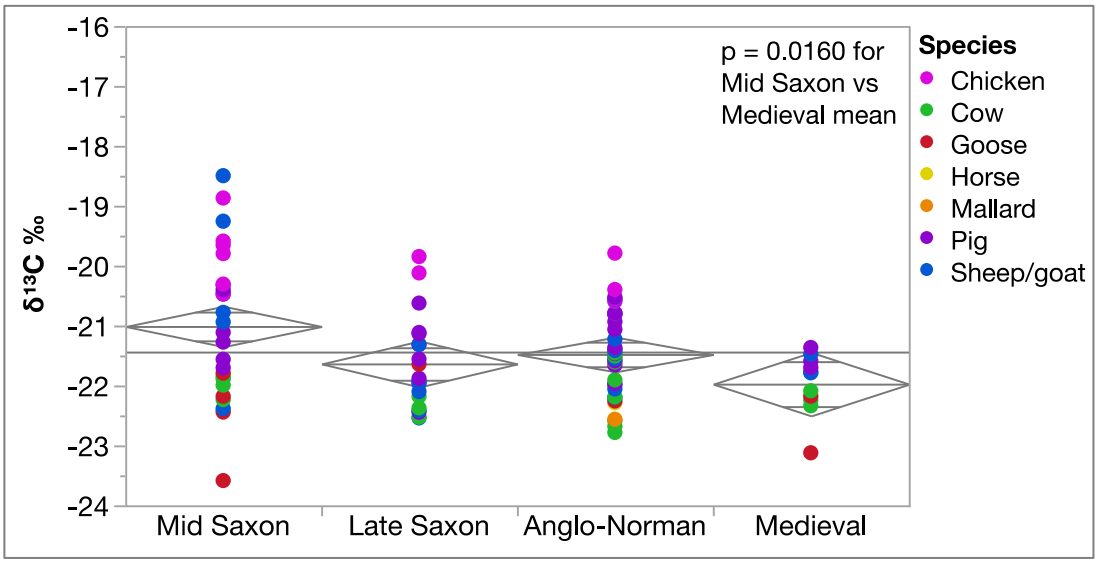


Figure 3.9b. Mean diamonds for Stoke Quay faunal $\delta^{13}C$ by time period, excluding carnivores and 1 goose (n = 96) with statistically significant differences by period (p = 0.0160, Tukey-Kramer HSD). Horizontal grey line shows group mean.

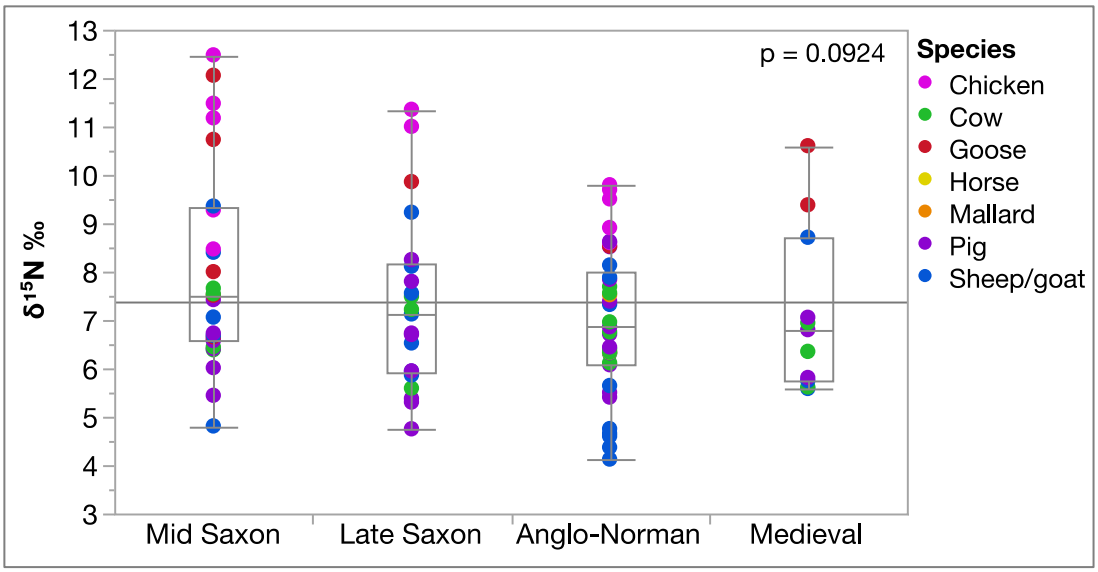


Figure 3.10a. Boxplots for Stoke Quay faunal $\delta^{15}N$ by period, excluding carnivores and 1 goose (n = 96), with no statistically significant differences by period (p = 0.0924, ANOVA). Horizontal grey line shows group mean.

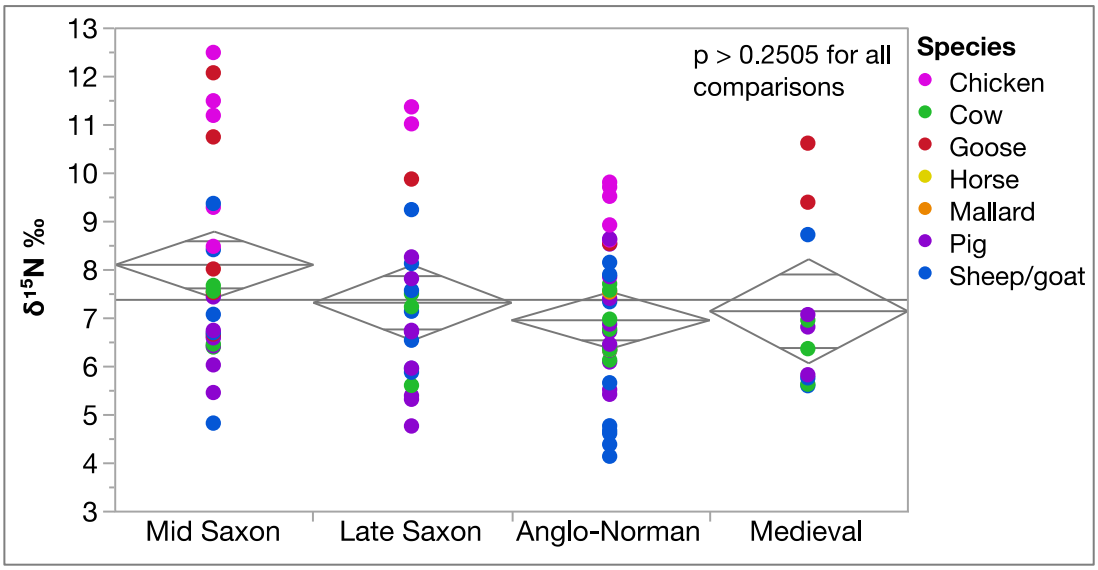


Figure 3.10b. Mean diamonds for Stoke Quay faunal $\delta^{15}N$ by period, excluding carnivores and 1 goose (n = 96), with no statistically significant differences (p > 0.2505 for all comparisons, Steel-Dwass). Horizontal grey line shows group mean.

Period	n	$\delta^{15}N$ mean	1σ	min	max	$\delta^{13}C$ mean	1σ	min	max
Mid Saxon	27	8.1	2.2	4.8	12.5	-21.0	1.2	-23.6	-18.5
Late Saxon	21	7.3	1.8	4.7	11.3	-21.6	0.8	-22.5	-19.8
Anglo-Norman	39	7.0	1.5	4.1	9.8	-21.5	0.7	-22.8	-19.8
Medieval	11	7.1	1.7	5.6	10.6	-22.0	0.5	-23.1	-21.4
Carnivores	2	12.2	0.2	12.0	12.3	-19.0	0.2	-19.2	-18.9

Table 3.7. Summary statistics for Stoke Quay faunal $\delta^{15}N$ and $\delta^{13}C$ by period (n = 97), with outlier goose removed and carnivores considered separately (values in ‰).

The Mid Saxon values exhibit the widest range, with $\delta^{13}C$ differing statistically significantly from the other groups. Even when the two sheep/goats with the highest $\delta^{13}C$ are removed (5432-OC5 and 5432-OC3), there are still statistically significant differences in means between the Mid Saxon and Medieval faunal groups (p = 0.0475, Tukey-Kramer HSD). Due to these differences, the Mid Saxon group was removed, and the ANOVA and means comparisons were run again (Figure 3.11a, b).

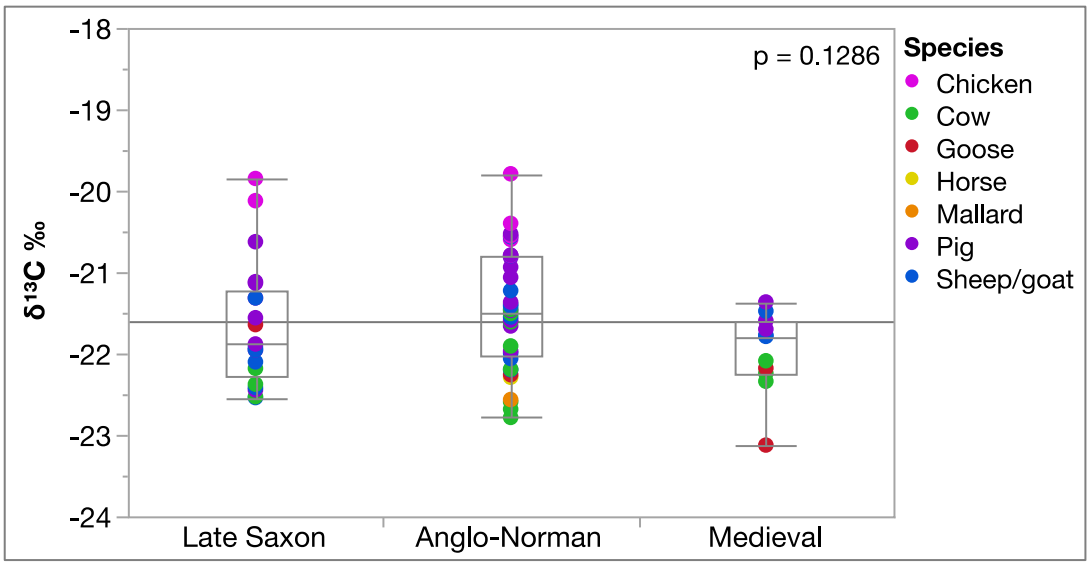


Figure 3.11a. $\delta^{13}C$ boxplots for Stoke Quay Late Saxon to Medieval fauna, excluding carnivores (n = 69), with no statistically significant differences (p = 0.1286, ANOVA).

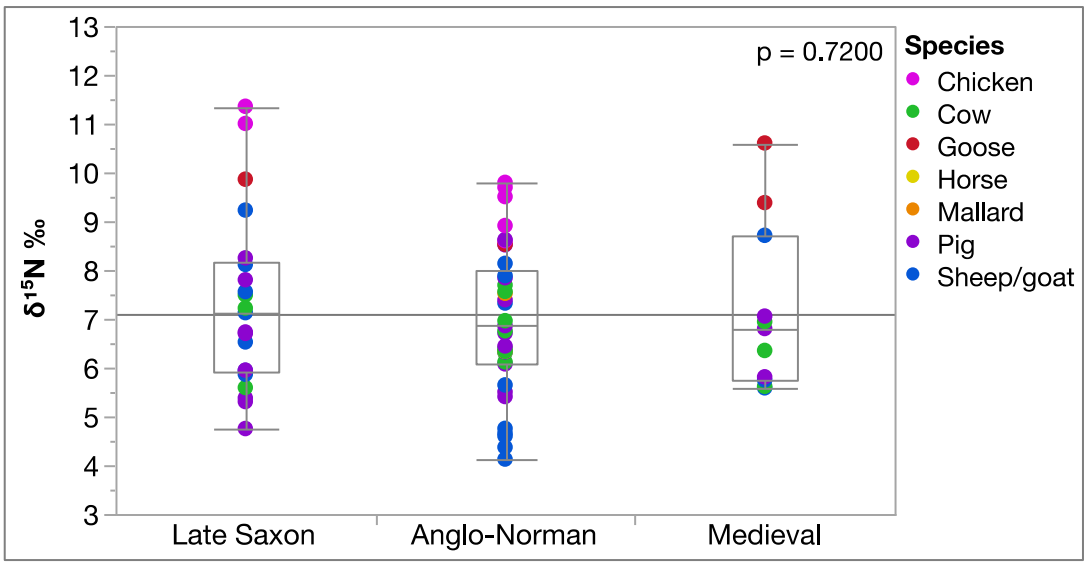


Figure 3.11b. $\delta^{15}N$ boxplots for Stoke Quay Late Saxon to Medieval fauna, excluding carnivores (n = 69), with no statistically significant differences by period (p = 0.7200, ANOVA).

The faunal values for the Late Saxon through Medieval periods show no statistically significant differences for either $\delta^{13}C$ or $\delta^{15}N$ ($\delta^{13}C$ $p = 0.1286$, $\delta^{15}N$ $p = 0.7200$, ANOVA). These results indicate that the Mid Saxon values were the cause of the statistically significant $\delta^{13}C$ differences in the previous analyses, and the Mid Saxon fauna should thus be considered separately from the other groups when modelling baseline dietary values for human $\delta^{13}C$ or $\delta^{15}N$ interpretation.

Indeed, despite variation in the $\delta^{13}C$ and $\delta^{15}N$ ranges of Late Saxon through Medieval fauna, the similar means for the later 3 periods indicate that, while husbandry methods and the source locations for butchered animals may have changed over time depending on trade relations and availability, the overall impact on human dietary values may have been fairly uniform across these time periods. In other words, an individual in Late Saxon Ipswich who consumed a mix of the three main domesticate species (cow, sheep/goat, and pig) and fowl (chicken and goose) would probably yield $\delta^{13}C$ and $\delta^{15}N$ values similar to an individual with a comparable terrestrial diet in the Medieval period. This means that any isotopic variability in humans would be driven by differences in the amounts of marine foods rather than differences in terrestrial food sources.

It is possible that a larger sample size would lead to different conclusions, but the fact that the means from the largest assemblage (Anglo-Norman period, $n = 37$), and the smallest assemblage (Medieval period, $n = 11$) only differ by 0.5‰ for $\delta^{13}C$, and 0.1‰ for $\delta^{15}N$, suggests that this result is not merely an artefact of small sample sizes. Rather, the similar mean values over time indicate that a purely terrestrial diet would have looked approximately the same in terms of human isotope values throughout the approximately 600 years in question.

Given the similarity in mean faunal values from the Late Saxon to Medieval periods, the combined faunal mean can be justifiably used to create a model for interpreting human consumption of marine fish at Stoke Quay during these periods. The Mid Saxon faunal means are used to create a separate model for interpreting human diet at Mid Saxon Stoke Quay (Table 3.8). Because of trophic enrichment, a human with an carnivorous terrestrial diet would be expected to yield $\delta^{13}C$ c. 1-2‰ above, and $\delta^{15}N$ c. 3-5‰ above the faunal means (see Section 2.2.1). A purely carnivorous diet is unlikely given what we know about medieval diet, but without any values from local archaeological plants, the carnivorous terrestrial range provides a conservative means to assess the influence of marine or freshwater fish.

Period	n	$\delta^{15}N$ mean	1σ	min	max	$\delta^{13}C$ mean	1σ	min	max
Mid Saxon	27	8.1	2.2	4.8	12.5	-21.0	1.2	-23.6	-18.5
Late Saxon-Medieval	69	7.3	1.8	4.7	11.3	-21.6	0.8	-22.5	-19.8

Table 3.8. Summary statistics for Stoke Quay faunal $\delta^{15}N$ and $\delta^{13}C$ groups used for modelling human dietary baselines (n = 96), excluding outlier goose and carnivores (values in ‰).

With a Mid Saxon faunal group $\delta^{13}C$ mean of -21.0‰, the corresponding estimated carnivorous human values would be between -20.0‰ and -19.0‰ for $\delta^{13}C$. Similarly, with a faunal group $\delta^{15}N$ mean of 8.1‰, the omnivorous human value would be estimated to be between 11.1‰ and 13.1‰ for $\delta^{15}N$.

For the Late Saxon to Medieval group with a $\delta^{13}C$ mean of -21.6‰, the corresponding estimated carnivorous human values would be between -20.6‰ and -19.6‰ for $\delta^{13}C$. The Late Saxon to Medieval faunal group $\delta^{15}N$ mean of 7.3‰ would correspond to estimated carnivorous human $\delta^{15}N$ values between

10.3 and 12.3‰. In comparison, the carnivore (one dog and one cat) means are -19.0‰ for $\delta^{13}C$ and 12.2‰ for $\delta^{15}N$, and these animals could have consumed some fish, particularly if they were scavenging human food waste.

The ranges given above are considered an appropriate model for a terrestrial carnivore diet. Individuals with values above the modelled terrestrial carnivore range can be interpreted as marine fish consumers, with greater confidence in this interpretation corresponding with distance from the modelled range. Published archaeological fish $\delta^{13}C$ and $\delta^{15}N$ from the literature are also used in the following chapters to aid in the interpretation of human values.

3.4 Establishing baseline environmental values

Given the multiple factors that can influence $^{87}Sr/^{86}Sr$ ratios and $\delta^{18}O$ values in human enamel (see Chapter 2, Section 2.3.1), a starting point for any interpretation is to establish baseline values for 'local' $\delta^{18}O$ and bioavailable $^{87}Sr/^{86}Sr$ ranges (Bentley 2006; Kendall et al. 2013). In this thesis, baseline $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ranges are established using two sources of complementary information: 1) previously published studies of $^{87}Sr/^{86}Sr$ ratios and $\delta^{18}O$ values across the British Isles, and 2) $^{87}Sr/^{86}Sr$ ratios from archaeological pig tooth enamel from Stoke Quay. An unsuccessful attempt to obtain local water samples is also discussed. Due to the lack of local water samples and the on-going debate regarding how to interpret $\delta^{18}O$ values in archaeological populations (see Chapter 2, Section 2.3.1), several methods are addressed for identifying 'local' and 'nonlocal' origins based on enamel carbonate $\delta^{18}O$ values.

3.4.1 Establishing baselines for bioavailable $^{87}Sr/^{86}Sr$ with published isoscapes and archaeological fauna

There is a general consensus that a combination of sample types are needed in order to generate an accurate range of bioavailable $^{87}Sr/^{86}Sr$, but there is much variation in the literature regarding the number of samples needed, and the relative importance of archaeological fauna, modern fauna, modern plants, and soil samples (e.g. Kendall et al. 2013; Bentley 2004; Knipper et al. 2015; Roberts et al. 2013).

Because of the budget constraints for this thesis, only a small sample could be accommodated for establishing baseline values while still allowing for the maximum number of analyses on human tissues. Bioavailable $^{87}Sr/^{86}Sr$ in England has been relatively well sampled and the number of local plant and modern animal samples needed to generate a local isoscape would be beyond the scope of this project. Given this situation, archaeological faunal samples were used to ascertain whether estimated 'local' ranges from published isoscapes would be applicable to the Ipswich area.

Published $^{87}Sr/^{86}Sr$ isoscapes

A number of previous studies have attempted to characterize local isotopic ranges for strontium in the British Isles. The most comprehensive published study for Britain is by Evans and colleagues (2010), which demonstrates that the diverse geology of England and Scotland yields a wide range of bioavailable $^{87}Sr/^{86}Sr$ ratios, from 0.707 in older igneous rocks to over 0.720 in Cairngorm granites. In Evans et al.'s study, plant, water, soil, and bone/dentine samples were selected from across Britain, then analysed for

$^{87}Sr/^{86}Sr$ ratios. The results were separated by geological time and rock type, and the mean and 1σ range for each category were calculated. The data were then split into intervals of 0.001, and a map of Britain was coloured by these ranges. The colouring primarily relied upon values from plants, supplemented by additional data when the plant data were deemed insufficient. The ranges for areas with sparse sampling cover were extrapolated from lithologically similar rock types (Evans et al. 2010, Appendix).

In the Evans et al. (2010) biosphere strontium map, the Ipswich area falls into the 0.709 – 0.710 range, coloured green (Figure 3.12). However, as shown in Figure 3.13, no samples in the study came from East Anglia.

To better define a useful 'local' range, archaeological fauna from Stoke Quay were analysed. The results are presented in the following section.

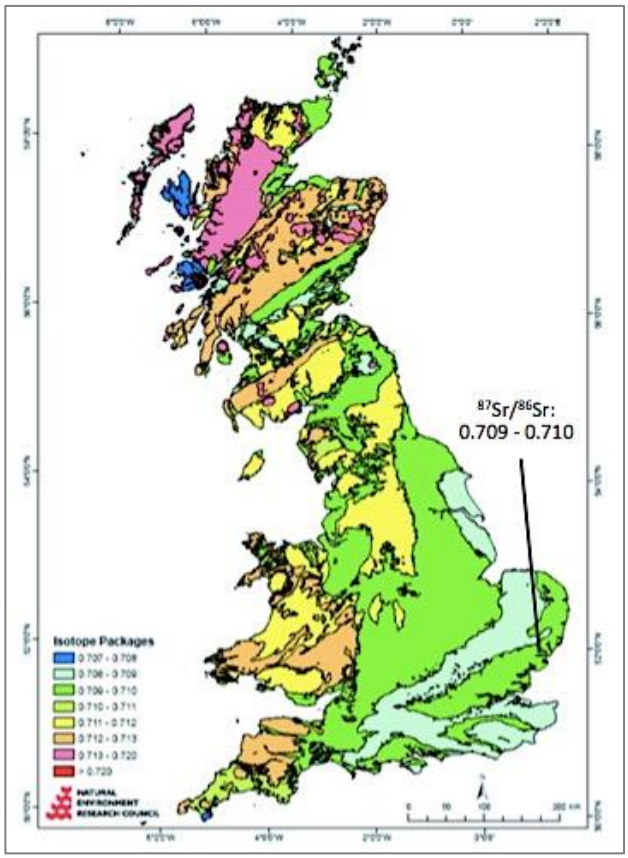


Figure 3.12. $^{87}Sr/^{86}Sr$ isoscape map based on bedrock geology around Britain, with line indicating the expected range for the Ipswich area. From Evans et al. 2010 (Figure 1b).

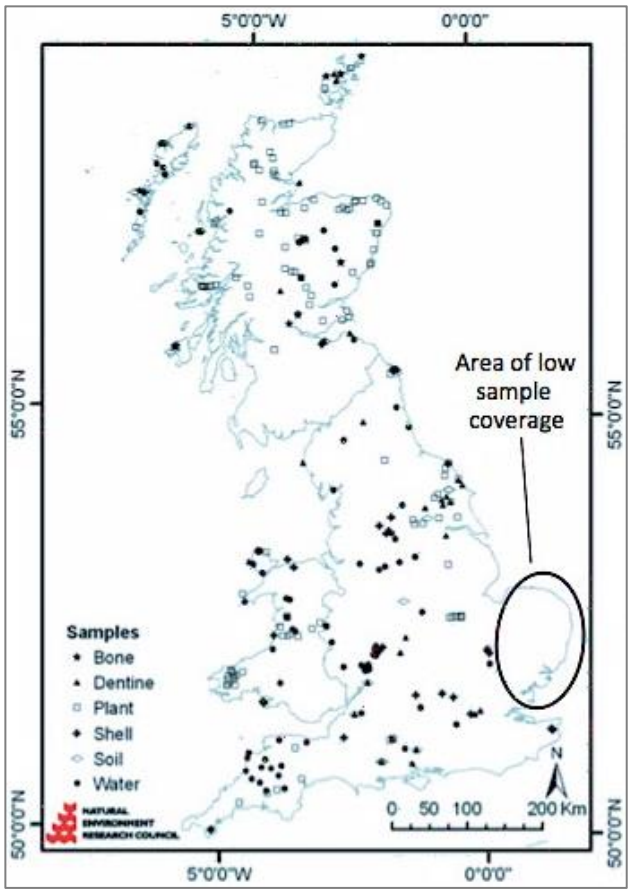


Figure 3.13. Sample type and distribution for map shown in Figure 3.12, with area of low sample coverage circled in black. From Evans et al. 2010 (Figure 1a).

Faunal materials and methods for $^{87}Sr/^{86}Sr$ analysis

To better define the 'local' baseline $^{87}Sr/^{86}Sr$ values, tooth enamel was analysed from 6 pigs dating to the Mid Saxon through Medieval periods at Stoke Quay. Medieval pigs were traditionally reared on pannage (seasonal foraging in wooded environments) but this only occurred in autumn and early winter (Albarella 2006). For the rest of the year, and in areas without woodland, pigs could be fed legumes, cereals, grazed on pastureland, or kept in backyards and fed food scraps (Albarella 2006; Dyer 2003; Trow-Smith 1957). In urban areas, pigs could be kept in sties and fed an omnivorous diet or let loose to scavenge in the streets (Albarella 2006; Dyer 2003; Wiseman 2004). Given their often-varied diets during the medieval period, pigs provide a sensible proxy for foods likely influencing human $^{87}Sr/^{86}Sr$ ratios.

The presence of neonatal pigs in an urban environment would likely indicate that some pigs were locally reared (Albarella 2005, 2006), and a number of very young pigs were found at Stoke Quay (Rielly, in press). However, not all pigs would have necessarily been reared in town, so a variety of ages and tooth types were selected to capture potential variability in pig rearing locations (Table 3.9). Pigs were selected from the Mid Saxon to Medieval periods to account for potential temporal differences in origins.

Pig teeth were selected from individuals already chosen for the faunal dietary baseline sample described in Section 3.3. Enamel powder was drilled using the methods described in Section 2.3.3, then sent for analysis at the Department of Geological Sciences at the University of Cape Town (Laboratory Manager: Petrus LeRoux). Strontium extraction and analysis followed the methods used for human samples (Section 2.3.3).

Sample ID	Period	Age (months)[1]	Age category[2]	Tooth	Side
5432_S6	Mid Saxon	6	Juvenile	M1	R
5432_S7	Mid Saxon	23-26	Sub-adult	M3	R
7308_S5	Late Saxon	12-26	Sub-adult	M2	R
5752_S3	Anglo-Norman	23-26	Sub-adult	M2	L
5752_S5	Anglo-Norman	23-26	Sub-adult	M2	R
8490_S2	Medieval	6-12	Immature	M1	R

Table 3.9. Sample information for the Stoke Quay pigs analysed for $^{87}Sr/^{86}Sr$ (n = 6). Age ranges were determined following methods of 1) Matschke 1967, and 2) O'Connor 2003.

Faunal $^{87}Sr/^{86}Sr$ results

The $^{87}Sr/^{86}Sr$ results for the six archaeological pig samples are given in Table 3.10, and shown in Figure 3.14. The values are clustered fairly tightly, ranging from 0.709068 to 0.709377 (mean: 0.709225 ±0.000106, 1σ), and they do not deviate from the Normal distribution (Shapiro-Wilk W test). A range of ±2σ from the mean equates to $^{87}Sr/^{86}Sr$ ratios of 0.709013 to 0.709438.

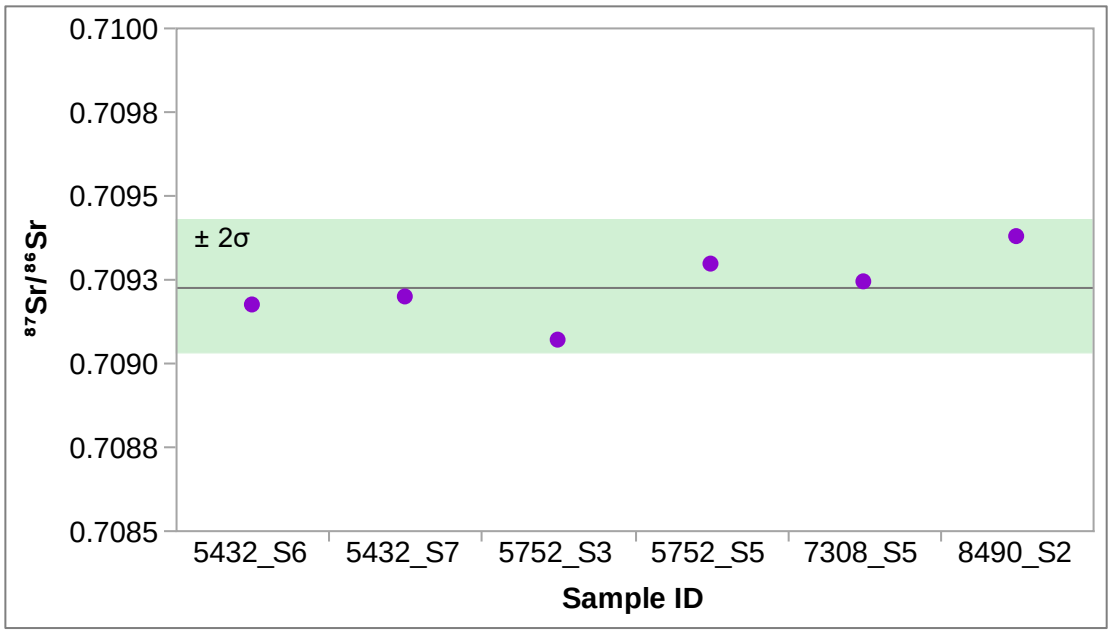


Figure 3.14. $^{87}Sr/^{86}Sr$ results for Stoke Quay pigs (n = 6). The grey line shows the group mean and the green band shows the ± 2σ range from the mean.

Sample #	$^{87}Sr/^{86}Sr$	$\delta^{13}C$	$\delta^{15}N$	Period	Age (months)[1]
5432_S6	0.709173	-20.5	5.4	Mid Saxon	6
5432_S7	0.709197	-21.1	6.7	Mid Saxon	23-26
7308_S5	0.709242	-22.4	6.7	Late Saxon	12-26
5752_S3	0.709068	-21.6	7.8	Anglo-Norman	23-26
5752_S5	0.709295	-20.9	5.4	Anglo-Norman	23-26
8490_S2	0.709377	-21.7	5.8	Medieval	6-12

Table 3.10. $^{87}Sr/^{86}Sr$ results by time period for Stoke Quay pigs (n = 6), with associated $\delta^{13}C$, $\delta^{15}N$, and age estimates based on Matschke 1967.

Combining faunal values with published $^{87}Sr/^{86}Sr$ ranges

The ±2σ range from the mean value of the 6 archaeological pig teeth (0.709013 to 0.709438) overlaps well with the expected 'local' range from Evans et al. 2010 (0.709 to 0.710), falling in the lower half of the expected range. Though the narrower range from the pig teeth may accurately reflect the 'local' bioavailable $^{87}Sr/^{86}Sr$ around Stoke Quay, the more conservative range of 0.709 to 0.710 is used to account for potential variation not captured in the pig enamel.

3.4.2 Establishing a 'local' $\delta^{18}O$ range

The ranges used to interpret human $\delta^{18}O$ in this thesis are presented here, along with the rationale behind their selection. The sampling strategy and sample location for modern local water samples around Stoke Quay is also discussed, as well as the reasons these samples were not used.

Ipswich water sampling to test the 'local' $\delta^{18}O$ range

Establishing a 'local' range is somewhat less straightforward for $\delta^{18}O$ than for $^{87}Sr/^{86}Sr$. Isoscapes modelling $\delta^{18}O$ ranges across Britain have been created from modern rainfall data (Darling et al. 2003a), modern groundwater samples (Darling et al. 2003b), and archaeological human $\delta^{18}O$ (Chenery et al. 2010; Evans et al. 2012; Knudson et al. 2012). However, there is still much debate over how to best measure 'local' water $\delta^{18}O$ ranges (see Pederzani & Britton 2019).

The groundwater isoscape was considered the best place to begin establishing a 'local' $\delta^{18}O$ range for Stoke Quay, as groundwater records long-term averages that are less susceptible to climatic shifts and seasonal variation than rainfall $\delta^{18}O$ (Darling et al. 2003b). Moreover, the inhabitants of Stoke Quay likely derived little of their fresh water from rainwater, instead relying on local wells uncovered during the excavations (Brown, in press). Based on an isoscape modelled from modern groundwater samples across Britain (Darling et al. 2003b), groundwater $\delta^{18}O$ around Ipswich should average between -7.5‰ and -7.0‰. However, Darling et al. did not sample water from Ipswich itself, thus necessitating further testing to confirm the modelled range (Figure 3.15).

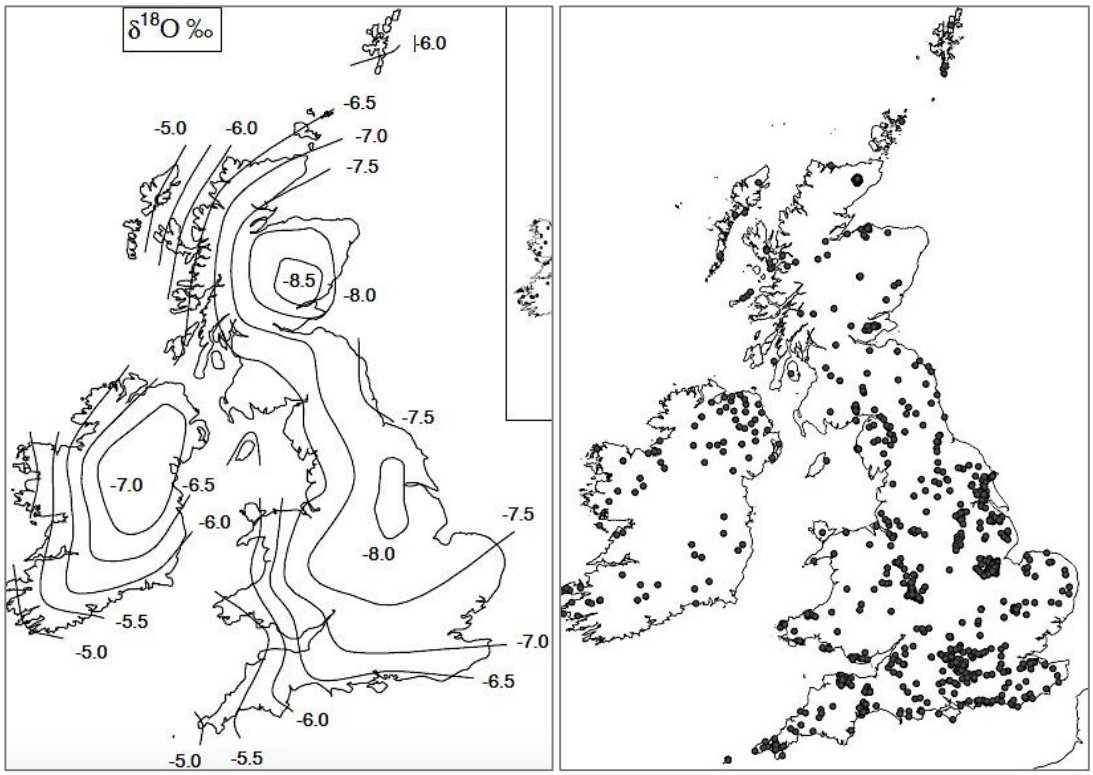


Figure 3.15. Groundwater $\delta^{18}O$ isoscape for Britain (from Darling et al. 2003b, Figure 6). The $\delta^{18}O$ contour map (left) gives a range of -7.5 to -7.0‰ for the Ipswich area on the east coast of England. The map on the right shows the sampling location density and the corresponding reliability of contouring. There are few samples from the Ipswich area.

Materials and methods

In order to test whether the ranges created by Darling and colleagues (2003b) were applicable for the area around Ipswich, a strategy was devised for collecting water samples from the area around Stoke Quay. Modern river water would be sampled to test the $\delta^{18}O$ value of the River Orwell, and local tap water would be sampled to serve as a proxy for groundwater values.

Ipswich's modern water supply is provided by Anglian Water's East Suffolk resource zone, which serves areas inland from the Stour, Orwell and Deben estuaries (Figure 3.16). Water is sourced from a combination of groundwater abstracted from the chalk, and surface water from the River Gipping, which is pumped for storage (Anglian Water 2015). Because a portion of the tap water is sourced from surface waters and storage times may vary,

sampling was to take place during both the winter and the summer months in order to evaluate the seasonal fluctuations in isotopic values for these water sources. River samples would also be taken during the winter and the summer, to attempt to capture the potential range of $\delta^{18}O$ in the Orwell catchment area.

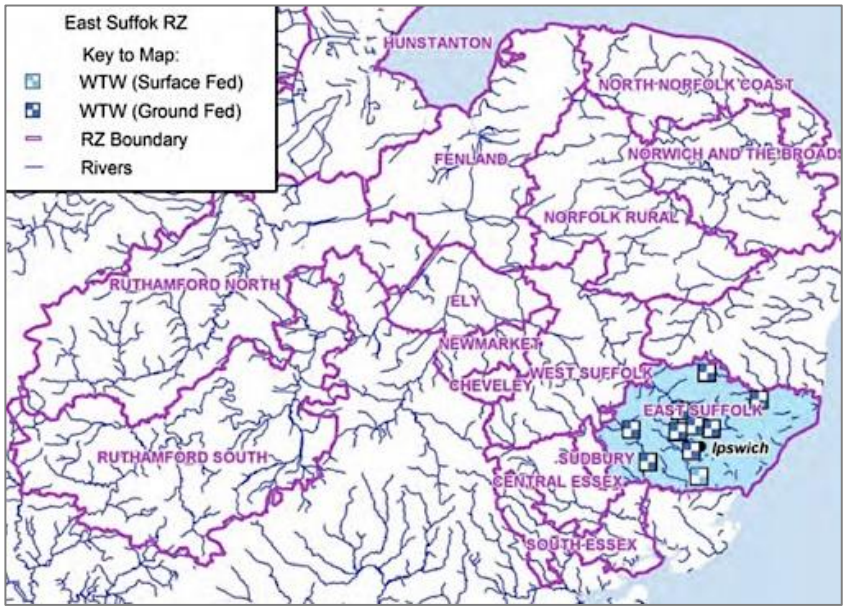


Figure 3.16. East Suffolk Resource Zone (RZ) Map (Anglian Water 2015:227).

In January 2017, water samples were collected from the banks of the River Orwell, adjacent to the site of Stoke Quay, and from the tap of a local business next to the site (Figure 3.17). The samples were decanted into brown glass vials with a septum lid and then frozen immediately to prevent the growth of algae and microbes and to await analysis in a Picarro analyser at the Research Laboratory for Archaeology and the History of Art at the University of Oxford.

Several issues arose at this point. First, the Picarro machine broke down and could not be repaired. Subsequently, the glass vials broke and the water samples defrosted during laboratory renovations in the summer of 2017. With the samples destroyed, plans for analysing local water $\delta^{18}O$ were abandoned, and an alternative method for establishing 'local' $\delta^{18}O$ ranges was sought from the published literature.

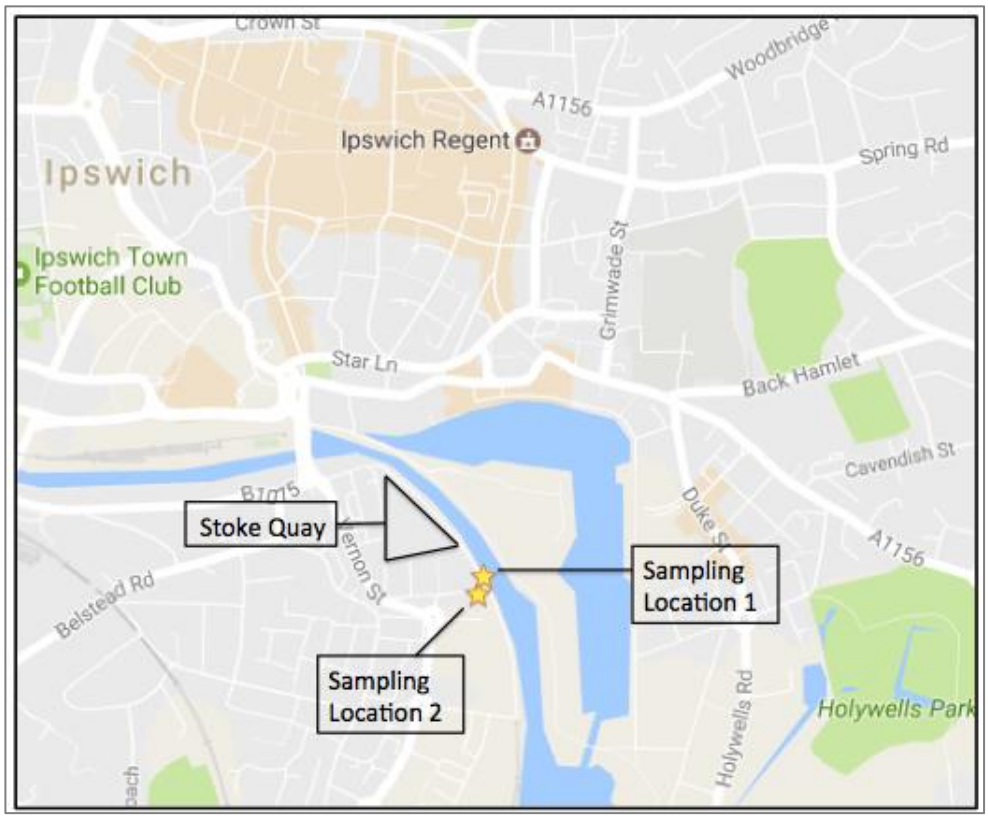


Figure 3.17. Water sampling locations relative to the Stoke Quay excavation site. Sampling location 1: the site of water collection from the River Orwell. Sampling location 2: the site of tap water collection.

Establishing 'local' $\delta^{18}O$ from published isoscapes

In order to use the 'local' values for Ipswich from the Darling et al. (2003b) groundwater isoscape map, the $\delta^{18}O_{C\text{-}VPDB}$ results from Stoke Quay human tooth enamel would have to be converted to ingested water values ($\delta^{18}O_{iw}$). This is because of the fractionation that occurs between ingested water and bioapatite oxygen ($\delta^{18}O_{bioapatite}$) during metabolic routing and tissue formation. Both the carbonate and phosphate groups of bioapatite are formed in equilibrium with body water $\delta^{18}O$, with a temperature-dependent fractionation (Iacumin et al. 1996; Daux et al. 2008; Longinelli 1984).

The equations currently in use for converting $\delta^{18}O_{C\text{-}VPDB}$ values to $\delta^{18}O_{iw}$ values add considerable statistical uncertainty, and different equations can yield very different $\delta^{18}O_{iw}$ values. These conversion equations were developed from

regression lines calculated from archaeological human enamel values, which can exaggerate the spread of values toward the endpoints, and are influenced by the climate and $\delta^{18}O$ sources for the populations in question (e.g. Daux et al. 2008; Levinson 1987, Longinelli 1984, Luz 1984). These sources of error are discussed in depth by Pollard et al. 2011. In light of the uncertainties surrounding the use of these conversion equations, they have been avoided here. Instead, interpretations are based on values obtained from a survey of $\delta^{18}O_{Phosphate}$ ($\delta^{18}O_P$) in archaeological human enamel from Britain (Evans et al. 2012).

The $\delta^{18}O_P$ values used by Evans and colleagues derive from archaeological human tooth enamel from individuals thought to be local to the areas where they were buried; they therefore start with an unknown, much like the datasets used to generate conversion equations for drinking water $\delta^{18}O$ values. However, an important difference is that rather than developing regression equations based on datasets from different source locations and climates, Evans et al. use only basic statistical analyses based on sample distributions from Britain, where Ipswich is located. The $\delta^{18}O_P$ distribution from archaeological materials in Britain follows a near-normal distribution, and based on the mean and standard deviations, Evans and colleagues calculated a likely $\delta^{18}O_P$ range for Britain of 17.7 (±0.7,1σ) (Evans et al. 2012: 757).

Evans and colleagues identified two biogeographic climate groups within the $\delta^{18}O_P$ data, and linked the distribution of $\delta^{18}O_P$ to variations in rainfall levels in Britain. The data were shown to vary geographically between 'high rainfall' areas, primarily located in the western and southern areas of Britain, with a higher mean $\delta^{18}O_P$ of 18.2‰ ±1.0 (2σ), and 'low rainfall' areas, primarily in eastern Britain, with lower $\delta^{18}O_P$ values of 17.2‰ ±1.3 (2σ)(Figure 3.18).

Ipswich falls within the 'low rainfall' area, and though climate during the medieval period is known to have fluctuated, it is expected that overall weather patterns including high versus low relative rainfall would remain largely unchanged (Darling et al. 2003).

The 'low rainfall' range is more conservative than the $\delta^{18}O_{iw}$ ranges based on conversion equations, but less conservative than the $\delta^{18}O_P$ range of 16.8‰ to 18.6‰ previously suggested by Chenery and colleagues (2010) for individuals born in Britain. Therefore, bearing in mind that a 'local' range based on $\delta^{18}O_P$ from archaeological skeletal remains is still only an estimate of expected local values, the 'low rainfall' mean of 17.2‰ ±1.3 (2σ) is used in this thesis.

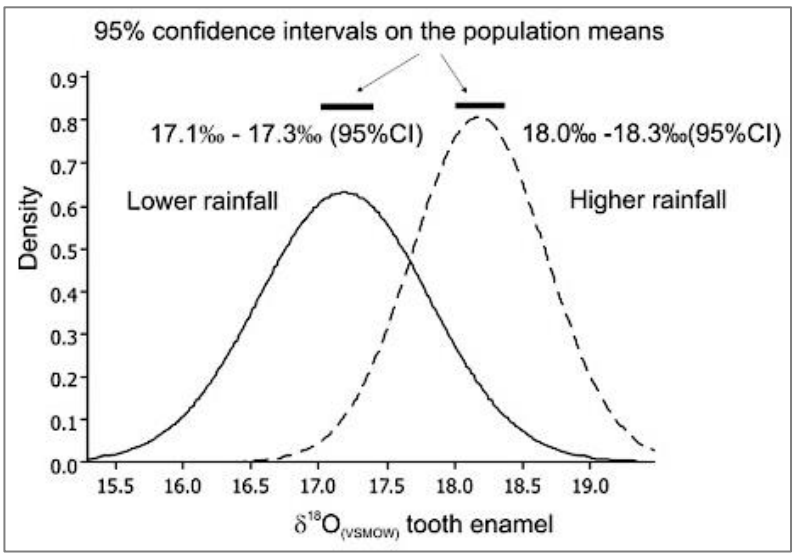


Figure 3.18. A comparison of the normally distributed $\delta^{18}O_P$ for archaeological human tooth enamel from 'low rainfall' and 'high rainfall' areas in Britain (from Evans et al. 2012, Figure 9).

Transforming $\delta^{18}O_{C\text{-}VPDB}$ to $\delta^{18}O_P$ for interpretations of human mobility

The $\delta^{18}O_{C\text{-}VPDB}$ values yielded from $\delta^{18}O$ analysis of tooth enamel carbonate are transformed to $\delta^{18}O_P$ by first adjusting the $\delta^{18}O_{C\text{-}VPDB}$ to $\delta^{18}O_{C\text{-}VSMOW}$ using the equation from Coplen et al. (1983):

$$\delta^{18}O_{V\text{-}SMOW} = 1.03091 * \delta^{18}O_{PDB} + 30.91$$

The $\delta^{18}O_{C\text{-}VSMOW}$ values are then transformed to $\delta^{18}O_P$ values through a calculation based on the constant offset between bioapatite $\delta^{18}O_P$ and $\delta^{18}O_C$, using the equation from Chenery et al. (2012):

$$\delta^{18}O_P = 1.0322 * \delta^{18}O_C - 9.6849$$

This regression equation was selected instead those by Bryant et al. (1996) or Iacumin et al. (1996) because it was formulated from paired $\delta^{18}O_P$ and $\delta^{18}O_C$ analyses on human teeth, rather than nonhuman mammals. However, it should be noted that all three equations yield very similar values.

Following the application of these equations, the human enamel values are interpreted as 'Local' or 'Nonlocal' based on the expected 'local' $\delta^{18}O_P$ range for the 'low rainfall' area around Ipswich, using the mean of 17.2‰ ±1.3 (2σ) from Evans et al. 2012, which results in a $\delta^{18}O_P$ range of 15.9 to 18.5‰.

Looking to the North Sea:
Isotopic and osteological evidence for medieval diet, mobility, and health at Stoke Quay, Ipswich

Volume II of II

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Part 2: The Mid Saxon through Medieval Periods

Chapter 4: Stoke Quay and the North Sea *emporia* (late 6th- late 9th centuries)

4.1 Introduction

The late 6th-9th centuries were a formative time for Anglo-Saxon England and the greater North Sea zone. This period saw the consolidation and growth of the major Anglo-Saxon kingdoms and their accompanying trade centres known as *emporia* – of which Ipswich was one – as well as the beginnings of what would become an extended conflict with Scandinavian groups also known as 'Vikings'.

It was during this time that the first major signs of human activity became evident at Stoke Quay. From the late 6th to early 8th centuries the southeastern area of the site was used as a burial ground, with no accompanying evidence for a settlement. Following the cessation of burials, a settlement evidently arose in the area, with habitation and craftworking areas including a well-preserved Ipswich Ware kiln. This chapter focuses on analyses of the human burials, set within the broader landscape of the *emporium* at Ipswich. The later settlement site is also discussed in order to contextualise the human burials and the site's development.

This chapter begins with a brief overview of the growth and function of the North Sea *emporia*, as well as evidence for trade at Ipswich and Stoke Quay itself during the Mid Saxon era. Hypotheses and research questions specific to this period are then discussed, followed by the materials used here to address the hypotheses. The isotopic results for this assemblage are presented, followed by a discussion of the results with intra- and inter-site comparisons with contemporary populations.

4.2 Ipswich and the North Sea *emporia*

To better understand the historical and economic forces affecting Stoke Quay during the Mid Saxon period, this section briefly reviews the current consensus regarding the growth and function of the North Sea *emporia* as well as the evidence for trade across the North Sea into Ipswich and Stoke Quay.

4.2.1 The character and function of the North Sea emporia

Following the decline of the Western Roman Empire, a number of trading sites were established along major waterways and coastal locations around the North Sea basin. These sites, also known as *emporia* or *wics*[1], were major nodes in the trading networks that developed during the 7th-8th centuries (Loveluck & Tys 2006). Some were short-lived, lasting only a couple of centuries, while others continued to play an important role in international trade. The major continental *emporia* during the 7th-8th centuries were Ribe and Haithabu/Hedeby (modern Denmark), Birka (modern Sweden), Dorestad (modern Netherlands), and Quentovic (modern France). In England there were four major *emporia*: *Eoforwic* (York), *Hamwic* (Southampton), *Lundenwic* (London), and *Gippeswic* (Ipswich) (Hodges 1982; Pestell 2012).

The general consensus regarding the nature and function of the *emporia* has shifted since the first major excavations of many of these sites took place in the 1960s and 1970s. Building off of earlier work by Henri Pirenne (1937), Richard Hodges (1982) saw the *emporia* as primarily the result of aristocratic forces creating a system for the control and exchange of prestige goods. Though

[1] For more on the meaning and use of the terms *emporia* and *wic*, see Pestell 2012; Rumble 2001; Clarke & Ambrosiani 1991.

Hodges' work continues to have considerable influence on early medieval scholarship, his view of the "evolution" of these sites, from temporary coastal markets into places of regional and international importance, has come under criticism in the years since the publication of his seminal book.

More than two decades of excavations at settlements in the 'contact zones' on both sides of the Channel and around the North Sea have led to a different viewpoint, that the southern North Sea was actually a complex multi-tiered trade network during the early Middle Ages. This viewpoint is supported by the range of imported items such as fine-ware pottery and metalwork excavated from smaller beachside sites across the North Sea, particularly in Frisia and along the Rhine (Cunliffe 2001; Loveluck & Tys 2006).

The presence of these imported items in settlements that lack high-status structures or other evidence of regional importance indicates that the trade in luxury goods was not limited to the *emporia*, but rather was conducted at coastal and riverine sites of all sizes. Thus far, this seems to be a uniquely coastal phenomenon. Indeed, as Loveluck and Tys (2006) have hypothesised, the location of coastal societies in areas that were at once marginal to inland society and also central to maritime communication and trade may have created a unique social landscape that was not subject to the same rules that governed inland populations.

With this newfound evidence for the widespread coastal exchange of imported items, it seems likely that the *emporia* were primarily used by the elite to collect tolls on bulk imports, rather than to control the flow of luxury goods. Thus, while many of these sites likely did benefit from some royal or aristocratic provisioning and oversight, they were also important centres for the trade of

more pedestrian goods, including pottery, quernstones and wine (Blinkhorn 1999; Kelly 1992; Astill 2012).

In addition to serving as sites for the importation and taxing of bulk goods, the *emporia* also became important centres for production and craftworking. The scarcity of arable land in coastal zones likely spurred the development of specialist artisans and producers, who may have had a certain freedom in choosing with whom to exchange their goods (Verhulst 2002; Loveluck 2005). The wool, textile, and salt production industries in particular were very active in the 8th and 9th centuries along the Channel and North Sea coasts (Verhulst 2002).

The combination of production and consumption of all manner of goods in the *emporia* created an environment clearly different from other settlements, particularly by the 8th and 9th centuries. The major *emporia* were larger and more densely occupied, and exhibit greater evidence for overseas trade and intensive craftworking, than contemporary settlements. Taken together, the archaeological record suggests that the *emporia* were major population centres that functioned as central nodes in a widespread regional and overseas trade network (Scull 2013).

Previous excavations at *Hamwic*, *Lundenwic*, and *Eoforwic* have revealed evidence of the scale of these sites and their involvement in trade and craftworking, but Ipswich has been less widely excavated than the other English *emporia*, and most excavations have not been fully published. However, the excavations at Stoke Quay can offer insight into the origin and function of Mid Saxon *Gippeswic*, contributing much to the greater discussion of these important trading sites.

The following section looks more closely at the extent and development of Ipswich, and the evidence it has yielded for specialist activities and both regional and international trade.

4.2.2 Ipswich: foundation and evidence for trade, production and diet

Ipswich occupies a strategic location along the River Orwell near its confluence with the River Gipping, at what was historically the highest navigable point for seagoing vessels and the lowest fordable point in the River Orwell (Brown, in press). Though there were Romano-British settlements in the area, it appears that Ipswich itself was founded on previously unoccupied land (Wade 1988). However, inter-regional exchange networks were likely already in place around the Orwell estuary, and the development of Ipswich may have been a natural consequence of an intensification of these networks (Scull 2013).

The 7th century settlement at Ipswich was centred on the northern shore of the Orwell, near the later site of the Stoke Bridge. The size of the settlement at that time has been estimated at around 15ha, although at its greatest extent in the pre-Viking period it may have been as large as 50ha (Wade 1988; Scull 2013). Much of our understanding of the early development and growth of Ipswich comes from a series of small rescue excavations that took place from the 1970s-1990s as part of the Origins of Ipswich Project (Figure 4.1, Table 4.1)(Wade 2014). Full reports have not been published for most of these excavations, but summaries are available through the Archaeological Data Service.

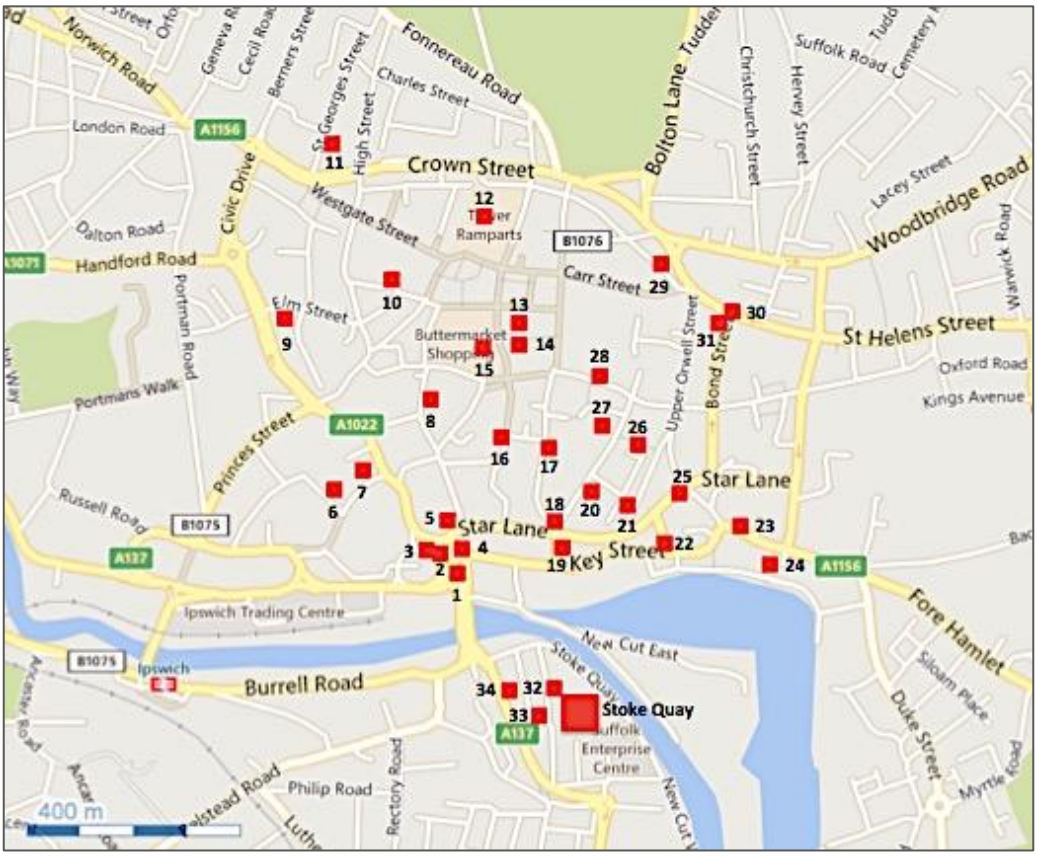


Figure 4.1. Map of interventions yielding Mid Saxon materials at Ipswich (adapted from Archaeology Data Service Interactive Map, 2018).

#	Site Name	Site Code	#	Site Name	Site Code
1	Bridge Street	IAS6202	18	Lower Brook St/Foundation St	IAS5505
2	Greyfriars Road	IAS5201	19	Foundation St.	IAS5801
3	Greyfriars Rd (Island site)	IAS5204	20	Smart Street	IAS5701
4	Greyfriars Rd/St. Peter's St	IAS5202	21	Shire Hall Yard	IAS6904
5	St Peter's Street	IAS5203	22	Key Street	IAS5901
6	Cecilia Street	IAS5001	23	85-87 Fore Street	IAS6106
7	Franciscan Way	IAS5003	24	Neptune Quay	IAS6601
8	St Nicholas Street	IAS4201	25	Fore Street	IAS5902
9	Elm Street	IAS3902	26	School St/Foundation St	IAS4801
10	8-10 Arcade Street	IAS1804	27	Wingfield St./Foundation St.	IAS4601
11	St. George's Street	IAS9802	28	Tacket Street	IAS3410
12	Tower Ramparts School	IAS0802	29	Old Foundry Road	IAS1501
13	32-38 Buttermarket	IAS3201	30	St. Helen's Street	IAS8804
14	St. Stephen's Church	IAS3203	31	24 St. Helen's Street	IAS3601
15	St. Stephen's Lane	IAS3104	32	Vernon St/Great Whip St	IAS7501
16	Turret Lane	IAS4302	33	Little Whip Street	IAS7404
17	15-17 Lower Brook Street	IAS5502	34	Vernon Street	IAS7402

Table 4.1. Site names and codes for the excavations shown in Figure 4.1.

Early activity and development

North of the River Orwell, most evidence for activity before the 9th century comes from burials, the earliest of which were excavated from cemeteries outside the historical centre at Boss Hall and Hadleigh Road (Brown, in press; Wade 2014). Both cemeteries yielded inhumation and cremation burials, many of which were richly furnished with weapons and high status dress items. These burials indicate an aristocratic presence in the area before the first signs of settlement at Ipswich itself in the late 6th-early 7th centuries (Scull 2009).

Archaeological interventions within Ipswich have also revealed much about the early development of the *emporium* during the 7th and 8th centuries, and its international character. Excavations along the waterfront at St. Peter's Street/Greyfriar's Road uncovered *Grubenhauser* (sunken-featured buildings) and pits containing pre-Ipswich Ware pottery, some handmade and some imported from the Continent. The early settlement assemblage is difficult to date precisely, but a 7th century (pre-720 AD) date has been established (Wade 1993; Scull 2009).

More specific dates have been obtained from grave goods and radiocarbon dating of burials from the Buttermarket cemetery in the modern centre of the town. The burial ground was located north of the initial settlement area, and likely served as the population's primary cemetery until its abandonment before the end of the 7th century. Burials at Buttermarket reflected a complex expression of cultural identity, including a number of richly furnished weapons burials containing imported grave goods that have been interpreted as those of foreign traders, possibly of Frankish origin. In addition to potential foreign traders, other burials at the cemetery also include continental elements

relating to status, social roles, and gender, and indicate the strong economic and cultural ties between 7th-century Ipswich and the Merovingian Continent (Scull 2009, 2011, 2013).

Similarly furnished graves with weapons and continental goods such as glass palm cups have been found at contemporary cemeteries in *Hamwic* and *Lundenwic*, providing supporting evidence that the *emporia* were exceptional settlements with strong connections to the Continent (Scull 2011; Stoodley 2005; Burton 2007). *Hamwic* in particular is notable for its high proportion of Merovingian-type weapon burials, interpreted as indicators of high status or close connections to the Frankish areas of northern France, Belgium, and the southern Netherlands (Stoodley 2005).

In the late 7th to 8th centuries, the area previously occupied by the Buttermarket cemetery was transformed into an area for habitation and craft activities. At this stage, the settlement extended north of the original settlement site, as well as south of the River Orwell, with streets organised in an orthogonal pattern. The settlement expanded to around 50ha, and it was larger and more densely populated than contemporary settlements in rural Suffolk (Wade 2014). Ipswich maintained connections with the hinterland through a network of estates that traded their surplus with the burgeoning settlement (Scull 2013).

Trade and production

The study of ceramics has provided an important window into production and trade at Ipswich during this early period. As the settlement expanded in the 8th century, the northeastern area of the settlement became an important focus for the large-scale production of ceramics known as Ipswich Ware, the first

industrially produced pottery since the Roman period (Blinkhorn 1999). Ipswich Ware has been found at nearly all rural Mid Saxon sites in the kingdom of East Anglia, often in large numbers. Outside of East Anglia, these ceramics have been found at high-status secular and religious sites as distant as Kent and Yorkshire (Wade 1988).

Coin and pottery finds at Ipswich point to a shift in patterns of trade and cultural affiliation with the Continent from the earliest phase of settlement to the later part of the Mid Saxon period. In the 7th century, trade and social affiliations were focused on the Merovingian areas of northern France and Flanders, while in the 8th and 9th centuries this focus shifted toward the Rhineland, through increasing contacts with the *emporia* at Domburg and then Dorestad (Wade 1988; Scull 2013).

Frisian merchants were likely the main exporters of agricultural and craft products from the Rhineland to eastern England as well as Jutland (Lebecq 1992). These trends can be seen in the large quantity of imported pottery excavated from Ipswich during this time, with 14% of the ceramic assemblage coming from the Continent (Scull 2013). The imported wares appear to have originated in the Rhineland (in the Vorgebirge and near Mayen), Flanders (Meuse Valley), and northern France, further supporting the continued trade between Ipswich and its Continental counterparts (Wade 1988; Hodges 1978).

Diet

From the archaeological record and the few written sources that exist for the Anglo-Saxon period, it appears that diet at this time was largely based on bread and cereals, and meat and dairy products from domesticated animals

(Hagen 1992). Meat was sourced from cattle, pigs, sheep/goats, and fowl such as chickens and geese, and some sites show evidence for the consumption of wild species such as boar, birds, deer, eel, and other fish (Crabtree 1990; Hagen 1992; O'Connell & Hull 2012). Other food sources include vegetables such as carrots, celery and cabbage, fruits such as elderberries, apples, and blackberries, and legumes such as peas and beans (McCobb & Briggs 2001; Hagen 1992).

Differences in diet based on sex have been found at some Anglo-Saxon sites but not at others. In a survey of Anglo-Saxon sites across Norfolk, Suffolk, Oxfordshire and Hampshire, O'Connell and Hull (2012) found that in Suffolk, females tend to have higher $\delta^{15}N$ than males, while in Hampshire, males generally have higher $\delta^{15}N$ than females. A different pattern is seen in Norfolk and Oxfordshire, where males and females tend to have similar $\delta^{15}N$ ranges when sites are grouped together by region. At all sites there is a range in isotopic values within each sex, and this was particularly seen in the $\delta^{15}N$ values, indicating some social divisions in Anglo-Saxon society (O'Connell & Hull 2012).

A similar mix of outcomes is seen when $\delta^{13}C$ and $\delta^{15}N$ results from Anglo-Saxon sites are compared by inferred wealth or status based on grave goods. At three sites in Hampshire and one site in Norfolk, males buried with weapons had significantly higher $\delta^{15}N$ than those buried without weapons, but the opposite trend is seen at three other sites in Hampshire, two in Norfolk, and one each in Suffolk and Oxfordshire (O'Connell & Hull 2012; Privat et al. 2002; Hull 2008).

At Berinsfield, a difference in isotopic values was seen between 'wealthy' and 'poor' individuals based on gendered and non-gendered grave good assemblages, with 'poor' individuals yielding higher $\delta^{15}N$. A proposed explanation for this pattern is the consumption of freshwater fish or pigs by

these less wealthy individuals, or the consumption of domestic birds (Privat et al. 2002; O'Connell & Hull 2012). Again, this trend was seen at some other sites but not at others. Fish remains are rare at earlier Saxon sites, but they have been found with more regularity on sites excavated with modern sieving techniques, albeit in small numbers (Barrett et al. 2004a; O'Connell & Hull 2012).

O'Connell and Hull (2012) also found temporal changes in diet in Anglo-Saxon East Anglia, with an increase in $\delta^{13}C$ and $\delta^{15}N$ from the 5th-7th centuries to the 7th-9th centuries that may relate to increases in the exploitation of marine and possibly freshwater fish. However, the Mid Saxon (7th-9th century) sites are all early monastic communities, which may have impacted the amount of fish consumed at these sites, as fish was a permitted food on fasting days when meat was prohibited (O'Connell & Hull 2012; Barrett et al. 2004a). The possibility of temporal changes in diet at secular sites in East Anglia has not been tested.

4.2.3 Stoke Quay: evidence for craftworking, trade and diet

Studies of Ipswich have been hampered by the fact that, unlike the other major English *emporia,* which have shifted from their early medieval locations, modern Ipswich occupies the same location as its medieval predecessor. Though programmes like the Origins of Ipswich Project have added valuable information from small-scale excavations scattered across the historic core of the town, few habitation and craftworking sites have actually been located. This has resulted in a rather piecemeal understanding of the development of this important site. Recent large-scale excavations south of the River Orwell, however, have greatly expanded our understanding of Ipswich and its relationship to the broader landscape.

As mentioned in Chapter 1, Stoke Quay is located across the River Orwell from the historic centre of Ipswich, in what later became the parish of St. Augustine's. At 1.2 hectares, Stoke Quay is larger than many sites excavated at Ipswich, which has enabled a broad investigation of settlement patterns, craftworking, and burial away from the historical core of the settlement (Brown, in press). Like other sites in Ipswich, excavations at Stoke Quay revealed evidence of long-distance trade and specialist activities during the Mid Saxon period (late 6th-9th centuries).

No habitation evidence survives from the 6th-7th centuries at the site, but there is evidence of human activity in the form of a collection of barrows and clustered inhumations toward the eastern side of the centre of the site (see Section 4.3.1 for a description and map). Following the cessation of burial at the site around the end of the 7th century, a settlement arose to the north and west of the barrows. Fence lines appear to have separated the land into several areas, each potentially representing separate properties (Brown, in press).

Similar land divisions have been found at Fishergate, York, in the form of ditches, and at *Hamwic* in the form of pit alignments. This manner of dividing land has been interpreted as a potential indication of central control at other sites, and as an implication that the concept of property rights was developing by this time (Hinton 2000). If this were the case at Stoke Quay, it would suggest that the site might have been closely connected to central Ipswich even at this early date.

Each area of Stoke Quay exhibited a somewhat different set of features and finds (see Teague, in press). The numerous structures, pits, and wells yielded

a wealth of evidence for specialist activities, craftworking, and trade, which are briefly described below.

Craftworking

Over 200 small finds were recorded from the later Mid Saxon (Phase 3) deposits at Stoke Quay, including a large number of production-related items and waste products. The widespread distribution of finds related to manufacturing suggests the presence of numerous workshops across the site, which, combined with a low frequency of personal dress items and luxury goods, indicates a greater focus on production than consumption (Popescu & Gaimster, in press).

The production of worked antler combs is suggested by comb fragments and bone- and antler-working waste recovered from features across the site. Also recovered were worked whale, ovicaprid, and pig bones, as well as goat horn waste. Horn waste has been found in association with permanent workshops at other Anglo-Saxon urban sites, and its presence at Stoke Quay bolsters the evidence for significant permanent craftworking at the site (Riddler 2014; Popescu & Gaimster, in press).

The later Mid Saxon deposits also included evidence of textile production. Several iron pins were recovered, likely teeth from wool combs used to clean and separate wool, or from flax hecklers used to separate processed stalks into fibres (Popescu & Gaimster, in press). The recovery of spindle whorls of varying sizes and weights suggest that different qualities of yarn, with varying fineness, would have been produced at the site. The technologies used in wool and linen production involved loom weights and pin beaters, both of which were found in the 8th-9th century deposits, along with whole or fragmentary bone needles. With

their varied size and shape, the needles could have been used for many activities including sewing, weaving, knitting, basketry, and repairing fishing nets and sailcloth (Margeson 1993; Andersson 1993; Popescu & Gaimster, in press).

Evidence for metalworking at Stoke Quay is minimal, but includes small quantities of iron-rich slag, six incomplete knife blades, and a small amount of lead waste concentrated in an area where a lead belt buckle with runic inscriptions was found (Popescu & Gaimster, in press). Based on these materials, it appears that small-scale metalworking was taking place at Stoke Quay during the Mid Saxon period, but it was likely less intensive than the bone, horn, and antler-working activities.

Of particular note amongst the evidence for craftworking and specialised trades at Mid Saxon Stoke Quay is the presence of a well-preserved Ipswich Ware kiln next to Barrows 5 and 6. This kiln is the only example of its kind south of the River Orwell, and its location suggests a broader scope for the production of this important pottery industry (Poole, in press). Furthermore, though the Ipswich Ware Project recently refined the dating of this pottery industry to between c. 720 to 850 AD (Blinkhorn 2012), the direct dating evidence at Stoke Quay may push the start date back to between 650 and 715 AD (Sudds, in press).

Trade

Stoke Quay's involvement in trade within England and across the North Sea is attested to by the presence of coins and imported goods recovered from the Mid Saxon features. The coin evidence includes 15 base silver coins found in the Mid Saxon settlement features, and based on the concentration of these finds, trade and commerce may have been focused in Area A in the northern part of the

site, between the River Orwell to the north and the road called *Losegatewaye* (later Great Whip Street) to the west (Figure 4.2)(Popescu & Gaimster, in press; Teague, in press).

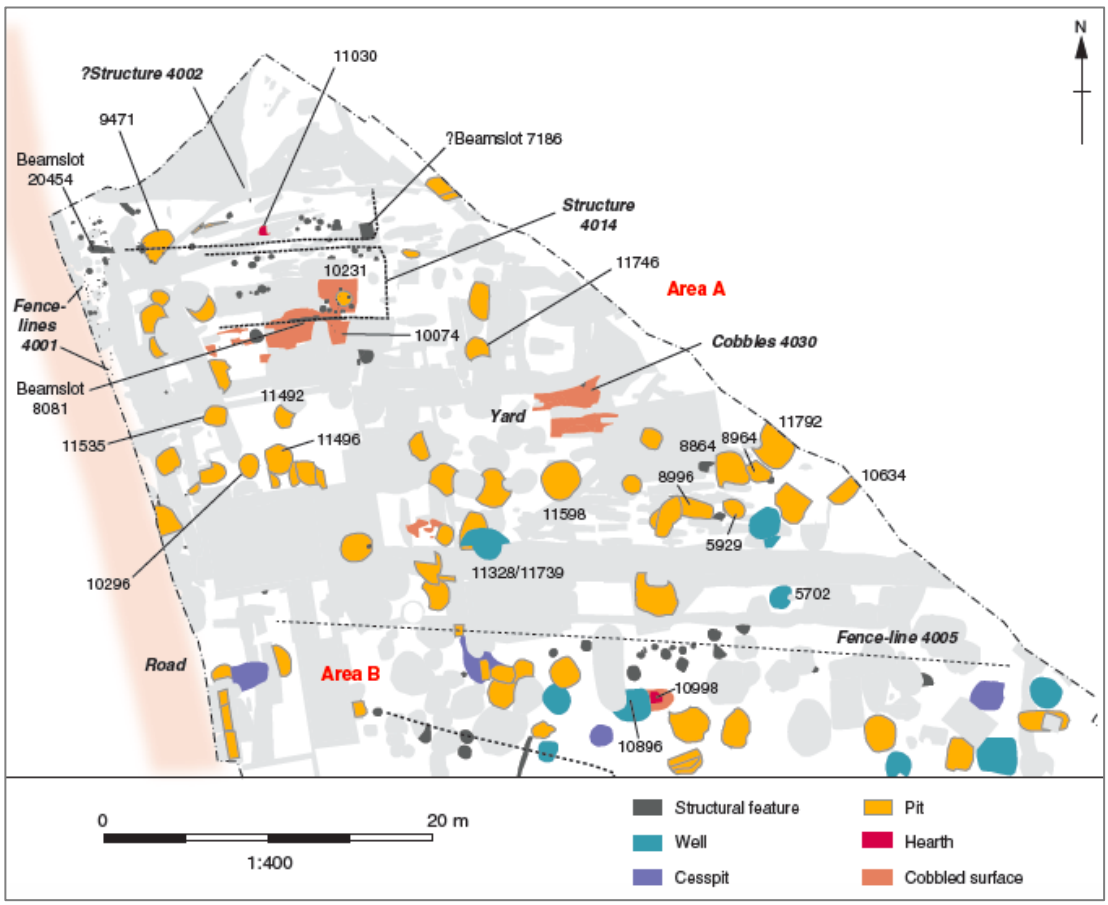


Figure 4.2. Map of Mid Saxon Stoke Quay, Area A, located in the northwestern area of the site. Based on finds concentrations, trade and commerce may have been based in this area (image from Teague, in press: Figure 3.17).

A variety of imported goods recovered from the Mid Saxon deposits reflect the widespread trade occurring at the *emporium*. Some of these goods, such as glassware, indicate higher status, and include palm cups, beakers, and squat jars, which were likely produced on the Continent (Jarrett, in press). The palm cups likely originated in the Frankish areas of northern France, Belgium, or the southern Netherlands (Scull 2011; Hinton 2000, 2005). Palm cups have been found in or near all of the English *emporia* except York, and have been

interpreted as indications of the presence of wealthy merchants (Blackmore 2000; Scull 2011; Dalwood 2018). A palm cup was also found in Barrow 7 in the early Mid Saxon barrow cemetery, though unfortunately, no skeletal remains were preserved (Teague, in press).

More quotidian imported items included dozens of quern stone fragments, which indicate the practice of cereal grinding at Stoke Quay from perhaps the 8th century. Many were made of lavastone from the Rhineland, and their presence attests to site's strong trading ties with that area via Dorestad (Hayward, in press). Similar quantities of quern stones have been found at a Late Saxon waterfront embankment on the Thames in London, perhaps on their way to rural inland sites (Freshwater 1996; Hamerow 2007). The presence of these stones at Stoke Quay indicates that Ipswich was an additional port of entry for these widely used goods. The use of basalt quern stones in food processing could potentially introduce lower $^{87}Sr/^{86}Sr$ ratios into the diet, so their presence at the site bears keeping in mind.

Further evidence of trade is demonstrated by wooden casks used as linings in several wells. The unusually well-preserved casks were likely for storing and transporting wine, and tree-ring analysis revealed that at least one cask was made of oak from the Mainz region of the Rhineland (Goodburn, in press). Together with a similar example excavated at Greyfriar's, Ipswich, these casks represent tangible evidence that wine was being imported across the North Sea from the Rhineland to ports such as *Gippeswic* and *Lundenwic*. This trade may have been driven by Frisian merchants based along the Rhine, who traded heavily with the Thames estuary region, and evidently, the Orwell estuary (Goodburn, in press; Ellmers 1990).

A final piece of evidence linking Stoke Quay to the Continent is found in the later Mid Saxon pottery assemblage, which is dominated by Ipswich Ware but also includes imported wares from northern France and the Rhineland. It is possible that the North French wares date to the 7th and early 8th century, with an increase in Rhenish Badorf ware in the later 8th century (Sudds, in press). Some imported pottery may have been used to transport goods such as honey, while others would have been destined for domestic use (Dalwood 2018).

North French imported pottery has also been found at *Hamwic*, and its presence has been interpreted as evidence for foreign merchants and other immigrants living in the *emporium* and maintaining strong cross-Channel connections (Dalwood 2018; Hinton 1990). The higher concentrations of Rhenish Badorf pitchers and amphorae and of glass drinking vessels in the northern area of Stoke Quay suggests the presence of higher status individuals in the northern properties (Jarrett, in press; Sudds, in press). Given its location along both water and land routes into Ipswich, this area would have been ideal for trade operations.

Diet

The Mid Saxon faunal assemblage is by far the largest of any period at Stoke Quay, with over 12,000 bone fragments recovered from a variety of cut features. Most of the bones came from pits, though some were also found in well fills and in one case, in a possible sunken-featured building. About one third of the features produced more than 100 bones, but several produced over 1,000 (Brown, in press).

Species representation during this phase was dominated by the major domesticates. Based on total fragment counts, over 50% of the major domesticate bones were from cattle, 27.5% were from sheep/goats, and 22% were from pigs. An analysis of the diagnostic elements used to distinguish sheep from goats revealed a roughly 2.5:1 ratio of sheep to goat horn cores, and a nearly 16:1 ratio of sheep to goat proximal radii. Based on this evidence, most sheep/goat bones from this period likely belong to sheep, while goats were used primarily for horn-working and probably contributed very little to the meat diet (Rielly, in press).

Other animals formed a lesser component of the faunal assemblage but comprised a fairly wide range of species, with notable quantities of poultry (chicken, goose and some duck), as well as smaller numbers of other game animals and birds. Some of the goose and duck bones may be from wild rather than domestic birds. The majority of poultry bones were from adult individuals, signifying a greater reliance on eggs than on meat, though the presence of juvenile chickens indicates that some were culled for consumption early in life. The presence of a few very young birds may suggest that some chickens were locally reared (Rielly, in press).

The later Mid Saxon deposits contained over 6,000 fish bones, nearly 5,000 of which were from eel. In addition to eel, most deposits also contained bones from small flatfish, particularly plaice and flounder, totalling over 300 flatfish bones. Almost 300 herring bones were also recovered. Some deposits also contained smaller amounts of gadids (totalling nearly 200 bones), mackerel, and rays, along with numerous other species (Nicholson, in press).

Based on the faunal and fish bone data, it would appear that the later Mid Saxon residents of Stoke Quay consumed a large amount of fish, particularly eel. Whether this was the case for the early Mid Saxon group is less certain.

4.2.4 Research questions and hypotheses

This section has provided information on the development of Ipswich and its role in trade and craftworking, as well as the evidence for these activities at later Mid Saxon Stoke Quay in the 8th and 9th centuries. However, as mentioned above, there is no settlement evidence at Stoke Quay from the late 6th-7th centuries, a crucial period in the formation of Ipswich. The skeletal remains from early Mid Saxon Stoke Quay thus provide the only window into the nature of the site and its inhabitants prior to the formation of the later settlement. The skeletal remains provide an important resource for investigating how people at Mid Saxon *Gippeswic* lived, including diet, health, social status and geographic origins.

The analysis in the next section is focused on several research questions and hypotheses based on the historical and archaeological evidence presented here. These questions are specific to the Mid Saxon assemblage but they fit within the overarching questions about diet and mobility addressed throughout this thesis and described in Chapter 1. Health is not discussed due to the poor preservation of the early Mid Saxon burials.

The first set of questions relate to diet at the site. As discussed in Section 4.2.2, isotopic analyses of Anglo-Saxon diet in southeastern England have found conflicting evidence for dietary differences by sex or by status inferred from grave goods. For instance, females at sites in Suffolk have yielded higher $\delta^{15}N$ than males (O'Connell & Hull 2012). Does this pattern hold true at Stoke Quay?

Additionally, at Westgarth Gardens, Suffolk, males buried without weapons and individuals with 'poorer' grave goods had significantly higher $\delta^{15}N$ than those buried with weapons or with 'wealthier' grave goods (Hull 2008). As grave goods are present in some of the early Mid Saxon graves at Stoke Quay, are there differences in $\delta^{13}C$ and $\delta^{15}N$ between individuals buried with different types of grave goods? Can the consumption of marine fish indicated by the fish bone evidence at later Mid Saxon Stoke Quay be seen in the earlier skeletal assemblage? Finally, how does the dietary evidence at Stoke Quay compare to what is seen at contemporary English sites? Is diet at Stoke Quay more closely linked to that seen at coastal sites or to sites in the hinterland?

To approach these questions, $\delta^{13}C$ and $\delta^{15}N$ analyses on the early Mid Saxon skeletal assemblage are performed with the hypothesis that sex-based and status-based differences will be visible. It is hypothesised that males will exhibit more evidence for fish consumption than females, given the possibility that merchants are buried at the site as they were at Buttermarket. The isotopic results from Stoke Quay are also compared to contemporary assemblages in order to gauge whether diet at Stoke Quay was more closely linked to other estuarine and coastal sites versus inland sites, with the hypothesis that similarities will be found between Stoke Quay and coastal/estuarine sites.

The second main question relates to the presence of nonlocals at early Mid Saxon Stoke Quay. At Buttermarket and at *Hamwic* and *Lundenwic*, grave good evidence indicates the presence of merchants from northern France, Belgium, and the southern Netherlands in the population. With several burials furnished with imported goods, is there evidence for merchants living at Stoke

Quay? If merchants were living at Stoke Quay and trading overseas, there may have been individuals living at the site who were born elsewhere.

This can be tested through $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of tooth enamel, first to establish the presence of 'nonlocals', then to determine if their isotopic values are consistent with origins in the aforementioned areas. It is hypothesised that if nonlocals are found, they are likely to come from areas such as northern France and the Netherlands, with which Ipswich maintained close trading ties.

4.3 Materials

Excavations at Stoke Quay revealed an early Mid Saxon barrow burial landscape along with additional inhumation burials near the barrows. The burials date to the late 6th - early 8th centuries, but most are likely 7th century in date (Brown, in press). The following section provides an overview of the human skeletal assemblage for this early Mid Saxon burial landscape, followed by a description of the samples selected for isotopic analysis.

4.3.1 The Mid Saxon burials

The Mid Saxon burial landscape at Stoke Quay was situated on a break of slope at c. 2.0-2.2m OD in the central-eastern portion of the site. At the time of their construction, they would have been visible from the River Orwell, located about 80-120m to the east. The landscape contained seven barrows with centrally placed burials encircled by ring ditches, as well as two possible additional barrows. To the north and south of the barrows were two clusters of 10 inhumation burials and three isolated burials (Figure 4.3)(Teague in press; Loe et al., in press).

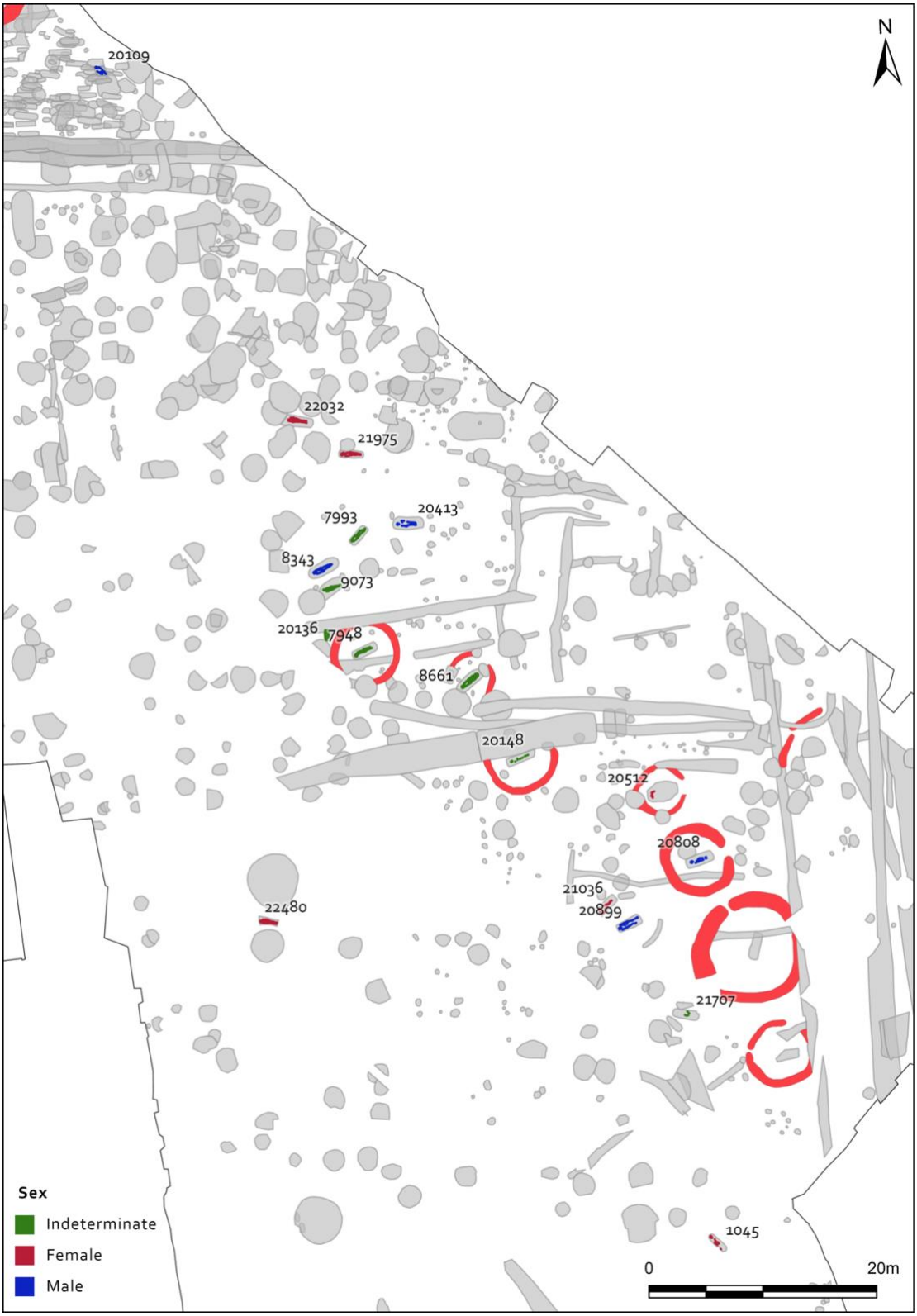


Figure 4.3. The Stoke Quay Mid Saxon burial landscape, with barrow ditches in red and burials coloured by estimated biological sex and labelled with burial numbers.

The slightly elevated location of the Mid Saxon burials likely made them vulnerable to cycles of wetting and drying, which would have contributed to post-depositional damage (Teague, in press). The overall skeletal preservation of this group was very poor and incomplete, and bone surfaces were generally highly abraded, hindering morphological analysis and measurements. The barrow burials were the worst preserved, as the additional soil over the burials and larger grave size may have been more vulnerable to groundwater penetration. Skeletal remains were only preserved in six of the nine possible barrow burials, in contrast to the 13 other burials which all retained at least some skeletal material. In total, 19 graves contained skeletal material (Teague, in press)(Table 4.2).

Burial type	Area	Number	Description
Barrow burials	Southwest area	7, plus 2 possible	Encircled by ditches
Grave Group 1	North of Barrow 1	7, plus 1 possible empty grave	Inhumation burial cluster
Grave Group 2	West of Barrows 5 and 6	3	Inhumation burial cluster
Isolated burials	Southwest of barrows	3	Isolated burials

Table 4.2. Descriptive information for the Stoke Quay Mid Saxon burial types.

Due to the poor preservation and high fragmentation of many of the burials, biological sex could only be estimated for 11 out of 19 individuals, of which six were female (including ??F, ?F, and F designations) and five were male (including ??M, ?M, and M designations). All skeletal remains were from adults, except for one adolescent, aged 13-17 years. Age-at-death was assessed for all individuals, but two could only be classified as 'Adult,' meaning 18+ years old (Figure 4.4).

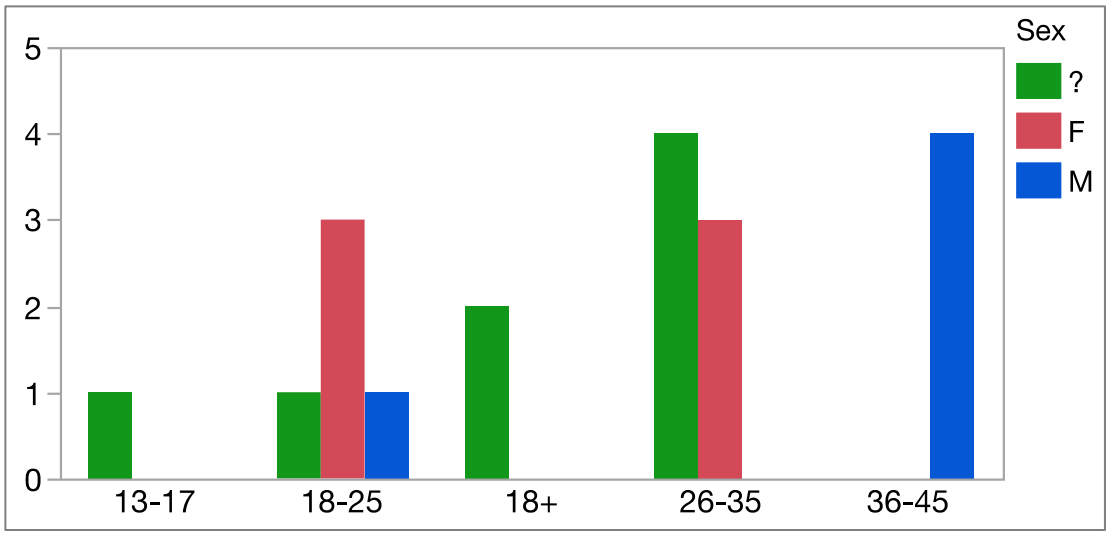


Figure 4.4. Estimated age-at-death and sex for the Stoke Quay Mid Saxon burials (n = 19).

4.3.2 Samples for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis

Of the 19 Mid Saxon burials that retained some skeletal material, 18 were sampled for $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen. The remaining individual, Sk 20938, was ultimately excluded due to extremely poor preservation (Table 4.3).

Bone samples were taken from ribs, or long bones if no ribs were preserved. A cranial fragment was used for Sk 20512 due to very poor long bone preservation. The bone selection was less uniform for this period than for later periods, but priority was placed on obtaining the maximum number of analyses possible from this important phase in the development of the site and of Ipswich. Bone collagen extraction and analyses were performed as described in Chapter 2, Section 2.2.3.

Sk ID	Age	Sex	Grave Group	Grave Goods	^{14}C Dates	Bone Sampled	yield?
1045	26-35	F??	Isolated	Iron knife (Evison type 3, e6th-8th cen.)	-	L femur	yes
7948	26-35	?	Barrow	-	-	L tibia	no
7993	18+	?	GG1	-	-	R tibia	yes
8343	36-45	M?	GG1	Cattle bones; Badorf-type ware sherd (670-850 AD) in fill	-	rib (unsided)	yes
8661	26-35	?	Barrow	Possible burnt plant offering	-	L tibia	no
9073	18-25	?	GG1	-	-	L rib	no
20109	36-45	M?	Barrow	Iron seax, possible scabbard	551-646 cal AD (95.4%)	rib (unsided)	yes
20136	26-35	?	GG1	Sceat primary series B (685-700 AD); North French blackware (600-850 AD) sherd in fill	-	R tibia	yes
20148	26-35	?	Barrow	-	-	R(?) femur	no
20413	36-45	M??	GG1	2 Cu alloy pins (late 7th-8th cen.)	-	R fibula	no
20512	26-35	F	Barrow	-	-	R parietal(?)	yes
20808	36-45	M	Barrow	Cu alloy knife(?), food offering	647-808 cal AD (95.1%)	L tibia	yes
20899	18-25	M??	GG2	Possible coffin board/wooden board	-	L tibia	no
20938	13-17	?	GG2	-	-	-	-
21036	26-35	F??	GG2	-	-	L tibia	no
21707	18+	?	Isolated	-	-	L leg shaft	yes
21975	18-25	F??	GG1	-	-	R rib	no
22032	18-25	F	GG1	Coffin lid/wooden board; cow mandible	-	R rib	yes
22480	18-25	F	Isolated	-	-	R rib	yes

Table 4.3. Basic demographic, burial, and sample information the Stoke Quay Mid Saxon burials, including whether collagen extraction was successful.

4.3.3 Samples for tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

The samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis included two barrow burials, both men aged 36-45 years. They were part of the pilot study, and both were radiocarbon dated (Farber & Lee-Thorp, in press; Teague, in press) (Table 4.4). The date for Sk 20808 was corrected for a small marine reservoir effect of 13% (with a standard error of ±10%) (Popescu 2020, personal communication).

Burial number	Age	Sex	Date	Grave Goods	Tooth sampled	Skeletal information
Sk 20109	36-45	M?	551-646 cal AD (95.4%)	Iron seax, scabbard(?)	L mand. P_4	Periodontitis, dental caries
Sk 20808	36-45	M	647-808 cal AD (95.1%)	Wooden board, food offering, Cu alloy knife(?)	R max. C	Sharp force cranial trauma, fractured nasal/maxilla, cribra orbitalia, Caucasian, caries, periapical cavity

Table 4.4. Mid Saxon $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ sample demographics, dates, and burial information.

4.4 Results

This section presents the $\delta^{13}C$ and $\delta^{15}N$ isotope results for the human assemblage, including summary statistics and descriptions of data distributions. Next, the human strontium and oxygen isotope results are given. The results are discussed and interpreted in Section 4.5.

4.4.1 $\delta^{13}C$ and $\delta^{15}N$ results

Only ten of the 18 human samples yielded well-preserved collagen meeting the quality standards described in Chapter 2 (Table 4.5). Despite the generally poorer macroscopic appearance of the Barrow skeletal materials, the successful collagen extraction rate was 50%. Grave Group 1 had a mixed success rate, while all three skeletons from the isolated graves yielded acceptable

collagen. Burials from Grave Group 2 had the poorest collagen preservation, with none of the three sampled burials yielding acceptable collagen.

Cemetery Group	# Sampled	# Yielding Collagen	Extraction Success Rate
Barrow	6	3	50%
GG1	7	4	57%
GG2	3	0	0%
Isolated	3	3	100%

Table 4.5. Collagen extraction outcomes for the Mid Saxon human skeletal assemblage.

The $\delta^{13}C$ and $\delta^{15}N$ results are plotted in Figure 4.5. The $\delta^{13}C$ mean is -20‰ (± 0.4, 1σ), and the $\delta^{15}N$ mean is 11.1‰ (±1.6, 1σ). A line of best fit shows a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.71$, $p = 0.0023$). The $\delta^{13}C$ and $\delta^{15}N$ data do not depart from the Normal distribution, so parametric statistical tests are appropriate for both datasets ($\delta^{13}C$ W= 0.970, p = 0.8947; $\delta^{15}N$ W= 0.967, p = 0.8653, Shapiro-Wilks W test). The $\delta^{13}C$ and $\delta^{15}N$ results for the successful extractions are shown in Table 4.6.

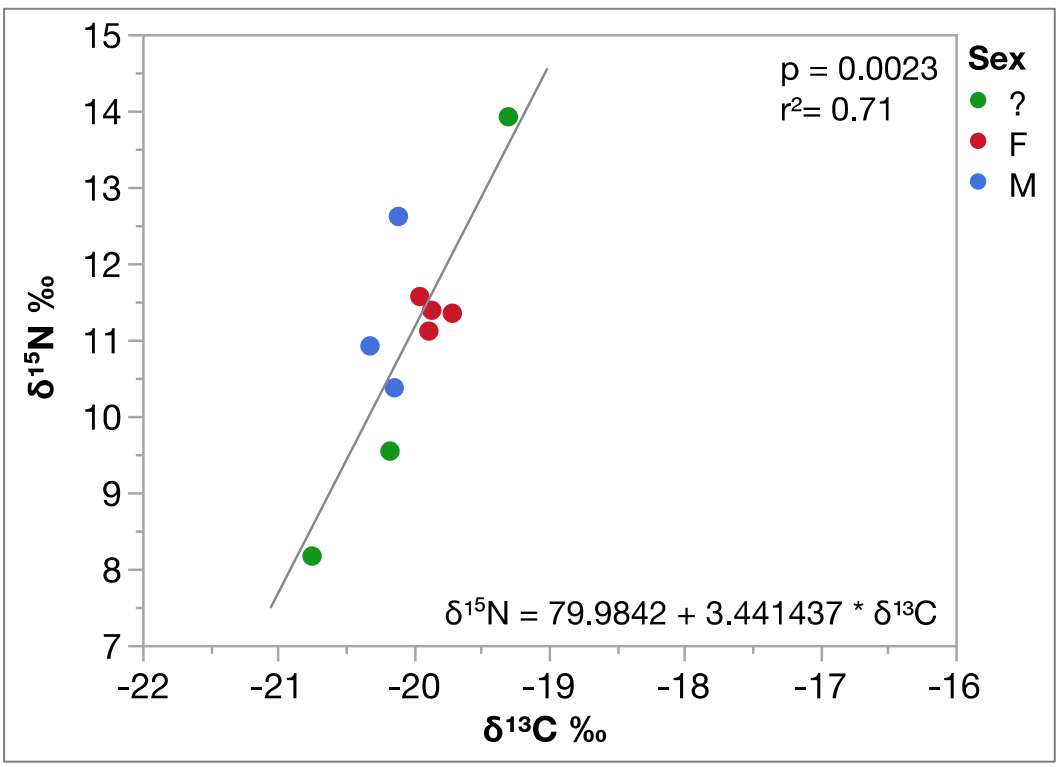


Figure 4.5. Scatterplot of Stoke Quay Mid Saxon $\delta^{15}N$ and $\delta^{13}C$ results coloured by sex (n = 10), with a line of best fit showing high statistical correlation (r = 0.71; p = 0.0023).

Skeleton	Age	Sex	Location	$\delta^{15}N$	$\delta^{13}C$	%C	%N	C:N	% Coll
1045	26-35	F??	Isolated	11.3	-19.7	44.7	15.5	3.3	7.9
7993	18+	?	GG1	9.5	-20.2	35.5	12.6	3.3	1.9
8343	36-45	M?	GG1	10.4	-20.1	25.4	8.9	3.3	1.0
20109	36-45	M?	Barrow	10.9	-20.3	40.4	14.6	3.2	10.6
20136	26-35	?	GG1	8.2	-20.7	16.3	5.5	3.4	4.9
20512	26-35	F	Barrow	11.1	-19.9	42.6	15.2	3.3	8.9
20808	36-45	M	Barrow	12.6	-20.1	30.6	10.7	3.3	9.5
21707	18+	?	Isolated	13.9	-19.3	45.0	16	3.3	6.9
22032	18-25	F	GG1	11.6	-19.9	31.1	11	3.3	5.0
22480	18-25	F	Isolated	11.4	-19.9	43.9	15.7	3.2	6.3

Table 4.6. Mid Saxon $\delta^{13}C$ and $\delta^{15}N$ results and collagen quality indicators (n = 10).

4.4.2 $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results

Both individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ yielded results (Figure 4.6). Because of the small sample size (n = 2) the isotopic values for these two individuals are given in Table 4.7 without summary statistics.

Burial number	$^{87}Sr/^{86}Sr$	$\delta^{18}O_{C\text{-}VPDB}$	$\delta^{18}O_P$
20109	0.710398	-4.6	17.3
20808	0.709642	-3.9	18.1

Table 4.7. Mid Saxon $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{C\text{-}VPDB}$ enamel carbonate results, with calculated phosphate values ($\delta^{18}O_P$)(Chenery et al. 2012).

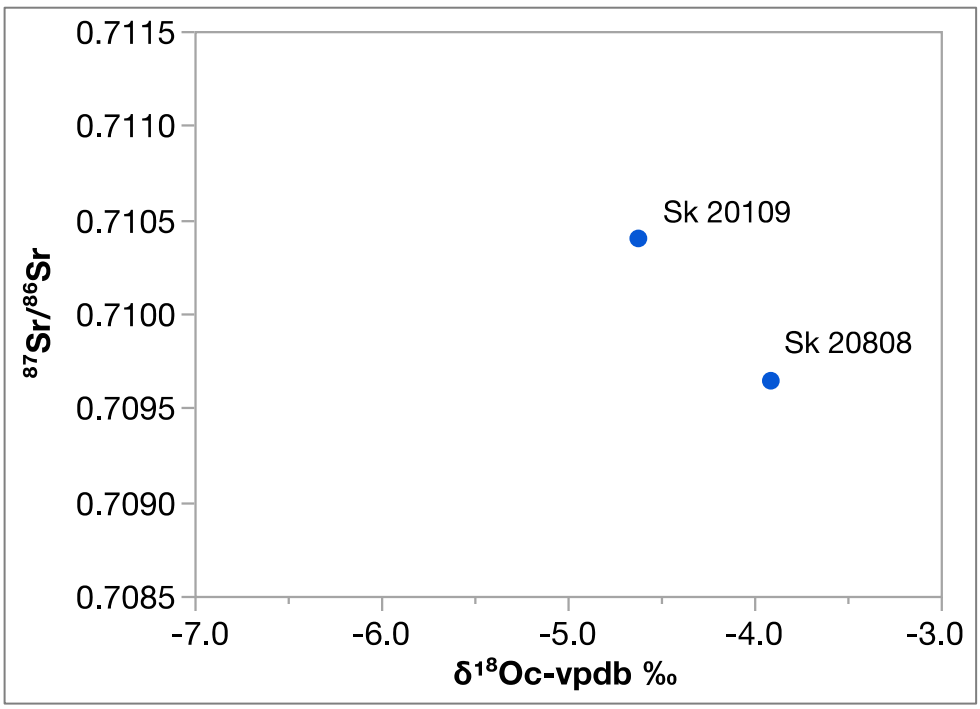


Figure 4.6. Scatterplot of Stoke Quay Mid Saxon $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{C\text{-}VPDB}$ results (n = 2).

4.5 Discussion

In this section, the human $\delta^{13}C$ and $\delta^{15}N$ results are analysed for potential dietary patterns. Comparisons are made between the sexes and with results from contemporary British sites. The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are also discussed, and interpretations of mobility are presented.

4.5.1 Human diet

The human $\delta^{13}C$ and $\delta^{15}N$ results are explored in further depth in this section. Interpretations of diet are made with reference to faunal baseline values produced through $\delta^{13}C$ and $\delta^{15}N$ analysis of roughly contemporary faunal bones from the site (Chapter 3, Section 3.3.5), as well as isotopic values of fish bones from the literature. The $\delta^{13}C$ and $\delta^{15}N$ results are also compared by sex and by the presence of different grave goods in order to evaluate potential sex- and status-based difference in diet at Stoke Quay. The results are also compared to those at contemporary sites from inland, coastal, and estuarine areas, in order to place diet at Stoke Quay within a broader regional context.

Overall interpretations of diet

As discussed in Chapter 3, the Mid Saxon human $\delta^{13}C$ and $\delta^{15}N$ results are interpreted through a separate framework from the one used in Chapter 5-7, because the Mid Saxon faunal values were statistically significantly different from those in the later periods. Based on the faunal values discussed in Chapter 3, Stoke Quay Mid Saxon humans consuming an omnivorous terrestrial diet would be expected to have $\delta^{13}C$ values up to -20.0‰ to -19.0‰, and $\delta^{15}N$ values up to 11.1-13.1‰. These ranges should be taken as estimations meant to aid

interpretations of dietary patterns, and not as rigid cut-off lines. The human $\delta^{13}C$ and $\delta^{15}N$ results are shown in Figure 4.7, along with the expected terrestrial carnivore ranges and published isotopic values (mean ±1σ) for marine, freshwater, and catadromous fish (data from Müldner & Richards 2005, Jay 2008; Barrett et al. 2011).

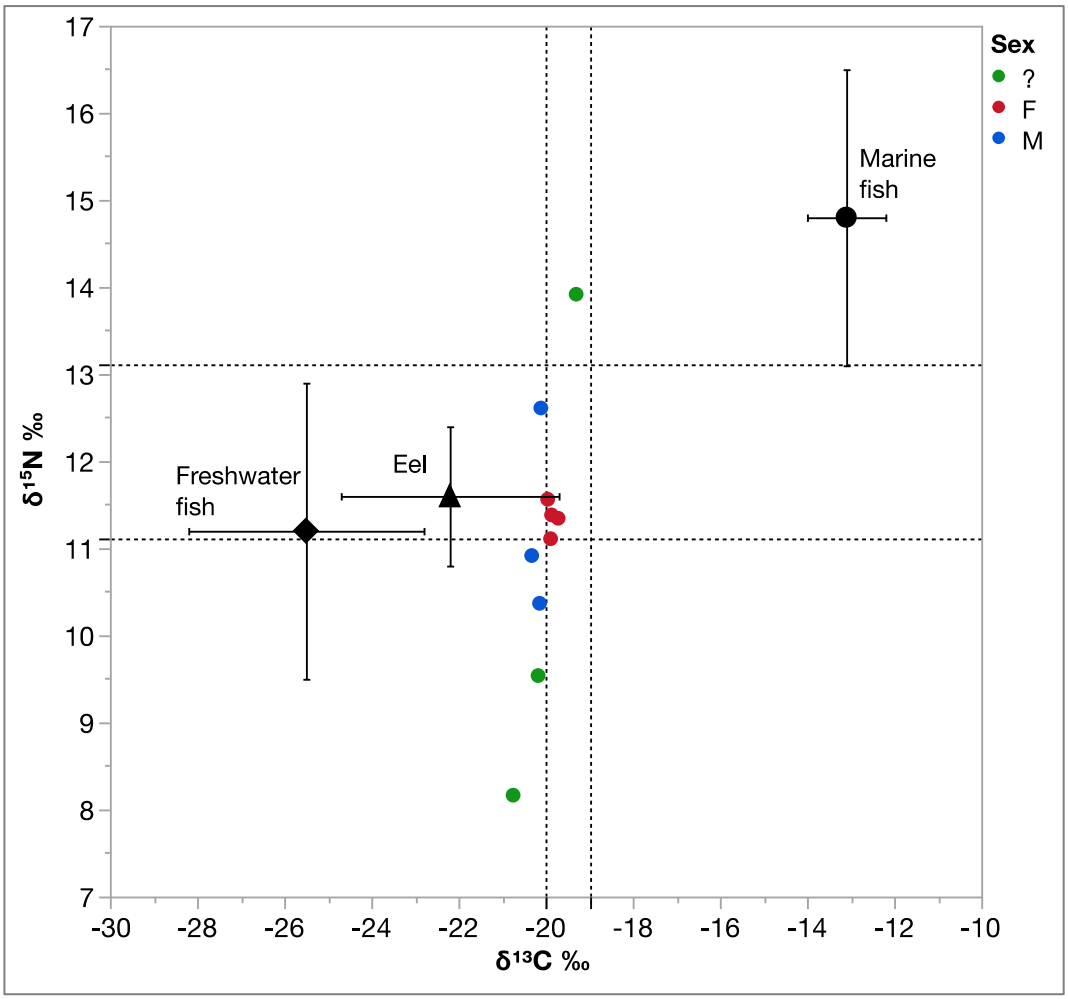


Figure 4.7. Stoke Quay Mid Saxon human $\delta^{13}C$ and $\delta^{15}N$, coloured by sex. Dotted lines indicate the expected $\delta^{13}C$ and $\delta^{15}N$ ranges for terrestrial carnivores, and published values of fish from different habitats are shown as black symbols with lines indicating ±1σ (fish data from Müldner & Richards 2005; Jay 2008; Barrett et al. 2011).

As shown in Figure 4.7, the four females in this assemblage group very tightly together and all fall in the lower part of the expected terrestrial carnivore range, based on both isotopic systems. If the range obtained from the Mid Saxon

faunal values is an accurate reflection of the $\delta^{13}C$ and $\delta^{15}N$ for available animal protein, the females would thus appear to be consuming a diet of primarily terrestrial plants and animals, with little variation between individuals.

The $\delta^{13}C$ and $\delta^{15}N$ for the males and the individuals of unknown sex are more dispersed, and a wider range of dietary interpretations is possible. One individual, an adult of unknown sex, yielded $\delta^{13}C$ within the terrestrial carnivore range, but $\delta^{15}N$ well above that range. This individual, Sk 21707, may have consumed a larger proportion of meat that included species with higher $\delta^{15}N$, such as poultry and sheep grazed on salt marshes, or they may have consumed some fish, as their $\delta^{15}N$ overlaps with the $\pm1\sigma$ range for the marine fish values (see also Chapter 3, Section 3.3.4).

One male yielded $\delta^{13}C$ just below the expected terrestrial carnivore range and $\delta^{15}N$ toward the upper part of the range. With a fairly high $\delta^{15}N$ of 12.6‰ and a lower than expected $\delta^{13}C$ of -20.1‰, this individual may have consumed some freshwater or catadromous fish, with $\delta^{13}C$ values overlapping with the $\pm1\sigma$ range for eel (catadromous fish). .

The final dietary grouping includes two males and two adults of unknown sex, all of whom yielded $\delta^{13}C$ and $\delta^{15}N$ values below the expected ranges for terrestrial carnivores. Three of these individuals likely consumed more limited amounts of animal protein, potentially with some freshwater fish or eel. The fourth individual, with the lowest $\delta^{13}C$ and $\delta^{15}N$ of the assemblage at -20.7‰ and 8.2‰, respectively, yielded values similar to the faunal means of -21.0‰ ($\delta^{13}C$) and 8.1‰ ($\delta^{15}N$). This individual, Sk 20136, appears to have consumed a largely vegetarian diet, though the occasional consumption of animal protein cannot be ruled out.

Dietary differences by sex

As touched up on briefly above, the female isotopic values show very little variation while the male values are more dispersed. To test these patterns for statistically significant differences between the sexes, the $\delta^{13}C$ and $\delta^{15}N$ are compared by sex (Figure 4.8). Because the three individuals of unknown sex could belong to either sex, they are excluded from this analysis, but summary statistics are included in Table 4.8, along with those for males and females. It is important to note, however, that interpretations of sex-based differences in diet could be very different if the individuals of unknown sex were found to include females.

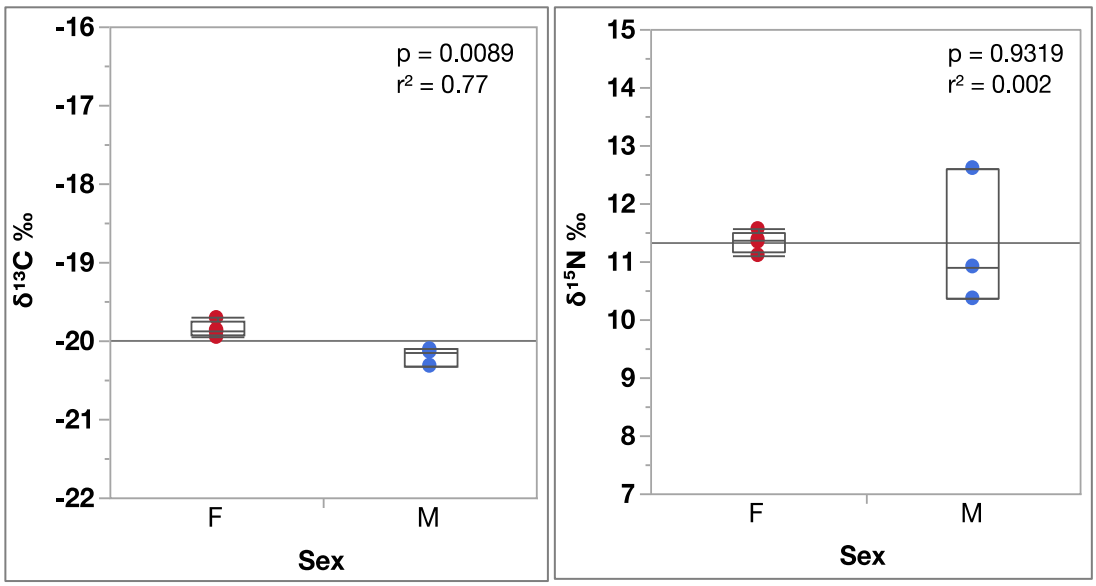


Figure 4.8. Boxplots showing $\delta^{13}C$ (left) and $\delta^{15}N$ (right) by sex, with statistically significant differences between sexes for $\delta^{13}C$ ($p = 0.0089$), but not for $\delta^{15}N$ ($p = 0.9319$)(ANOVA).

Sex	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Males	3	11.3	1.2	10.4	12.6	-20.2	0.2	-20.3	-20.1
Females	4	11.3	0.2	11.1	11.6	-19.8	0.1	-19.9	-19.7
Indeterminate	3	10.5	3.0	8.2	13.9	-20.1	0.7	-20.7	-19.3

Table 4.8. Summary statistics for Mid Saxon $\delta^{13}C$ and $\delta^{15}N$ by sex (n = 10).

Based on ANOVA, there are statistically significant differences between male and female $\delta^{13}C$ results, but not $\delta^{15}N$ results. This is in contrast to what has been seen at contemporary Anglo-Saxon sites, which show differences in $\delta^{15}N$ but not $\delta^{13}C$ (O'Connell & Hull 2012). The female results for both isotopic systems are very tightly clustered, with a range of only 0.2‰ for $\delta^{13}C$, and 0.5 for $\delta^{15}N$, thus indicating little variation in female diet. The Mid Saxon males show a similar lack of variability in their $\delta^{13}C$ values, with a range of only 0.2‰, but more variability in their $\delta^{15}N$ values with a range of 2.2‰. However, even the $\delta^{15}N$ range is fairly narrow, indicating very little overall variation.

The relatively low $\delta^{13}C$ for the males, paired with a small range in $\delta^{15}N$, could indicate that dietary differences between males were influenced by the consumption of some freshwater fish or eel. Depending on their trophic level and the source of carbon in the body of water, these species could exhibit a range of $\delta^{15}N$ in combination with a narrow range of $\delta^{13}C$ (Dufour et al. 1999). This interpretation requires further testing of fish bones from the site, as the published values used in Figure 4.7 come from catchment areas outside the Ipswich area (Müldner & Richards 2005; Jay 2008).

Dietary differences by inferred status

In addition to sex, status may have influenced diet at Stoke Quay. As discussed in Section 4.2.2, other published studies of Anglo-Saxon assemblages have differed in their interpretations of the impact of status on dietary isotope values. Some researchers have suggested that status may have played a part in food access and dietary choices (e.g. Privat et al. 2002), while others have found little to no evidence of such status-based differences (e.g. Hannah et al. 2008).

At Stoke Quay, the Mid Saxon female $\delta^{15}N$ are so tightly clustered that there are no discernable differences between the individuals with no grave goods and those with either food offerings or a knife (Figure 4.9a). The male $\delta^{15}N$, however, show enough variation to make some limited observations possible, though the single values for each type of grave good preclude the use of statistical comparisons such as ANOVA (Figure 4.9b). The three individuals of indeterminate sex are not included in the status-based comparison because two of these individuals could not be aged more precisely than '18+', which means that age-related differences cannot be accounted for.

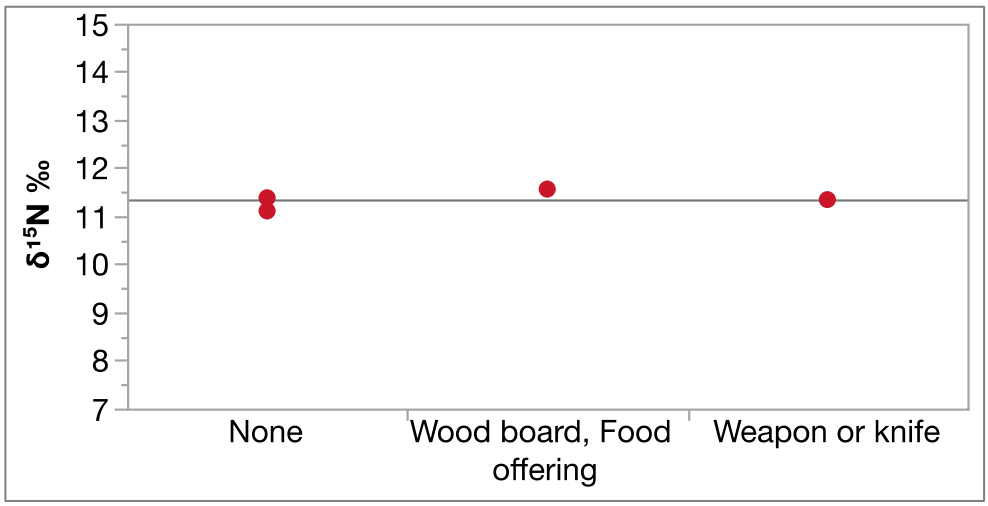


Figure 4.9a. Stoke Quay Mid Saxon female $\delta^{15}N$ plotted by grave goods present (n = 4).

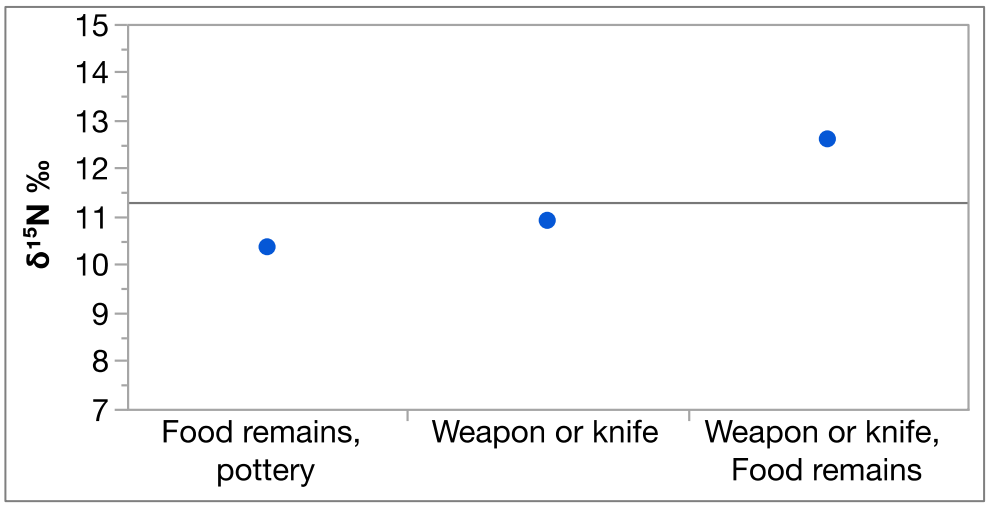


Figure 4.9b. Stoke Quay Mid Saxon male $\delta^{15}N$ plotted by grave goods present (n = 3).

All males had some type of grave good, and there is a trend toward higher $\delta^{15}N$ for the males buried with weapons. The male buried with the food offerings and pottery yielded the lowest $\delta^{15}N$ (Sk 8343), the male with a weapon had a higher $\delta^{15}N$ value (Sk 20109), and the male buried with both a weapon and food remains had the highest $\delta^{15}N$ (Sk 20808). The sample size for this comparison is very small, but if it is representative of the site, it would suggest that dietary differences in males may have been related to status.

In sum, females at Stoke Quay during this period seem to have had more restricted diets than males, which may relate to occupational patterns or status. For instance, women carrying out domestic tasks might have access to more limited foods, while men were engaged in trade outside the domestic sphere might exhibit more varied diets. Males with higher status may also have had more opportunities to consume animals and possibly freshwater fish or eels.

Further conclusions may be drawn from a comparison of the Stoke Quay $\delta^{13}C$ and $\delta^{15}N$ results with results from contemporary British sites.

Comparative assemblages

To provide context for the Mid Saxon Stoke Quay isotopic results, they are compared with published $\delta^{13}C$ and $\delta^{15}N$ values from nine contemporary English sites, all dating to the 5th- early 8th centuries. A total of 267 individuals aged 14+ years are considered in this comparison, with sample sizes from 6-70 individuals per site. For comparability with the source literature for some of these sites (Mays & Beavan 2012), they are classified as Coastal if they are located less than 10 km from the coast, as Inland if they are located more than 10km from the coast, and as Riverine/Estuarine sites if they are located along major rivers or

estuaries with access to the North Sea. The sites are listed by location classification in Table 4.9.

As shown in Figure 4.10, there is considerable overlap between the Coastal and Inland $\delta^{15}N$ means but all fall below 10‰, while all Riverine/Estuarine means are above 10‰. All Coastal site $\delta^{13}C$ means are above -20‰, while Inland and Riverine/Estuarine site means are below this threshold.

Site	N	Date	Loc. Code	$\delta^{15}N$ Mean	$\delta^{15}N$ 1σ	$\delta^{13}C$ Mean	$\delta^{13}C$ 1σ
Belle Vue House/Lamel Hill [b]	32	7th- 8th c.	R/E	10.3	0.9	-20.0	0.3
Berinsfield [c]	70	5th- 7th c.	I	9.8	0.8	-20.1	0.3
Buttermarket, Ipswich [d]	16	6th-8th c.	R/E	10.6	1.0	-20.0	0.3
Castledyke S. [a]	7	6th- 7th c.	R/E	10.2	0.8	-20.8	0.4
Dover Buckland [a]	6	5th- 8th c.	C	9.6	0.5	-19.8	0.1
Melbourn [e]	54	6th-7th c.	I	9.9	0.6	-20.2	0.2
Mill Hill, Deal [a]	8	6th c.	C	9.7	0.5	-19.8	0.4
Polhill [e]	49	7th- 8th c.	I	9.7	0.8	-20.4	0.2
Stoke Quay, Ipswich	10	7th-8th c.	R/E	11.1	1.6	-20.0	0.4
St Peter's Tip [a]	12	6th- 8th c.	C	9.5	0.7	-19.9	0.2

Table 4.9. Comparative sites and summary statistics. Location codes: I = Inland, R/E = Riverine/Estuarine, C = Coastal. Sources: a) Mays & Beavan 2012, b) Müldner & Richards 2007, c) Privat et al. 2002, d) Beavan & Mays 2009, e) Hannah et al. 2018.

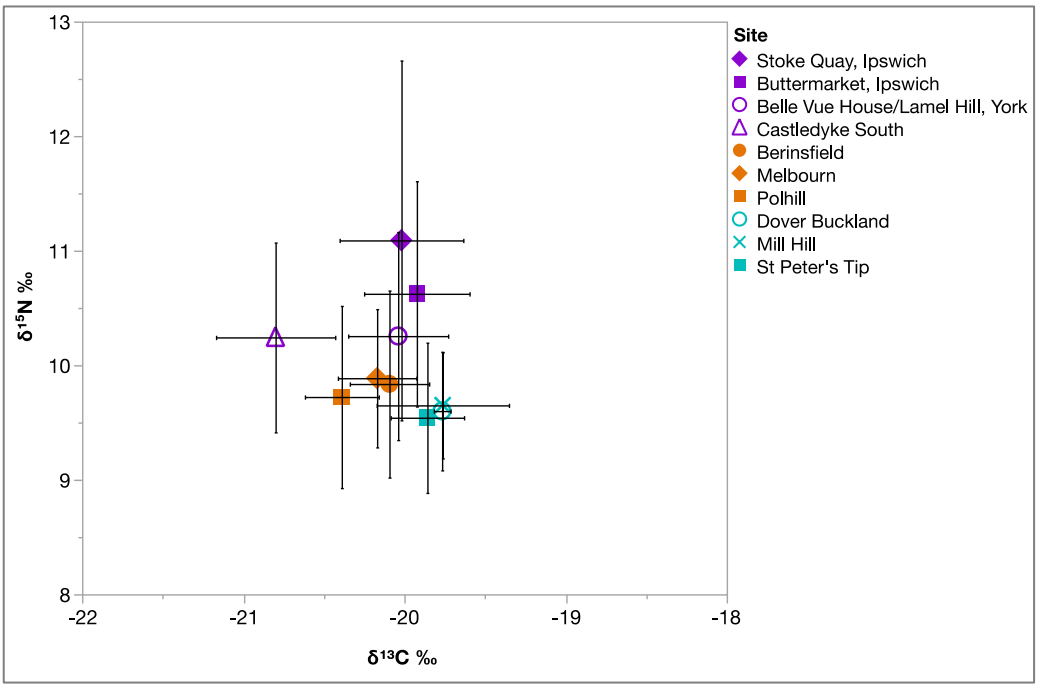


Figure 4.10. $\delta^{15}N$ and $\delta^{13}C$ means (± 1σ) for Mid Saxon Stoke Quay and 9 Early to Mid Saxon sites, colour-coded by location (purple: Riverine/Estuarine, orange: Inland, teal: Coastal). See Table 4.9 for site dates, summary statistics, and sources.

The differences between site locations noted above are visually apparent, but they are also statistically significant. When individual $\delta^{13}C$ and $\delta^{15}N$ values are plotted by site location category, there are highly significant differences ($\delta^{13}C$ $p < 0.0001$, $\delta^{15}N$ $p < 0.0001$, ANOVA). A nonparametric means comparison (Steel-Dwass test) shows statistically significant differences between all location categories for $\delta^{13}C$, and between Riverine/Estuarine sites and both other categories for $\delta^{15}N$ (Table 4.10; Figure 4.11a,b, see captions for p-values).

As indicated in Table 4.10 and Figures 4.11a and b, the differences in $\delta^{13}C$ between locations indicate that, as might be expected, the Coastal groups may have consumed some marine resources. Based on the low average $\delta^{15}N$ for this group, these marine foods would have likely occupied lower trophic levels. The Inland sites show a range of values for both $\delta^{13}C$ and $\delta^{15}N$, but the median values indicate a predominantly terrestrial, C_3 diet, which is, again, not surprising.

The Riverine/Estuarine sites show the largest ranges for both isotopes, with $\delta^{13}C$ intermediate between the Coastal and Inland sites, and median $\delta^{15}N$ values above those of the Coastal and Inland sites. This could indicate some consumption of freshwater or estuarine fish, though the $\delta^{13}C$ and $\delta^{15}N$ may also be influenced by the soil and environmental conditions at these sites.

These comparisons show that Riverine/Estuarine sites may have been exceptional for the range of dietary options available to their inhabitants. The wide range of both $\delta^{13}C$ and $\delta^{15}N$ at Riverine/Estuarine sites indicates that a variety of protein sources were exploited by these groups, and speaks to the possibility of greater overall autonomy in coastal/trading sites with regard to food choices. This may be a further indication that inhabitants of these types of sites, particularly the *emporia* (3/4 sites in the Riverine/Estuarine category),

may have had more social and economic freedom than their inland counterparts (Loveluck and Tys 2006).

Location Category	n	Mean $\delta^{15}N$	1σ	Mi n	Max	Mean $\delta^{13}C$	1σ	Min	Max
Coastal	26	9.6	0.5	8.3	10.6	-19.8	0.3	-20.3	-19.1
Inland	176	9.7	0.7	7.9	12	-20.2	0.2	-21.0	-19.1
Riverine/Estuarine	65	10.5	1.1	7.6	13.9	-20.1	0.4	-21.3	-19.2

Table 4.10. Summary statistics for combined Mid Saxon Stoke Quay and comparative $\delta^{13}C$ and $\delta^{15}N$ by location (n = 267).

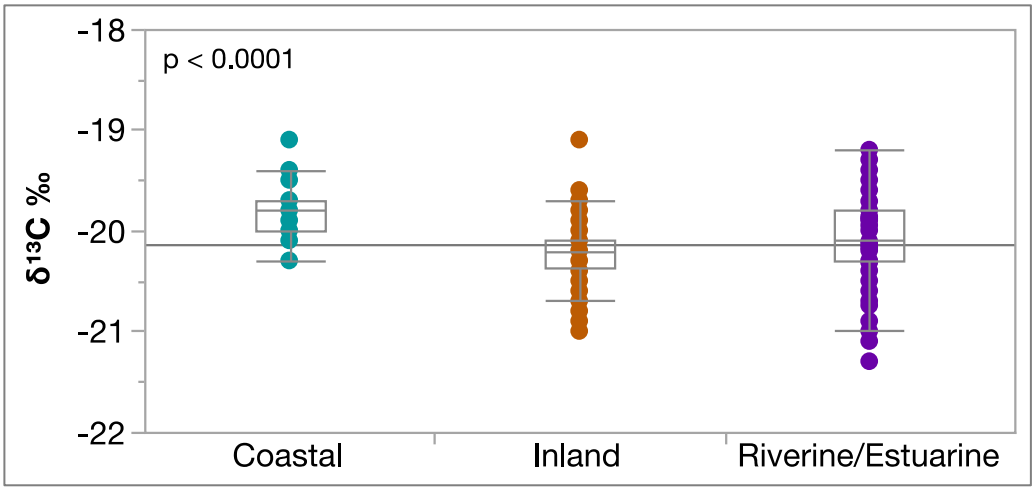


Figure 4.11a. $\delta^{13}C$ boxplots by location for Stoke Quay and comparative sites, with statistically significant differences ($p < 0.0001$, ANOVA). A means comparison shows statistically significant differences for Coastal vs. Inland ($p < 0.0001$), Coastal vs. Riverine/Estuarine ($p = 0.0026$), and Riverine/Estuarine vs. Inland ($p = 0.005$) sites (nonparametric, Steel-Dwass).

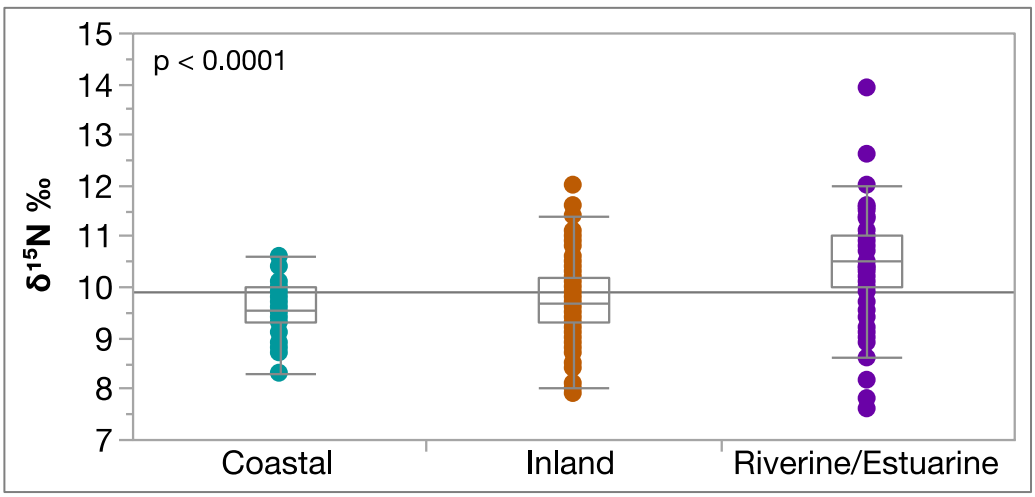


Figure 4.11b. $\delta^{15}N$ boxplots by location for Stoke Quay and comparative sites, with statistically significant differences ($p < 0.0001$, ANOVA). A means comparison shows statistically significant differences between Riverine/Estuarine sites and both Inland ($p < 0.0001$) and Coastal sites ($p < 0.0001$)(nonparametric Steel-Dwass).

Some of the isotopic variability for the Riverine/Estuarine sites may be due to variation between the $\delta^{13}C$ and $\delta^{15}N$ of different rivers and estuaries, but a wide range of values at each site is evident even when the Riverine/Estuarine sites are compared to one another. Figures 4.12a and 4.12b show statistically significant differences in $\delta^{13}C$ between the site of Castledyke South and all three other sites, but no significant differences between sites for $\delta^{15}N$.

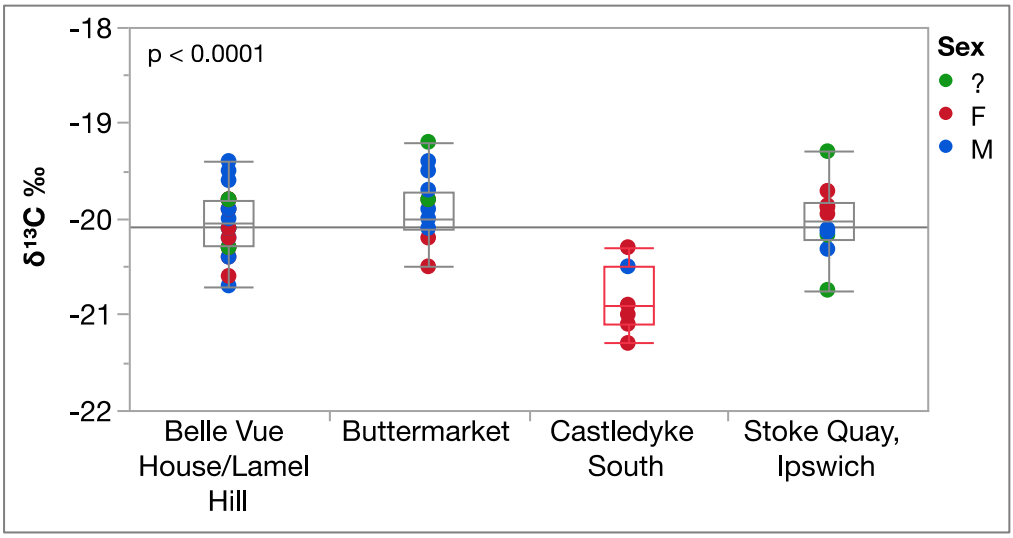


Figure 4.12a. $\delta^{13}C$ boxplots for Stoke Quay and comparative Riverine/Estuarine sites coloured by sex, with statistically significant differences ($p < 0.0001$, ANOVA). Means comparisons show significant differences between Castledyke South and each site ($p < 0.0001$, Tukey-Kramer HSD).

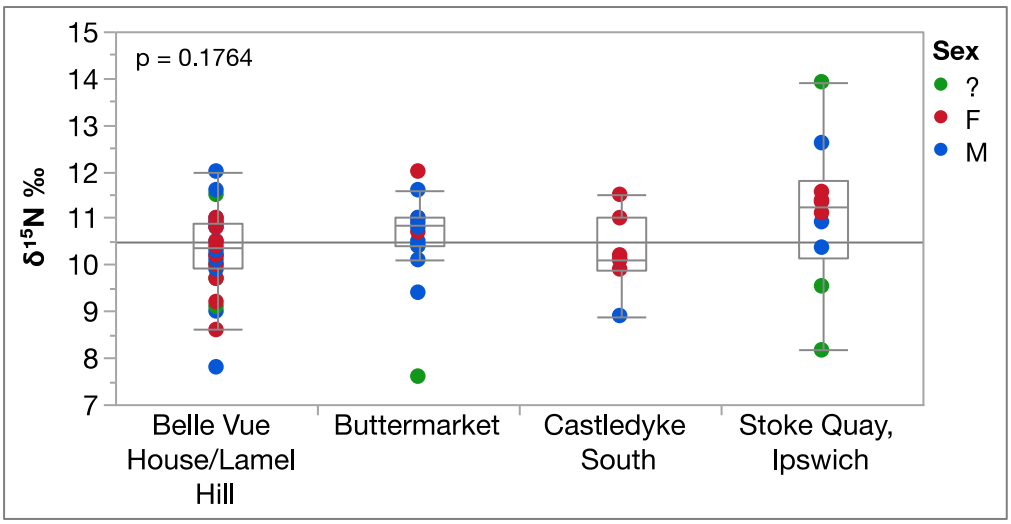


Figure 4.12b. $\delta^{15}N$ boxplots for Stoke Quay and comparative Riverine/Estuarine sites, coloured by sex, with no statistically significant differences between sites (ANOVA).

The site comparisons also show that Stoke Quay has the widest range in values of all sites for both isotopic systems but particularly for $\delta^{15}N$, indicating that diet at Stoke Quay was more diverse than at any other site evaluated in this comparison. This could suggest that diet at Stoke Quay may have been less tightly controlled than at contemporary sites, or that despite its size, the burial ground at Stoke Quay incorporated individuals with different status.

Another explanation could be that the group buried at early Mid Saxon Stoke Quay came from multiple places of origin, which would in turn influence their diet. This possibility is explored further in the following section.

4.5.2 Evidence for mobility

As discussed in Chapter 3, interpretations of mobility in this thesis are based on the expected 'local' bioavailable $^{87}Sr/^{86}Sr$ range of 0.709-0.710 (Evans et al. 2010), and the English 'low rainfall' $\delta^{18}O_P$ range of 15.9 - 18.5‰ (Evans et al. 2012). Individuals with results outside of one or both ranges are interpreted as 'Nonlocals'.

Tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was performed on two individuals from the early Mid Saxon skeletal assemblage (see Section 4.4.2). Both individuals, Sk 20109 and Sk 20808, were males aged 36-45 years buried with weapons and in barrows. The $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results are presented in Figure 4.13, along with the expected 'local' ranges for both isotopes.

As shown in Figure 4.13, the isotopic results for one individual are inconsistent with a 'local' origin, while the second individual falls within the 'local' ranges but toward the higher end of the $\delta^{18}O_P$ range. Sk 20109 yielded 'local' $\delta^{18}O_P$ but 'nonlocal' $^{87}Sr/^{86}Sr$, while Sk 20808 yielded 'local' $\delta^{18}O_P$ (but

toward the upper boundary of the range) and 'local' $^{87}Sr/^{86}Sr$. Interestingly, despite being interred in similar ways in the same small burial ground, these individuals do not appear to have come from the same location. Further insights may be gleaned from a closer examination of the skeletal, funerary, and isotopic evidence for each individual.

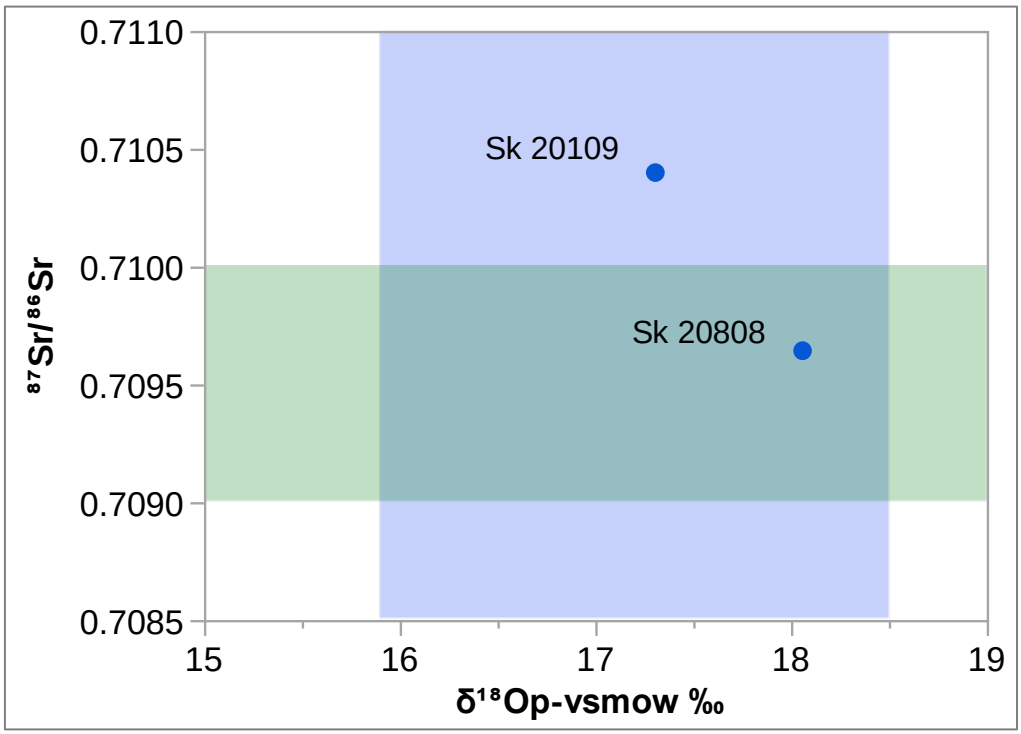


Figure 4.13. $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{P-VSMOW}$ results for two early Mid Saxon (Phase 2) males, with the 'local' bioavailable $^{87}Sr/^{86}Sr$ range in light green and the 'low rainfall' $\delta^{18}O_{P-VSMOW}$ range for eastern England in light blue. Sk 20109 falls outside the 'local' range.

Sk 20109 (possible Barrow 8) was buried with an iron seax of the short, narrow type, as well as remains of a possible leather sheath or scabbard, and an iron loop that may have been part of the scabbard. The seax bears close similarity to one found at Buttermarket, Ipswich in grave 3243, which was dated to the first half of the 7th century (Gaimster, in press; Scull 2009). This corresponds well to the ^{14}C date of 551-646 cal AD for Sk 20109 (95.4% probability; SUERC-47689). The burial was somewhat isolated, further north from the rest of the barrows (see Figure 4.14).

With an $^{87}Sr/^{86}Sr$ ratio of 0.710398 and a $\delta^{18}O_P$ of 17.3‰, this male likely originated from somewhere with older bedrock lithology but similar rainfall and climate. Parts of northern France near Quentovic may have similar values, and closer to Ipswich, there are some isolated areas of East Anglia with this combination of values, including around Beccles, Ely, and Peterborough (Willmes et al. 2014; Hughes et al. 2014; Evans et al. 2018). An origin in northern France would not be unexpected, given the evidence for trade with this region in the form of imported pottery and other goods, but a number of other locations in England and Western Europe could also fit this combination of values.

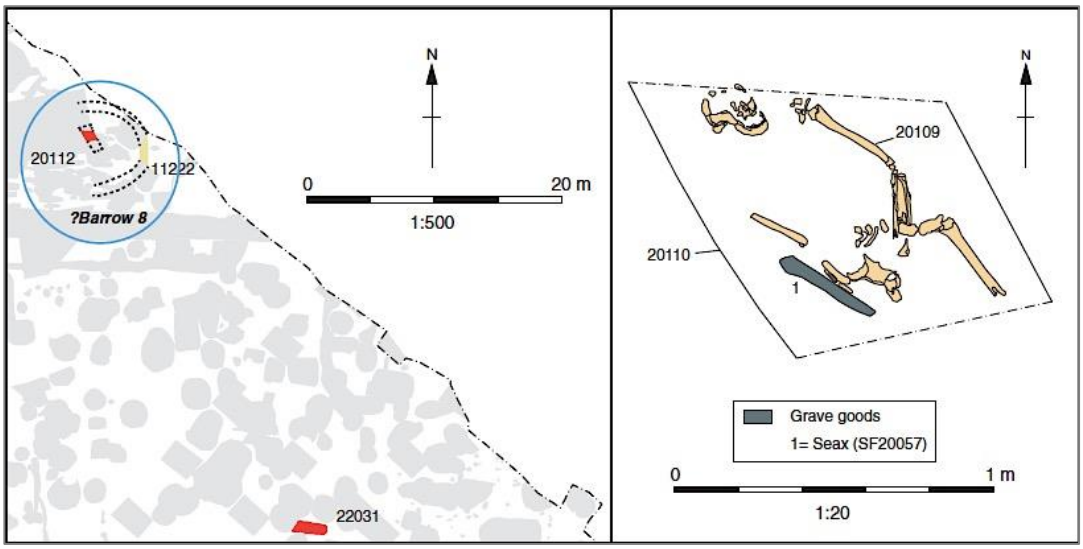


Figure 4.14. The location of possible Barrow 8 (left) and a grave plan (right) for Sk 20109 (from Teague, in press, Figure 3.9).

Sk 20808 (Barrow 5) was buried with a copper alley knife-like object as well as a food 'offering' of cattle, sheep/goat, and pig bones (Gaimster, in press). The skeleton was below the decayed remains of a wooden board, on top of which were the faunal bones (Teague, in press). This male was ^{14}C-dated to 647-808 cal AD (95.1% probability, SUERC 59360), and the barrow was located roughly in line with three other barrows in the southeastern area of the site (Figure 4.15).

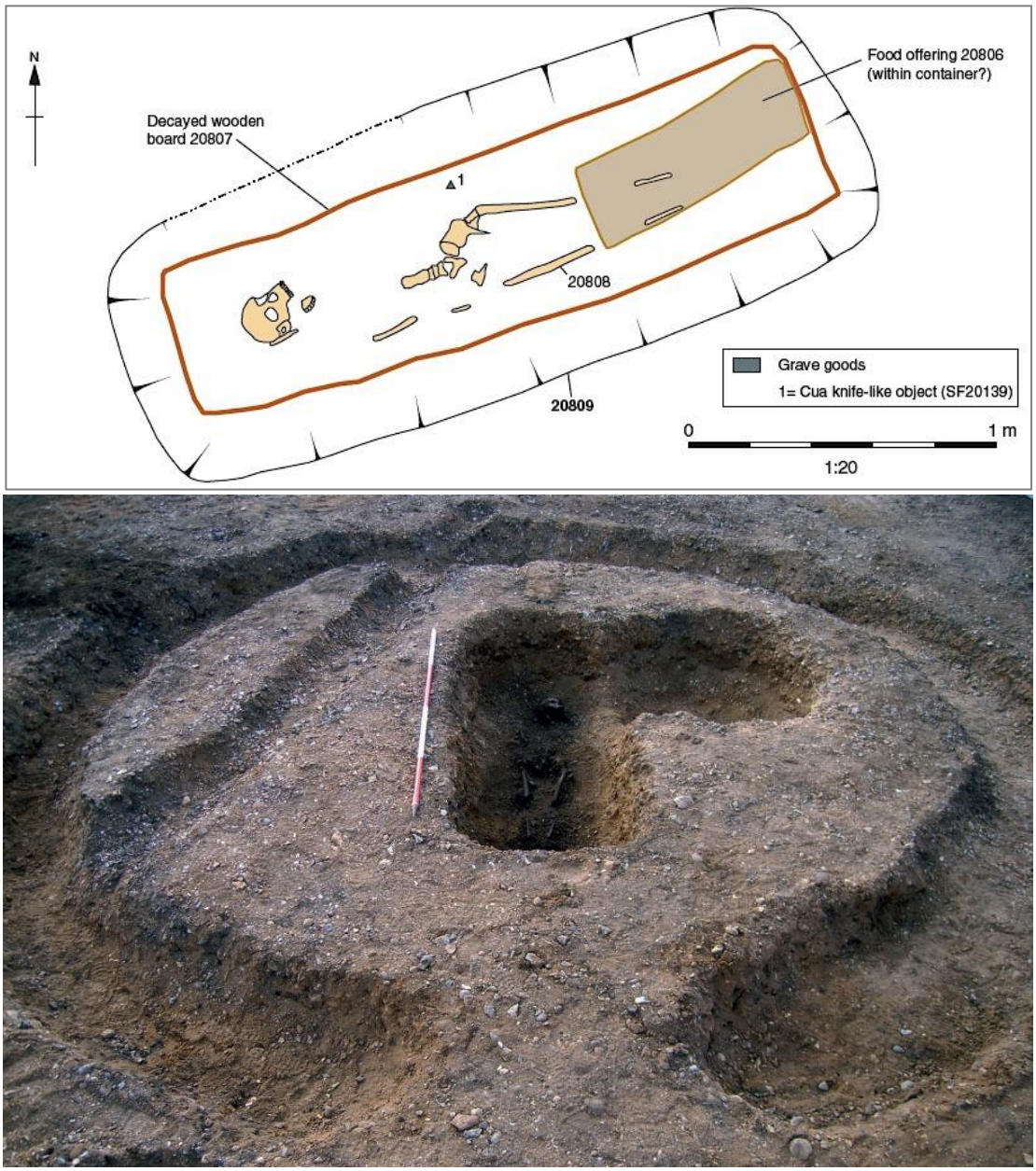


Figure 4.15. Burial plan for Sk 20808 (top) and image of the skeleton in excavated Barrow 5 at Stoke Quay (image from Teague, in press, Figure 3.6).

With an $^{87}Sr/^{86}Sr$ ratio of 0.709642 and a $\delta^{18}O_P$ of 18.1‰, Sk 20808 falls within the 'local' range for both isotopes, but the $\delta^{18}O_P$ is the third highest of all 35 individuals who yielded $\delta^{18}O_P$. The combination of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ is unlikely to be found in East Anglia, but it is possible that this individual may have come from an area with similar geology to the Ipswich area but a warmer and/or rainier climate. The combination of the $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ is consistent with

areas on the south coast of Kent as well as the around *Hamwic* and parts of the western coast of England and Wales (Evans et al. 2018). This isotopic combination is also not consistent with the Netherlands, Belgium, or northern France, the continental locations likely to have traded frequently with Ipswich, but it is possible that this individual could have come from areas in southern coastal France (Scull 2011; Wade 2014; Willmes et al. 2014; Hughes et al. 2014).

The presence of these two men at the small early Mid Saxon burial ground of Stoke Quay, who were of the same age but with different likely origins, highlights the complex international character of Mid Saxon Ipswich. The similar burial characteristics of these individuals also points to the danger of assuming that similar suites of grave goods indicate similar status and place of origin.

4.6 Summary and conclusions

This chapter has evaluated the early and later Mid Saxon evidence for burial and habitation at Stoke Quay. Section 4.2 presented the historical and archaeological background for the formation and function of the North Sea *emporia*, as well as the development of Ipswich and Stoke Quay and the evidence for trade, craftworking, and diet in the town and at the site. This background gave rise to the research questions and hypothesis that guided the analysis in the remainder of the chapter. Section 4.3 presented the results of $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of human skeletal remains from the site, while Section 4.4 evaluated these results, testing the hypotheses presented in the previous section and placing them in a broader regional context through comparisons with contemporary assemblages.

Returning to the hypotheses presented in Section 4.2, the $\delta^{13}C$ and $\delta^{15}N$ analysis aimed to test whether there were differences in diet at Stoke Quay based on sex or status. It was hypothesised that males would exhibit more evidence for fish consumption than females because of the expectation that males would have been involved in trade with better access to freshwater and marine resources. Female $\delta^{13}C$ and $\delta^{15}N$ values were tightly clustered and indicated a diet focused on terrestrial C_3 foods with little to no fish consumption. Males showed more variability, with all $\delta^{13}C$ values falling below those for the females and with $\delta^{15}N$ above and below the cluster of female values. The range of male $\delta^{15}N$ would indicate that males had more varied diets than females, and that these diets may have included poultry or freshwater fish.

A second hypothesis was that status-based differences would be visible in the $\delta^{13}C$ and $\delta^{15}N$ data when burials were categorised by the type of grave goods. When the results were categorised in this way, differences were found between males buried with and without weapons, but no differences were found for the females. These results again support the conclusion that males had more variable diet than females, and that this diet was linked to status.

A comparison of the Stoke Quay $\delta^{13}C$ and $\delta^{15}N$ results with those from nine broadly contemporary sites across eastern and southeastern England revealed statistically significant differences between the Riverine/Estuarine sites and both Inland and Coastal sites for both $\delta^{13}C$ and $\delta^{15}N$, and between Inland and Coastal sites for $\delta^{13}C$. Additionally, the Riverine/Estuarine sites exhibited the widest range of values for both $\delta^{13}C$ and $\delta^{15}N$. Notably, three of the four Riverine/Estuarine sites (including Stoke Quay and Buttermarket, Ipswich) were located in or near *emporia*, suggesting that diet at these sites was less tightly

constrained than at contemporary inland and coastal sites. Furthermore, the range of values at Stoke Quay was greater than at any of the other Riverine/Estuarine sites, despite the small sample size at Stoke Quay, indicating a wider variety of potential food sources for this group.

Finally, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was carried out on two males from Stoke Quay, with the hypothesis that 'nonlocal' isotopic combinations consistent with origins in northern Frankia (northern France, Belgium and the southern Netherlands) would be found, as these areas appear to have had close trading relationships with Ipswich. One male (Sk 20109) was interpreted as 'nonlocal', with $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ consistent (but not limited to) expected values for northern Frankia. The other individual (Sk 20808) was interpreted as potentially local, but with a combination of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ that may indicate origins in another coastal location in southwestern England, or else possibly from the warmer regions of coastal France. These results suggest that mobility at Stoke Quay was not limited to any single geographical area, and that some mobility may have been possible between Ipswich and other *emporia* or coastal areas.

Looking at the combined isotopic and funerary evidence, the early Mid Saxon population at Stoke Quay, though small in number and likely representing only some members of the living population, appears to have been relatively diverse. Females in this group show little evidence of dietary variation, despite differences in burial type and grave goods. Males, in contrast, show differences based on inferred status and date of burial. On the whole, the evidence for variation within the site and in relation to other locales indicates that the population buried at Stoke Quay, or at least the males, had greater freedom of movement and of resource procurement than many contemporary populations.

Chapter 5: Disruption and adaptation in the late 9th- late 11th centuries

5.1 Introduction

The late 6th-early 9th centuries could be described as a time of formation and development, as the Anglo-Saxon kingdoms emerged and gained power and the *emporia* were established, enabling these kingdoms to connect with wider trading networks. The late 9th- late 11th centuries, in contrast, can be seen as a time of disruption of the status quo and subsequent adaptations to those disruptions. A major disruptive force in this period was the arrival of the Vikings in Britain. Due in large part to the prolonged conflicts with Vikings, life in Britain changed on several fronts, affecting trade, settlement layouts, political structures, and patterns of warfare and violence.

At a local level, life in Ipswich was impacted by repeated Viking raids, with the town falling under Danish control for a period of nearly 50 years (Malster 2000). On a broader scale, the *emporia* grew and their layouts were reorganised during the Late Saxon period, and new defended settlements called *burhs* were established as a defence against Viking raids. Many of the *burhs* grew into large towns (Palliser 2008). The populations of these increasingly urban settlements required food and raw materials from the countryside, and there is evidence that those near the coasts began to more intensively exploit marine fish (Barrett et al. 2004a). However, the precise timing of the increase in marine fish exploitation is unclear, as is its potential impact on human diet, because the evidence for higher frequencies of fish bones at *emporia* has not been adequately tested through human bone collagen isotope analyses (see Chapter 1).

This chapter presents the largest study of $\delta^{13}C$ and $\delta^{15}N$ conducted thus far on a 9th-11th century English port population, providing the first major test of Barrett et al.'s (2004a) argument that the 'fish event horizon' occurred first among males at port sites, before spreading inland. In addition to this primary focus, this chapter also aims to evaluate the Scandinavian impact on Ipswich by assessing the skeletal evidence at Stoke Quay for pathologies consistent with urban living environments and interpersonal trauma. The $\delta^{13}C$ and $\delta^{15}N$ results for Stoke Quay are compared with published results from urban and probable Viking groups, in order to test for dietary affinities with these groups. Finally, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis on tooth enamel from a subsample of individuals is conducted to test for the presence of nonlocals at Stoke Quay, and the possibility that some nonlocals could have Scandinavian origins is explored.

5.2 Vikings, fish, and urbanisation in Late Saxon East Anglia

5.2.1 The limitations of the historical and archaeological evidence

There is a relative paucity of historical and archaeological evidence for the Late Saxon period in East Anglia. Most documentary evidence from before the Norman Conquest comes from earlier sources, such as Bede and Gildas, later sources, such as Domesday Book, or sources focusing on other geographical regions, such as the Burghal Hidage. Ipswich itself is not mentioned by name in any written source until 993, despite its clear importance as a centre for trade and production beginning centuries earlier (Brodt 2008).

The archaeological evidence is similarly sparse, particularly for Ipswich. The most informative recent work on the archaeology of Ipswich concerns the burial evidence at Boss Hall and Buttermarket dating to the 7th century and

earlier (Scull 2009, 2011, 2013). The Origins of Ipswich project, discussed in Chapter 4, did produce information about the medieval town, but excavations were relatively small in scale and the findings are only published as individual site reports in the grey literature. To date there has been no synthesis of the archaeological evidence for medieval Ipswich, resulting in a rather piecemeal view of the town's development and growth. This makes it very difficult to obtain a clear picture of life and death in the Late Saxon and early Anglo-Norman town.

Given these limitations in available contextual evidence for the character and development of Late Saxon Ipswich, this section provides a brief overview of the current understanding of the Vikings' impact on East Anglia and Ipswich, the evidence for the onset of the 'fish event horizon' at the *emporia*, and indications of trade patterns at Ipswich. The section ends with a series of research questions raised by the existing evidence, and the lack thereof, and proposes several hypotheses that guide the analyses of the Late Saxon assemblage at Stoke Quay.

5.2.2 The changing political and economic landscape

Overview

The earliest known Viking attack in Britain occurred at the monastery on Lindisfarne in June of 793. Over the next 250 years, attacks continued to shift in focus and in scope between Ireland, England, Western Europe, and the Baltic region, with significant effects on trading patterns, political systems and local infrastructure (Sawyer 1998).

In 865, a "Great Army" comprised of several Danish and Frisian leaders banded together and landed in East Anglia. Within five years, the kingdoms of Northumbria and East Anglia had fallen, and Mercia had been broken up. Before

long, Scandinavians, mainly Danes, controlled almost all of eastern and northern Britain, forming what became known as the Danelaw (Ijssennegger 2013; Sawyer 2003; Holman 2018).

In the early 10th century, the West Saxon kings reclaimed much of the Danelaw, and the former kingdoms of England were united under King Athelstan by 927 (Malster 2000; Breen, in press). The kingdom was divided again after his death until 952 or 954, when the last of the Danish kings was expelled. Though Britain remained one kingdom after 952/954, raids began again in the 980s, continuing until 1013, when the Danish leader Sven Forkbeard successfully conquered England. England remained in Danish hands for several decades until the reign of the King Edward of Wessex. When Edward died in 1066 he was succeeded by Harold Godwinson, but soon afterward Harold was killed in battle at Hastings against William, Duke of Normandy. William was crowned King of England on Christmas Day (Hall 2012; Sawyer 2003).

East Anglia and Ipswich under the Vikings

With the initial invasion by the Great Army in 865, many monasteries and churches in the kingdom of East Anglia were destroyed. The Danish leader Guthrum declared himself King of East Anglia, and by 878 he had accepted Christianity. From this time until 918, East Anglia was intensely settled by Danes, who would have also accepted Christianity by this time (Breen, in press). Many of the new settlers began to farm, and based on place names in the conquered areas they exerted a significant effect on the local language and culture (Sawyer 2003). However, there is little archaeological evidence of a lasting Scandinavian

presence in East Anglia, and much debate still exists regarding the true impact of Scandinavian influence on urban development in the region (Hall 2012).

Ipswich was fortified some time in the early 10th century, likely to defend against possible attempts by the West Saxons to re-conquer the town from its Scandinavian rulers. Some streets were closed and others rerouted as part of the fortifications, which included a circular ditch and bank around the town on the northern side of the river. Along with changes to the town layout, sunken-featured buildings (*grubenhauser*) became more common during this period (Malster 2000; Wade 2014).

Ipswich and East Anglia remained under the Danelaw until it was re-taken by King Edward of Wessex in 917 (Malster 2000). The next several decades in East Anglia were apparently relatively peaceful, but Ipswich was raided again in 991 by a force that was later bought off with the first recorded payment of the Danegeld, and again in 1010 (Breen, in press). Little is known about the precise impact of the period of Danish rule on daily life at Ipswich. However, by the time of the Norman Conquest in 1066, tax records indicate that Ipswich was a prosperous town (Brodt 2000).

Economy and trade in Late Saxon Ipswich

The Viking raids on coastal areas may have begun to impact trade routes by the early 9th century, which in some areas seems to have inhibited expansion. For example, occupation ceased at Fishergate, York in the mid-9th century, and *Hamwic* was largely abandoned shortly thereafter. Ipswich expanded in the early 9th century, but it is presently unknown if the town endured a mid-9th century crisis similar to that seen at *Hamwic* and York (Hinton 2008). During the later

part of the Late Saxon period, however, the archaeological record at Ipswich shows an increase in craftworking, especially metalworking, which included iron smelting and smithing as well as copper alloy working and brooch manufacture from moulds. A new pottery industry known as Thetford-type Ware developed, focused in the northeastern part of Ipswich as well as in other Scandinavian-controlled towns such as Norwich and Thetford itself (Wade 2014).

Along with craft production, the Ipswich economy continued to be based on trade, and the town acquired a mint sometime between 959 and 975. Based on the isolated excavations in Ipswich, trade in the 10th century appears to have focused more on regional markets, especially the east Midlands, but international trade appears to have resumed in the 11th century. The town evidently did not expand much between its re-conquest in 918 and the Norman Conquest in 1066 (Wade 2014). However, by 1086 the total population of Ipswich was around 1,600, and by this point it had been surpassed by several other East Anglian towns including Thetford (c. 2,000) and Norwich (at least 5,000). In terms of Ipswich's wealth and importance, it was the sixth wealthiest town while Norwich was second (Brodt 2000).

In addition to being overtaken in population numbers by towns such as Thetford and Norwich, the decline in Ipswich's fortunes was also affected by something catastrophic that occurred between 1066 and 1086. The town experienced a sharp decline shortly after the Norman Conquest, illustrated by the dramatic decrease in the number of taxpaying burgesses (inhabitants of towns or boroughs with full rights of citizenship) in Ipswich from the 538 recorded in 1066 and the 220 recorded in Domesday Book in 1086. Domesday Book records that only 110 of the burgesses were able to pay their tax, while the

remaining half could only afford to pay a penny each. Domesday Book also records that, "in the Borough, there have been laid waste 328 dwellings, which paid a levy to the king's tax before 1066" (Malster 2000). It therefore appears that both in terms of population and in terms of wealth, Ipswich had declined in the 20 years since the Norman Conquest.

The situation presented in Domesday Book is echoed at least to some degree in the archaeological record from late 11th to early 12th century Ipswich. Excavations at the sites of Buttermarket and Foundation Street demonstrated that a number of buildings went out of use between the late 11th and early 12th centuries, with some only redeveloped in the 13th century. Some of the buildings were also burned down, preserving architectural details as well as building contents (Wade 2014). However, it is presently unknown whether fires and destruction were widespread or only affected certain areas of the town.

The destruction recorded at Ipswich may have been inflicted in 1069, when a Danish army supporting a rebellion in the north landed at the town. According to some sources, the invading forces "dispersed themselves to pillage the neighbourhood; but the country people assembled, and slaying thirty of them, compelled the rest to save themselves by flight" (Orderic Vitalis; Forrester 1854:25; Brown et al., in press). Alternatively, or perhaps in addition to damage at the hands of the Danes, the destruction may have been a result of King William's suppression in 1075 of an uprising against him, led by Ralph, Earl of East Anglia (Wade 2014). The revolt had a number of supporters in Ipswich, which may have made the town a target for the king's wrath (Brodt 2000).

If the uprising against King William were the cause of the damage at Ipswich, the town was not alone in suffering the consequences of rebellion.

Domesday Book also records a reduction in the number of burgesses at Norwich, from 1,320 to 655, as well as 190 empty houses. At Norwich, the Domesday scribe explains that "Those fleeing and the others remaining have been utterly devastated partly because of Earl Ralph's forfeitures, partly because of fires" (Malster 2000). The similar evidence for abandoned properties and fire at Ipswich suggests that both incidents may have had a common cause, though there is no documentary evidence at Ipswich to prove this.

Interestingly, there is no evidence for this type of destruction at Stoke Quay, despite the site's relatively vulnerable position outside the town's defences (Breen, in press). Aside from the evidence at Buttermarket and Foundation Street, and the tax records provided in Domesday Book, little is known about the state of the town in the late 11th century.

5.2.3 Urbanisation and health

East Anglia had a high population density in the Late Saxon period, with a number of major towns as well as many smaller ones. The major towns included Ipswich, Bury St Edmunds, and Dunwich in modern Suffolk, Norwich and Thetford and Yarmouth in Norfolk, and Cambridge in modern Cambridgeshire. By the writing of Domesday Book in 1086, Suffolk was the most densely populated English shire, with markets in Ipswich, Bury St. Edmunds, and Dunwich, which were categorized as *burgi*, as well as markets at smaller towns such as Beccles, Clare, Eye, and Hoxne, to name a few (Brodt 2000).

The increased population densities in the growing number of towns, as well as the arrival of newcomers to East Anglia from Scandinavia and beyond, likely impacted daily life and health in these urban spaces, with some areas such

as 10th-11th century York showing evidence for large numbers of intestinal parasites (Hall et al. 1983; Roberts & Cox 2003). As discussed in Chapter 2 (Section 2.4), chronic parasitic infections can impair nutrient absorption and, along with other metabolic issues, can cause lesions in the eye orbits known as *cribra orbitalia* (Waldron 2009; Walker 2009).

Poor sanitation and infections can also contribute to nonspecific stress indicators such as periostitis. Urban housing with internal wood-burning hearths produced high levels of smoke depending on how well ventilated the dwellings were, and as discussed in Chapter 2 (Section 2.4), such pollution can lead to inflammatory responses such as sinusitis (Roberts & Cox 2003). Furthermore, the violent encounters between Scandinavian incomers and local populations, either in battle or in raids, likely led to traumatic injuries for both parties.

5.2.4 Changing diets and the exploitation of fish

As discussed in Chapter 1, one of the overarching questions explored in this thesis is when, and to what extent, the increase in marine fish consumption (the 'fish event horizon') began at Ipswich. Barrett and colleagues (2004a), argued that large increases in the catches of herring (*Clupea harengus*) and cod (*Gadus morhua*) occurred within a few decades of AD 1000, and that many of these fish were probably traded (2004: 619). They also hypothesised that this trend began in coastal locations including *wics* or *emporia*, and that men would have been the earliest intensive consumers of marine fish.

Evidence supporting Barrett and colleagues' argument for early adoption of marine fish is seen in the fish assemblages at several sites in southern England, such as Sandtun, Bishopstone and Lyminge. The zooarchaeological

evidence from these sites shows an association between the early adoption of marine fishing, and either a location on the coast or elite status (Reynolds 2016).

Fish assemblages at York provide further information about the 10th-11th century transition from predominantly freshwater fish or eels, to offshore marine fish such as herring and gadids. Herring was the first marine taxon to reach importance at York, followed by cod and later haddock (Harland et al. 2016; Barrett 2016). A similar situation is seen at London, as well as increases in flatfish around the turn of the millennium (Locker 1997; Orton et al. 2014). At *Hamwic*, herring and other marine fish were more abundant than freshwater fish and eel by the early 11th century (Hamilton-Dyer 1997; Barrett 2016).

Outside of Britain, other studies have shown an increase in marine fish consumption during this period. Many studies refer to locations in Belgium, where herring and flatfish were the most abundant marine taxa in the mid-10th century, followed in later centuries by gadids (Van Neer and Ervynck 2016). In Viking Age Ribe, Denmark, flatfish were the most common marine fish, followed by cod of moderate size (35-65cm long), while those at Selso-Vestby reached lengths of up to 105cm around the same time (Enghoff 2016).

The increase in marine fish consumption at some coastal and trading sites does appear to have affected males first, followed by females (Barrett & Richards 2004; Barrett et al. 2004b; Müldner & Richards 2006). However, as mentioned in Section 5.1, this has not been rigorously tested through stable isotope analysis of human skeletal remains from southern coastal English sites. The documentary evidence is similarly lacking. Domesday Book contains few references to sea fishing, most of which refer to sea weirs, marine fishermen, and tax payments by herring renders. In contrast, Domesday mentions several hundred freshwater

fisheries in mill-ponds or rivers. Few references include specific fish, but where they are present, they refer primarily to eels, and sometimes to salmon. The vast majority of herring renders were in East Anglia, and in Sussex and Kent, while in Suffolk, more than 20 places had herring rents or renders (Kowaleski 2016).

As discussed in Chapter 6, the higher recorded herring renders in Suffolk likely reflect the productivity of the herring fisheries off the east coast of England. In the 11th-12th centuries a number of important fishing communities developed in Norfolk and Suffolk, the wealthiest and most powerful of which was Great Yarmouth. The commercialization of the east coast herring fisheries did not fully develop until the early 12th century, but a permanent settlement of fishermen at Yarmouth was established by at least the early 11th century, and may have supplied developing local markets (Kowaleski 2003, 2016).

5.2.5 Research questions and hypotheses

The previous sections have provided contextual information about Late Saxon Ipswich and East Anglia, while also highlighting the limitations of the documentary and archaeological evidence. Particular gaps in our knowledge of the time period relate to the timing and extent of the 'fish event horizon', the degree of Danish influence on the living environment and population demographics at Ipswich, and the presence and precise causes of crises and destruction in the Late Saxon town. The large sample size, likely low to middling socioeconomic status of the population buried at Stoke Quay, and the detailed osteological analyses on this cemetery population carried out by Oxford Archaeology enable a more in-depth and focused examination of the character

and development of Late Saxon Ipswich than has been possible to this point. The analyses in this chapter address the following questions and hypotheses:

1) Is a major shift toward intensive marine fish exploitation visible at Stoke Quay? If so, is there any evidence for the timing of this shift, or for certain groups in the population adopting intensive marine fish consumption earlier than others? This is explored through $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen and comparisons of isotopic results from different groups within the Stoke Quay Late Saxon sample, with the hypothesis that, as an east coast port town, a shift will be visible and that it will affect males more than females.

2) How did Late Saxon diet at Ipswich compare to diet at other urban and Scandinavian sites? This is tested through comparisons of the Late Saxon Stoke Quay isotope results with urban English and Scandinavian assemblages.

3) With the dearth of information regarding living conditions, the impact of Danish rule, and the level of urbanisation at Late Saxon Ipswich, what can osteological analyses of the Stoke Quay group tell us? More specifically, is there skeletal evidence for pathological lesions indicative of urban living environments, and is there evidence of interpersonal violence? This is addressed through comparisons of palaeopathological indicators at Stoke Quay with those from contemporary urban and Scandinavian sites, with a particular focus on pathologies related to urban living environments (see Section 2.4).

4) Is there evidence for individuals with nonlocal origins living in Ipswich during the Late Saxon period? If so, are they more or less likely to have experienced trauma and infectious disease than those who appear to have been born locally? This is tested through $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of tooth enamel from a subsample of individuals.

The following section presents the human skeletal materials used in this chapter to address the questions raised above.

5.3 Materials

As noted in Chapter 1, the excavations at Stoke Quay revealed an enclosed cemetery situated in the northern part of the site, dating to the Late Saxon period (late 9th-late 11th centuries), which predated the construction of the later stone church (Teague, in press). The Late Saxon skeletal assemblage and burial practices are summarised below, followed by a description of the individuals sampled for isotopic analysis.

5.3.1 The Late Saxon burials

Overview

The Late Saxon burials were situated at the northern end of the site, bounded to the west by the medieval road named *Losegateweye* (the predecessor to Great Whip Street), to the north by a lane and a ditch, and continuing to the east beyond the limit of the excavation (Figure 5.1). Though the extent of most of the cemetery was established during the excavation, it is likely that some burials located to the northeast were lost in the Victorian period due to works redirecting the river's path (Teague, in press).

Based on radiocarbon dating on five individuals, the earliest burials from this period are from the late 9th to late 10th centuries, while the latest date to the mid to late 11th century. A small number of burials may date to the early 12th century (Teague, in press). A total of 316 burials were assigned to this Late Saxon phase, including 16 infants, 127 children, and 173 adults. Almost 90% of

the burials from this period and the subsequent periods were given completeness, bone surface condition, and fragmentation classifications of good or fair (Loe et al., in press). The burials were divided into seven Cemetery Groups, based on spatial positioning or grave characteristics (Table 5.1.).

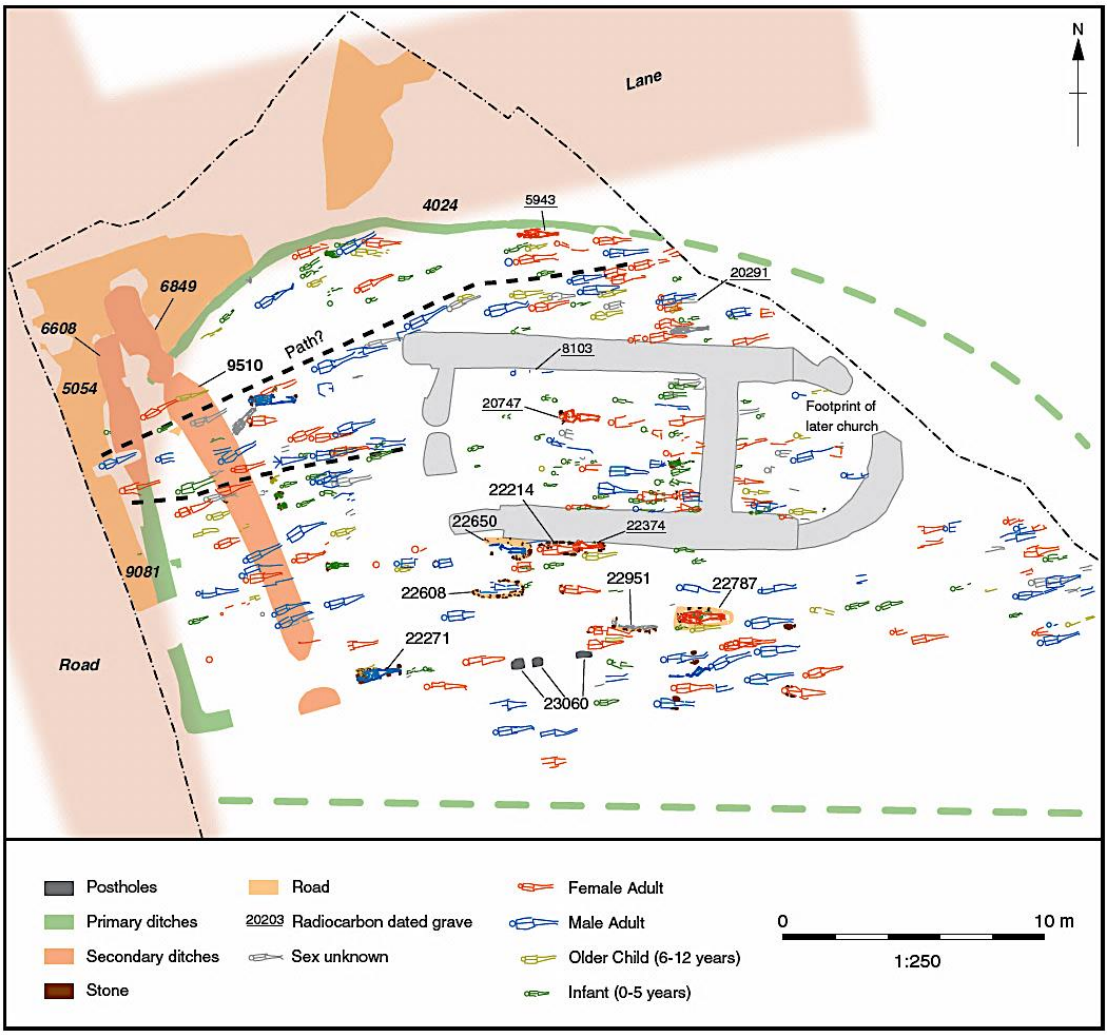


Figure 5.1. Cemetery plan for Late Saxon Stoke Quay. From Teague, in press, Figure 3.43.

Cemetery Group	Number of Burials	Location
CG 1	137	North of later church
CG 2B	20	Beneath inner footprint of later church
CG 2C	53	Beneath inner footprint of later church
CG 5	63	South of later church
CG 9	5	Cist burials (south of later church)
CG 9A	7	Subset of CG 9
CG 10	25	Stone 'pillow' burials (mostly south/west of later church)

Table 5.1. Cemetery Groups assigned to the Late Saxon burials at Stoke Quay (from Teague, in press).

Cemetery layout

The Late Saxon burials were distributed relatively evenly across the area, with little intercutting. No evidence for grave markers was found, but some visual indications of grave locations may have been present at one time, given the lack of disturbance of earlier burials. The earliest burials were aligned with the cemetery boundaries to the north and west, while those located toward the east had a more E-W alignment. Some graves were positioned beneath the area later occupied by the church nave and chancel walls, and the broader footprint of the later church overlay a concentration of infant and neonate burials from this period. Child burials were in some cases grouped together, including a row of three 'pillow' burials (see below) next to several other children who may have formed part of a family group. Another cluster of child burials located away from adults may have been unrelated to family groups (Teague, in press).

Most individuals were interred in a supine, extended position, with the exception of one possible female who was buried in a prone position. Though the majority of the group was buried in plain graves, a number of individuals were given more distinctive burials. The burials that appear to be the earliest in the stratigraphic sequence included 12 individuals in stone-lined graves, in which one or more large stones were placed around the sides of the grave (Cemetery Groups 9 and 9A). In at least four graves, a yellow sandy mortar bonded the stones together into a coffin-like structure, which may have been covered with a wooden lid (Figure 5.2). Two of the burials with no mortar in the stone linings also yielded nails indicating the presence of some form of wooden coffin or structure (Teague, in press).



Figure 5.2. Photograph of a Late Saxon mortared, stone-lined grave at Stoke Quay (Sk 22785)(from Teague, in press, Figure 3.45).

Another interesting group of early burials included 32 individuals (mainly in Cemetery Group 10) buried with stones around or to either side of the skull, traditionally termed 'ear muffs'. Half of this group was comprised of adults, while 34.4% were young children aged 1-5 years. Many of the 'ear muffs' appear to have been placed in order to prevent the movement of the skull after burial, and

some of these burials also included a stone placed below the mandible, at the front of the skull (Teague, in press).



Figure 5.3. Photograph of a Late Saxon burial at Stoke Quay with 'pillow stones' (Sk 20748)(from Teague, in press, Figure 3.48).

These types of 'ear muff,' 'pillow stone,' or 'head cist' burials have been found in other Mid-Late Saxon cemeteries (Buckberry 2010), including Raunds Furnells (Boddington 1996), and have been used to assign an Anglo-Saxon date to cemeteries where they are found. In some places their use reportedly extended to the 12th century, as at St. Mary's, Stow (Field 1984; Buckberry 2010). These types of burials have also been found in association with layers of charcoal in burials, in locations such as Hereford Castle Green (Shoesmith 1980; Holloway 2010). The placement of charcoal and other grave-cut linings such as chalk and stones may have been seen as symbols of cleanliness or incorruptibility, protecting the body from the earth around it (Holloway 2010; Thompson 2004). Whatever the meaning, these variations in burial treatment have been interpreted as indications of status or identity after grave goods ceased to be widely used (Hadley 2012).

Finally, 75 individuals were buried in coffins, as evidenced by nails outlining the sides of the body, and in some cases, timber staining in the soil. Clench bolts were found in three burials, likely from reused boat timbers (Teague, in press). These bolts are characteristic of Scandinavian-style clinker-boats, which are built with overlapping planks fastened together to form the outer shell of the boat (Brookes 2007; Greenhill 1988; Figure 5.4). Two of the Stoke Quay Late Saxon clench-bolt burials included a single rove each, while a third contained four complete clench bolts in a line from the stomach toward the legs. At least for the third burial, it appears that part of a boat was used as a cover for the lower half of the body (Gaimster, in press).

Clench bolt burials have been found in a number of Mid-Late Saxon cemeteries in Kent and other English regions. For example, 13 graves with clench

bolts were found at the cemetery of Caistor-on-Sea, Norfolk, from burials dating to the 8th- early 9th centuries (Gaimster, in press; Darling & Gurney 1993), and several other examples were seen at Dover Buckland and Mill Hill Deal (Brooks 2007; Parfitt and Brugmann 1997). A version of this was also seen at York Minster, where one male burial was found with a wooden bier of clinker-built caulked planks, as well as 'pillow stones'. This burial has been interpreted as reminiscent of Scandinavian boat burials, though the accuracy of this interpretation has been questioned (Kjølbye-Biddle 1995; Graham-Campbell 2007; Hinton 2000).

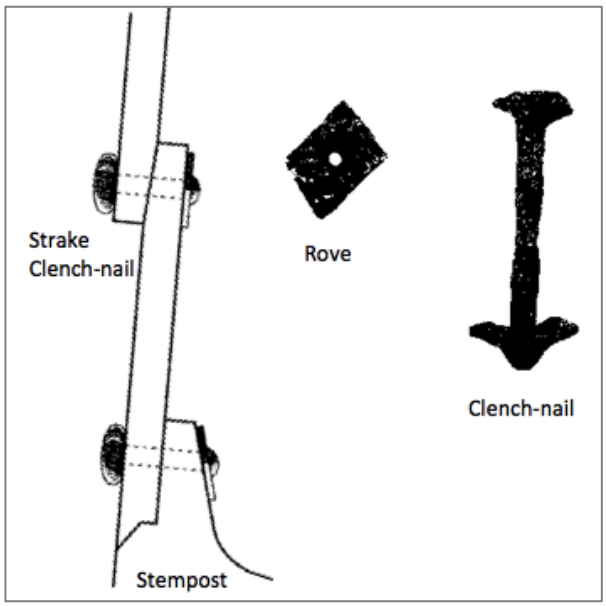


Figure 5.4. Examples of a clench-nail (or bolt) and rove from Anglo-Saxon contexts in Kent, and a schematic of their use in clinker-boats (modified from Brooks 2007).

Several other examples of boat-building materials used in graves were seen at Stoke Quay during this period. They include grave 22673 (Sk 22674), which contained the remains of a possible clinker-built lid, and grave 21220, which contained an iron sintel, a small rectangular staple associated with Frisian boat building (Gaimster, in press). There is only one other published example of iron sintels in England, in the form of a boat fragment with a sintel excavated at

Bull Wharf, London, and dated to the mid-late 10th century (Goodburn 1994; Gaimster, in press).

The range of burial styles at Late Saxon Stoke Quay may be linked to ideas of status or group affinities, though the precise meaning of these practices is unknown. Differences in status can be tested through bone collagen carbon and nitrogen isotope analysis, and the individuals selected for these analyses are described in the following section.

5.3.2 Human bone samples for $\delta^{13}C$ and $\delta^{15}N$ analysis

A total of 116 individuals from this phase were selected for stable carbon and nitrogen isotope analysis of bone collagen, representing 37% of the total Late Saxon skeletal assemblage. The group is comprised of 37 subadults (<18 years old), 38 adult females, and 41 adult males. Though the aim was to sample 20 adults from each age group (see Section 2.2.2), only 13 young adults (age 18-25) could be included due to their low numbers in this phase. A total of 26 individuals aged 36-45 years were included, comprising 6 individuals from the pilot and 20 selected for the main study.

The sex and age distributions are shown graphically in Figures 5.5 and 5.6, and maps of the sex, age, and Cemetery Group distribution of sampled skeletons are shown in Figures 5.7-9. Bone collagen was extracted and analysed following methods described in Chapter 2 section 2.2.3.

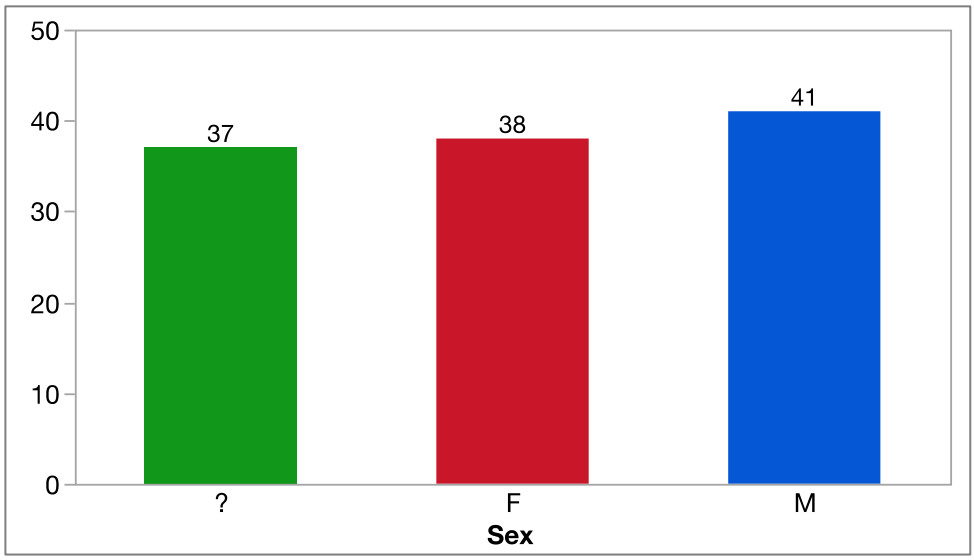


Figure 5.5. Sex distribution for the Late Saxon Stoke Quay skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis (n = 116).

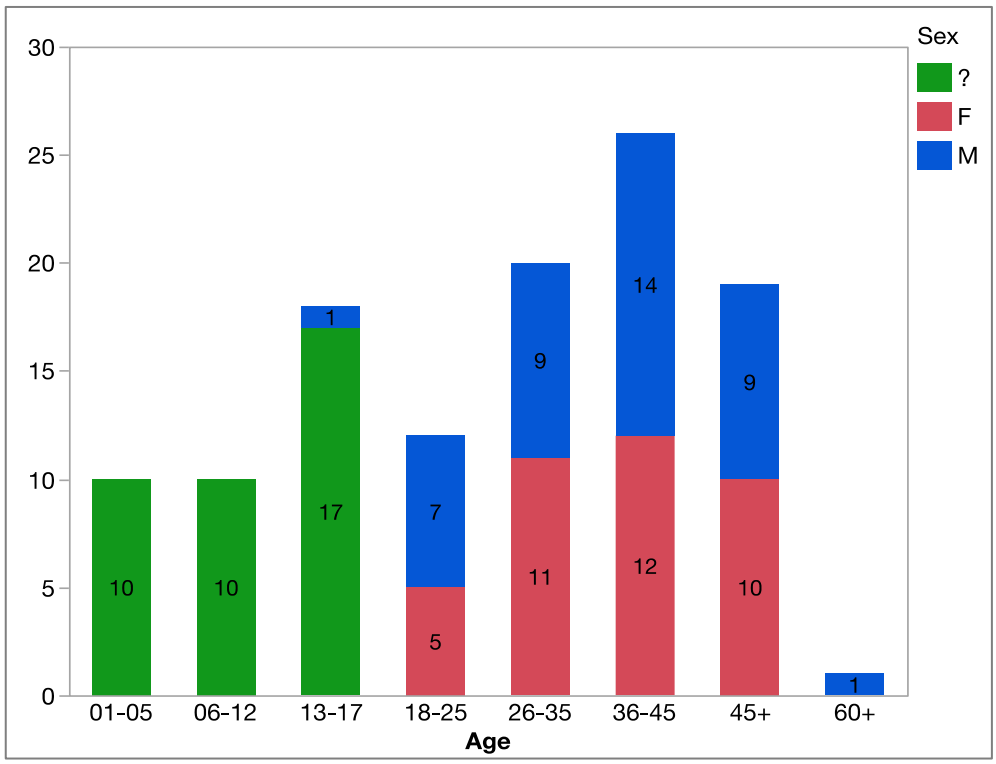


Figure 5.6. Age distribution by sex for the Late Saxon Stoke Quay skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis (n = 116).

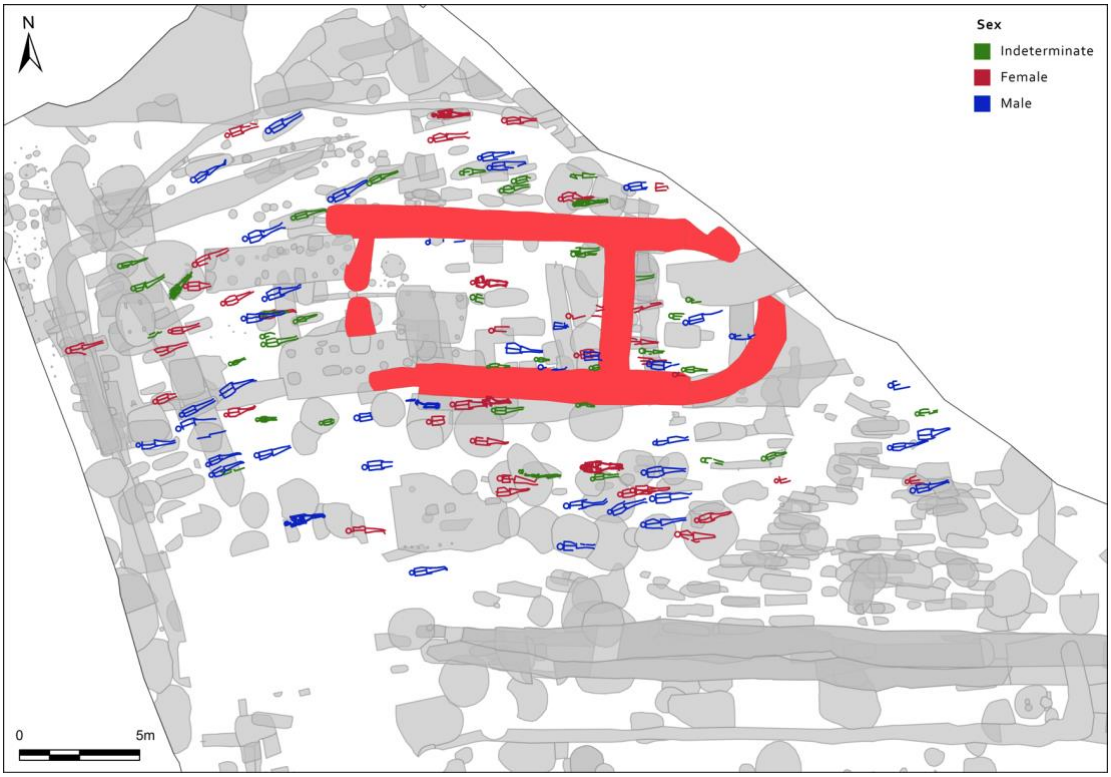


Figure 5.7. Map showing the Late Saxon Stoke Quay skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by estimated sex.



Figure 5.8. Map showing the Late Saxon Stoke Quay skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by estimated age at death.



Figure 5.9. Map showing the Late Saxon Stoke Quay skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by Cemetery Group.

5.3.3 Samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

Tooth enamel from eleven individuals was sampled for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis, including seven for the main study (Chapter 2, Section 2.3.2) and four from the pilot study (Farber & Lee-Thorp, in press). Age and sex information for the sample are presented in Figure 5.10, and are listed in Table 5.2 along with Cemetery Group, reason for sample selection, and tooth sampled. Tooth enamel was sampled and analysed following the methods outlined in Chapter 2, Section 2.3.3.

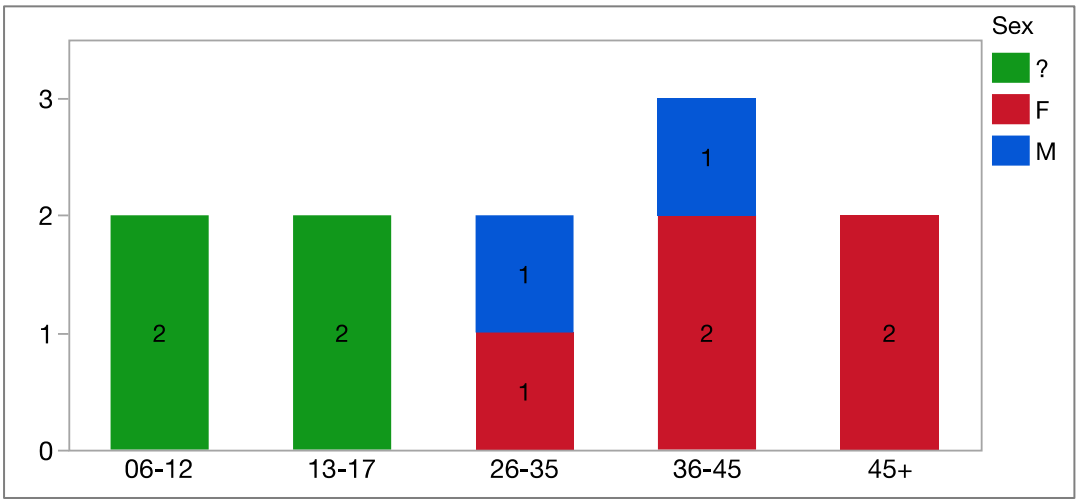


Figure 5.10. Sex and age distribution for the Late Saxon samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis (n = 11).

Sk ID	Age	Sex	Ancestry assessment	Reason for selection	Cemetery Group	Tooth sampled
5347	6-12	?	-	Average diet	1	L mand M2
*5909	45+	F	-	Pathology	1	L mand C
6500	6-12	?	-	Unusual diet	1	R mand M2
7279	13-17	?	-	Average diet	1	R mand M2
*8104	36-45	M	-	^{14}C dated	2B	R mand M2
20207	36-45	F	Caucasoid	Pathology	2B	L mand M2
*20292	13-17	?	-	Trauma	1	R mand M2
*20748	26-35	F	Caucasoid	Burial type	10A	L mand M2
20894	45+	F	Mixed/ uncertain	Average diet	1	R mand M2
21166	36-45	F	Caucasoid	Trauma	5	R mand M2
23133	26-35	M	-	Average diet	5	R mand M2

Table 5.2. Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ samples with demographic and burial information, reason for selection and teeth sampled (n = 11). * Samples from the pilot study (Farber & Lee-Thorp, in press).

5.4 Results

This section presents the $\delta^{13}C$ and $\delta^{15}N$ results for the Late Saxon samples, including general statistical summaries. Next, the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are given, followed by a summary of the skeletal indicators for urban living environments and estimated statures for the sampled assemblage. Interpretations and a discussion of the significance of these results are provided in Section 5.5.

5.4.1 $\delta^{13}C$ and $\delta^{15}N$ results

Out of 116 individuals sampled, 115 yielded collagen meeting quality controls (see Section 2.2.3). Summary statistics for adults, subadults, and all 115 samples are shown in Table 5.3. Individual results are reported in Appendix 2. The group $\delta^{13}C$ mean is -18.9‰ (±0.6, 1σ,), and the $\delta^{15}N$ mean is 12.2‰ (±1.2, 1σ,). Both datasets are normally distributed, so parametric statistical tests are used (Shapiro-Wilk W, $\delta^{13}C$ W= 0.9897, p = 0.5379; $\delta^{15}N$ W= 0.9923, p = 0.7754).

The $\delta^{13}C$ and $\delta^{15}N$ data are plotted in Figure 5.11. There is a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.60$, $p < 0.0001$). The $\delta^{13}C$ and $\delta^{15}N$ results are plotted separately when testing relationships with non-numerical factors such as age, sex, burial location, or pathology.

Group	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Subadults	37	11.8	1.3	9.1	15.2	-19.1	0.5	-20.3	-18.1
Adults	78	12.4	1.2	8.9	14.9	-18.8	0.6	-20.0	-17.2
All	115	12.2	1.2	8.9	15.2	-18.9	0.6	-20.3	-17.2

Table 5.3. Summary statistics by age category for Late Saxon bone collagen $\delta^{13}C$ and $\delta^{15}N$ (n = 115).

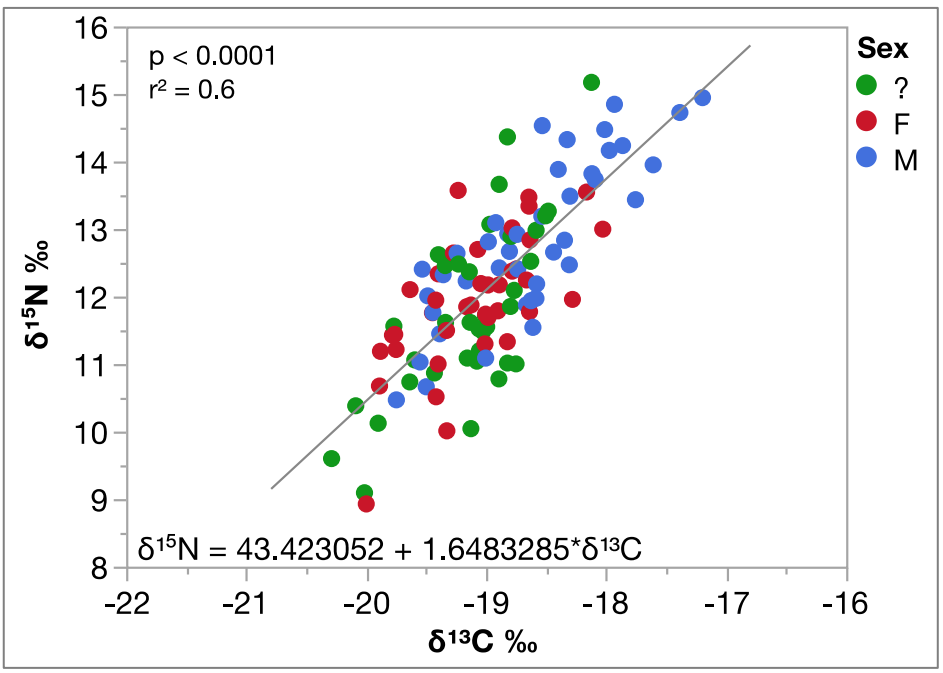


Figure 5.11. $\delta^{13}C$ and $\delta^{15}N$ for Late Saxon Stoke Quay (n = 115), with a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.60$, $p < 0.0001$).

5.4.2 $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results

Summary statistics for both $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ are given in Table 5.4, and individual results are given in Table 5.5 and Appendix 3. All 11 individuals selected for $^{87}Sr/^{86}Sr$ analysis yielded results (see Chapter 2, Section 2.3.3 for methods and standards for measurements). The $^{87}Sr/^{86}Sr$ results range from 0.7090 to 0.7113 (mean 0.7095 ± 0.0007), and the dataset are not normally distributed (see Table 5.4), warranting the use of non-parametric tests for further statistical analyses.

The same individuals were analysed for $\delta^{18}O$, but only 8 yielded acceptable results (see Chapter 2 Section 2.3.3 for methods and a discussion of issues encountered with the $\delta^{18}O$ analysis). The $\delta^{18}O_{VPDB}$ results do not depart from the Normal distribution (see Table 5.4), so parametric tests are appropriate for further statistical analyses. The $^{87}Sr/^{86}Sr$ results are plotted in Figure 5.12, and the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are plotted together in Figure 5.13.

$\delta^{18}O$	n	Mean	1σ	Min	Max	Shapiro-Wilk W	p-value
$^{87}Sr/^{86}Sr$	11	0.7095	0.0007	0.709	0.7112	0.743788	0.0017
$\delta^{18}O_{C\text{-}VPDB}$	8	-4.9	0.7	-6.1	-3.8	0.914369	0.3859
$\delta^{18}O_{P\text{-}VSMOW}$	8	17.3	0.8	16.1	18.45	0.901665	0.2991

Table 5.4. Summary statistics for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, with $\delta^{18}O$ carbonate values relative to VPDB, and calculated $\delta^{18}O$ phosphate values (Chenery et al. 2012) relative to VSMOW.

Sk ID	$^{87}Sr/^{86}Sr$	$\delta^{18}O_{C\text{-}VPDB}$	$\delta^{18}O_{P\text{-}VSMOW}$	Sex	Age
5347	0.709090	-	-	?	06-12
5909	0.709635	-3.9	18.1	F	45+
6500	0.709135	-5.0	16.9	?	06-12
7279	0.709011	-	-	?	13-17
8104	0.709633	-4.9	17.0	M	36-45
20207	0.709994	-3.8	18.2	F	36-45
20292	0.708960	-6.1	15.8	?	13-17
20748	0.709012	-4.9	17.0	F	26-35
20894	0.709179	-5.0	16.9	F	45+
21166	0.711297	-5.4	16.4	F	36-45
23133	0.709364	-	-	M	26-35

Table 5.5. Individual $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{c\text{-}VPDB}$ results for Late Saxon Stoke Quay, with calculated $\delta^{18}O_P$ values (Chenery et al. 2012) and estimated sex and age-at-death.

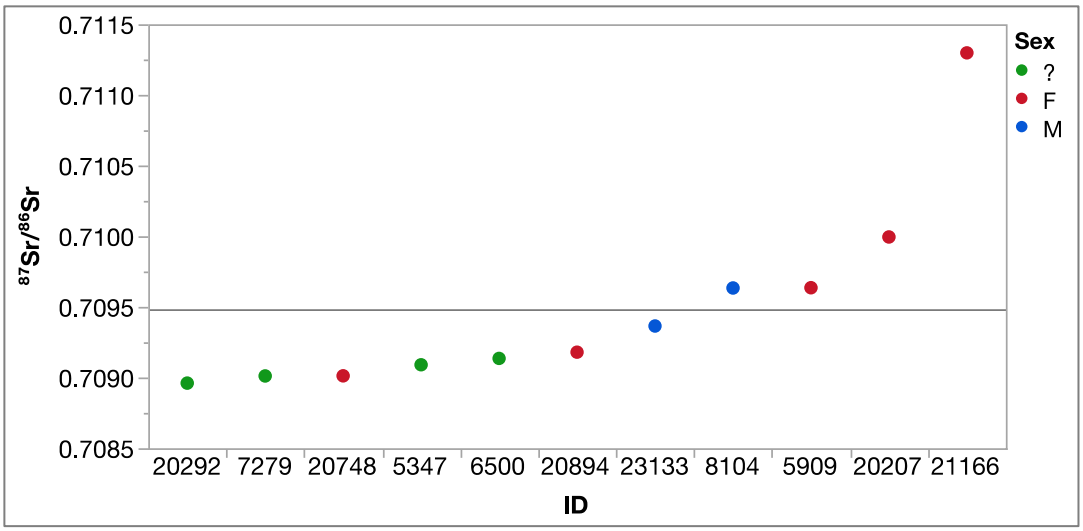


Figure 5.12. Plot of Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ results by skeleton ID number, coloured by sex (n = 11). The horizontal line shows the group mean.

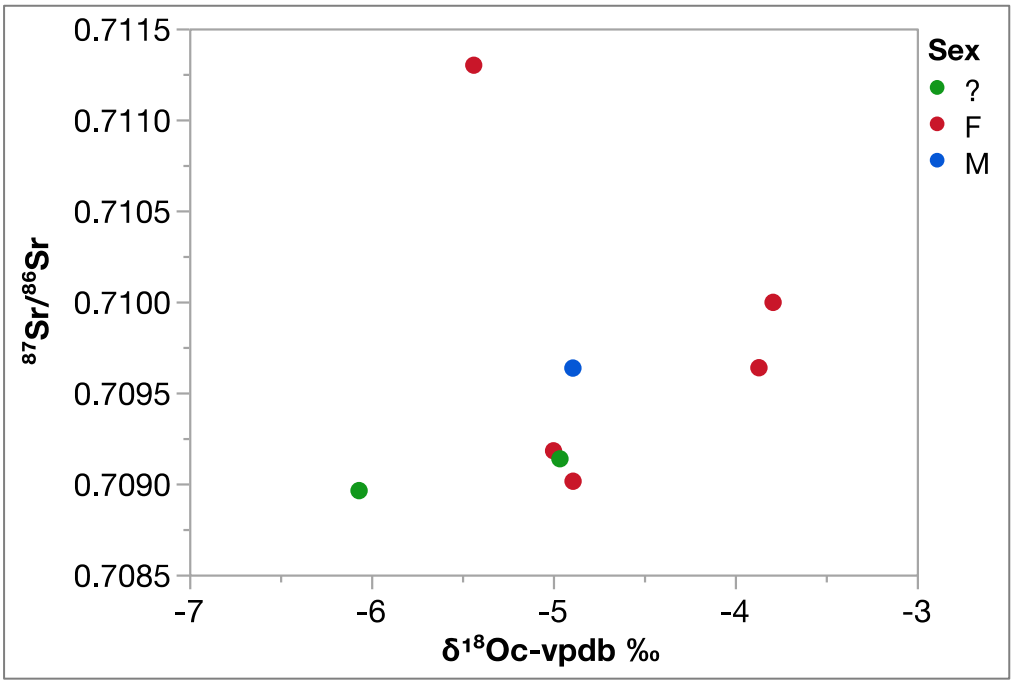


Figure 5.13. Bivariate plot of Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{C\text{-}VPDB}$ results, coloured by sex (n = 8).

5.5 Discussion

This section applies the isotopic and osteological results for Late Saxon Stoke Quay to the questions raised in Section 5.2. Specifically, this section evaluates the evidence for the timing of the 'fish event horizon' and whether certain members of the population consumed fish more intensively than others.

Within-group trends are also explored, including differences by sex and age, along with childhood diet and weaning, in order to better characterise diet as a whole for the Late Saxon population buried at Stoke Quay. Temporal differences in diet within the Late Saxon sample are not explored here, but this could be a fruitful avenue for future research if additional radiocarbon dates are produced for the assemblage from this period.

Comparisons are also made between Stoke Quay and contemporary urban and Scandinavian sites, and interpretations of diet are compared with indicators for disease in order to explore the degree of urbanisation at Late Saxon Ipswich. Finally, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are discussed, and interpretations of possible nonlocals are given, along with a comparison of trauma rates and other health indicators based on local and nonlocal origins.

5.5.1 Dietary trends

Overall interpretations of diet

The Late Saxon human $\delta^{13}C$ and $\delta^{15}N$ results are discussed in further detail in this section. Interpretations of the consumption of marine fish are guided by the expected terrestrial carnivore range derived from faunal $\delta^{13}C$ and $\delta^{15}N$ analyses, discussed in Chapter 3, Section 3.3.5. Based on the mean values for Late Saxon through Medieval fauna, the expected terrestrial carnivore $\delta^{13}C$ range is -20.6‰ to -19.6‰, and the $\delta^{15}N$ range is 10.3‰ to 12.3‰.

The $\delta^{13}C$ and $\delta^{15}N$ results for the Late Saxon sample are shown in Figure 5.14, with dotted lines indicating the expected terrestrial carnivore range, and black symbols indicating mean values (±1σ) for eels, marine, and freshwater fish (Müldner & Richards 2005; Jay 2008; Barrett et al. 2011).

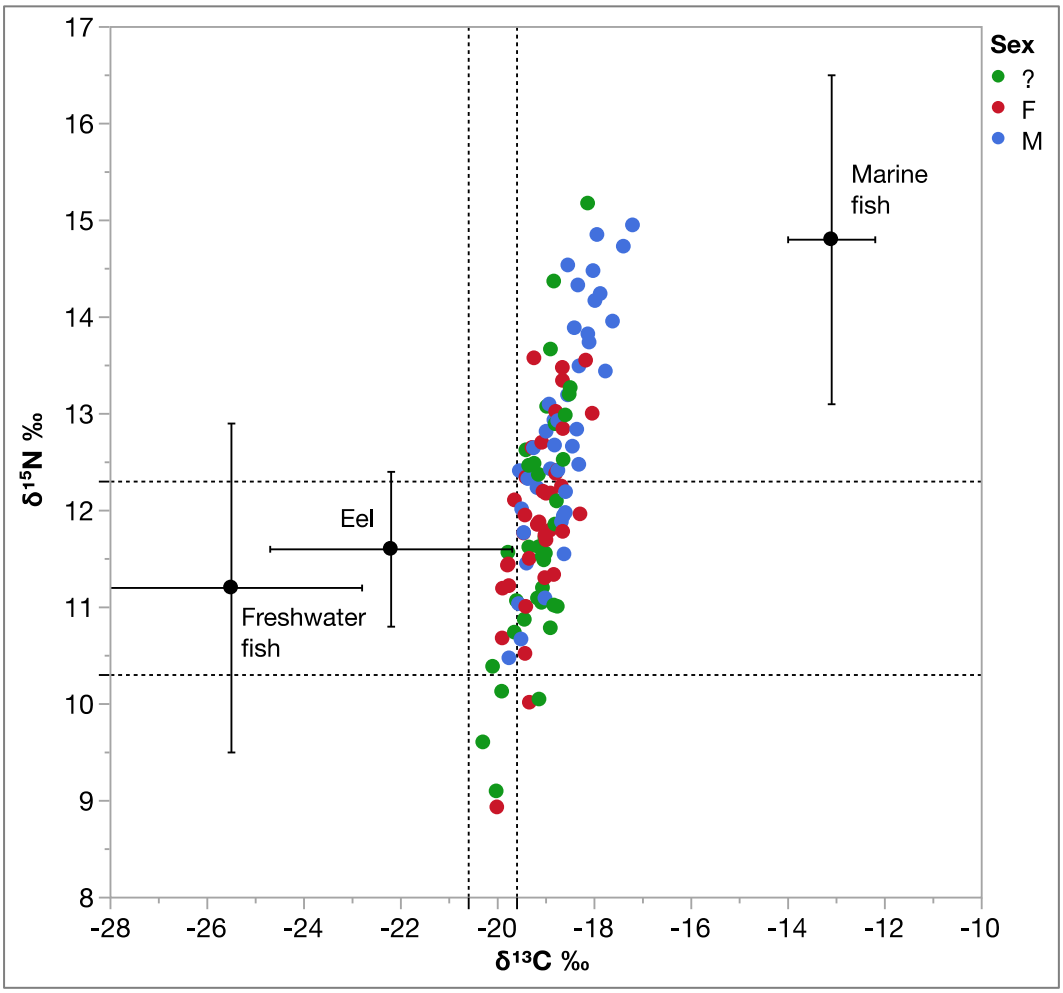


Figure 5.14. Scatterplot of Late Saxon Stoke Quay $\delta^{13}C$ and $\delta^{15}N$, coloured by sex, with dotted lines showing the expected terrestrial carnivore ranges based on faunal means, and black symbols showing mean fish values for different habitats (±1σ).

As shown in Figure 5.14, only 11 out of 115 individuals yielded $\delta^{13}C$ and $\delta^{15}N$ results indicative of carnivorous terrestrial diets. Furthermore, only four individuals, including three subadults, yielded $\delta^{13}C$ and $\delta^{15}N$ values indicative of terrestrial diets without significant animal protein (see the following section for age-related differences in diet). With values trending toward the marine fish range, a large proportion of the Late Saxon sample appear to have consumed some marine fish, while a smaller but still sizeable number have high $\delta^{13}C$ and $\delta^{15}N$ values that indicate more substantial marine fish consumption. To better

define demographic patterns in dietary inputs, the results are compared by age group and by sex.

Dietary differences by age

The Late Saxon $\delta^{13}C$ and $\delta^{15}N$ results are compared by age group in Figures 5.15a and 5.15b (see Table 5.6 for summary statistics). There are no statistically significant differences by age group for $\delta^{13}C$ ($p = 0.1171$, ANOVA), but there are for $\delta^{15}N$ ($p = 0.0099$, ANOVA). A means comparison shows significant differences between adolescents aged 13-17 years and both 36-45 year-olds ($p = 0.0085$), and 45+ year-olds ($p = 0.0379$; Tukey-Kramer HSD).

Additional ANOVA tests between adult age groups show no statistically significant differences when males and females are grouped together, or when they are analysed separately, and no statistically significant differences are found between subadult age groups. The observed pattern for $\delta^{13}C$ and $\delta^{15}N$ is typical for pre-industrial populations, with elevated values for infants due to a positive trophic level shift from breastfeeding, followed by a sharp dip with the post-weaning diet, and a subsequent rise toward the adult mean (Jay et al. 2008).

Because these are bone collagen values, they represent a longer average time period than, for instance, tooth dentine, which develops over a more restricted period (Hedges et al. 2007; Hillson 1996). The subadult $\delta^{13}C$ and $\delta^{15}N$ are examined in the following section, followed by differences by sex.

Age (years)	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
1-5	10	12.5	1.5	10.0	15.2	-18.9	0.4	-19.4	-18.1
6-12	9	11.7	1.3	9.6	13.7	-19.2	0.5	-20.3	-18.5
13-17	18	11.4	1.0	9.1	13.1	-19.2	0.5	-20.1	-18.6
18-25	12	12.0	0.9	10.5	13.4	-19.0	0.6	-19.8	-17.8
26-35	20	12.2	1.4	8.9	14.9	-18.9	0.7	-20.0	-17.2
36-45	26	12.7	1.1	11.2	14.7	-18.8	0.6	-19.9	-17.4
45+	20	12.6	1.2	10.7	14.8	-18.8	0.5	-19.9	-17.9

Table 5.6. Summary statistics by age group for Late Saxon Stoke Quay bone collagen $\delta^{13}C$ and $\delta^{15}N$ results (n = 115).

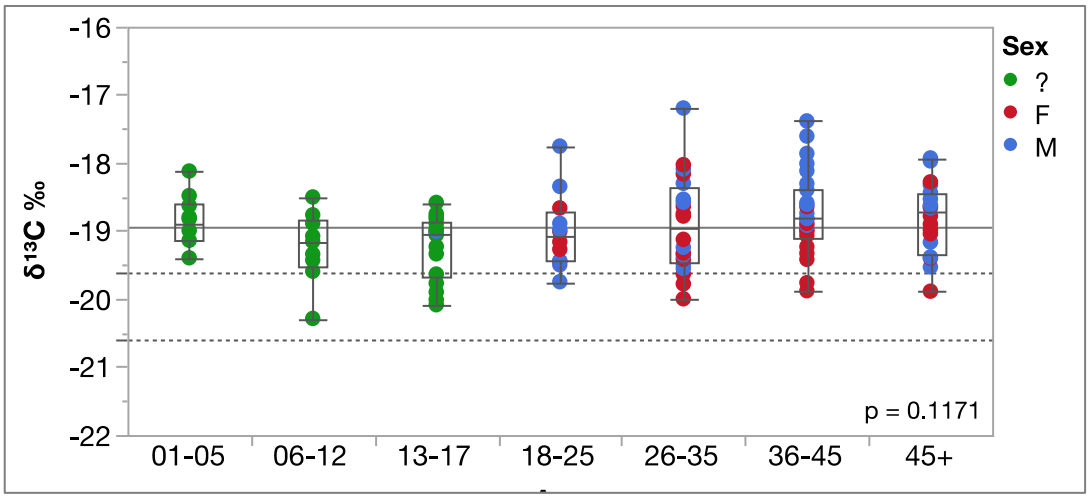


Figure 5.15a. $\delta^{13}C$ Boxplots for Late Saxon Stoke Quay by age, coloured by sex, with no statistically significant differences between age groups (p = 0.1171, ANOVA). Dotted grey lines: expected terrestrial carnivore range; solid grey line: group mean.

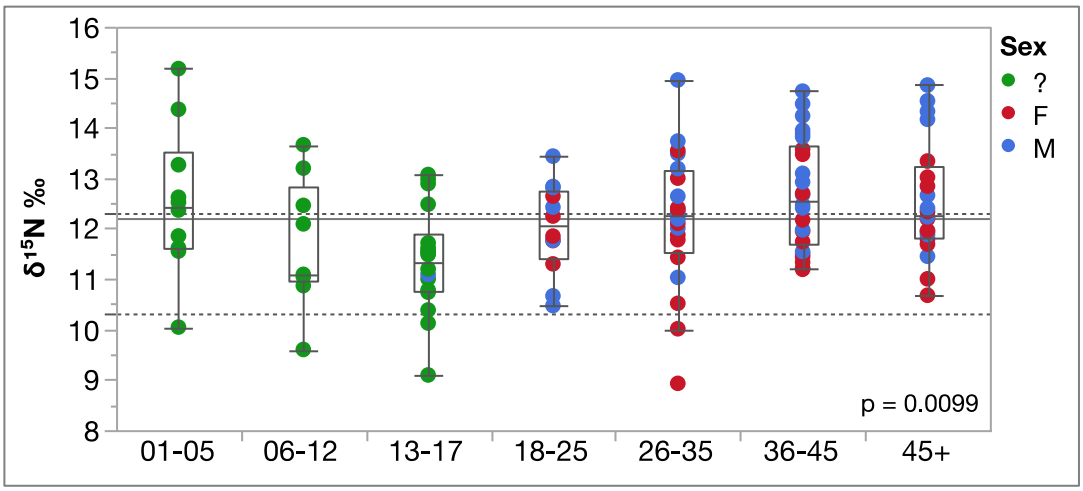


Figure 5.15b. $\delta^{15}N$ Boxplots for Late Saxon Stoke Quay by age, coloured by sex, with statistically significant differences between age groups (p = 0.0099, ANOVA). Means comparisons show significant differences between 13-17 year olds and both 36-45 (p = 0.0085) and 45+ year olds (p = 0.0379, Tukey-Kramer HSD). Dotted grey lines: expected terrestrial carnivore range; solid grey line: group mean.

Subadult diet and weaning

Several quantitative models have been developed to calculate weaning age in past populations (e.g. Millard 2000; Schurr 1997; Pearson et al. 2010). However, recent publications caution against overly precise determinations of weaning times based on isotopic evidence from bone collagen, as most studies rely on insufficient sample numbers and there can be considerable uncertainty in the accuracy of aging methods, depending on the site (Reynard and Tuross 2015; Jay et al. 2008). Due to the small sample size for infants and young children, weaning age is considered only briefly here.

To better visualise isotopic patterns in the Latest Saxon subadult sample, the $\delta^{13}C$ and $\delta^{15}N$ values for this group are plotted with estimated age-at-death. Age-at-death estimations are given as a range, so this range was averaged in order to arrive at a single value for each individual (Fig. 5.16a, b). The $\delta^{13}C$ plot shows a general trend from high values to lower values with age, while the $\delta^{15}N$ plot shows a sharp decline in values from the youngest individuals followed by a smaller rise and second decline at late adolescence.

Based on these plots, weaning may have taken place between 1-2 years of age, though this is highly speculative given the small sample (n = 3) from the 0-2 year age range. These individuals also represent those who did not survive to adulthood, so they may not reflect the population norm (Wood 1992; see Richards et al. 2002, Mays et al. 2010 for further discussion). However, if the observed trend is accurate, it follows the pattern seen at Wharram Percy (Richards et al. 2002), Raunds Furnells (Buckberry et al. 2013), and Berinsfield (Privat et al. 2002). Bearing in mind the caveats above, this rather typical age of weaning suggests that at least for these individuals, the Viking conflicts and

possible destruction to the Late Saxon town of Ipswich did not necessarily impact time of weaning.

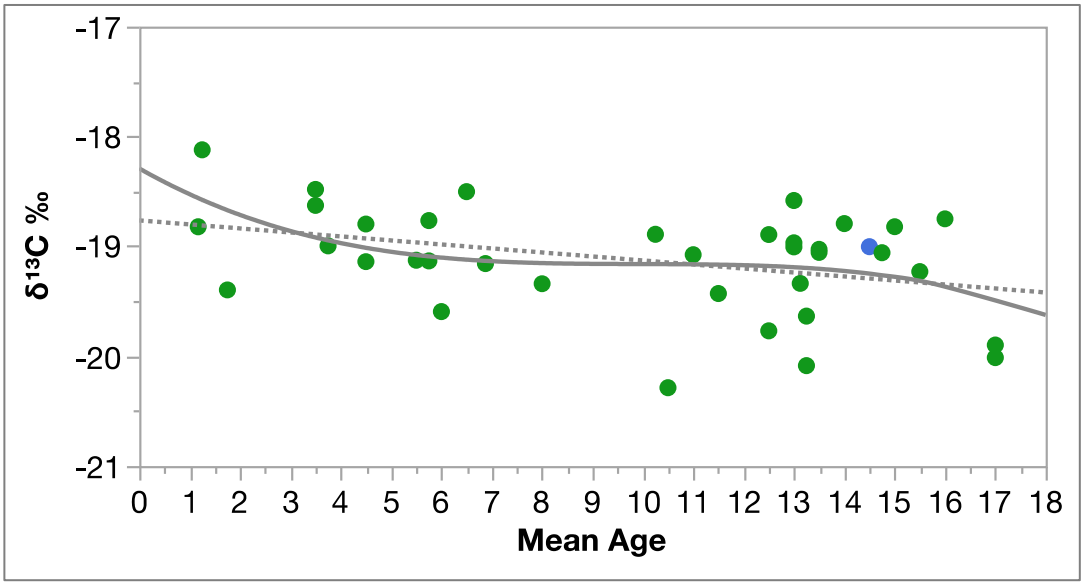


Figure 5.16a. $\delta^{13}C$ by age for Stoke Quay Late Saxon subadults (n = 37). A line of best fit (dotted grey) shows low correlation but statistical significance ($r^2 = 0.14$, $p = 0.0222$). A cubic polynomial curve (solid grey) shows slightly higher correlation but no statistical significance ($r^2 = 0.18$, $p = 0.0878$).

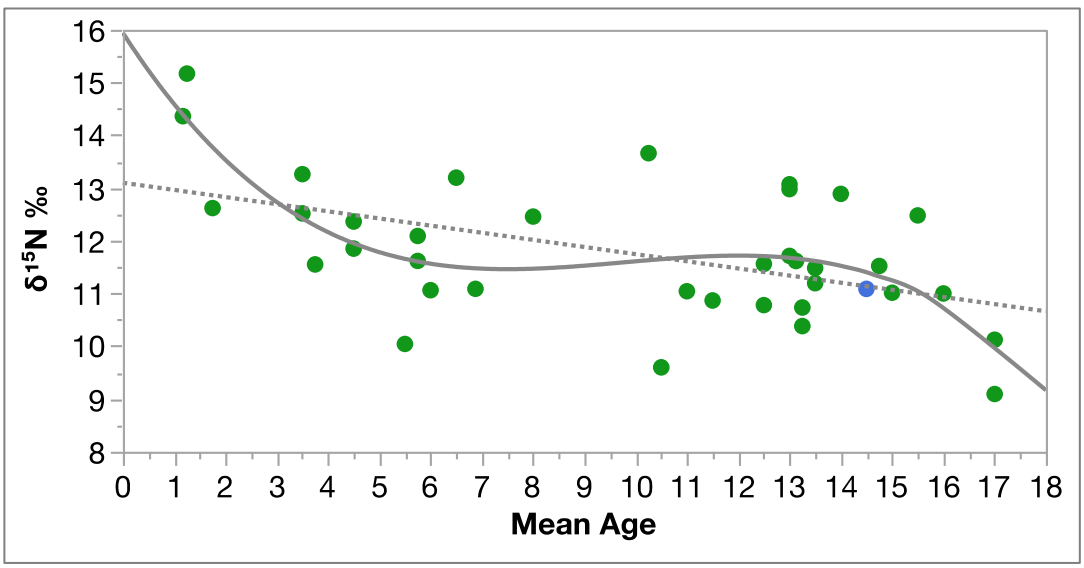


Figure 5.16b. $\delta^{15}N$ by age for Stoke Quay Late Saxon subadults (n = 37). A line of best fit (dotted grey) shows low correlation and statistical significance ($r^2 = 0.26$, $p = 0.0012$). A cubic polynomial curve (solid grey) shows higher correlation and greater statistical significance ($r^2 = 0.45$, $p = 0.0002$).

Sex-based differences in diet

To determine whether males consumed significantly higher proportions of marine fish than females, as hypothesised by Barrett and colleagues (2004a), sex-based differences in diet are evaluated for the adult individuals. As shown in Figure 5.17, an ANOVA shows statistically significant differences between males and females for both $\delta^{13}C$ and $\delta^{15}N$ ($p = 0.0002$ for both datasets). Though there is considerable overlap between the sexes, males generally have more positive values for both isotopic systems. As with the Mid Saxon assemblage, the Late Saxon males exhibit a greater range of $\delta^{13}C$ values than females, though the differences between the ranges are subtler in this phase than in the previous period (male range = 2.5‰, female range = 2.0‰) (Table 5.7).

In contrast to the previous period, Latest Saxon males actually have a narrower range of $\delta^{15}N$ values than females, at 4.4‰ and 4.7‰, respectively. However, the female $\delta^{15}N$ range is strongly affected by one female outlier, Sk 20748, whose $\delta^{15}N$ of 8.9‰ is more than 1‰ below all other females. When Sk 20748 is removed, the range for the remaining 37 females is only 3.6‰, thus broadly following the pattern from the previous time period.

Unlike the Mid Saxon $\delta^{13}C$ and $\delta^{15}N$ results, which showed a predominantly terrestrial C_3 diet, the Late Saxon male $\delta^{13}C$ and $\delta^{15}N$ indicate substantial consumption of marine fish. All but one male yielded $\delta^{13}C$ above the expected terrestrial carnivore range, and the upper three quartiles of the male $\delta^{15}N$ also fall above the expected terrestrial carnivore range.

Sex	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Female	38	11.9	1.0	8.9	13.6	-19.1	0.5	-20.0	-18.0
Male	40	12.9	1.1	10.5	14.9	-18.6	0.6	-19.7	-17.2

Table 5.7. Summary statistics by sex for $\delta^{13}C$ and $\delta^{15}N$ analysis of Late Saxon Stoke Quay adults (n = 78).

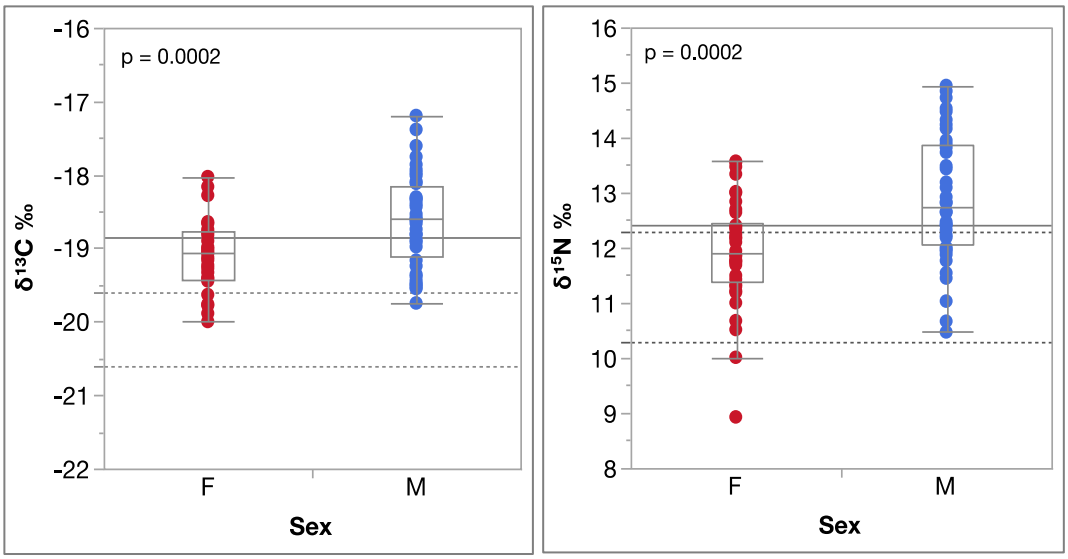


Figure 5.17. Late Saxon adult $\delta^{13}C$ (L) and $\delta^{15}N$ (R) boxplots by sex, with statistically significant differences between sexes for both datasets (p = 0.0002, ANOVA). Dotted grey lines: expected terrestrial carnivore values; solid grey line: group mean.

While the boxplots in Figure 5.17 can help illustrate differences between males and females for each isotopic system, $\delta^{13}C$ and $\delta^{15}N$ are more instructive when used together. The adult male and female $\delta^{13}C$ and $\delta^{15}N$ are plotted again in Figure 5.18, with 95% density ellipses for each sex, and the maximum expected terrestrial carnivore values. As shown in Figure 5.18, there is substantial overlap between the sexes. Interestingly, the $\delta^{13}C$ and $\delta^{15}N$ for most males but also many females fall above the maximum expected terrestrial carnivore range, thus indicating that both males and females at Late Saxon Stoke Quay consumed marine fish, which would argue against Barrett and colleagues' hypothesis that only men would have consumed marine fish at this early date (Barrett et al. 2004a).

However, despite this overlap, the females likely consuming marine fish appear to be either consuming less fish overall, or lower trophic level fish, indicated by the limit of the 95% density ellipse showing their generally lower values. Notably, the group with the highest combined $\delta^{13}C$ and $\delta^{15}N$ values is

composed entirely of males. This group (n = 10) is illustrated in Figure 5.18 by the male values extending beyond the female 95% density ellipse.

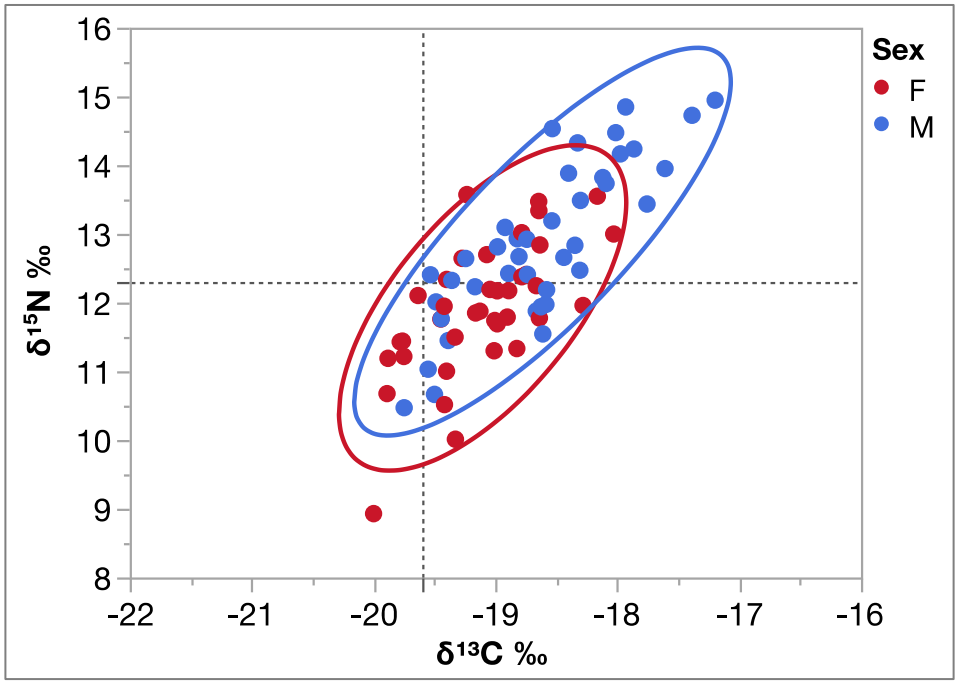


Figure 5.18. $\delta^{13}C$ and $\delta^{15}N$ for Late Saxon adult males and females, with 95% density ellipses around each group. Dotted grey lines indicate maximum expected terrestrial carnivore ranges.

Comparative assemblages

The evidence for increased marine fish consumption at Late Saxon Stoke Quay, Ipswich, has been demonstrated above, as has the particularly high consumption of marine fish by a subset of the male population. But how does Stoke Quay compare to other sites? Is the dietary evidence for Stoke Quay unusual compared to groups interpreted as Vikings, or town-dwellers in Scandinavia or East Anglia? These questions are addressed through comparisons between the adult $\delta^{13}C$ and $\delta^{15}N$ at Stoke Quay and those at contemporary sites in Norwich, Sweden, Dorset, and Oxford (Table 5.8; Figure 5.19). None of the assemblages are of a comparable size to the Stoke Quay adult group from this period (n = 78), ranging instead from 13-38 individuals.

Site	N	Location	Description	Period
St. John the Baptist, Timberhill, Norwich[1]	13	Norwich, Norfolk	Possible leper hospital within Norwich walls.	10th-13th cen. AD
Ridgeway Hill, Weymouth, Dorset[2]	38	Weymouth, Dorset	Mass burial of 38 beheaded males. Possible executed raiding party.	late 10th-early 11th cen. AD
St. John's College, Oxford[3]	19	Oxford, Oxfordshire	Mass burial of 37+ males, mostly young adults. Possibly an executed raiding party or locally settled Danes.	9th-10th cen. AD
Birka, Sweden[4]	21	Birka, Sweden	Trading centre founded in mid-8th cen. Major contacts with W Europe and Scandinavia, then in 9th-10th cen. traded with Byzantium.	Mid-late 8th – 10th cen. AD
Sigtuna, Sweden[5]	37	Sigtuna, Sweden	Town founded in 10th century on Lake Mälaren (inlet near the Baltic Sea coast). Traded with W Europe, Byzantium, and Kiev.	c. 900-1100 AD

Table 5.8. Summary information for the 5 contemporary assemblages discussed in the text. Sources: 1) Bayliss et al. 2004; 2) Chenery et al. 2014; 3) Pollard et al. 2012; 4) Linderholm et al. 2008; 5) Kjellström et al. 2009.

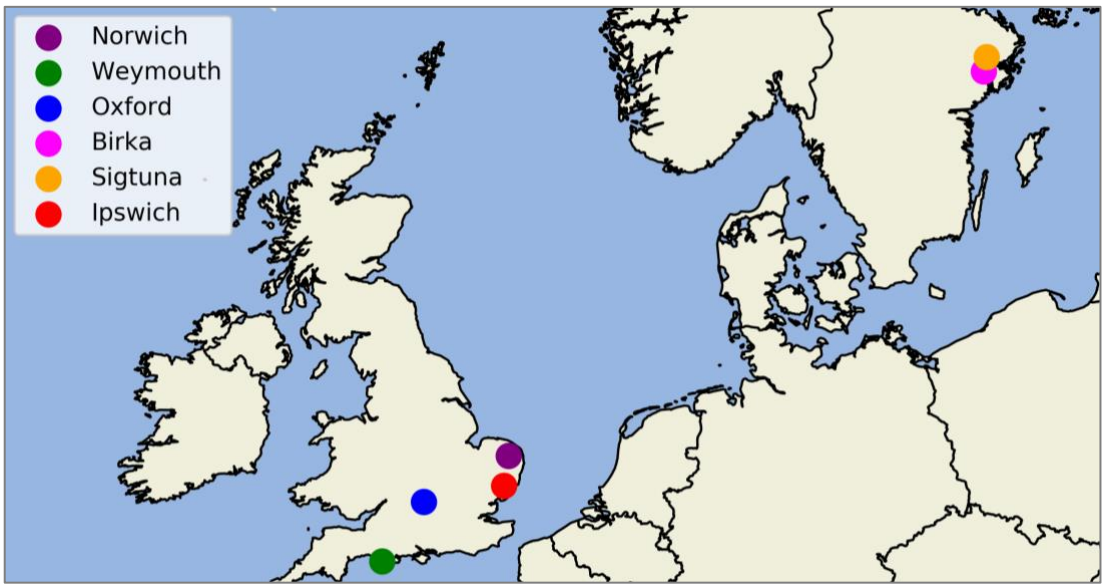


Figure 5.19. Colour-coded map showing the comparative sites discussed in this chapter (image credit: Richard Allen).

The comparative assemblages form a useful framework for interpreting the Late Saxon results from Stoke Quay, with the sample from Norwich representing the closest locality to Ipswich for which data are available. The two mass burials, at Ridgeway Hill, Weymouth, Dorset, and St. John's College, Oxford,

may represent Vikings who were captured and executed (though see Evans et al. 2018b). The two assemblages from Sweden, at Birka and nearby Sigtuna, represent actual Scandinavian populations from trading areas that may have been counterparts to early urban centres such as Ipswich.

The mean $\delta^{13}C$ and $\delta^{15}N$ (±1σ) for Stoke Quay and each of the comparative sites are plotted in Figure 5.20. Compared to the other assemblages, the Stoke Quay group has the highest mean $\delta^{13}C$, and the third-highest $\delta^{15}N$. While Stoke Quay does not have the highest $\delta^{15}N$, the combination of both isotopes, particularly the high $\delta^{15}N$ in combination with the highest $\delta^{13}C$ range, does indicate that the Stoke Quay sample has the highest marine fish consumption. The high $\delta^{15}N$ but terrestrial-range $\delta^{13}C$ at Birka suggest the consumption of freshwater fish, which may be linked to the high status of the Birka burials as interpreted by the site's excavators (Linderholm et al. 2008).

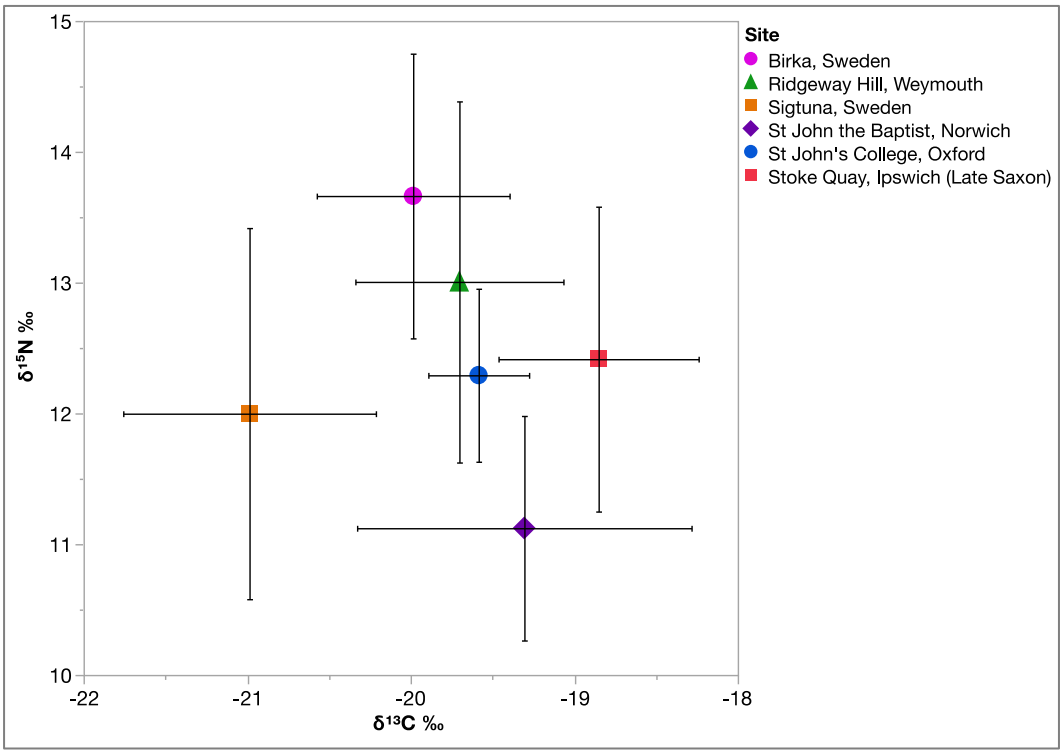


Figure 5.20. Mean $\delta^{13}C$ and $\delta^{15}N$ (±1σ) for Late Saxon Stoke Quay and 5 comparative assemblages (summary statistics given in Table 5.9).

Sex	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
St John, Norwich	18	11.1	0.9	9.8	13.5	-19.3	1.0	-20.9	-17.0
Weymouth, Dorset	38	13.0	1.4	9.5	16.0	-19.7	0.6	-21.1	-17.9
St John's, Oxford	19	12.3	0.7	10.9	13.4	-19.6	0.3	-20.0	-18.7
Birka, Sweden	21	13.7	1.1	11.5	16.5	-20.0	0.6	-21.1	-19.0
Sigtuna, Sweden	37	12.0	1.4	8.2	14.6	-21.0	0.8	-22.2	-19.0
Stoke Quay (Late Saxon)	78	12.4	1.2	8.9	14.9	-18.8	0.6	-20.0	-17.2

Table 5.9. $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Late Saxon Stoke Quay and contemporary sites (see Figure 5.20 for plot of site means and standard deviations).

Sigtuna stands out with its ^{13}C-depleted values, which are indicative of freshwater fish consumption. This interpretation is supported by the large amounts of local freshwater fish remains excavated from medieval town's habitation layers (Ericson 1989, Kjellström et al. 2009). The group from St. John's College, Oxford, exhibits values suggesting a largely terrestrial omnivorous diet, which might be expected if the group represents local Danes executed on St Brice's Day, one of the hypotheses tested by Pollard et al. (2012).

The Ridgeway, Weymouth group, possibly representing an executed Viking raiding party, have lower $\delta^{13}C$ than would be expected for a diet high in marine fish, though the fairly high $\delta^{15}N$ suggests that this group may have consumed some freshwater or brackish fish. Notably, the sample from Norwich has a wide range of $\delta^{13}C$ but low mean $\delta^{15}N$, indicating that some individuals at this site may have consumed some marine protein, but if so, it was likely of lower trophic levels, or in relatively small quantities. As a possible leper hospital within the Norwich town walls, the more terrestrial isotopic values for this group may be a reflection of the diet provided to the sick individuals (Bayliss et al. 2004).

As shown by the comparisons discussed above, the amount of marine fish consumption by adults at Stoke Quay appears to have been higher than at any contemporary site for which data are available. This is all the more remarkable considering that the Stoke Quay burials date to the late 9th-late 11th century, while those from Norwich, Dorset, and Sigtuna date to slightly later. The comparisons demonstrate that Ipswich may indeed have been one of the earliest towns to exploit marine fish.

5.5.2 Skeletal indicators for health and disease at Stoke Quay

The Late Saxon population at Stoke Quay appears to have consumed more marine fish than those at contemporary towns, but how did their health compare? To assess the potential effects of urbanisation and the Viking conflicts on health during the Late Saxon period, the crude prevalence rates for the pathologies associated with 'urban living' at Late Saxon Stoke Quay (see Chapter 2, Section 2.4) are compared to rates from the other important towns of Norwich and York. These rates are also compared to those derived from a survey of other early medieval assemblages throughout Britain, compiled by Roberts and Cox (2003)(Table 5.10). Though the definition of 'early medieval' in the comparative site survey is broadly given as c. 410- c. 1050, the survey nonetheless provides a useful benchmark for averages across a sites over a number of centuries.

As shown in Table 5.13, the Late Saxon assemblage at Stoke Quay exhibits higher crude prevalence rates (CPR) of maxillary sinusitis than the average for early medieval British sites or the rates seen at York Minster. Stoke Quay also has a higher CPR of *cribra orbitalia* than York Minster, Castle Mall, Norwich, or the average for early medieval British sites.

Pathology	Late Saxon Stoke Quay, Ipswich[1]	York Minster[2]	Farmer's Avenue, Castle Mall, Norwich[2]	Survey[2] of early medieval sites (# of sites)
Maxillary sinusitis	Total: 8.2% (26/316) Adults: 13.3% (23/173) Males: 14.9% (11/74) Females: 14.8% (12/81)	6.7% (4/60)	-	4.7% (93/1992) (14 sites)
Periostitis	Total: 35.1% (111/316) Adults: 49.7% (86/173) Males: 59.5% (44.74) Females: 46.9% (38/81)	-	-	-
Cribra orbitalia	Total: 42.7% (135/316) Adults: 39.3% (68/173) Males: 44.6% (33/74) Females: 42.0% (34/81)	10% (6/60)	31.8% (29/91)	7.6% (404/5334) (45 sites)
Tuberculosis	All periods: 1.7% (19/1142)	-	-	0.9% (18/2056) (13 sites)

Table 5.10. Crude prevalence rates for pathologies related to living environment at Late Saxon Stoke Quay (late 9th-late 11th cen.) and comparative sites. References: 1) Loe et al., in press, Appendix 5; 2) Data compiled by Roberts & Cox 2003 (York Minster: Lee, no date; Castle Mall: Anderson, 1996).

Notably, the *cribra orbitalia* crude prevalence rate for Castle Mall, Norwich, is the highest of the 45 sites, both urban and rural, surveyed by Roberts & Cox (2003). The CPR for cribra orbitalia at Stoke Quay is thus high not only in comparison to the average value from all sites, but it is well above even the highest rate in the survey. This indicates that anaemia or associated nutrient deficiencies likely including those caused by parasitic infections, were widespread in the Stoke Quay population.

Unfortunately, no comparative rates for periostitis are included in the early medieval survey conducted by Roberts and Cox (2003), but the crude prevalence rate for the condition at Stoke Quay is nevertheless high. High rates of periostitis are particularly evident amongst the Stoke Quay adults, with nearly half of the adults (86/173) exhibiting this pathological condition.

As discussed in Chapter 1, health is heavily affected by diet, and estimated adult stature can be a useful indication of nutritional status (Roberts & Manchester 2010). The mean estimated stature for Late Saxon Stoke Quay adults is given in Table 5.11 (Gibson et al., in press), along with the mean estimated stature for early medieval Britain (Roberts & Cox 2003). Despite the evidence for marine fish consumption by both males and females at Late Saxon Stoke Quay, the mean stature at the site is lower than the average for contemporary British sites. However, the range of estimated statures for both females and males at Stoke Quay is much wider than mean ranges in early medieval Britain.

The wide range of estimated adult stature at Late Saxon Stoke Quay may be due to a number of factors, including diet and environment, but it may also be an indication that the Late Saxon population at Stoke Quay was composed of people from diverse backgrounds. Status does not appear to have impacted stature, insofar as Cemetery Groups might reflect stature. An ANOVA did not indicate any statistically significant differences in stature by cemetery group for either sex (female $p = 0.0632$, male $p = 0.7770$). Whether some of these individuals were from outside Ipswich is explored in the following section.

Sex	Late Saxon Stoke Quay		Early Medieval Britain[1]			
	mean (cm)	range (cm)	mean (cm)	mean range (cm)	n	# sites
Female	157.9	142.8-174.1	161	152-170	751	-
Male	169.5	158.7-179.5	172	170-182	996	-

Table 5.11. Mean estimated stature for Late Saxon Stoke Quay and comparative early medieval British mean statures (Gibson et al., in press; Roberts & Cox 2003).

5.5.3 Evidence for mobility

As discussed in Chapter 3, Section 3.4, interpretations of mobility in this thesis are based on the expected 'local' bioavailable $^{87}Sr/^{86}Sr$ range of 0.709-

0.710 (Evans et al. 2010), and the English 'low rainfall' $\delta^{18}O_P$ range of 15.9-18.5‰ (Evans et al. 2012). Individuals with results outside of one or both ranges are interpreted as 'Nonlocals'.

Tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was performed on 11 individuals from the Late Saxon skeletal assemblage (see Section 5.3.3, 5.4.2). The $^{87}Sr/^{86}Sr$ results (n = 11) are shown in Figure 5.21 with the expected local bioavailable $^{87}Sr/^{86}Sr$ range. The $^{87}Sr/^{86}Sr$ and calculated $\delta^{18}O_P$ values for the individuals yielding results for both isotopic systems are shown in Figure 5.22 (n = 8; see Chapter 2, Section 2.3.3 for issues with $\delta^{18}O$ analysis), along with the expected 'local' ranges for both isotopes.

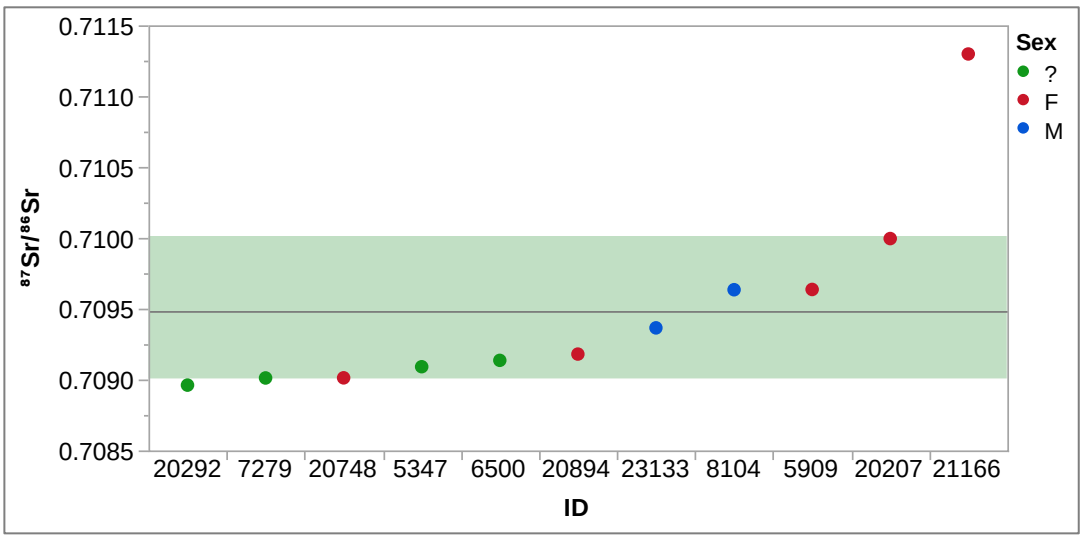


Figure 5.21. Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ results (n = 11). The black horizontal line indicates the group mean, and thegreen band indicates the expected local bioavailable $^{87}Sr/^{86}Sr$ range (Evans et al. 2010).

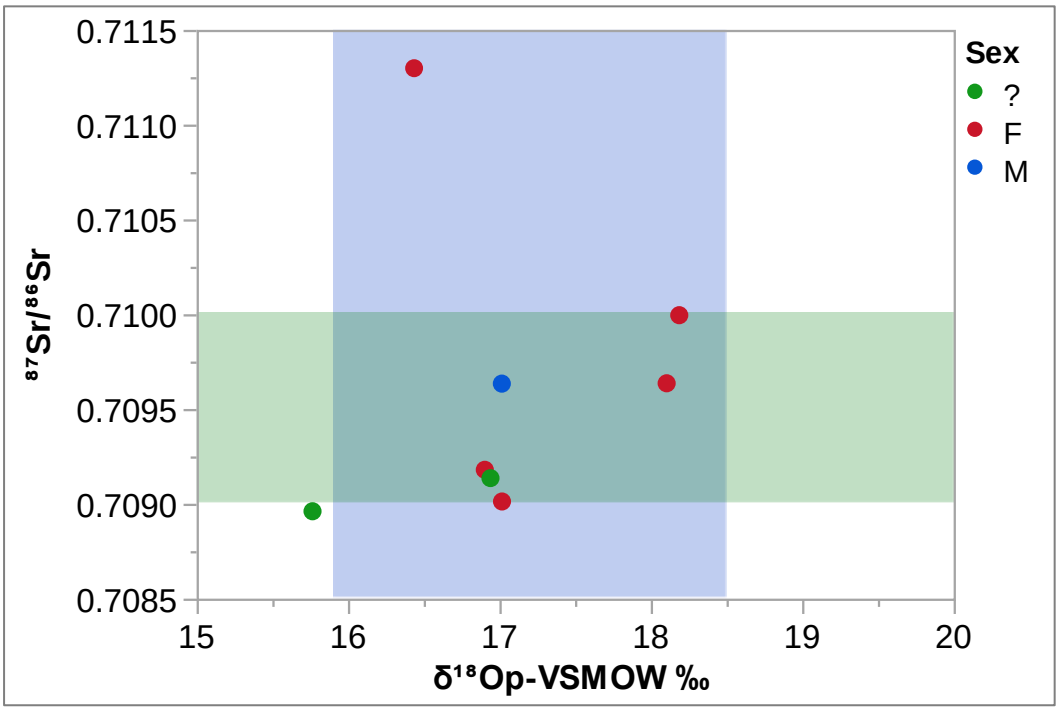


Figure 5.22. Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results. Coloured bands indicate expected 'local' ranges: green: $^{87}Sr/^{86}Sr$ (Evans et al. 2010), blue: $\delta^{18}O_P$ (Evans et al. 2012).

As shown in Figure 5.22, of the eight individuals yielding results for both isotopic systems, the paired $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ values for six individuals fall within the combined expected local range, while two have values outside of the range. Two of the females fall within the 'local' range but have the second- and third-highest $\delta^{18}O_P$ of all 35 individuals yielding $\delta^{18}O$ results. Of these two, Sk 20207 also yielded an $^{87}Sr/^{86}Sr$ ratio of 0.709994, which falls at the upper limit of the 'local' $^{87}Sr/^{86}Sr$ range. This individual is therefore tentatively interpreted as 'nonlocal'.

Unfortunately, only one of the two males yielded $\delta^{18}O$ results, and the unequal numbers of males (n = 2) and females (n = 5) make it difficult to compare sex-based differences in mobility at Late Saxon Stoke Quay. However, it is interesting to note that both males are interpreted as 'locals' while two out of

five females are interpreted as 'nonlocals' (including Sk 20207). The interpretations for each individual are shown in Table 5.12.

Sk ID	Age	Sex	Reason for selection	Cemetery Group	Interpretation: $^{87}Sr/^{86}Sr$	Interpretation: $\delta^{18}O$
5347	6-12	?	Average diet	1	Local	-
*5909	45+	F	Pathology	1	Local	Local?
6500	6-12	?	Unusual diet	1	Local	Local
7279	13-17	?	Average diet	1	Local	-
*8104	36-45	M	^{14}C dated	2B	Local	Local
20207	36-45	F	Pathology	2B	Nonlocal?	Local?
*20292	13-17	?	Trauma	1	Nonlocal?	Nonlocal
*20748	26-35	F	Burial type	10A	Local	Local
20894	45+	F	Average diet	1	Local	Local
21166	36-45	F	Trauma	5	Nonlocal	Local
23133	26-35	M	Average diet	5	Local	-

Table 5.12. Late Saxon Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ interpretations with demographic information and reason for selection (n = 11). * Samples from pilot study (Farber & Lee-Thorp, in press).

Perhaps not surprisingly, the two children aged 6-12 years are interpreted as 'locals'. However, one of the two adolescents aged 13-17 years, is interpreted as 'nonlocal' based particularly on the $\delta^{18}O_P$ results. This individual is discussed in greater detail below. Two of the three females selected because of trauma and pathology are interpreted as 'nonlocals', while the female with 'average' diet and the female chosen because of burial type are both interpreted as 'locals'.

The small sample sizes for the interpreted 'local' and 'nonlocal' groups preclude the use of statistical comparisons such as Chi-Square tests, but some general observations can be made regarding differences and similarities in pathology frequencies between the two groups. Table 5.13 shows the percentage of individuals for the 'local' and 'nonlocal' groups with skeletal evidence of maxillary sinusitis, *cribra orbitalia*, periostitis, infectious disease, and trauma.

Pathology	Locals (% of total)	Comparison	Nonlocals (% of total)
Maxillary sinusitis	1/8 (12.5%)	<	1/3 (33.3%)
Cribra orbitalia	5/8 (62.5%)	>	1/3 (33.3%)
Periostitis	3/8 (37.5%)	<	1/3 (33.3%)
Trauma	2/8 (25%)	<	3/4 (100%)
Infectious disease	1/8 (12.5%)	<	1/3 (33.3%)

Table 5.13. Comparison of percentages of Late Saxon 'locals' and 'nonlocals' with skeletal evidence for pathology and trauma.

The most striking differences between the 'local' and 'nonlocal' groups are seen in the rates of *cribra orbitalia* and trauma. Five out of eight 'locals' have *cribra orbitalia*, while only one of three 'nonlocals' has the condition, though it should be noted that three of the 'local' individuals with *cribra orbitalia* are subadults.

Out of two cases of likely infectious disease (syphilis and leprosy) in the $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ sample group, one (Sk 5909) is interpreted as 'Local' and one (Sk 20207) as 'Nonlocal'. However, as mentioned above, though Sk 5909 is included in the 'Local' group, this female had the third-highest $\delta^{18}O_P$ of the 35 individuals yielding results. It is possible that this individual was also born outside of Ipswich, though this cannot be ascertained with any certainty using the current 'local' ranges. If both Sk 5909 and Sk 20207 were interpreted as 'Nonlocals', it could indicate that 'nonlocals' may have been more vulnerable to infectious disease in Late Saxon Ipswich. Further refinement of the 'local' ranges could help elucidate this issue.

Further differences are seen in the trauma rates for the two groups. All three 'Nonlocals' have skeletal evidence for trauma, compared to only two out of eight 'Locals' with trauma. More tellingly, perhaps, the two instances of trauma

consistent with interpersonal violence (see Section 2.4) are both in the 'Nonlocal' group. These cases bear closer examination.

The first case of interpersonal violence is seen in Sk 20207, a 36-45 year-old female, with cranial features suggesting Caucasian ancestry. This female has a healed depression fracture to the superior aspect of the right parietal bone of the cranium, a location above the 'hat-brim line' and consistent with interpersonal violence (Krakowka 2017a; see Section 2.4). Sk 20207 also has dense nodules of new bone growth on the frontal bone and parietals, as well as porous bone growth on the posterior aspect of the parietal bones, which may be indicative of early stages of syphilis (according to the OA database).

With an $^{87}Sr/^{86}Sr$ ratio of 0.709994 falling at the maximum of the expected local bioavailable range (0.710) and the highest $\delta^{18}O_P$ of the group at 18.2‰, this female may have come from a warmer or wetter location. Areas with this combination of higher $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ are seen in the western extremes of Britain, as well as some parts of Kent and what would have been Wessex. Abroad, this combination may be found in southwestern France, though other locations cannot be ruled out (Evans et al. 2018; Hughes et al. 2014; Willmes et al. 2014).

The other 'nonlocal' individual with skeletal trauma consistent with interpersonal violence is Sk 20292, an adolescent aged approximately 13.5-16 years. Sk 20292 may have been male, based on marked muscle attachments and the morphology of the anterior mandible (OA database). This adolescent exhibited perimortem sharp-force trauma to four cervical vertebrae. The cuts were likely delivered in two blows from behind using a bladed instrument, and would have nearly beheaded this individual (Gibson et all, in press). The violent

manner in which this young person died could have been due to execution as punishment for crimes or due to injuries in armed conflict (see Carty 2015; Loe et al. 2014), or from an attack by Vikings or other individuals. Sk 20292 was radiocarbon dated to 860-1040 cal AD at 93% probability (SUERC-59356, 16% marine correction ±10%), which places the time of death within the period of Viking conflicts, including the period in which Ipswich was under the Danelaw (see Section 5.2).

Further clues as to the story of this youth's death may lie in the isotopic evidence. With an $^{87}Sr/^{86}Sr$ ratio of 0.708960 falling just below the minimum expected local bioavailable range (0.709) and the lowest $\delta^{18}O_P$ of the group at 15.8‰, the isotopic values for Sk 20292 are not consistent with an origin anywhere in Britain. Possible places of origin may be parts of Scandinavia including eastern Denmark, or inland Western Europe (Evans et al. 2018; Hughes et al. 2014; Frei & Price 2012). Given the combination of manner and date of death and non-British origin, it is possible that Sk 20292 was a Viking, or a Danish settler.

As noted above, the sample size for this $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis is small, making it difficult to gauge the degree of mobility in the wider population. However, if the results and interpretation of the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values are representative of the Stoke Quay population as a whole, these findings suggest that this was a mobile and diverse population, with incomers of different ages and both sexes. The combined trauma and isotopic evidence also suggests that nonlocals may have been at greater risk for violence. This possible association between 'nonlocals' and interpersonal violence is further assessed in the following chapters.

5.6 Conclusions

This chapter has set out to shed some light on the hitherto underexplored Late Saxon period at Ipswich, through a combination of bone collagen and tooth enamel isotopic analysis as well as palaeopathological observations.

Section 5.1 provided a brief introduction to the period, while Section 5.2 presented an overview of the state of affairs of Ipswich and the surrounding areas in the Late Saxon period, based on the rather sparse historical and archaeological evidence available. The primary focuses of the overview were the timing of the 'fish event horizon', the conquest of Ipswich and East Anglia by Viking forces and subsequent crises befalling the town, and the increase in urban areas during this period. A number of hypotheses were set forth, and Section 5.3 discussed the materials used to test these hypotheses. Section 5.4 presented the isotopic results and distributions of palaeopathology, and Section 5.5 discussed these results in the context of the research questions and hypotheses from Section 5.2. The findings are summarised below.

The first research question was whether a major shift toward intensive marine fish consumption would be visible at Late Saxon Stoke Quay, and if so, whether certain groups appeared to have adopted this greater fish consumption earlier than others. It was hypothesised that as a coastal port town, the shift would be visible, and that it would affect males more than females. The $\delta^{13}C$ and $\delta^{15}N$ results supported this hypothesis, with a large proportion of the sample population interpreted as consuming at least some marine fish, while a subgroup of males was shown to have consumed higher quantities.

These findings thus support the hypothesis put forth by Barrett et al. (2004a) regarding the overall timing and earliest locations of the 'fish event'.

However, somewhat contradicting expectations, females at Stoke Quay evidently also consumed marine fish in detectable quantities. It therefore appears that marine fish consumption differed by degree, and not by presence or absence, between the sexes at Stoke Quay. Within-group differences based on age were also seen at Stoke Quay, in that individuals who died in adolescence appear to have consumed less marine fish than adults. These findings support the idea that marine fish was consumed in higher quantities by those involved in its catch and possibly its trade.

A second question was how diet at Late Saxon Ipswich compared to diet at other urban and Scandinavian sites. The results indicate that diet at Late Saxon Stoke Quay included more marine fish than diets at the comparative sites for which data were available, even those sites thought to include captured Vikings. Fish consumption at Stoke Quay thus appears to have begun earlier than at contemporary urban trading centres, which further supports the idea that this fish was being caught relatively locally and not yet widely traded within and beyond England.

In spite of the evidence for intensive marine fish consumption among members of the Late Saxon assemblage at Stoke Quay, nonspecific stress indicators suggest a high disease burden for this population, with nutritional deficiencies and/or parasitic infections indicated by high crude prevalence rates for *cribra orbitalia*. Stature at Stoke Quay was also shown to be below average compared to mean statures in contemporary Britain, but the wide range in statures at Stoke Quay points to the possible presence of a diverse population.

The final research question was whether there would be evidence for 'nonlocals' at Late Saxon Stoke Quay, and if there were such evidence, whether

they would be more or less likely than 'locals' to experience trauma and contract infectious diseases. Three out of 11 individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ yielded results consistent with nonlocal origins, and these interpreted 'Nonlocals' were also shown to have experienced higher rates of trauma, especially interpersonal violence (and possibly infectious disease), than their 'Local' counterparts. Combined isotopic and osteological analyses also indicated that at least one individual buried at Late Saxon Stoke Quay may have been a Viking or Danish settler, though other options cannot be ruled out.

In sum, the population buried at Late Saxon Stoke Quay appears to have been mobile and from diverse locations, with varied diets and occupations likely including seafaring and fishing. In this time of disruption and change, violence and disease may have been widespread, but it is possible that access to marine fish provided some measure of stability and nutrition to a population that was otherwise vulnerable to disruptions in trade patterns and attack from both sea and land.

Chapter 6: Urbanisation and economic growth in the late 11th-late 12th centuries

6.1 Introduction

Following the disruption and conflict of Late Saxon England, the Anglo-Norman period of the late 11th-early 12th centuries was one of relative stability and growth. Though there was some political upheaval in the form of war with Scotland and France, day-to-day life for many people in eastern England was more settled than in the preceding centuries. With a country united under one monarch and the threat of invasions diminished, the process of urbanisation, which had begun in the 9th and 10th centuries, could continue unabated.

Another process that continued in this period was the expansion in marine fish consumption that had begun in the previous period. As argued by several researchers (e.g. Barrett et al. 2004a; Reynolds 2016) and shown in Chapter 5, this increase in marine fish consumption started earlier at ports before spreading inland after roughly 1000 AD. The rise in the procurement, trade, and consumption of marine fish continued in the late 11th-late 12th centuries, both fuelling and fuelled by the economic expansion of the period.

This chapter addresses the impact of fishing and seafaring on town life in the late 11th- late 12th century, using Stoke Quay as a proxy for the changes that were occurring more broadly in eastern England and the country as a whole. Of particular focus are changes in diet and health, and the potential effects of increased trade and urbanisation on mobility.

The following section (6.2) provides further historical and archaeological background to the issues of increased urbanisation, trade, and fish consumption mentioned above, and concludes with a series of research questions and

hypotheses that guide the analyses in this chapter. The skeletal assemblage from Anglo-Norman Stoke Quay is described in Section 6.3, along with a description of the samples used for $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen and $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of tooth enamel. Section 6.4 presents the results, and Section 6.5 discusses the results with respect to the research questions and hypotheses specific to this chapter. Finally, Section 6.6 summarises the findings and discusses whether the hypotheses have been supported by the results.

6.2 Historical background and research questions

6.2.1 Urbanisation

Beginning around the year 1000 AD, the Medieval Warm Epoch brought a roughly 200-year period of generally warmer and more stable climate, which led to increased agricultural production. This agricultural production in turn supported an increase in population numbers and population densities, particularly in urban areas (Dyer 1989; Lamb 1995).

The number of individuals living in urban environments increased markedly in the Anglo-Norman period, in comparison to the preceding centuries. By the time of the Norman Conquest 7-10% of the population lived in towns, and by 1086 Domesday Book records 112 boroughs, including trading settlements, royal residences, burhs, and major centres such as London and York. Economic and urban growth appears to have increased significantly after around 1180, by which time London had begun to dominate trade (Schofield & Vince 2003).

As places with growing wealth and power, governed by monetary exchanges more than service obligations, towns were able to challenge some of the traditional aristocratic power structures that dominated more rural areas.

With their dynamic social structures, towns played an important role in some of the social changes that began in the 12th century and took root after the 14th century (Hinton 1990). Changes in diet, trade patterns, and occupation are discussed in the following sections.

6.2.2 Overseas trade in the Anglo-Norman period

By the 12th century many small towns had weekly markets, which allowed merchants from these places to engage in overseas trade by importing goods to sell in the hinterlands and shipping out locally produced items to a broader market. Overseas trade was facilitated by port towns along coasts and major rivers where seagoing vessels could pull up to port, such as Lincoln, Norwich, and Ipswich (Schofield & Vince 2003). At this time, the seagoing vessels would have been one of two main types: clinker-built ships and cogs, both of which had oars as well as single square sails (Greenhill 1988).

Clinker-built ships were a Scandinavian-style (see Chapter 5), while cogs were a German and Friesian tradition, used in coastal waters and rivers since the 7th century but increasing in number around the mid 12th century with the foundation of the trading town of Lübeck in Germany. Cogs were cheaper and easier to build than clinker-built ships, and soon they were the most commonly used type of vessel in northern Europe. Cogs had a carrying capacity from under 40 to over 300 *tuns* (the standard wine barrels from Bordeaux used to measure cargo capacity), and their average size increased rapidly from the 12th century (Rose 2012; Greenhill 1988).

The larger hold capacities of ships in the post-Viking period meant that larger shipments of goods could be transported overseas at one time. This

became more important throughout the medieval period, as long-distance trade grew into a powerful economic force that was increasingly global in scale (Barrett 2018). In the late 11th- late 12th centuries, one of the most widely traded products was fish.

The flourishing fish trade impacted many aspects of town life in 11th- 12th century East Anglia. Fishing and sailing provided employment, selling fish provided a living for merchants, and the taxes generated from this trade contributed to the growth of towns (Barrett 2016). Boatbuilding provided employment for labourers and profit for owners, while investment in fishing boats provided capital for wealthy investors and landowners. Through commissioning the building of boats, even inland landowners could profit from the fishing trade. Fishermen could also pool their capital by contributing elements such as oars, cords, or their labour as shares in a fishing venture, which allowed them to earn a percentage of the catch (Kowaleski 2016).

Many products were traded in the Anglo-Norman period, but as discussed below, the fish trade may have been particularly important for Ipswich.

6.2.3 The east coast herring fisheries

The increase in marine fish consumption that had begun in the 9th-11th centuries (see Chapter 4) developed further during the Anglo-Norman period, aided by the larger carrying capacities of ships as noted above. Many areas on the east coast of England and Scotland were heavily involved in the fishing industry, particularly the herring fishery. Herring have a wide distribution and travel in dense shoals that rise up to shallower waters at night, which would have made them easily accessible to fishermen. These fish migrate seasonally to

spawn in coastal waters, with various populations migrating to different locations during different months (Barrett 2016). In the North Sea, the spawning season began in late summer in the north, and moved down the coast of Scotland to eastern England in the autumn, where they could be easily caught in large numbers (Kowaleski 2016).

Herring could be caught from boats in the open water using gill nets, or near the shore using seine or pound nets (Starkey & Nielssen 2009; Barrett 2016). During the 11th and 12th centuries, catches were brought to shore to be preserved through salting, smoking, or drying, depending on the location and climate. Salt availability thus became an immensely important factor in determining the success of fisheries, for herring as well as cod and other fish (Barrett 2018; Kowaleski 2016).

The herring fisheries located off the coast of eastern England were engaged in trade from the 10th and early 11th centuries, but their commercialisation increased markedly throughout the 11th and early 12th centuries (Kowaleski 2016). East Anglia was particularly well positioned to dominate the English herring fishery, with saltworks located in Norfolk (including towns such as Kings Lynn), fuel for the saltworks provided by nearby peat mines of the Norfolk Broads, and with the herring migratory path located close to shore (Kowaleski 2016; Clarke 2016).

Dunwich was the major focus of the East Anglian herring fishery from around the 11th-12th centuries, but was overtaken by Great Yarmouth in the 12th and 13th centuries (Barrett 2018). A large-scale fishing industry was already in operation in Yarmouth by the 11th century, and documentary evidence for the great Yarmouth herring fair is first seen in 1208 (Kowaleski 2016). By the 12th

century, hundreds if not thousands of Continental fishermen were participating in the Yarmouth fishery (Campbell 2002; Barrett 2018), including a fleet of 40 ships from the Low Countries mentioned in a saint's life (Bethell 1970; Kowaleski 2016). In terms of number of fisheries, the highest number of recorded herring fisheries in the 11th century were from Suffolk, which included more than 30 places with rents or renders paid in herring (Kowaleski 2016).

In addition to the fishermen of places like Great Yarmouth, or those that followed the herring shoals along the eastern coast, many residents of port towns were also involved the fishing industry to some degree. Men in particular could find occupations as fishers, sailors for hire, boat builders, fishermen, and fishmongers (Kowaleski 2008; Dyer 2000). There is little documentary evidence for the occupations of women in port towns during this period, but they are likely to have been employed in the production of food and drink (Goldberg 1992). Women and children could also harvest shellfish from coastal areas, either for direct consumption or for sale, thereby contributing to the household food supply or accounts (Serjeantson & Woolgar 2006; Bailey 1990).

6.2.4 Diet in the Anglo-Norman period

Generally speaking, diet in the late 11th-late 12th centuries was relatively similar to the preceding centuries. Stews were a common dish, as evidenced by the sagging-based cooking pots that could sit in an open fire, in use throughout the country by the 12th century (McCarthy & Brooks 1988; Hinton 1990). Fish, however, played an increasingly important dietary role. Preserved fish were an important source of protein for people across the country during lean times and during times of religious fasting (Barrett 2018). Freshly caught fish would have

only been available to the wealthier inhabitants of inland areas, but would have been more easily procured by coastal inhabitants, especially those involved in the fishing industry (Kowaleski 2016).

It is also important to note that though herring is the primary focus of this chapter due to its importance in East Anglia during the 11th and 12th centuries, cod was also increasing in popularity, while flatfish from shallow waters continued to be eaten, particularly in coastal areas (Serjeantson & Woolgar 2006; Harland et al. 2016). As top marine predators, cod have higher $\delta^{13}C$ and $\delta^{15}N$ values than terrestrial foods, while herring occupy a lower trophic level and therefore have less distinctively 'marine' $\delta^{13}C$ and $\delta^{15}N$. More herring protein in the diet would be required in order to be recognisable in human isotope values, as opposed to the lower amount of cod protein required to effect the same impact on human isotopes (Müldner 2016; see Figure 6.1).

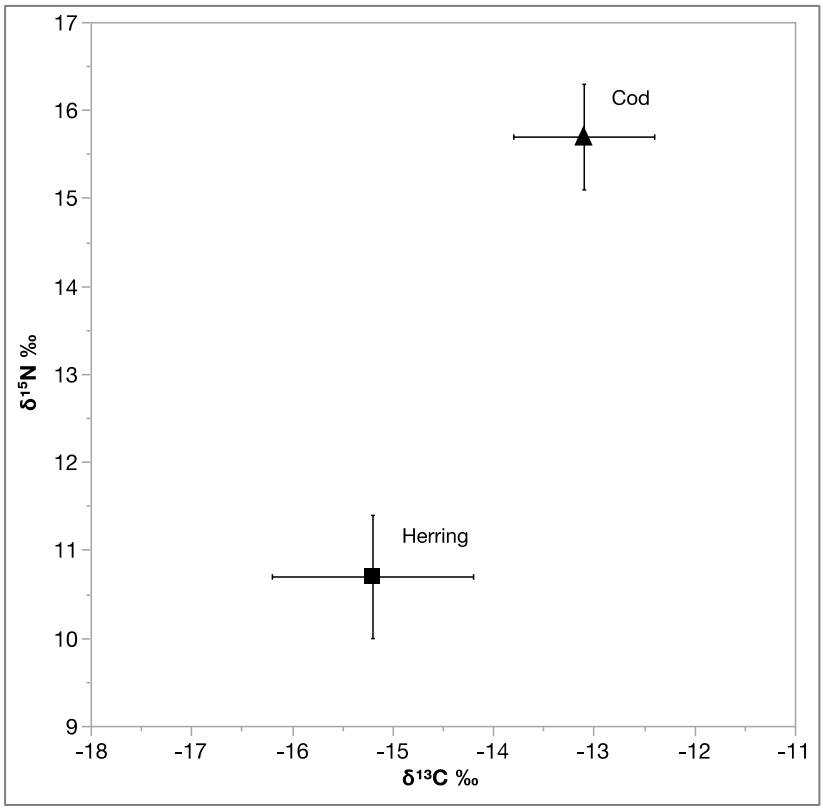


Figure 6.1. $\delta^{13}C$ and $\delta^{15}N$ means (±1σ) for published herring (n = 3; Müldner & Richards 2005) and cod values (n = 27; Barrett et al. 2011).

6.2.5 Ipswich in the late 11th- late 12th centuries

Ipswich, with its estuarine location and position less than 100 kilometres from Yarmouth, was likely also heavily involved in the fishing trade. While the herring fishery was busiest during the autumn, coastal waters provided other types of fish year-round (Kowaleski 2003). Offshore fishing was generally a male activity, while women could be employed in tasks such as brewing, baking, selling produce and foods at market, and potentially salting and preserving fish (Dyer 2000; Kowaleski 2013). By the late 13th century, toll lists from Ipswich mention red herring and fresh or salt herring, as well as whale meat, sturgeon and salmon. However, it is likely that tolls had already been collected on fish for some time prior to the creation of such lists (Kowaleski 2016).

Little is known about Ipswich's waterfront during this period, but it is clear that there were a number of inlets along the shoreline, which could have been used to unload goods from small vessels into warehouses along the river, or as shipyards. One such inlet appears to have been located at the edge of St. Augustine's parish. Shipbuilding was a local industry in Ipswich from an early period, with the earliest reference to ship construction in 1295, by which point the local shipbuilders were capable of constructing a large galley commissioned by the king (Malster 2000; Breen, in press; Brown & Popescu, in press).

Members of St. Augustine's parish may have been involved in shipbuilding and seafaring, though without documentary evidence it is difficult to confirm this. Some clarity may be provided through osteological evidence of occupational injuries from the Anglo-Norman assemblage at Stoke Quay, discussed above.

6.2.6 Research questions and hypotheses

The processes of urbanisation, fuelled in part by the herring fisheries and the burgeoning overseas trade, contributed to a social environment that was in many ways distinct from the previous period. Increased prosperity may have led to better health outcomes for some, but the process of urbanisation may have been a mixed blessing to others—providing employment but also exposing townspeople to higher pathogen loads and unsanitary conditions (see Section 1.3.2 and 2.4). These contradictory outcomes invite a host of questions regarding the experience of urban dwellers and the composition of urban populations in late 11th-12th century England, which can be examined through the contemporary assemblage at Stoke Quay, Ipswich.

The most general question is whether the continued increase in marine fish consumption attested to in the zooarchaeological and historical evidence for this period can be seen at Stoke Quay, and whether there are differences compared to the previous period, with the hypothesis that increased marine fish consumption will be detected. This is tested through $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen from Anglo-Norman Stoke Quay. Male and female dietary isotope results are compared to evaluate dietary differences between the sexes, and the results are compared by age group to assess age-based dietary differences. The adult dietary isotope results are also compared to a contemporary assemblage from Fishergate, York, to investigate regional differences in diet, and whether a coastal port town isotopic 'signature' can be detected.

Another question that arises is whether the prosperity attested to in the historical records and the impacts of urbanisation can be seen osteologically at Stoke Quay, with the hypothesis that differences will be seen between this period

and the Late Saxon period. This is explored through examining potential temporal changes in stature, as well as comparisons of the incidence of nonspecific stress indicators, infectious disease, and trauma.

Finally, with the expansion in trade and increasing urbanisation of the Anglo-Norman period, and the draw of the nearby herring fisheries to foreign fishermen, can individuals of nonlocal origin be identified in the Anglo-Norman assemblage from Stoke Quay? This is explored through $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of a subsample of the skeletal assemblage, with the hypothesis that increased mobility will be visible. Evidence for disparities in patterns of trauma and palaeopathology are also discussed in order to evaluate differences in treatment between those raised in Ipswich and those coming from elsewhere.

The following section (6.3) describes the materials used to assess the questions and hypotheses discussed above. Background information is given regarding the site of Stoke Quay during the late 11th-late 12th centuries, and the human skeletal remains are discussed, along with details on the samples selected for stable isotope analysis.

6.3 Materials

Activity at Stoke Quay dating from the late 11th to late 12th centuries was assigned to Phase 5 by the site excavators, and is referred to here as the Anglo-Norman period. This period saw the construction of a stone church in the northern part of the site, which became the parish church of St. Augustine. If a timber church structure had existed in the Late Saxon period (see Chapter 5), this was replaced by the stone structure at this time (Teague, in press; Breen, in press). During the Anglo-Norman period at Stoke Quay, cemetery burials

continued in the northern part of the site but the areas to the south of the cemetery became progressively less active. The southernmost area may have been used for pasture, and the eastern part of the site may have included animal enclosures (Rielly, in press).

The following section describes the human remains from the Anglo-Norman period, including the total number of burials and the selection of samples for this study.

6.3.1 The Anglo-Norman burials

Overview

Though the foundation date is not known, the stone church of St. Augustine was certainly in place by 1086, and is named in Domesday Book. The two-celled church contained a rounded chancel to the east and a rectangular nave to the west. Most of the stone from the building and its foundations was robbed during the later medieval period, but the robber trenches left a clear indication of the church's footprint (Teague, in press)(Figure 6.2).

A total of 558 individuals were assigned to the Anglo-Norman period, making it the largest assemblage of the burial phases. The assemblage from this period includes 254 juveniles and 304 adults (Table 6.1). Skeletal preservation was generally good, with over 90% scored as 'good' or 'fair' with regards to bone surface condition, completeness, and fragmentation, and more than half the assemblage had skeletal completeness of over 50% (Loe et al., in press).

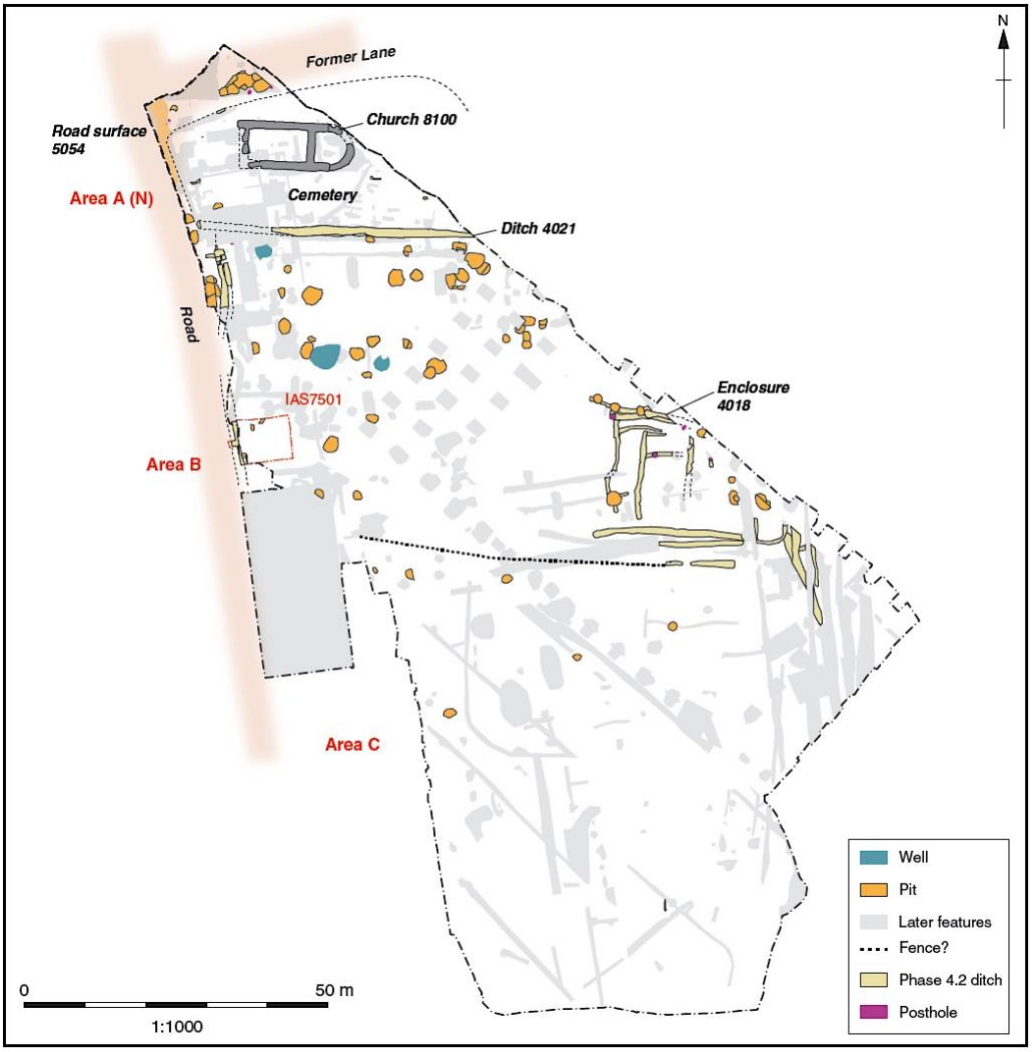


Figure 6.2. Map of Anglo-Norman Stoke Quay (Phase 5, late 11th-late 12th cen.). From Teague, in press, Figure 3.52).

Age Category	Age range (years)	Male	Female	Total
Juvenile				
Preterm	<37 wks gestation	-	-	5
Neonate	Birth- 1 month	-	-	15
Infant	1-12 months	-	-	31
Young child	1-5	-	-	104
Older child	6-12	-	-	73
Adolescent	13-17	2	-	26
Juvenile (unspec.)	<18	-	-	-
Adult				
Young adult	18-25	14	15	30
Prime adult	26-35	28	28	57
Middle adult	36-45	40	39	80
Mature adult	>45	24	24	49
Mature adult+	>60	-	1	1
Adult (unspec.)	>18	18	16	87
TOTAL	All	126	123	558

Table 6.1. Anglo-Norman age and sex distribution (combined M/?M/??M, and F/?F/??F) (adapted from Loe et al., in press, Table A5.13: Phase 5 age and sex distribution).

Cemetery layout

The Anglo-Norman burials were in a more orderly alignment than in the previous period, generally orientated east-west and distributed in rows that may have been organised in family groups. In contrast to the previous period, all the Anglo-Norman burials were in earth-cut graves without stone linings or head supports. A small number of shroud pins and possible textile remnants indicate that some individuals were buried in shrouds, a practice that began in the 12th century. Coffin nails were preserved in 21% of the Anglo-Norman graves, an increase from the previous period. Burial in coffins would suggest higher status, due to the labour and cost associated with procuring wood and building coffins (Brown et al., in press).

Twelve burials included clench bolts, a continuation of the Late Saxon tradition noted in Chapter 5. The continued use of boat timbers at this date is rare in the archaeological record, though other examples are seen at St. Peter's, Barton on Humber. At Stoke Quay these burials include both males and females, possibly indicating a symbolic association with the shipping industry as opposed to a direct relationship to seafarers (Mould 2011a). Alternatively, if this population was heavily involved in seafaring and ship building, the reuse of boat timbers might have been an economical source for coffin wood.

Almost the entire Anglo-Norman assemblage was buried in an extended, supine position, but two individuals were buried in a prone position. At least one of these prone burials was likely in a coffin. Prone burial is relatively uncommon in this time period, and may have been associated with criminality, deviance, or penitence in the later Anglo-Saxon period (Reynolds 2002; Gilchrist & Sloane 2005). However, a number of carefully arranged prone burials at the cemetery of

Bowl Howl, Bamburgh have been interpreted as a sign that such burials may not always have negative connotations (Groves 2010).

The Anglo-Norman burials were assigned to Cemetery Groups based on spatial positioning or grave type, in this case consisting of eight groups (Figure 6.3, Table 6.2). The majority of burials were located to the south of the church, extending further south than in the previous phase and bounded by a new ditch. The areas to the north and east of the church were more sparsely used, with 51 and 13 graves, respectively. Unlike later periods, there were no Anglo-Norman burials within the church, but some were grouped along the outer north and south church walls and along the southern boundary (Brown et al., in press).

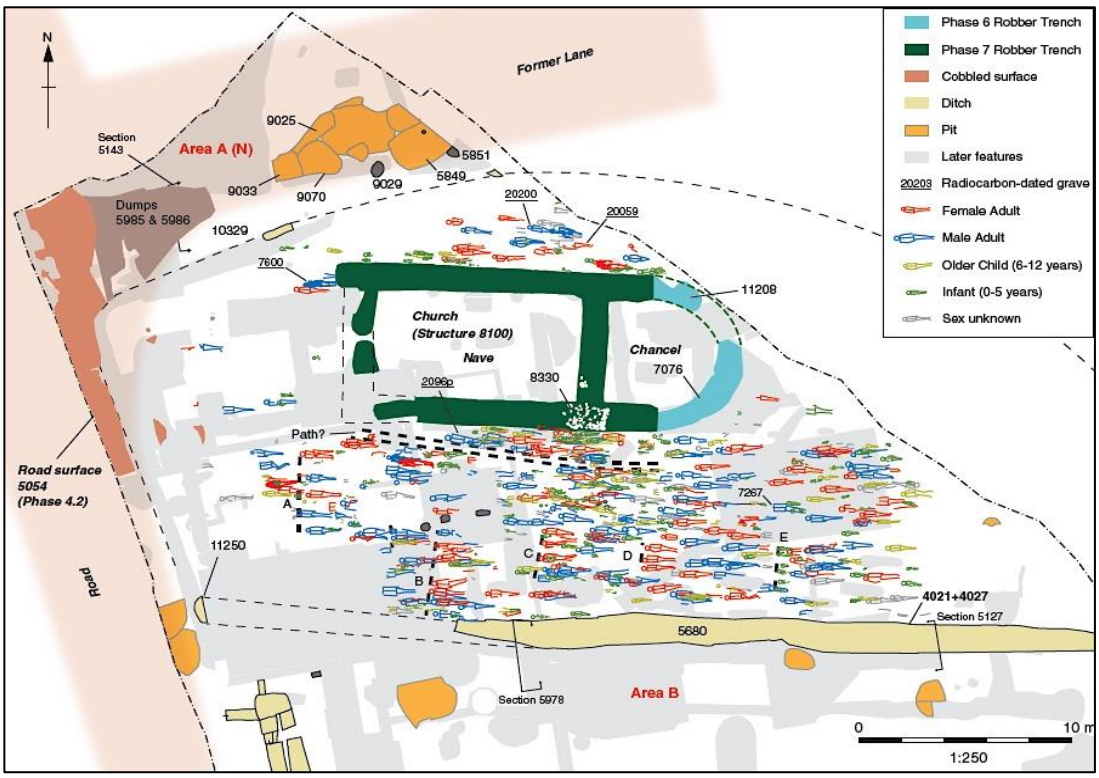


Figure 6.3. Map of Anglo-Norman features and burials. From Teague, in press, Figure 3.53.

Cemetery Group	# of Burials	Location
CG 3	51	North of church
CG 6	13	West of church
CG 7A	84	Immediately south of church, north of possible path
CG 7B	141	South of path and CG 7A (central area)
CG 7C	100	South of path and CG7A (western area)
CG 7D	63	Graves clustered north of earliest southern cemetery boundary
CG 7E	100	South of path and CG7A (eastern area)
CG 8A	5	Graves predating chancel remodelling

Table 6.2. Anglo-Norman Cemetery Groups and distributions at Stoke Quay.

A line of child burials was aligned with the northern church wall, a pattern seen in other pre-Conquest cemeteries. The placement of these 'eaves-drip' burials may have been used to mitigate the unbaptised status of infants and some young children, with the water running off the church eaves providing a post-mortem baptism of sorts (Daniell 1998). The 'eaves-drip' burials at St. Augustine's may indicate a longer duration for the practice, or that the church was built before the Conquest (Brown et al., in press).

The site excavators also noted more females than males buried to the north of the church—an area traditionally considered unfavourable due to the damper and darker conditions in the shadow of the church (Dawes and Magilton 1980; Brown et al., in press). Female burial north of the church or close to infants and church walls may have related to death during childbirth or shortly thereafter (Craig-Atkins 2014; Brown et al, in press). The placement of female and child burials at St. Augustine's is similar to that at 10th-11th century Raunds Furnells, Northamptonshire (Boddington 1987).

6.3.2 Samples for $\delta^{13}C$ and $\delta^{15}N$ analysis

A total of 121 individuals from this phase were selected for $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen (Figures 6.4-6.8). The group is comprised of 37

subadults (<18 years old), 40 adult females, and 44 adult males. The aim was to sample 20 adults per age group (see Chapter 2), but the numbers vary slightly in this period depending on the number of well-preserved skeletons from each age group. The 36-45 and 45+ age groups each contain 20 individuals from the main study along with 3 individuals from the pilot study. Bone collagen extraction and analysis followed methods described in Chapter 2 Section 2.2.3.

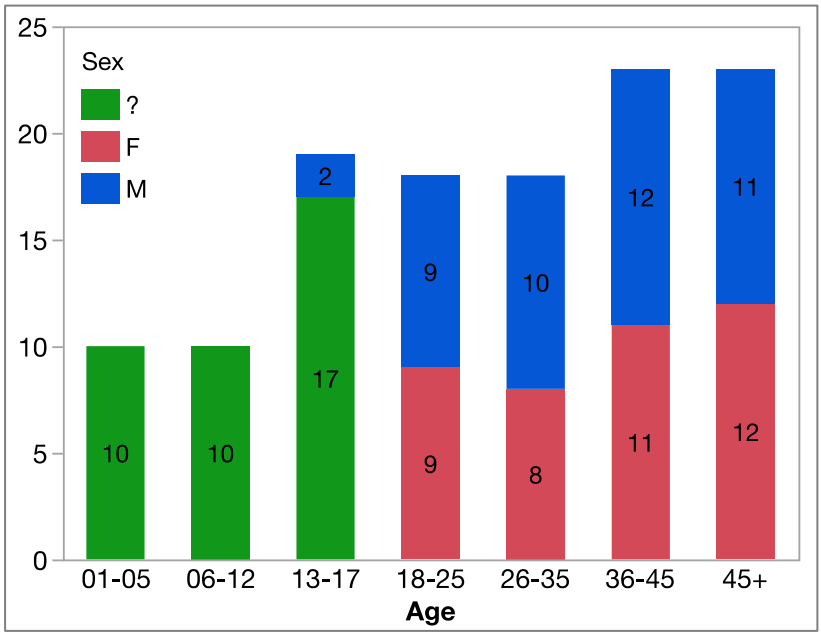


Figure 6.4. Age distribution for Anglo-Norman $\delta^{13}C$ and $\delta^{15}N$ samples (n = 121).

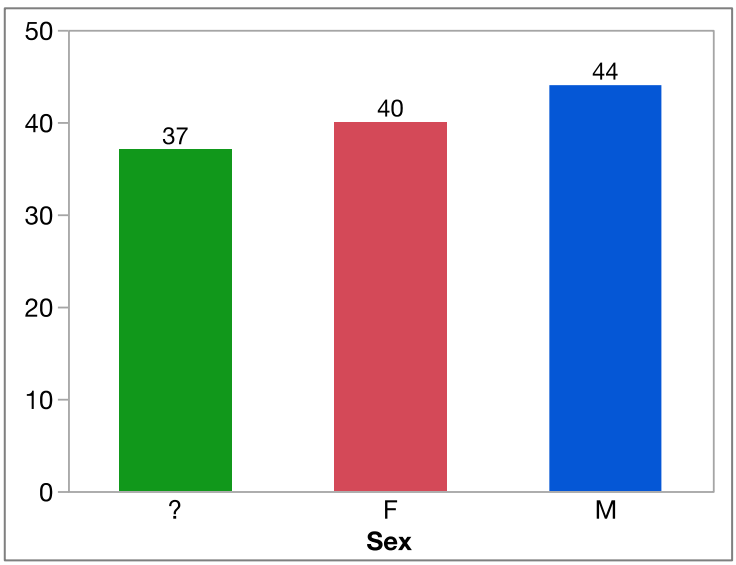


Figure 6.5. Sex distribution for Anglo-Norman $\delta^{13}C$ and $\delta^{15}N$ samples (n = 121).



Figure 6.6. Map of Anglo-Norman skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by Cemetery Group.

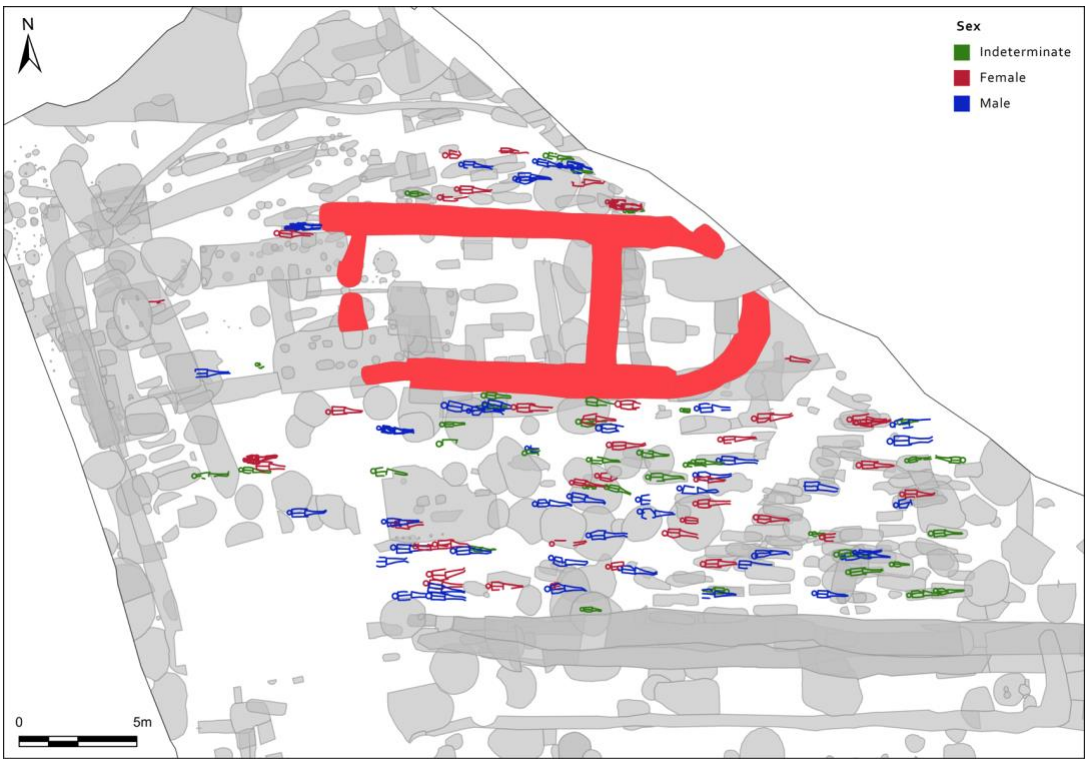


Figure 6.7. Map of Anglo-Norman skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by sex.



Figure 6.8. Map of Anglo-Norman skeletons sampled for bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by age group.

6.3.3 Samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

Tooth enamel from 14 Anglo-Norman individuals was chosen for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis. Table 6.3 lists the sampled skeletons with the reason for selecting each individual. Age and sex distributions are shown in Figure 6.9.

Sk ID	Age	Sex	Ancestry	Selection Reason	CG	Tooth
6443	36-45	M	Caucasoid	Cranial morph, path	7E	R max. M2
6783	36-45	F	Caucasoid	Pathology (TB)	7E	L max. M2
6955	06-12	?		Average diet	7E	L max. M2
*7599	26-35	M	Negroid	Path (Sy), ancestry	6	L mand. M2
7968	36-45	M	Caucasoid	Trauma	7E	L mand M2
8866	45+	F		Unusual diet	7A	R max. M2
20580	26-35	M		Unusual diet	7A	R mand. M2
21079	13-17	M	Caucasoid	Average diet	7B	L max. M2
21759	45+	F	Caucasoid	Path (TB)	7B	L mand. M2
21776	45+	F		Possible dwarfism	7B	R max. M2
21996	36-45	F	Caucasoid	Average diet	7D	R mand. M2
*22114	26-35	M		Normal E-W burial	7D	L mand. C
22219	26-35	M		Unusual diet, trauma	7C	R max. M2
22727	45+	M	Mixed/?	Trauma	7E	L mand. M2

Table 6.3. Anglo-Norman samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis, including demographics, reason for selection, and tooth sampled (n = 14). * Samples from the pilot study (Farber & Lee-Thorp, in press).

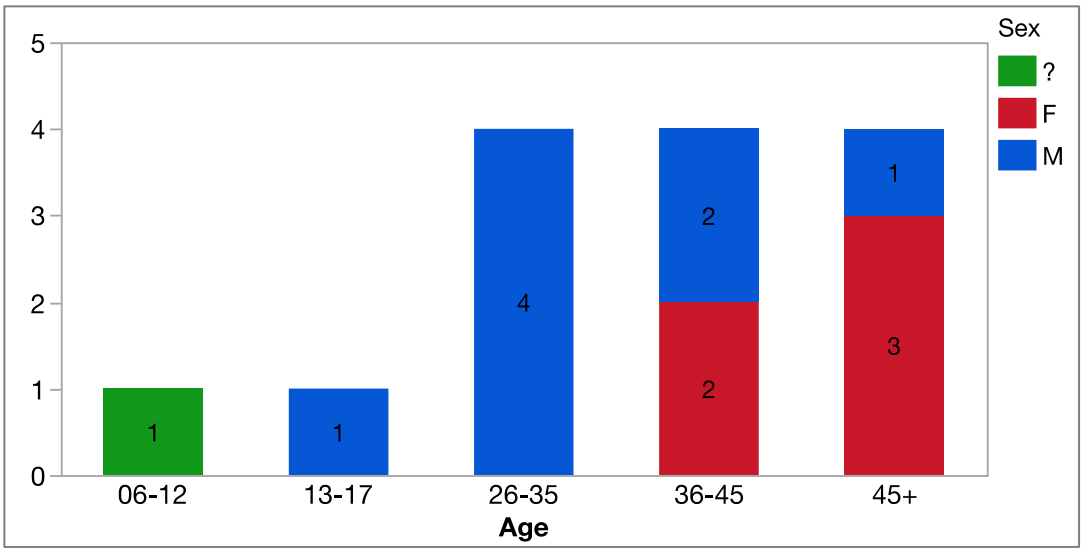


Figure 6.9. Age and sex distribution for Anglo-Norman individuals sampled for enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis (n = 14).

6.4 Results

This section presents the $\delta^{13}C$ and $\delta^{15}N$ results for the Anglo-Norman samples, followed by the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results. Interpretations and a discussion of the significance of these results are provided in Section 6.5.

6.4.1 $\delta^{13}C$ and $\delta^{15}N$ results

Out of the 121 individuals sampled, 118 yielded acceptable collagen (see Section 2.2.3 for the quality indicators used in this thesis). Individual results are reported in Appendix 2. Summary statistics for the subadult and adult groups, as well as all 118 individuals, are shown in Table 6.4.

The $\delta^{13}C$ mean is -18.8‰ (±0.5, 1σ), ranging from -19.8 to -17.5‰, and the $\delta^{15}N$ mean is 12.6‰ (±1,1, 1σ), ranging from 9.8 to 15.1‰. The $\delta^{13}C$ values are not normally distributed, so they are analysed with nonparametric tests (Shapiro-Wilk W Test, W= 0.9766, p = 0.0370). The $\delta^{15}N$ values do not depart from the Normal distribution, so parametric tests are used (Shapiro-Wilk W Test, W= 0.9915, p = 0.6851).

The $\delta^{13}C$ and $\delta^{15}N$ data are plotted in Figure 6.10. Based on a line of best fit, there is a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.66$, $p < 0.0001$). The $\delta^{13}C$ and $\delta^{15}N$ results are plotted separately when testing relationships between isotopic values and non-numerical factors such as age, sex, burial location, or pathology.

Group	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Subadults	37	11.9	0.9	9.8	13.8	-19.0	0.3	-19.7	-18.3
Adults	81	12.8	1.0	10.0	15.1	-18.7	0.6	-19.8	-17.5
All	118	12.6	1.1	9.8	15.1	-18.8	0.5	-19.8	-17.5

Table 6.4 Summary statistics by age category for Anglo-Norman bone collagen $\delta^{13}C$ and $\delta^{15}N$ results (n = 118).

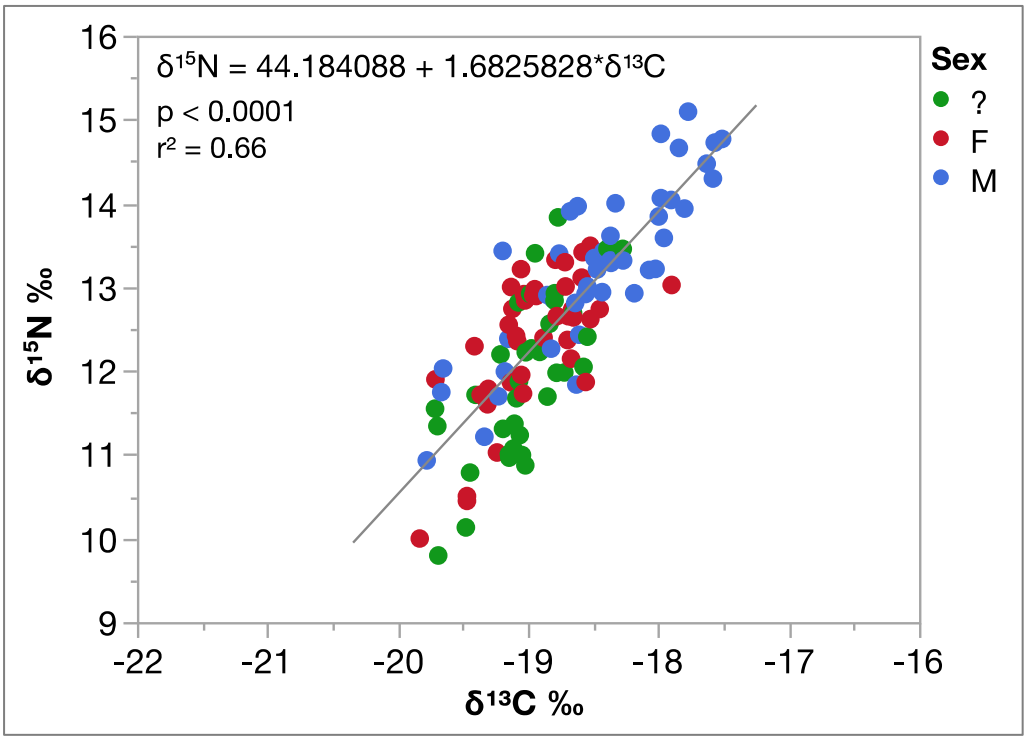


Figure 6.10. Scatterplot of Anglo-Norman bone collagen $\delta^{13}C$ and $\delta^{15}N$ results (n = 118). A line of best fit shows a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ ($p < 0.0001$, $r^2 = 0.66$).

6.4.2 $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results

All 14 individuals selected for $^{87}Sr/^{86}Sr$ analysis yielded results, ranging from 0.708745 to 0.710627 (mean 0.709603 ± 0.000521). The $^{87}Sr/^{86}Sr$

distribution does not depart from normality, (Shapiro-Wilk W Test, W= 0.9443, p = 0.4764), so parametric tests are used for further analyses.

Of the 14 individuals selected for $\delta^{18}O$ analysis, only 10 yielded acceptable results (see Chapter 2, Section 2.3.3 regarding issues with $\delta^{18}O$ analysis). Summary statistics for $\delta^{18}O_{VPDB}$ results and calculated $\delta^{18}O_P$ values are given in Table 6.5. The $\delta^{18}O$ distributions are normal (Shapiro-Wilk W Test, W = 0.9549, p = 0.7264), so parametric tests are appropriate for additional analyses.

The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are shown in Figure 6.11 and listed in Appendix 3. A line of best fit shows a weak, negative correlation between the two datasets, but this is not statistically significant ($r^2 = 0.20$, $p = 0.1873$).

Dataset	n	Mean	1σ	Min	Max
$^{87}Sr/^{86}Sr$	14	0.709603	0.000521	0.708745	0.710627
$\delta^{18}O_{C\text{-}VPDB}$	10	-5.0	0.3	-5.5	-4.4
$\delta^{18}O_{P\text{-}VSMOW}$	10	16.9	0.4	16.3	17.5

Table 6.5. Summary statistics for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results, with carbonate values relative to VPDB, and calculated phosphate values relative to VSMOW (Chenery et al. 2012).

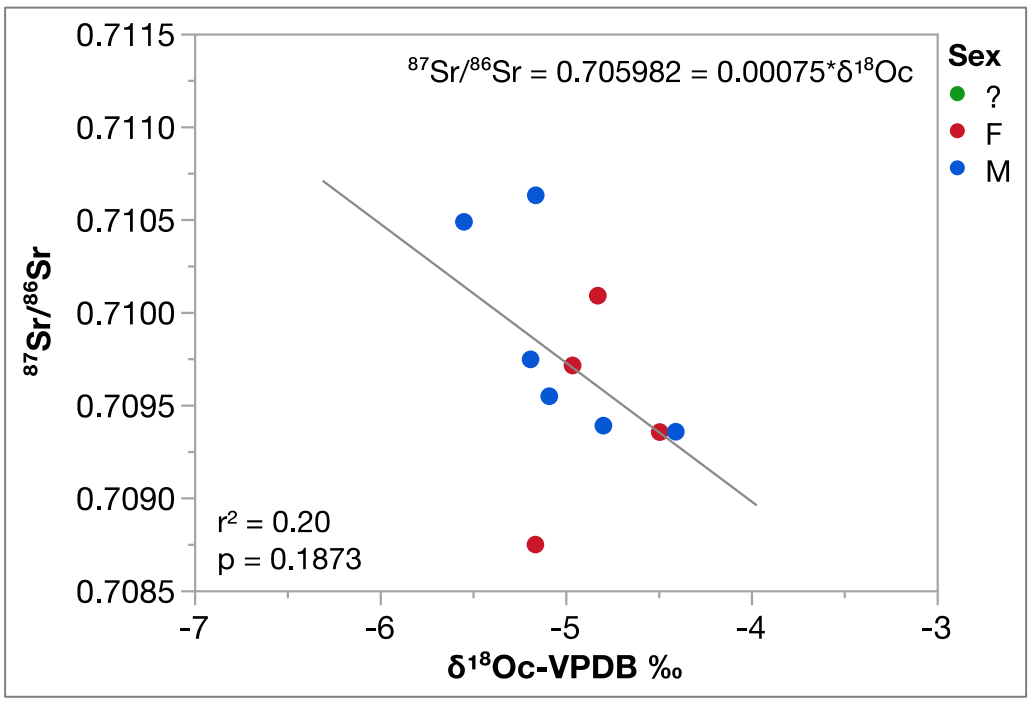


Figure 6.11. Scatterplot of Anglo-Norman $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results coloured by sex. A line of best fit shows a weak negative correlation between $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ but this is not statistically significant ($p = 0.1873$, $r^2 = 0.20$).

6.5 Discussion

This section aims to address the research questions outlined in Section 6.2, by assessing the impact of marine fish on the Anglo-Norman diet at Stoke Quay, and analysing potential dietary differences by sex and age group. The $\delta^{13}C$ and $\delta^{15}N$ results are compared to those from contemporary Fishergate, York, to investigate potential regional and sex-based differences in diet.

The isotopic results are then compared to osteological indicators of living standards and urbanisation including stature, nonspecific stress indicators, infectious disease, and trauma. Observations for the Anglo-Norman assemblage are compared briefly to those in the Late Saxon assemblage to evaluate changes in health, disease, and trauma over time.

Next, the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are discussed, and 'local' and 'nonlocal' interpretations are made using the expected baseline values from Chapter 2. The 'local' and 'nonlocal' groups are compared based on evidence for trauma, disease, and diet, to test for disparities between the two groups and to gain a better understanding of the character and composition of Anglo-Norman Ipswich.

6.5.1 Diet

Overall interpretations of diet and fish consumption

As discussed in Section 6.2, the first question addressed in this discussion is whether the consumption of marine fish rises at Stoke Quay during this period. To test the hypothesis that increased marine fish consumption can be detected in this population, the Anglo-Norman $\delta^{13}C$ and $\delta^{15}N$ are plotted in Figure 6.12 with the expected terrestrial carnivore range and the mean values ($\pm 1\sigma$) for fish from

different habitats, obtained from the literature (Müldner & Richards 2005; Jay 2008; Barrett et al. 2011). Individuals consuming a carnivorous terrestrial-based diet would be expected to yield $\delta^{13}C$ between -20.6‰ and -19.6‰, and $\delta^{15}N$ between 10.3‰ and 12.3‰ (see Chapter 3, Section 3.3.5).

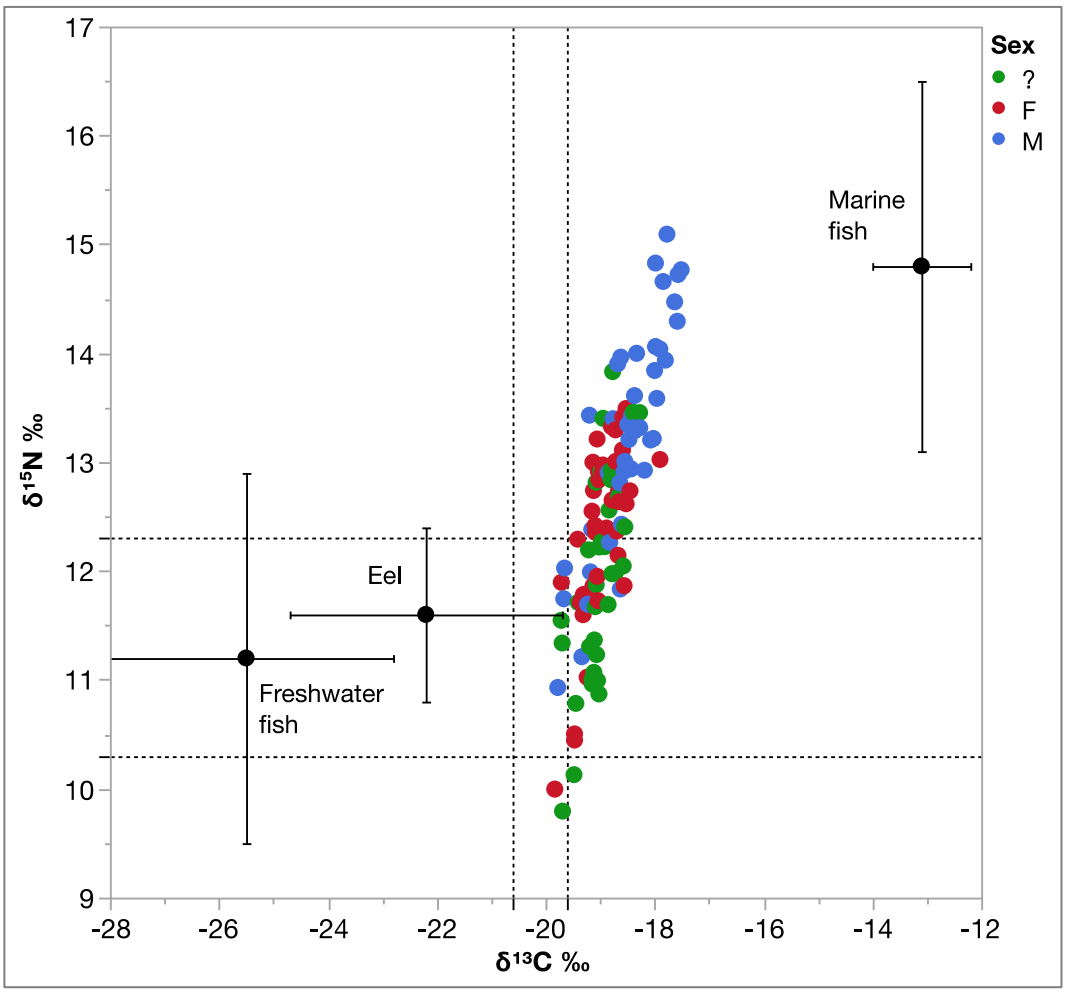


Figure 6.12. Scatterplot of Anglo-Norman $\delta^{13}C$ and $\delta^{15}N$ coloured by sex, with expected terrestrial carnivore ranges shown as dotted lines, and mean fish values (±1σ) from the literature (Müldner & Richards 2005; Jay 2008; Barrett et al. 2011).

As shown in Figure 6.12, only six out of 118 individuals yielded both $\delta^{13}C$ and $\delta^{15}N$ within the expected terrestrial carnivore range, with many individuals showing a trend toward the marine fish range. The two individuals with the lowest values, a female and an adolescent, appear to have consumed a C_3 diet but with little animal protein, at least compared to the rest of the group. Well over

half of the group (58%, or 68 out of 118 individuals) yielded $\delta^{13}C$ and $\delta^{15}N$ above the expected terrestrial carnivore range, an increase from the previous period. While some females and subadults have high $\delta^{13}C$ and $\delta^{15}N$, the group with the highest values is exclusively male. This group is examined in greater detail further below, while age-related differences are explored next.

Overall age patterns

As shown in Figure 6.12, there is a large range in isotopic values for the Anglo-Norman assemblage, with $\delta^{13}C$ and $\delta^{15}N$ ranges of 2.2‰ and 5.3‰, respectively. These $\delta^{13}C$ and $\delta^{15}N$ results are compared by age group to better characterise the data distributions and evaluate the presence of age-related differences in diet (Table 6.6 Figure 6.13a, b).

The $\delta^{13}C$ results show statistically significant differences by age ($p = 0.0126$, ANOVA), but a means comparison does not reveal significant differences between age groups (Tukey Kramer HSD)(Figure 6.13a). Statistically significant differences are also seen in the $\delta^{15}N$ values when compared by age ($p = 0.0006$, ANOVA), and a means comparison shows statistically significant differences between 13-17 year-olds and 18-25 year-olds ($p = 0.0177$), 36-45 year-olds ($p = 0.0023$), and 45+ year-olds ($p = 0.0220$), as well as between children aged 6-12 years and adults aged 36-45 years ($p = 0.0270$; Steel-Dwass)(Figure 6.13b). Based on these results, it appears that age-related dietary differences existed between subadults and adults in this period. Each group is considered in greater detail below.

Age (years)	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
1-5	9	12.5	1.1	10.8	13.8	-18.9	0.3	-19.4	-18.4
6-12	10	11.9	0.7	11.0	12.8	-19.0	0.3	-19.7	-18.6
13-17	18	11.7	0.9	9.8	13.4	-19.0	0.4	-19.7	-18.3
18-25	17	12.9	0.8	11.7	14.5	-18.6	0.4	-19.4	-17.6
26-35	18	12.5	1.0	10.9	14.8	-19.0	0.6	-19.8	-18.0
36-45	23	12.9	0.9	10.0	14.7	-18.7	0.5	-19.8	-17.6
45+	23	13.0	1.3	10.5	15.1	-18.6	0.6	-19.5	-17.5

Table 6.6. Anglo-Norman Stoke Quay $\delta^{13}C$ and $\delta^{15}N$ summary statistics by age (n = 118).

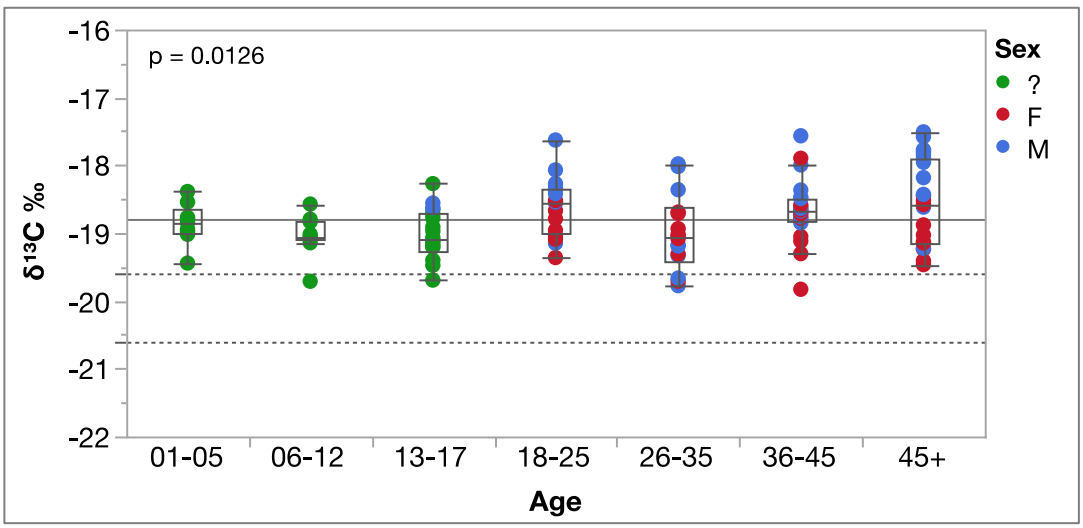


Figure 6.13a. $\delta^{13}C$ boxplots by age group for Anglo-Norman Stoke Quay, coloured by sex, with significant differences (p = 0.0126, ANOVA). Dotted grey lines: expected terrestrial carnivore range; solid black line: group mean.

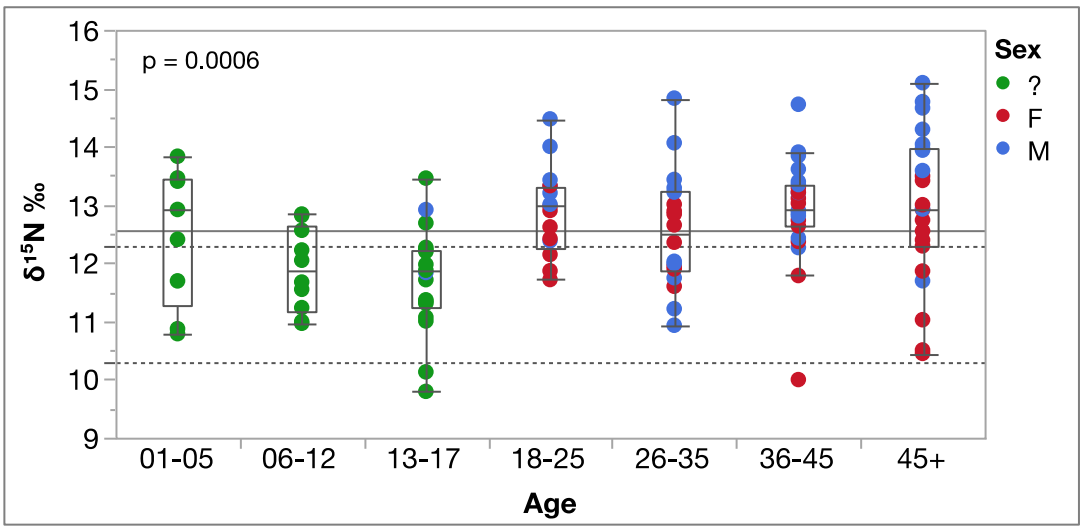


Figure 6.13b. $\delta^{15}N$ boxplots by age group for Anglo-Norman Stoke Quay, coloured by sex, with significant differences (p = 0.0006, ANOVA). Means comparison shows differences between 13-17 year and 18-25 year (p = 0.0177), 36-45 year (p = 0.0023), and 45+ year-olds (p = 0.022), and between 6-12 year and 36-45 year-olds (p = 0.027; Steel-Dwass). Dotted grey lines: expected terrestrial carnivore range; solid black line: group mean.

Subadult diet and weaning

The $\delta^{13}C$ and $\delta^{15}N$ values are plotted against age (mean value from estimated age-at-death ranges) in Figures 6.14a,b. The plots show almost no relationship between age and isotopic value, as evidenced by lines of best fit with nearly horizontal slopes and very low r^2 values. Cubic polynomial curves fitted to the data show similarly poor correlations ($r^2 < 0.1$ for both isotopes; see captions, Figures 6.14a, b). Neither plot shows clear weaning trends, in contrast to the more typical pattern seen for the Late Saxon subadults (Fig 5.16a, b).

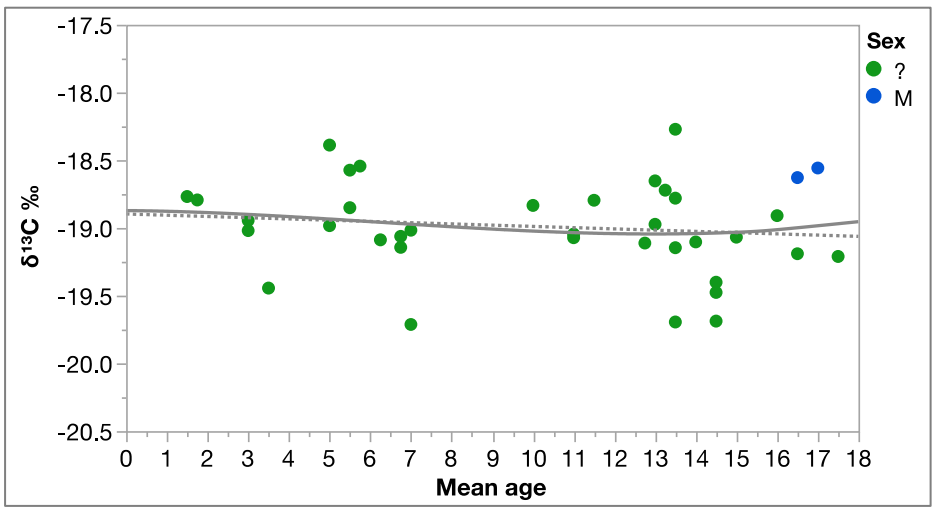


Figure 6.14a. Anglo-Norman subadult $\delta^{13}C$ by age (n = 37). A line of best fit (dotted line) shows low correlation ($r^2 = 0.017$, slope = -0.009); a cubic polynomial curve (solid line) shows slightly higher correlation ($r^2 = 0.02$). Neither fit is statistically significant.

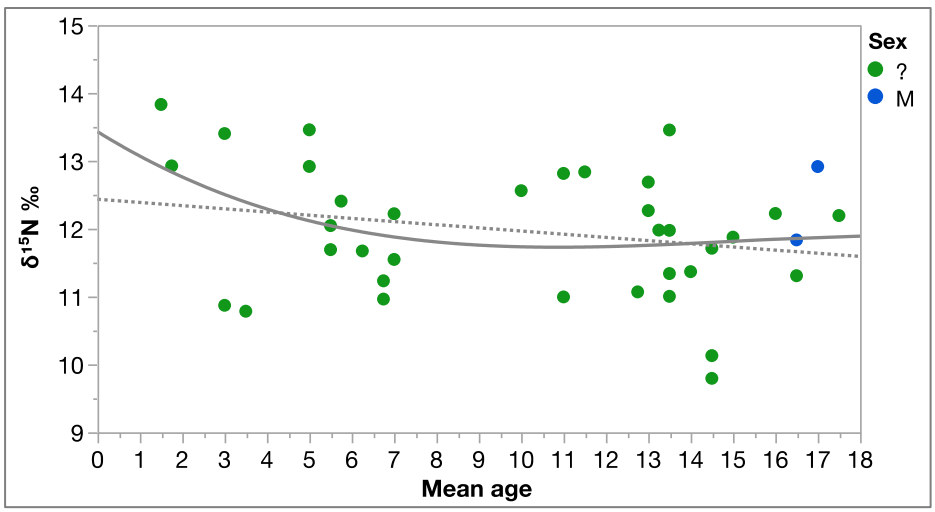


Figure 6.14b. Anglo-Norman subadult $\delta^{15}N$ by age (n = 37). A line of best fit (dotted line) shows low correlation ($r^2 = 0.06$, slope = -0.047); a cubic polynomial curve (solid line) shows slightly higher correlation ($r^2 = 0.10$). Neither fit is statistically significant.

The flat weaning curve for Anglo-Norman subadults is partly due to the more tightly grouped values for the youngest children compared to the previous period. The $\delta^{13}C$ for the two youngest Anglo-Norman children (<2 years) are both -18.8‰, the same as the mean for Late Saxon <2-year-olds, but the Late Saxon values range from -19.4 to -18.1‰. The mean $\delta^{15}N$ for Anglo-Norman <2-year-olds is also lower than for Late Saxons, at 13.3‰ and 14.1‰, respectively.

The lower, more tightly grouped isotopic values for the two youngest Anglo-Norman children may indicate very early weaning, perhaps even before age one. However, since these children died before age two, they may not represent the norm for this population, and the sample size is very small. Weaning age could be clarified with a larger sample of 0-5 year-olds, or serial dentine sampling of individuals who lived to adulthood.

The isotopic values for Anglo-Norman adolescents are also different from the Late Saxons, with higher means indicating marine fish consumption compared to the lower Late Saxon means indicating largely terrestrial diets. This difference may be influenced by sex, as two of the Anglo-Norman adolescents with high $\delta^{13}C$ and $\delta^{15}N$ are identified as likely males, while all of the Late Saxon adolescents are of unknown sex and could include more females.

Another factor potentially influencing the flattened polynomial curve in Figure 6.14b is the presence of two adolescents with much lower $\delta^{15}N$ than their peers. One potential explanation for their unusually low $\delta^{15}N$ could be that they were born inland with less access to marine fish, and came to Ipswich with their families or by themselves to become apprentices. There is little documentary evidence for mobility driven by apprenticeships in the 11th – 12th centuries, but ample documentation of this exists in subsequent centuries (e.g. Lewis 2002).

Sex-based differences in diet

Sex-based differences are evaluated only for adults. There are statistically significant differences between males and females for both $\delta^{13}C$ and $\delta^{15}N$ (Figure 6.15; $p < 0.0001$ for both $\delta^{13}C$ and $\delta^{15}N$, ANOVA). The male and female $\delta^{13}C$ and $\delta^{15}N$ are higher than in the previous period, indicating a population-wide increase in marine fish consumption (see discussion in Chapter 8). This correlates well with the currently accepted narrative regarding the 'fish event horizon', discussed in Section 6.2 and Chapter 5. As described above, males generally have more positive values for both isotopes, though as in the previous period there is considerable overlap between the sexes.

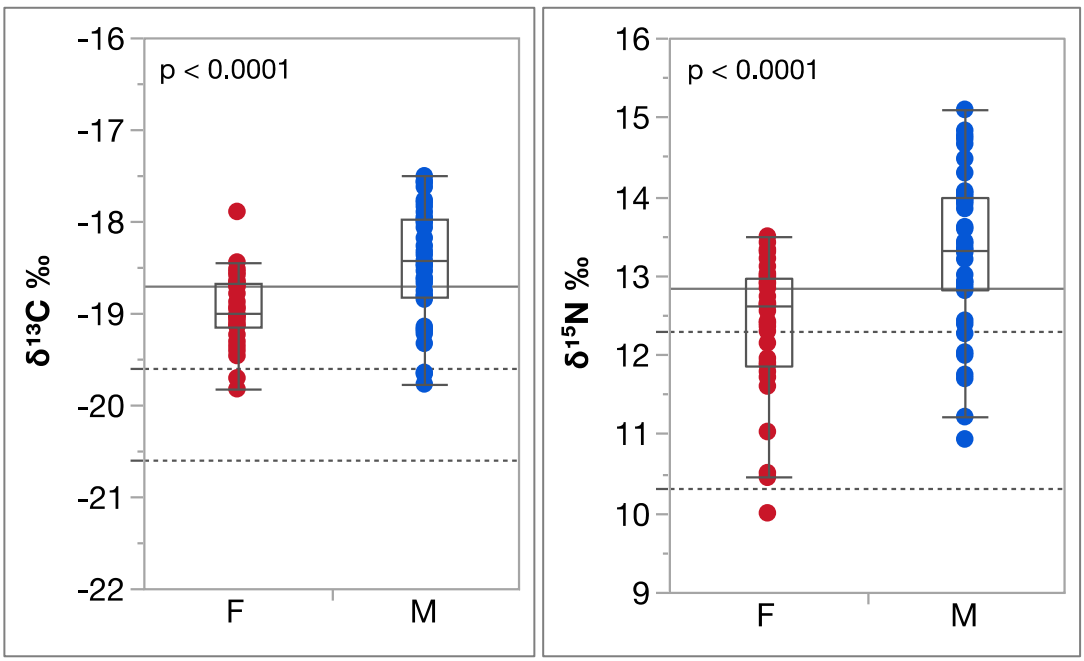


Figure 6.15. Boxplots by sex for Anglo-Norman adult $\delta^{13}C$ (left) and $\delta^{15}N$ (right), with statistically significant differences between males and females ($p < 0.0001$, ANOVA). Dotted grey lines: expected terrestrial carnivore values; solid grey lines: group means.

The Anglo-Norman males exhibit a greater range of $\delta^{13}C$ values than females, as was the case in the Late Saxon assemblage (Table 6.7). The differences between ranges are subtler in this phase than in the previous phase,

but if one female outlier with very high $\delta^{13}C$ is excluded (Sk 8866), differences are more pronounced, with a male range of 2.3‰ and a female range of 1.3‰.

Anglo-Norman males also show a wider range of $\delta^{15}N$ values than females, in contrast to the previous period (Table 6.7). The female range is similar to that of the Late Saxon females while the male range is actually narrower than the Late Saxon males. This indicates less variability in Anglo-Norman male diets compared to Late Saxon males, possibly a result of greater reliance on foods purchased at urban markets.

Sex	n	Mean $\delta^{15}N$	1σ	$\delta^{15}N$ Range	Mean $\delta^{13}C$	1σ	$\delta^{13}C$ Range
Female	40	12.4	0.8	10.0-13.5 (3.5)	-18.9	0.4	-19.8 to -17.9 (1.9)
Male	41	13.3	1.0	10.9-15.1 (4.2)	-18.5	0.6	-19.8 to -17.5 (2.3)

Table 6.7. Summary statistics by sex for Anglo-Norman Stoke Quay $\delta^{13}C$ and $\delta^{15}N$ (n = 81), with values in ‰.

The boxplots in Figure 6.15 illustrate differences between males and females for each isotopic system, but $\delta^{13}C$ and $\delta^{15}N$ are more instructive when used together. The $\delta^{13}C$ and $\delta^{15}N$ for adult males and females are plotted again in Figure 6.16 with 95% density ellipses for each sex and maximum expected terrestrial carnivore values, and there is substantial overlap between the sexes. As in the Late Saxon period, the $\delta^{13}C$ and $\delta^{15}N$ for most males but also a majority of females fall above the maximum expected terrestrial carnivore range, supporting the observation that both sexes at Anglo-Norman Stoke Quay consumed marine fish. The change in the number of likely female marine fish consumers from the Late Saxon to the Anglo-Norman period indicates that fish were widely available in port towns by the late 11th-late 12th centuries. This is tested further below with a comparative assemblage from York.

As in the Late Saxon period, the upper limit of the female 95% density ellipse shows that females consuming marine fish appear to be either eating less fish than men overall, or lower trophic level fish such as herring rather than higher trophic level fish such as cod (Müldner 2016). Also in common with the Late Saxon assemblage, there is a group of males with very high $\delta^{13}C$ and $\delta^{15}N$. This group (n = 14) is illustrated in Figure 6.16 by the male values extending beyond the female 95% density ellipse. Notably, of 11 males aged 45+ years, seven are in the group of men with the highest $\delta^{13}C$ and $\delta^{15}N$. This suggests that there may be age-related differences in diet, explored in the following section.

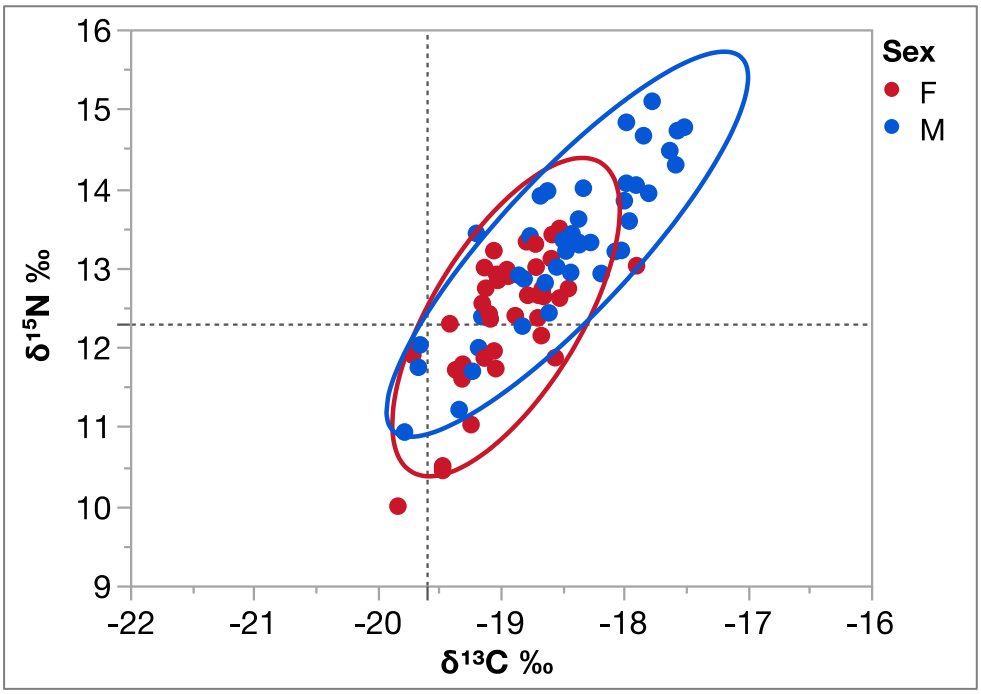


Figure 6.16. Bivariate plot of male and female $\delta^{13}C$ and $\delta^{15}N$ for Anglo-Norman adults, with 95% density ellipses around each group, and maximum expected terrestrial carnivore ranges shown as dotted grey lines.

Age-based differences in adult diet

When male and female $\delta^{13}C$ and $\delta^{15}N$ are compared separately by age, there are no statistically significant differences between females, but males show

statistically significant differences for $\delta^{13}C$ (Figure 6.17a; p = 0.0087, ANOVA). A means comparison shows statistically significant differences between males aged 26-35 years (mean = -18.9‰) and 45+ years (mean = -18.1‰; p = 0.0412, Steel-Dwass). However, to keep this in perspective, the difference between means for these age groups is only 0.8‰.

An ANOVA for male $\delta^{15}N$ does not reveal any statistically significant differences overall between age groups (Figure 6.17b), but means comparisons again show statistically significant differences between males aged 26-35 years and those aged 45+ years (p = 0.0407, Tukey-Kramer HSD). As with the $\delta^{13}C$ values, the actual differences between mean values are fairly small, at only 1.1‰ (26-35 mean = 12.7‰; 45+ mean = 13.8‰).

The dietary differences between prime adult males and older males may have several causes. Firstly, men engaged in the fishing trade may have had better, higher-protein diets, therefore living longer than those who worked on land. Another explanation could be that males who died in their prime adult years had poorer diets than some of their peers who survived to older adulthood. Poorer diets could also be associated with poorer overall health, or with lower social status. Health and stature are addressed in the following section.

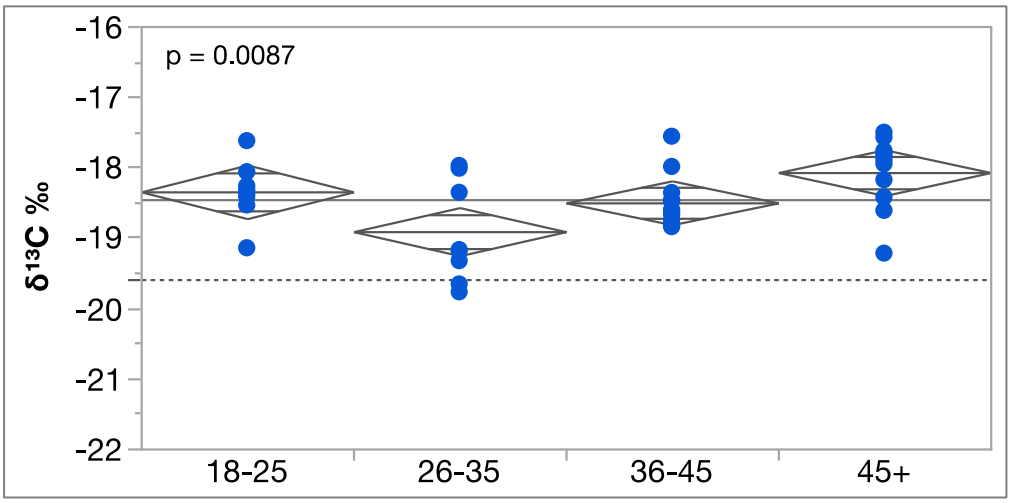


Figure 6.17a. $\delta^{13}C$ mean diamonds for males by age, with statistically significant differences (p = 0.0087, ANOVA). Means comparisons show significant differences between 26-35 and 45+ year age groups (p = 0.0412, Steel-Dwass). Dotted grey lines: expected terrestrial carnivore range; solid line: group mean.

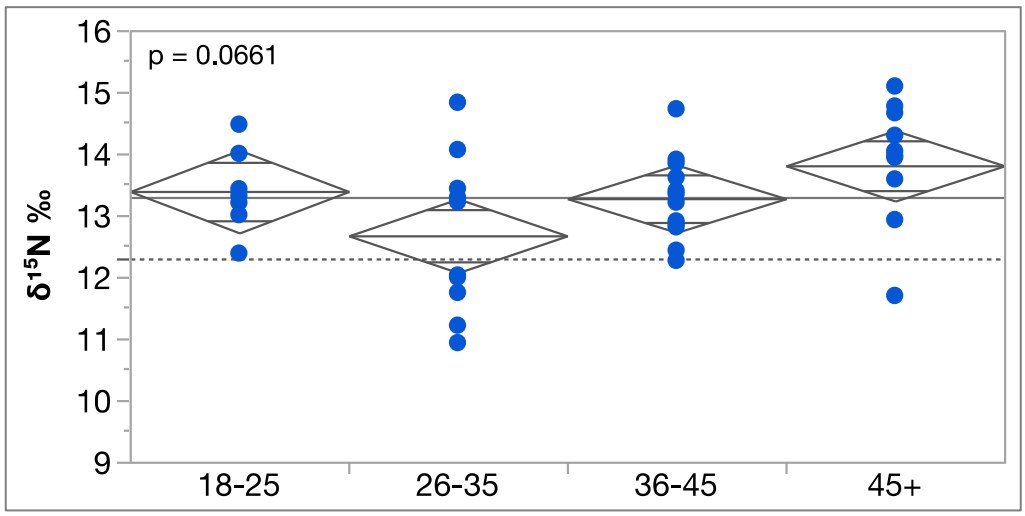


Figure 6.17b. $\delta^{15}N$ mean diamonds for males by age, with no statistically significant differences (p = 0.0661, ANOVA). Means comparisons show significant differences between 26-35 and 45+ year age groups (p = 0.0407, Tukey-Kramer HSD). Dotted grey lines: expected terrestrial carnivore range; solid line: group mean.

Palaeopathology and stature at Anglo-Norman Stoke Quay

To evaluate the impact of urbanisation in combination with greater prosperity in the Anglo-Norman period, crude prevalence rates for several palaeopathological indicators of urban living environments are considered below (see Section 2.4). Comparative values are shown for St Andrew's,

Fishergate, York; St Mary Spital, London; and sites surveyed by Roberts and Cox (2003) from the later medieval period (broadly defined as c. 1050- c. 1550 AD).

The crude prevalence rates for all conditions are higher for Anglo-Norman Stoke Quay than for comparative sites, except for periostitis, which is higher at St Mary Spital, London (Table 6.8). The rates for all pathologies at Stoke Quay increased compared to the Late Saxon assemblage, except for *cribra orbitalia*, which decreased. These rates indicate that the Anglo-Norman population at the site lived in difficult conditions with high rates of infection and airborne pollution. The decrease in *cribra orbitalia* however, suggests that diet at Stoke Quay may have improved, in agreement with the amount of marine fish consumption interpreted from the dietary isotope results. As a high protein, nutritious and relatively iron-rich food, it is possible that increased marine fish consumption contributed to better overall nutrition and lower rates of metabolic disease for this population (Barrett 2018).

Pathology	**Anglo-Norman Stoke Quay, Ipswich[1]**	**St. Andrew's, Fishergate, York[2]**	**St. Mary Spital, London[2]**	**Survey[2] of late medieval sites (# of sites)**
Maxillary sinusitis	Total: 9.9% (55/558) Adults: 13.5% (41/304) Males: 17.7% (22/124) Females: 14.6% (18/123)	-	-	13.3% (276/2076) (9 sites)
Periostitis	Total: 40.1% (224/558) Adults: 58.2% (117/304) Males: 68.5% (85/124) Females: 57.7% (71/123)	24% (59/402)	44.1% (30/126)	14.1% (631/4479) (16 sites)
Cribra orbitalia	Total: 38.5% (215/558) Adults: 37.2% (113/304) Males: 49.2% (61/124) Females: 41.5% (51/123)	6.7% (27/402)	28.6% (36/126)	10.8% (640/5752) (33 sites)
Tuberculosis	All periods: 1.7% (19/1142)	1.5% (6/402)	-	0.9% (60/6796) (15 sites)

Table 6.8. Crude prevalence rates (CPR) for pathologies related to living environment at Anglo-Norman Stoke Quay (late 11th-late 12th cen.) and comparative sites. References: 1) Loe et al, in press, Appendix 5; 2) Data compiled by Roberts & Cox 2003 (Fishergate: Stroud & Kemp 1993; St Mary Spital: Conheeney 1992).

Nutrition can also be assessed by measuring stature, as nutrient-poor diets may lead to stunted growth while nutrient rich diets have the opposite effect (see Chapter 2, Section 2.4). Mean estimated statures for males and females at Anglo-Norman Stoke Quay are shown in Table 6.9, along with the means for sites surveyed by Roberts and Cox (2003) for late medieval Britain.

Sex	Anglo-Norman Stoke Quay		Late Medieval Britain[1]			
	mean (cm)	range (cm)	mean (cm)	mean range (cm)	n	# of sites
Female	159.7	148.4-172.5	159	154-165	7929	26
Male	169.8	155.4-180.9	171	167-174	8494	34

Table 6.9. Mean female and male stature at Anglo-Norman Stoke Quay and for late medieval British sites. [1]Roberts & Cox 2003.

As shown in Table 6.9, male stature at Anglo-Norman Stoke Quay is below the mean for Britain, while female stature is slightly higher. Additionally, the range of heights for both males and females at Stoke Quay is wider than the mean ranges for late medieval Britain. The higher female stature at Stoke Quay could be impacted by increased consumption of marine fish by women during this period, whereby better nutrition would positively impact adult height outcomes. This relationship may not be directly tied to $\delta^{13}C$ and $\delta^{15}N$ values though: linear regressions of stature by $\delta^{13}C$ and $\delta^{15}N$ showed low r^2 values and no statistical significance. Nevertheless, the wider ranges for males and females compared to the national averages support the notion that Anglo-Norman Stoke Quay was part of a diverse and cosmopolitan town, with people from different backgrounds and ways of life.

The combination of average to above-average stature at Stoke Quay and high crude prevalence rates for maxillary sinusitis and periostitis during this period provide what at first glance may be a conflicting view of the quality of life

at Stoke Quay. However, following on Wood's (1992) 'osteological paradox', the individuals who appear the sickest based on skeletal remains may in fact be those whose immune systems were strong enough to fight illnesses long enough to exhibit a bony reaction. With typical age-at-death profiles at Stoke Quay (Loe et al, in press), the higher rates of periostitis and other nonspecific stress indicators may in fact be a testament to the robustness of this population, in spite of difficult living conditions. With the high rates of marine fish consumption at the site, diet may have been a decisive factor.

Dietary isotope results are examined once more in the following section, in comparison to St Andrew's, Fishergate, York, in order to contextualise the patterns seen at Stoke Quay within a broader framework of urban diet.

Stoke Quay and St Andrew's, Fishergate

A number of isotopic studies have focused on diet in medieval England, but most date to either the beginning or end of the period (see Sections 4.5, 5.5, and 7.5 for examples). The published literature includes few isotopic analyses of 11th-12th century assemblages, an unfortunate situation given the importance of this period for understanding the process of urbanisation. However, one very appropriate comparative assemblage does exist, from the urban site of Fishergate, York (Müldner & Richards 2007).

The Fishergate, Period 4, assemblage derives from mid-11th to late 12th century deposits at the cemetery of St Andrew's church in York, likely founded before the Conquest (Stroud & Kemp 1993; Kemp & Graves 1996). Samples for $\delta^{13}C$ and $\delta^{15}N$ analysis, usually ribs, were obtained for 48 securely dated, aged, and sexed adults out of a total of 83 adults (Müldner & Richards 2007). Müldner

and Richards also analysed faunal samples from similarly dated contexts at 46-54 Fishergate (O'Connor 1991), discussed here in relation to the human values.

The $\delta^{13}C$ and $\delta^{15}N$ values for Fishergate, Period 4 are plotted alongside Anglo-Norman Stoke Quay adults in Figures 6.18a,b. There are statistically significant differences between the sites for both $\delta^{13}C$ and $\delta^{15}N$ ($p = <0.0001$, ANOVA). The Stoke Quay means are higher for both isotopic systems, but the ranges are smaller than for Fishergate (see Table 6.10).

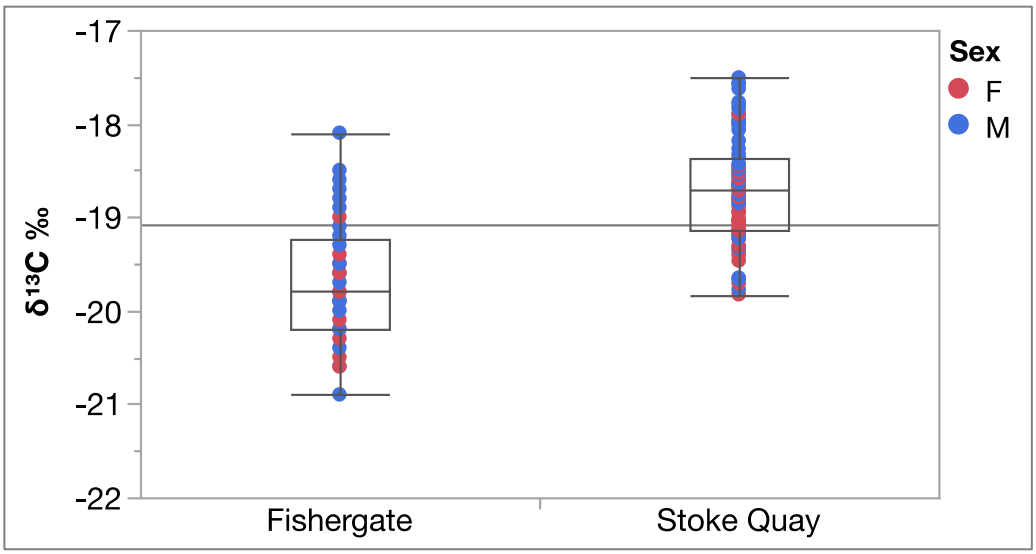


Figure 6.18a. $\delta^{13}C$ boxplots by site for Stoke Quay and St Andrew's, Fishergate, with statistically significant differences ($p = <0.0001$, ANOVA). Grey line: group mean.

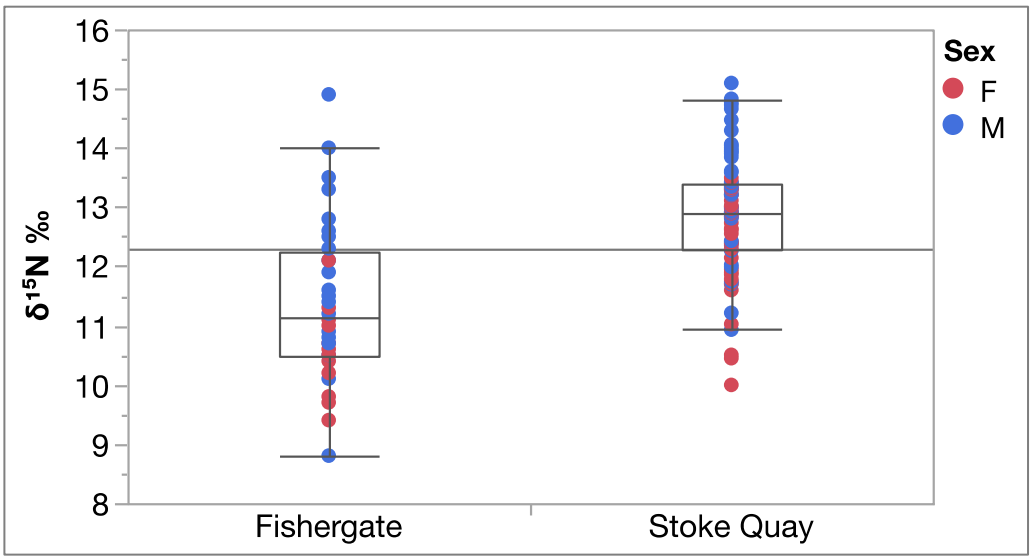


Figure 6.18b. $\delta^{15}N$ boxplots by site for Stoke Quay and St. Andrew's, Fishergate, with statistically significant differences ($p = <0.0001$, ANOVA). Grey line: group mean.

Site	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Fishergate	48	11.4	1.2	8.8	14.9	-19.7	0.6	-20.9	-18.1
Stoke Quay	81	12.8	1	10.0	15.1	-18.7	0.6	-19.8	-17.5

Table 6.10. Adult $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Fishergate, Period 4 (n = 48), and Anglo-Norman Stoke Quay (n = 81). Values are in ‰.

Similarly to the pattern seen at Stoke Quay, Fishergate males generally show higher values than females for both $\delta^{13}C$ and $\delta^{15}N$. To better explore this trend, the isotopic results are assessed by sex. As shown in Figure 6.19 and Table 6.11, there are statistically significant differences in $\delta^{13}C$ and $\delta^{15}N$ between sexes at both sites, but these are most significant at Stoke Quay. Stoke Quay $\delta^{13}C$ and $\delta^{15}N$ are also generally higher and more tightly grouped than at Fishergate.

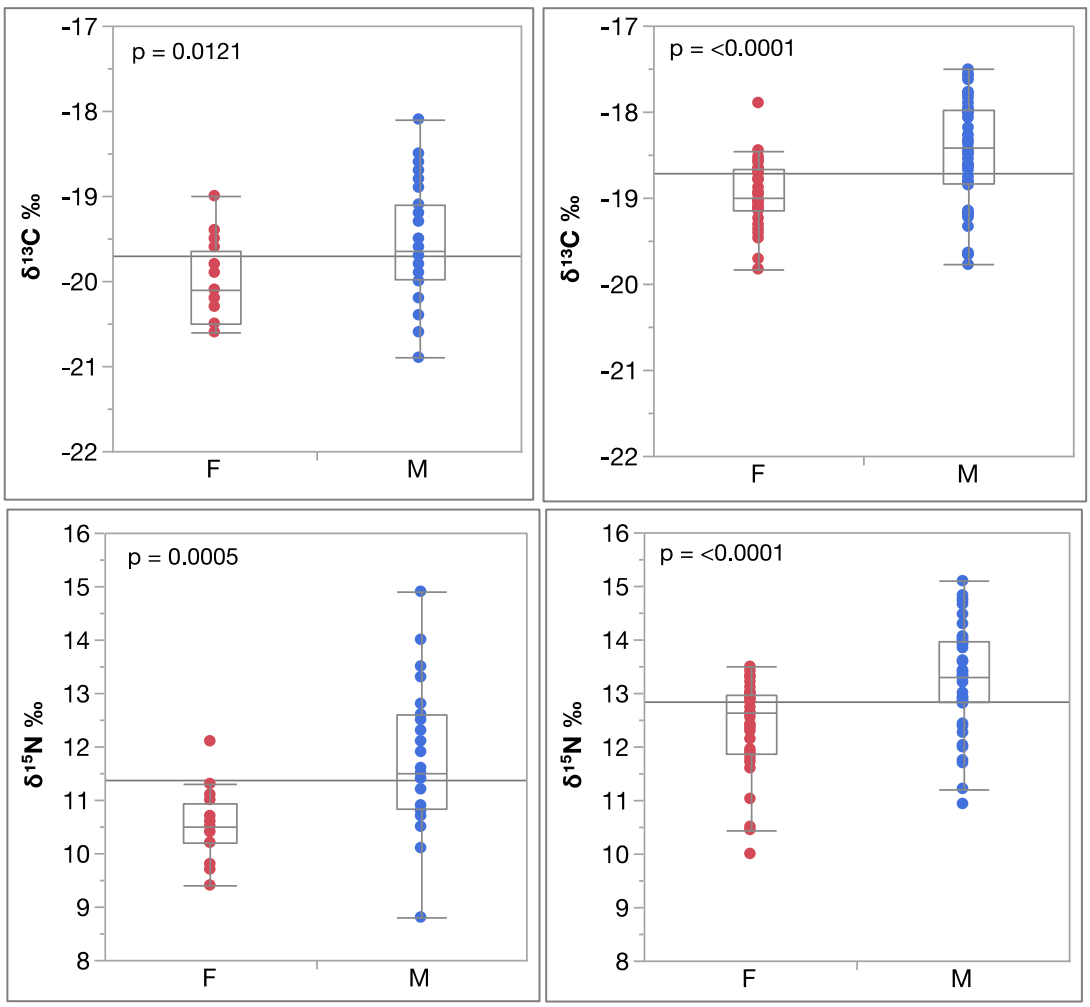


Figure 6.19. Boxplots comparing adult $\delta^{13}C$ (top row) and $\delta^{15}N$ (bottom row) by sex for St Andrew's Fishergate (L) and Stoke Quay (R). Both sites show statistically significant differences by sex for $\delta^{13}C$ and $\delta^{15}N$, with higher significance at Stoke Quay (ANOVA). Grey lines: group means.

Site	Sex	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Fishergate	F	16	10.5	0.6	9.4	12.1	-20.0	0.5	-20.6	-19.0
	M	32	11.8	1.2	8.8	14.9	-19.5	0.6	-20.9	-18.1
Stoke Quay	F	40	12.4	0.8	10.0	13.5	-18.9	0.4	-19.8	-17.9
	M	41	13.3	1	10.9	15.1	-18.5	0.6	-19.8	-17.5

Table 6.11. Summary statistics by sex for St Andrew's, Fishergate and Stoke Quay adults. Values are in ‰.

Fishergate males display the greatest isotopic variability, with a particularly large $\delta^{15}N$ range of 6.1‰ compared to a $\delta^{15}N$ range of 4.2‰ at Stoke Quay. Furthermore, the Fishergate male $\delta^{15}N$ range is more than double that of the female $\delta^{15}N$ range (2.7‰), indicating a far more restricted female diet. However, the female sample size from Fishergate is less than half the size of the male sample, so the evidence for dietary restrictions at the site may be impacted by unequal sample sizes. In comparison to the Stoke Quay females though, the Fishergate females appear to have consumed far less marine fish.

Müldner and Richards interpreted the 11th-12th century diet at Fishergate as largely terrestrial but with about 1/3 of individuals showing a heavier reliance on marine fish. This interpretation is based on the finding that some individuals had $\delta^{13}C$ and $\delta^{15}N$ values more than 3.8‰ and 9.1‰, respectively, above the herbivore baseline (Müldner & Richards 2007: 691). Notably, the individuals with the highest $\delta^{13}C$ and $\delta^{15}N$ values were exclusively men aged c. 20-30 years (Müldner 2009). As a relatively low-status parish with an association with the fishing trade, Müldner concluded that the earliest regular consumers of fish in this area were those directly involved in its trade (Müldner & Richards 2007; Müldner 2016). This explanation appears even more likely at Stoke Quay, with its high $\delta^{13}C$ and $\delta^{15}N$ values, particularly among the males.

This comparison demonstrates that diet at Anglo-Norman Stoke Quay was consistently higher in marine fish than at St. Andrew's, Fishergate, a site with known ties to fishing and fishermen. This further supports the hypothesis that the population buried at Stoke Quay included individuals involved in the fishing and seafaring trades. Whether any of these individuals were raised outside of Ipswich is explored in the following section.

6.5.2 Evidence for mobility

As discussed in Chapter 3 (Section 3.4), interpretations of mobility in this thesis are based on the expected 'local' bioavailable $^{87}Sr/^{86}Sr$ range of 0.709-0.710 (Evans et al. 2010), and the English 'low rainfall' $\delta^{18}O_P$ range of 15.9-18.5‰ (Evans et al. 2012). Individuals with results outside of one or both ranges are interpreted as 'Nonlocals'.

Tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was performed on 14 individuals from the Anglo-Norman skeletal assemblage (see Section 6.3.3, 6.4.2). The $^{87}Sr/^{86}Sr$ results (n = 14) are shown in Figure 6.20 with the expected local bioavailable $^{87}Sr/^{86}Sr$ range. The $^{87}Sr/^{86}Sr$ and calculated $\delta^{18}O_P$ values for the 10 individuals yielding results for both isotopic systems are shown in Figure 6.21 (n = 9; see Chapter 2, Section 2.3.3 for issues with $\delta^{18}O$ analysis), along with the expected 'local' ranges for both isotopes.

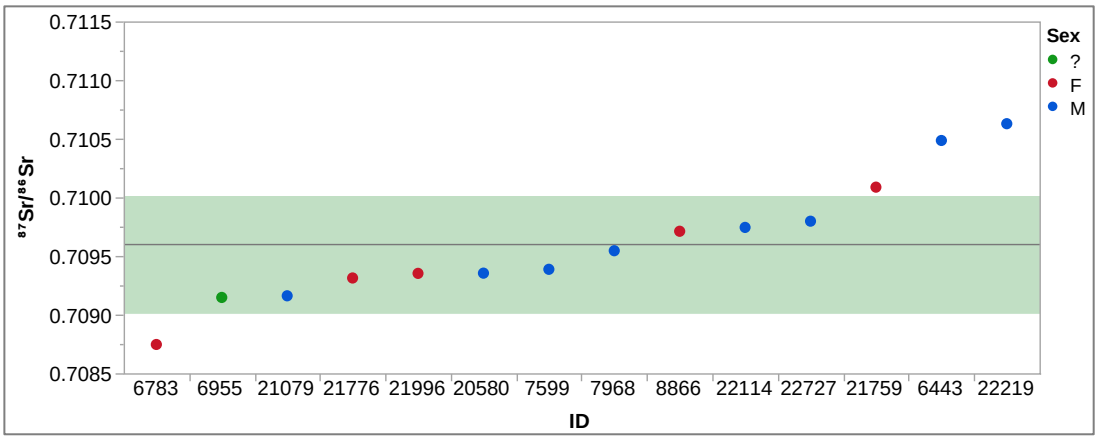


Figure 6.20. Anglo-Norman Stoke Quay $^{87}Sr/^{86}Sr$ results with the expected local bioavailable $^{87}Sr/^{86}Sr$ range shown as green band (Evans et al. 2010).

As shown in Figure 6.21, of ten individuals yielding results for both isotopic systems, the paired $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ for six individuals fall within the combined expected local range, while four are outside of this range. These four individuals are interpreted as 'Nonlocals', and include two females and two males. Individual interpretations are shown in Table 6.12.

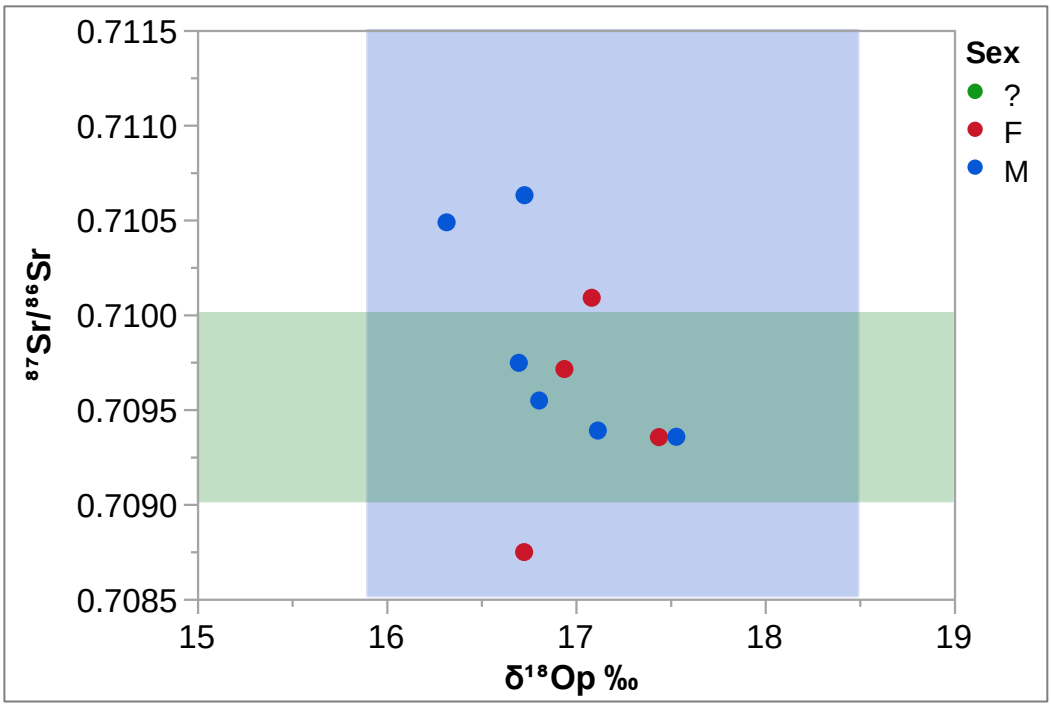


Figure 6.21. Anglo-Norman Stoke Quay paired $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results. Expected 'local' ranges shown as green band ($^{87}Sr/^{86}Sr$, Evans et al. 2010), and blue band ($\delta^{18}O_P$, Evans et al. 2012).

Sk ID	Age	Sex	Reason for Selection	Cemetery Group	Interpretation: $^{87}Sr/^{86}Sr$	$\delta^{18}O$
6443	36-45	M	Cranial morphology	7E	Nonlocal	Local
6783	36-45	F	Pathology (TB)	7E	Nonlocal	Local
6955	06-12	?	Average diet	7E	Local	-
*7599	26-35	M	Pathology (Sy), ancestry	6	Local	Local
7968	36-45	M	Trauma	7E	Local	Local
8866	45+	F	Unusual diet	7A	Local	Local
20580	26-35	M	Unusual diet	7A	Local	Local
21079	13-17	M	Average diet	7B	Local	-
21759	45+	F	Pathology (TB)	7B	Nonlocal	Local
21776	45+	F	Possible dwarfism	7B	Local	-
21996	36-45	F	Average diet	7D	Local	Local
*22114	26-35	M	Normal E-W burial	7D	Local	Local
22219	26-35	M	Unusual diet, trauma	7C	Nonlocal	Local
22727	45+	M	Trauma	7E	Local	-

Table 6.12. Anglo-Norman Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ interpretations with demographic information and reason for selection (n = 14). * Samples from the pilot study (Farber & Lee-Thorp, in press).

The two subadults in this assemblage, one aged 6-12 years and one aged 13-17 years, are both interpreted as 'locals', and both were selected as likely 'locals' based on their 'average' dietary isotope results. The other selection criteria returned rather mixed results, with one individual chosen partly for atypical dietary isotope values interpreted as 'nonlocal', while another two are interpreted as 'local'. Potential patterning in the correlations between different selection criteria and interpretations of mobility are discussed in Chapter 8.

Due to the small sample size for the interpreted 'local' and 'nonlocal' groups, statistical tests such as Chi-Square cannot be used reliably, but some general observations can be made regarding differences and similarities between groups. Table 6.13 shows the percentage of individuals in the two groups with skeletal evidence of maxillary sinusitis, *cribra orbitalia*, periostitis, infectious disease, and trauma.

Pathology	Locals (% of total)	Comparison	Nonlocals (% of total)
Maxillary sinusitis	3/10 (30%)	<	2/4 (50%)
Cribra orbitalia	7/10 (70%)	<	4/4 (100%)
Periostitis	7/10 (70%)	<	4/4 (100%)
Trauma	5/10 (50%)	=	2/4 (50%)
Infectious disease	1/10 (10%)	<	2/4 (50%)

Table 6.13. Comparison of percentages of Anglo-Norman 'locals' and 'nonlocals' with skeletal evidence for pathology and trauma.

As shown in Table 6.13, the interpreted 'nonlocals' have higher crude prevalence rates for four of the palaeopathological indicators. Though the smaller sample size for 'nonlocals' may skew the crude prevalence rates, all four nonlocals have both *cribra orbitalia* and periostitis, and two are females with skeletal evidence for infectious disease (tuberculosis), compared to one 'local' male with evidence for infectious disease (syphilis).

Finally, while skeletal trauma is seen on 7 of the 14 individuals sampled for $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ analysis, only two individuals have evidence for skeletal trauma that may indicate interpersonal violence. Sk 22727, a male aged 45+ years and interpreted as 'local', has a rib fracture possibly consistent with interpersonal violence, but it is difficult to tell whether this was an accidental injury or the result of violence.

The other individual with evidence for interpersonal violence is Sk 22219, a 26-35 year-old male interpreted as 'nonlocal', with a likely 'parry fracture' to the distal ulna. This single 'nonlocal' male with skeletal evidence for interpersonal violence is not sufficient to make broad observations about the treatment of foreigners in Anglo-Norman Ipswich, but it nonetheless contributes to the overall picture of recurrent cases of violence at Stoke Quay. Interpersonal violence and mobility for the total sample are discussed in Chapter 8.

6.6 Conclusions

This chapter has aimed to shed some light on the Anglo-Norman period at Ipswich, through a combination of bone collagen and tooth enamel isotopic analysis as well as palaeopathological observations.

Section 6.1 provided a brief introduction to the period, while Section 6.2 presented an overview of the historical and archaeological evidence for the expanding international trade in fish and other commodities, as well as the growth of towns and the increase in marine fish consumption in Ipswich and England at this time. From this overview, several research questions and hypotheses were put forth, and Section 6.3 discussed the materials used to test these hypotheses. Section 6.4 presented the isotopic results, and Section 6.5 discussed these results in the context of the research questions and hypotheses from Section 6.2. The findings are summarised below.

The first question posed in Section 6.2 was whether an increase in marine fish consumption would be discernable in the Anglo-Norman assemblage compared to the Late Saxon assemblage, with the hypothesis that an increase would indeed be seen. The $\delta^{13}C$ and $\delta^{15}N$ results supported this hypotheses, showing a continued increase in group values and increases in the proportion of individuals with values above the expected terrestrial carnivore mean.

As in the Late Saxon period, differences were observed between males and females, with considerable overlap between the $\delta^{13}C$ and $\delta^{15}N$ of these groups but a smaller group of males with values beyond the female range. This was interpreted as further potential evidence of male occupations in the growing east coast fishing industry. Differences were also seen between adults and subadults, with adults yielding statistically significantly higher $\delta^{13}C$ and $\delta^{15}N$

than subadults. An analysis of childhood diet showed a surprisingly flat weaning curve, possibly caused in part by the very low $\delta^{13}C$ and $\delta^{15}N$ of two adolescents.

The second line of enquiry for this chapter was whether the prosperity attested to in the historical record during the Anglo-Norman period could be seen osteologically at Stoke Quay. Stature was shown to rise compared to the previous period, though crude prevalence rates of nonspecific stress indicators associated with urban living environments also increased. This highlights the complex interplay between diet, health, and biases in the skeletal record with regards to differential survivorship.

Finally, the expansion in trade and the draw of the nearby herring fisheries prompted the question of whether individuals of likely 'nonlocal' origin could be identified in the Anglo-Norman assemblage, with the hypothesis that they would indeed be identified. The findings supported this hypothesis, with four out of 14 individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ interpreted as 'nonlocal'. Some evidence for higher rates of interpersonal violence and infectious disease in the 'nonlocal' group was seen, but it was unclear whether this could be taken as representative of the Stoke Quay assemblage as a whole.

In sum, the isotopic and osteological evidence for Anglo-Norman Stoke Quay illustrate the wide range of dietary practices at Ipswich during this time, and the continued pull of this bustling port town for individuals from the countryside and potentially overseas.

Chapter 7: Tumult and instability in the late 12th- late 15th centuries

7.1 Introduction

The Medieval period of the late 12th-late 15th centuries saw upheavals and immense change in England, as elsewhere in Europe. By the end of the period, the increasingly commercialised and international market of the Anglo-Norman period had developed into a global economy with westward explorations and the 'discovery' of the New World in 1492. The expansion in trade and mobility was facilitated by significant advances in shipbuilding technology, including the widespread adoption of the three-masted sailing ship (Greenhill 1988). With large cargo capacities and the ability to sail long distances, these ships also bolstered the offshore fishing industry, with English fishermen journeying to Iceland and beyond in search of cod and other profitable fish to sell in urban markets (Kowaleski 2016).

The long-distance voyages made possible by larger boats led to increased variety in the types of products and foods available for purchase, as well as a further development of the growing merchant classes, particularly in the increasingly urbanised port towns and in London (Kowaleski 2008). However, the greater distances and frequency of sea travel also had some terrible consequences, most notably the rapid spread of the Black Death, which struck England in 1348, likely entering at Weymouth and quickly moving to London and beyond (Hawkins 1990; Antoine 2008; Horrox 1994; Kendall et al. 2013). The Black Death caused widespread changes in demographics, settlement patterns, economy and power dynamics that affected England and the continent for decades to come (Roberts & Cox 2003).

This chapter focuses on the impact of fish, trade, and public health crises on urban life in the late 12th – late 15th centuries, using Stoke Quay as a proxy for changes occurring more broadly in England and Western Europe. Particular focus centres on changes in diet associated with the expanding fishing trade and greater resource availability after the crises of the 14th century; changes in health due to urbanisation and multiple public health crises; and the potential effects of extensive trade networks and changing labour markets on mobility.

The following section (7.2) begins with a brief overview of the historical and archaeological background to the issues of intensifying urbanisation, the growing fish trade, urban occupations, and the presence of 'nonlocals' in Medieval Ipswich, and concludes with a series of research questions and hypotheses that guide the analyses in this chapter. The skeletal assemblage from Medieval Stoke Quay is described in Section 7.3, along with a description of the samples for $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen and $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of tooth enamel. Section 7.4 presents the results, and Section 7.5 discusses the results with respect to the research questions and hypotheses specific to this chapter. Finally, Section 7.6 summarises the findings and discusses whether the hypotheses have been supported by the results.

7.2 Historical background and research questions

7.2.1 Health and living conditions

As highlighted in Chapter 6, the increased fertility and agricultural productivity of the 11th-late 13th centuries increased population numbers and led to higher population density, particularly in urban areas (Lamb 1995). The 14th century brought the end of this warm and fertile period, with a cooler and

unstable climate leading to heavy rainfall, flooding in low-lying areas, storms in the North Sea, and several decades of recurrent famines and animal moraines (Aberth 2000; Kershaw 1973; Kendall et al. 2013).

The most devastating famine lasted from 1315-18, a period of wet spring to autumn months followed by widespread famine and disease outbreaks among humans and domestic animals. This famine may have killed 10-25% of the population of England, particularly in rural areas (Roberts & Cox 2003; Jordan 1996). The Black Death a generation later reduced the population by a further 35-50% by some estimates, and affected settlement patterns, agrarian systems, and the distribution of wealth (Roberts & Cox 2003; Dyer 2000).

The rapid spread of the Black Death throughout England and Europe was likely facilitated by urbanisation, as growing urban populations pushed people into close contact, often in crowded houses with poor ventilation and little to no hygienic waste disposal (Roberts & Manchester 2012). The Black Death and other infectious diseases would have spread more easily in closely packed urban spaces, especially during unusually warm weather spells such as the one experienced in 1348 (Roberts & Cox 2003).

The continuing process of urbanisation in the Medieval period meant that towns and cities became increasingly unhealthy places to live. As discussed in Chapters 1 and 2, the many hygiene, pollution, and crowding issues associated with urbanisation can affect the human skeleton in numerous ways. Air pollution can cause maxillary sinusitis, which has been observed at higher frequencies in urban areas compared to rural areas in the later medieval period (Roberts et al. 1998). Periostitis may be caused by trauma, localised infection and infectious diseases such as syphilis, tuberculosis, and leprosy, and it is a general indication

of systemic stress (Roberts & Cox 2003). *Cribra orbitalia* has been linked to megaloblastic or iron deficiency anaemia, as well as the effects of gastrointestinal parasites and infections (Walker et al. 2009; Mays 1998a; Roberts & Cox 2003).

In addition to the numerous issues highlighted above, health can also be greatly affected by diet. The evidence for diet in Medieval towns is discussed below.

7.2.2 Diet and the changing fish trade

The core elements of the Medieval lower-class diet were similar to those of the previous period, but their relative quantities changed over time. Grain still supplied the bulk of daily calories in the form of bread and ale, and for the lower classes, porridge. Meat, generally beef, mutton, pork, or poultry, was consumed in smaller quantities earlier in the period, but increased in the late 14th century in response to the sharp decline in population after the Black Death (Dyer 2000).

Peasants living in the countryside could produce much of their own food, supplementing it when necessary with food purchases, but townspeople largely relied on the marketplace, as the density of occupation precluded large household gardens. Urban markets sold fresh meat and poultry, cheese, fish, spices, and imported wine. By the 12th century, many larger towns also had cook-shops where ready-made food could be purchased by the many urban dwellers without an oven or kitchen in their living quarters (Dyer 2000; Roberts & Cox 2003; Hammond 1993).

Fish consumption and trade continued to gain importance during the Medieval period. Herring remained the most profitable fish for the east coast fisheries at the beginning of the period, with productivity peaking in the 12th-

early 14th centuries. In the later 14th century, the Hundred Years' War took a toll on these fisheries, with many ships impressed into naval service by the Crown, while others were vulnerable to attack at sea or during French raids on fishing ports. Along with the effects of war, the eastern herring fisheries faced growing competition in the North Sea from the Dutch fisheries (Kowaleski 2003).

As the 14th century progressed, most of the herring consumed in England came from overseas or the growing west coast fisheries, while some east coast fishermen focused on other species such as sprat or mackerel (Kowaleski 2003). Competition with Dutch and Scandinavian fishers increased in the 14th century, causing east coast fishermen to focus more heavily on North Sea cod (Harland et al. 2016; Childs & Kowaleski 2000).

In the 15th century, imports of dried and salted cod increased. A large proportion of cod was imported by foreign or west coast fishers, but some east coast fishermen from Ipswich and nearby ports such Lynn also shifted their focus to the deep-sea cod-fishing grounds off the coast of Iceland (Kowaleski 2003). The long and perilous journey to distant waters was facilitated by the large, sturdy, and easily maintained three-masted sailing ships that dominated the period (Greenhill 1988). Though the number of east coast men involved in these costly ventures was small compared to the number previously working in the east coast herring fisheries, their participation in the Atlantic cod fishery speaks to both ability of the seamen and the lure of potential profits from cod fishing (Kowaleski 2003, 2016).

East coast and west coast fisheries also began to expand to include other species of gadids, including whiting, haddock, saithe and ling. These fish could be sold in many forms, including dried, salted, smoked, or cured in brine (Barrett

2016). As discussed in Chapter 6, the consumption of higher trophic level fish such as gadids can be readily visible in human dietary isotope values, while herring and other lower trophic level fish require greater consumption in order to be as visible isotopically (Müldner 2016). It follows then that if cod fishing and consumption were increasing, this would show in the human dietary isotopes.

Fish were sold and consumed in greater numbers and with more variety after the Black Death, when wages increased and allowed more people to purchase this high protein and long-lasting food (Kowaleski 2003; Barrett 2018). While the lower and middling classes consumed marine fish, often purchased in preserved form, the wealthier classes could afford fresh sea fish and freshwater fish, which was raised in carefully managed fishponds (Dyer 2000).

Fish could be purchased by people of all classes in medieval port towns, which, due to their geographical, economic, and social position, attracted a large variety of goods, traders, and labourers from England and beyond.

7.2.3 Status, occupation and mobility in medieval Ipswich

As a busy east coast port town, Medieval Ipswich would have been a lively and diverse place. Ports were crucial nodes connecting England with the continent and facilitating regional trade— busy hubs where people from different cultures and social strata interacted in the pursuit of commercial success. In contrast to rural settlements and even inland towns, port towns hosted people from varied backgrounds, from the gentry and the wealthy merchants from whom they purchased their goods, to mariners, shipbuilders, sellers of every type of commodity, bakers, brewers, labourers, and the poor (Schofield & Vince 2003; Dyer 2000).

Naturally, with their proximity to the sea, port towns saw a large contingent of foreign fishermen and merchants, who came to shore to process and sell their catch or to sell imported items. During the late 12th-early 14th centuries when the herring fisheries were operating at their maximum, eastern ports saw high volumes of foreign fishermen, who flocked to these productive fishing grounds in droves during the annual herring migration off the eastern coast of England. For instance, more than 150 Dutch fishing boats visited ports along the Suffolk and Norfolk coasts, including Ipswich, in a single year during the early 14th century (Kowaleski 2003).

In addition to visiting fishermen, Ipswich was evidently home to its own marine industries. Boatbuilding and seafaring appear to have been local occupations in Ipswich, as evidenced in the town seal featuring a cog ship, likely created around 1200 when the town received its royal charter (Malster 2000; Greenhill 1988). The presence of skilled local sailors is also shown in historical documents recounting the excellent service of Ipswich seamen in King Edward I's naval service in 1290. Local boatbuilding prowess is demonstrated by the successful completion in 1294 of a galley and barge commissioned by Edward for his war with the French (Malster 2000).

Foreigners in Ipswich would have come not only from overseas, but also from within Britain, particularly after the Black Death. While migration from rural areas to towns is documented in manorial court records before 1348, the changes in demographics and power structures brought about by the Black Death resulted in larger numbers of people moving between rural and urban areas in search of gainful employment (Dyer 2000). The movement of people into Ipswich was influenced by the presence of the port, with evidence of foreign

merchants and their families moving to the town Ipswich during this period (Malster 2000; Breen, in press).

From the 13th century records of town officers, there is evidence in the form of surnames that Ipswich was attracting men from the surrounding areas, including parts of Norfolk, Suffolk and Essex, and that these men were able to ascend to local positions of power. Examples of such names include Robert de Orford, John Horkslee (Great and Little Horkesley near Colchester), and Edward de Castleacre (Norfolk). The town officer records also include names likely to have come from further afield, including John de Ipre and William de Ipre, whose names are likely to have been a corruption of Ypres, in Flanders (Malster 2000).

Migration to towns like Ipswich was not limited to men. During the labour shortages of the post-Black Death period, many urban areas opened up the labour force to include more women, particularly for jobs as servants for the growing mercantile classes (Britnell 2008; Lewis 2016; Goldberg 1992). Urban women were often employed in the traditionally 'female' industries, as weavers and spinners in the growing textile manufacturing industry, as brewsters, hucksters, as hostellers and as victuallers. Women in urban areas also worked in the fish trade; for example, between 10-35% of fish stalls at late 14th century Norwich fish markets were run by women (Goldberg 1992: 108). Rural women could also contribute significantly to family budgets, or support themselves if they were single or widowed (Dyer 2000).

Urban violence

Adults were not the only migrants to urban areas. Children and adolescents of both sexes moved to towns and cities for apprenticeships, usually

between the ages of 7 and 14 years. These young people were vulnerable to a number of dangers, from occupational hazards to road accidents and from mistreatment by their masters. With immature immune systems and lack of previous exposure to many pathogens, these youths were also at risk of illness or death from communicable diseases (Lewis 2016; Barron 2007). In addition to risks associated with specific occupations and the health hazards of urban living environments, medieval port towns were rife with the threat of violence.

Historical evidence indicates that medieval Ipswich could be dangerous. The Peasant's Revolt of 1381 claimed several lives in the town, including church and town representatives, and led to robberies of high-ranking officials. By the mid 15th century, the threat of violence in Ipswich was severe enough to warrant enacting laws to improve public safety. In 1447 local officials ordered that anyone living in Ipswich who did not assist someone during an assault would be disenfranchised. In 1452 another order mandated that every shopkeeper keep a good staff available should trouble arise, while those of 'greater ability' should have "Jacks, Sallets, Bowes, arrowes, swords, Targetts, Poleaxes, and other weapons of warrre [sic] ready at an hower, to defende themselves and withstand the enemies of king and kingdom as they ought" (Malster 2000:49).

In a time of unrest, it was particularly perilous to be a foreigner. In addition to a 'foreign fine' that port towns levied on nonlocals, foreigners were taxed at a higher rate, and often had to register with local authorities. With rising nationalism due to the war with France, and growing suspicion of foreign merchants, Parliament passed a law in 1439 requiring foreign traders to lodge with an English host and provide daily accounts of their business. Anti-alien sentiment in London was especially rampant, with frequent attacks on Italian

and Flemish traders severe enough to cause many Italians to move their business to Southampton in the mid 15th century (Kowaleski 2008; Malster 2000).

The violence against foreigners was not limited to London. Ipswich coroners rolls also demonstrate violence enacted against foreigners. The rolls from the mid 14tt century describe enquiries into the death of Hugh de Coventry in a tavern brawl, William Arras from a stabbing to the heart, and Dany Ryrad (a Welshman) who was murdered by John Cole of Torksey (Malster 2000).

These examples of violence against foreigners and locals alike indicate that Ipswich could be unsafe. However, as discussed above, it was also a dynamic place filled with economic and social opportunities, some of which simply could not be found in rural or inland areas. This combination of advantages and disadvantages led to a unique environment that is still not fully understood. Studies such as this one can help fill some of the gaps left by the historical record.

7.2.4 Research questions and hypotheses

As the preceding sections demonstrate, Ipswich was multifaceted, both cosmopolitan and pedestrian, with self-ruling elites, unskilled labourers, and everything in between. To date, apart from London and York, few large-scale isotopic studies have been conducted on urban assemblages from this period, and none have involved comparably sized port towns. The analyses in the following sections therefore represent an important attempt to advance understanding of the environment of these places.

The preceding sections raise a number of questions regarding the experience of urban dwellers in 13th-15th century England, which can be examined through the contemporary assemblage at Stoke Quay, Ipswich.

1) Can changes in marine fish consumption related to the rise in cod fishing be seen in the $\delta^{13}C$ and $\delta^{15}N$ values of this group? If so, does the degree of marine fish consumption differ by sex, as it did in the previous periods? Were people of higher status or advanced age consuming a diet markedly different to that of younger or less wealthy individuals? These questions are tested through $\delta^{13}C$ and $\delta^{15}N$ analysis of bone collagen from Medieval Stoke Quay. With the rising urban merchant classes of the Medieval period, it is hypothesised that status-based differences in diet will be evident. It is also hypothesised that males will continue to have higher $\delta^{13}C$ and $\delta^{15}N$ than females, but that there may be a greater range in values than in the previous period.

2) Can links be found between isotopic values and other factors that would point to changes in quality of life during this period of increased urbanisation? Do individuals with nonspecific stress indicators have high or low $\delta^{13}C$ and $\delta^{15}N$ values? Do indicators of nutritional deficiencies or stature correlate with isotopic values? How does diet at Stoke Quay compare to other contemporary urban sites? These questions are addressed through comparisons of crude prevalence rates at Stoke Quay for palaeopathological indicators associated with urbanisation to rates from contemporary urban populations and mean values from Britain (see Section 2.4). It is hypothesised that indicators of 'urban' pathologies will increase, and that correlations will be found between individuals with nonspecific stress indicators and low $\delta^{13}C$ and $\delta^{15}N$.

3) What can this sample tell us about mobility and the experience of foreigners in Medieval Ipswich? Is there evidence for increased mobility during this period? Are individuals with evidence for infectious disease more or less likely to have come from outside Ipswich? Can the violence against foreigners

attested to in the historical record also be seen in the skeletal and isotopic records? These questions are addressed through $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of a subsample of the Medieval Stoke Quay assemblage, and comparisons of trauma rates between interpreted 'locals' and 'nonlocals', with the hypothesis that higher numbers of 'nonlocals' will be identified than in previous periods.

The following section (7.3) describes the materials used to assess the questions and hypotheses discussed above. Site information is given for late 12th- late 15th century Stoke Quay and the human skeletal remains are discussed, along with details on the samples selected for isotope analysis.

7.3 Materials

Activity at Stoke Quay from the late 12th- late 15th centuries was assigned to Phase 6 by the site excavators, and is referred to here as the Medieval period. In this period the road surface of *Losegateweye* (later Great Whip Street) was recobbled three times and a wall may have separated it from the cemetery, which lay to the immediate east of the road.

Around the 13th century, the church of St. Augustine was remodelled from apsidal to square-shaped. A small addition was made near the south nave wall, possibly a porch for the door in this wall or a baptistery for the font. This period also saw the construction of a rectangular stone structure west of the church, angled slightly between the church and the corner of the northwestern boundary wall. This may have been a priest's house, and stratigraphic relationships indicate it was constructed after the late 12th century (Brown et al., in press).

Burials may have ceased to the north and west of the church in this period, partly due to the addition of the possible priest's house in that area.

Burials continued to the east and south, and a small number of individuals were also buried within the church. The southern cemetery boundary was recut twice, each time further south (Figure 7.1). No clear indicator was found for the end of the cemetery's use, but burial likely ceased when the church was closed at the end of the 15th century (Teague, in press).

The following section describes the human remains from the Medieval period, including the total number of burials and samples selected for this study.

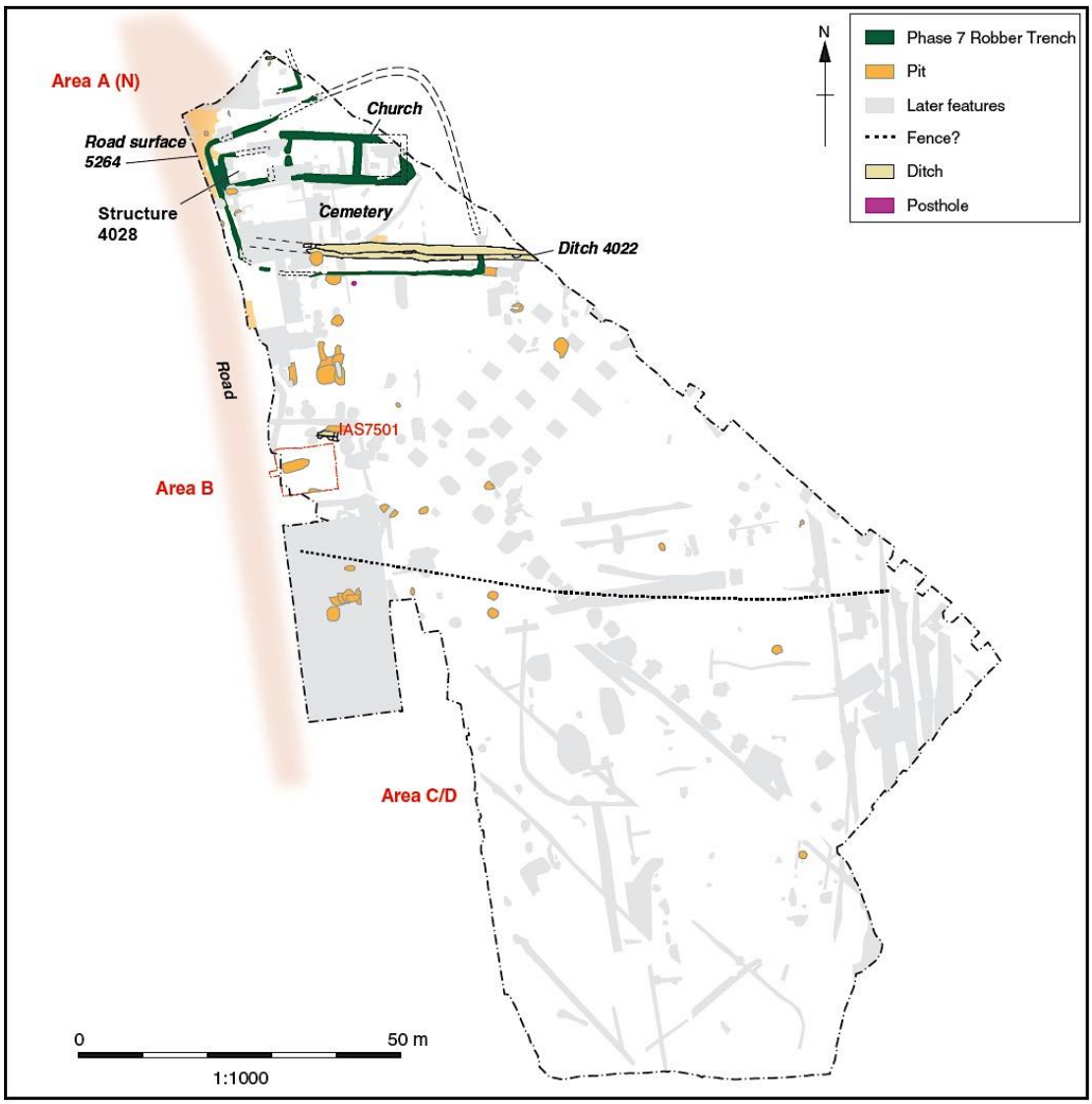


Figure 7.1. Map of Medieval Stoke Quay (Phase 6, late 12th-late 15th cen.). From Teague, in press, Figure 3.57).

7.3.1 The Medieval burials

Overview

The Medieval skeletal assemblage was the smallest of the three periods of the church cemetery's use (excluding the Mid Saxon burial landscape south of the later cemetery). A total of 259 individuals were assigned to this period, including 74 juveniles and 185 adults (Teague, in press)(Table 7.1; Figure 7.2).

As in the previous period, bone preservation was generally good, with over 90% scored as 'good' or 'fair' with regards to bone surface condition, completeness, and fragmentation, while more than half the assemblage had skeletal completeness of over 50% (Loe et al, in press).

Age Category	Age range (years)	Male (M, M?, M??)	Female (F, F?, F??)	Total (incl. unknown sex)
Juvenile				
Preterm	<37 weeks gestation	-	-	-
Neonate	Birth- 1 month	-	-	1
Infant	1-12 months	-	-	6
Young child	1-5	-	-	28
Older child	6-12	-	-	27
Adolescent	13-17	1	-	12
Juvenile (unspec.)	<18	-	-	-
Adult				
Young adult	18-25	8	12	21
Prime adult	26-35	28	30	58
Middle adult	36-45	24	17	42
Mature adult	>45	17	24	42
Mature adult+	>60	1	-	1
Adult (unspec.)	>18	7	8	21
TOTAL	All	86	91	259

Table 7.1. Medieval age and sex distribution (adapted from Loe et al., in press, Table A5.14).

Cemetery layout

The layout of burials was more orderly in this period, especially to the south where graves were in roughly parallel lines along the southern boundary

ditch. The area adjacent to the boundary may have been reserved for lower status burials, as all but one adult were buried without coffins. However, eight subadults in this area were buried in coffins. Eighteen individuals were buried within the church, a place of high status reflected in a larger proportion of coffin burials. Two burials were in the chancel, while the rest were in the nave. Some of the graves near the nave wall may have been in pairs, three of which were male and female pairs. All the burials within the church were adults except for three children under 5 years of age (Teague, in press).

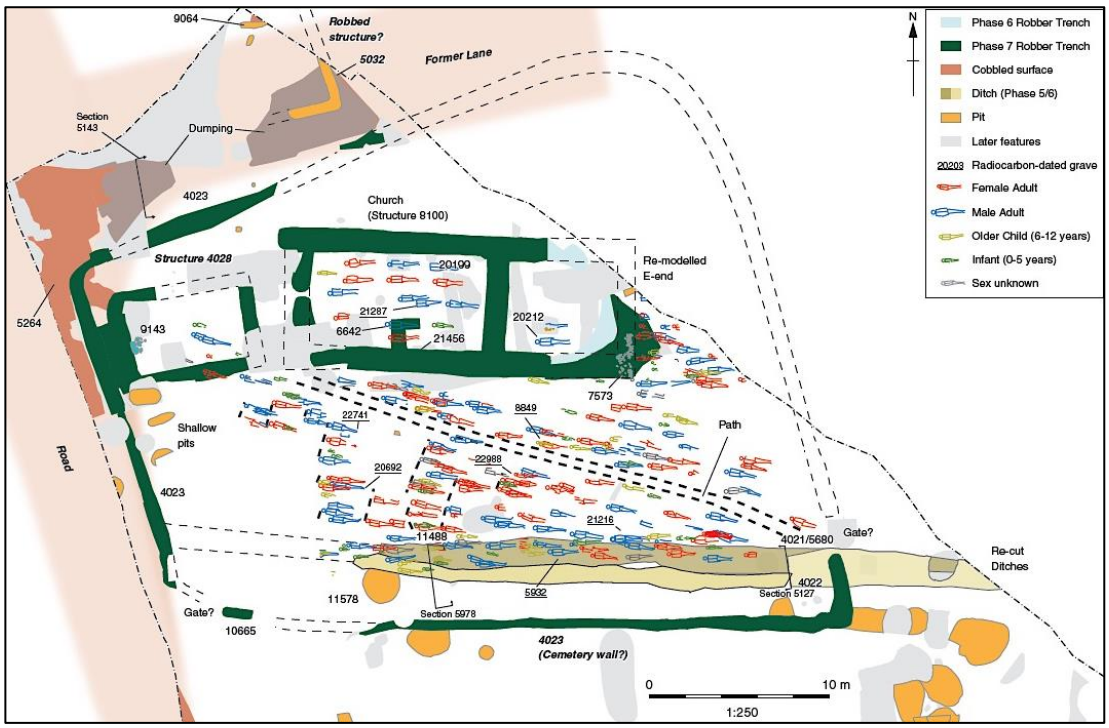


Figure 7.2. Map of Medieval Stoke Quay features and burials. From Teague, in press, Figure 3.58.

A total of 73 individuals from this period (28.2%) were buried in coffins, including 55 adults, 15 children, and three infants (Teague, in press: Table 3.12). Seven individuals, including five males, were buried in coffins built from reused boat timbers, revealed by the presence of clench bolts in the graves. Those not in coffins may have been buried in shrouds, though only seven graves included

shroud pins. Few personal items were found, but one individual, a male aged 36-45 years interred just south of the nave wall, was buried with a pewter chalice and paten, indicating that he was a priest (Gaimster, in press; Teague, in press).

Stratigraphic relationships between the Medieval burials were better preserved than in previous periods due to the lack of intercutting from later graves, which allowed for a finer grained chronology (Table 7.2). At the end of the period, the church went out of use and cemetery burials ceased. The church and its foundations were robbed of their stone in the 16th century, and eventually the exact location of the church was lost to memory, only to be rediscovered with the 2012 excavations at Stoke Quay (Teague, in press).

Cemetery Group	Number of Burials	Dating	Location
CG 2A	18	13th-15th cen.	Burials within the church
CG 4	156	13th-15th cen.	Main cemetery, mostly south of the church
CG 8	29	?mid 13th-15th cen.	East of church, possibly contemporary with remodel
CG 11	37	?12th-14th cen.	Graves later than the 1st south cemetery ditch
CG 12	9	?14th cen.	Graves later than the 2nd south cemetery ditch
CG 13	10	?14th-15th cen.	Graves later than the 3rd (latest) south cemetery ditch

Table 7.2. Medieval Cemetery Groups and distributions at Stoke Quay.

7.3.2 Samples for $\delta^{13}C$ and $\delta^{15}N$ analysis

A total of 108 Medieval individuals were selected for $\delta^{13}C$ and $\delta^{15}N$ analysis, including 19 subadults (<18 years old), 45 adult females and 44 adult males (Figures 7.3-7.7). The aim was to sample 20 adults per age group (see Ch. 2), but the numbers vary based on the presence of well-preserved skeletons from each age group. The Medieval assemblage contained 12 adolescents, of which nine were well enough preserved for sampling. Unfortunately, 01-05 year-olds from this period could not be obtained. The 26-35 year-old, 36-45 year-old,

and 45+ year-old groups each contain 20 individuals from the main study, with an additional 9 individuals from the pilot.

Bone collagen was extracted following methods described in Chapter 2 Section 2.2.3.

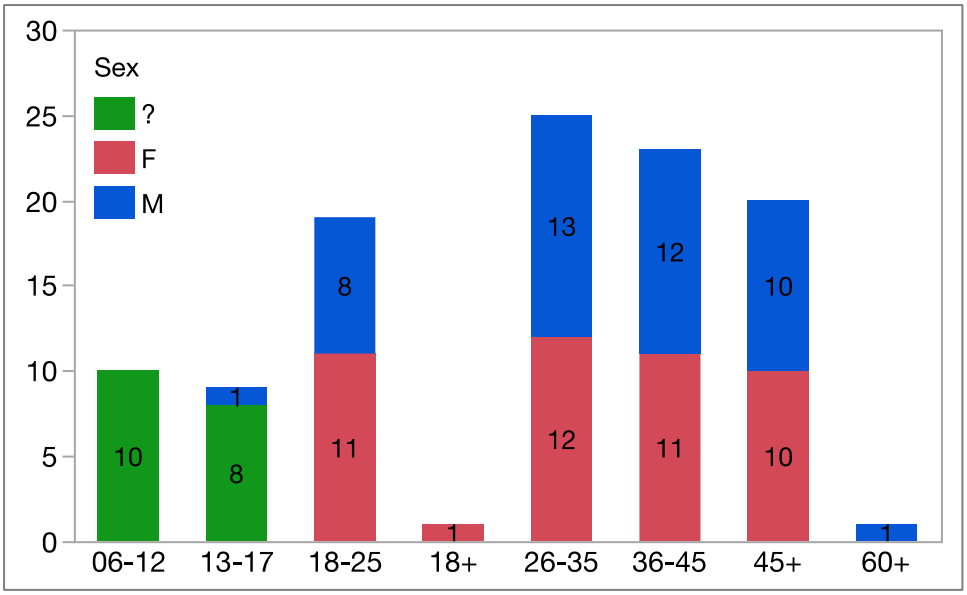


Figure 7.3. Age and sex distribution for Medieval $\delta^{13}C$ and $\delta^{15}N$ analysis (n = 108).

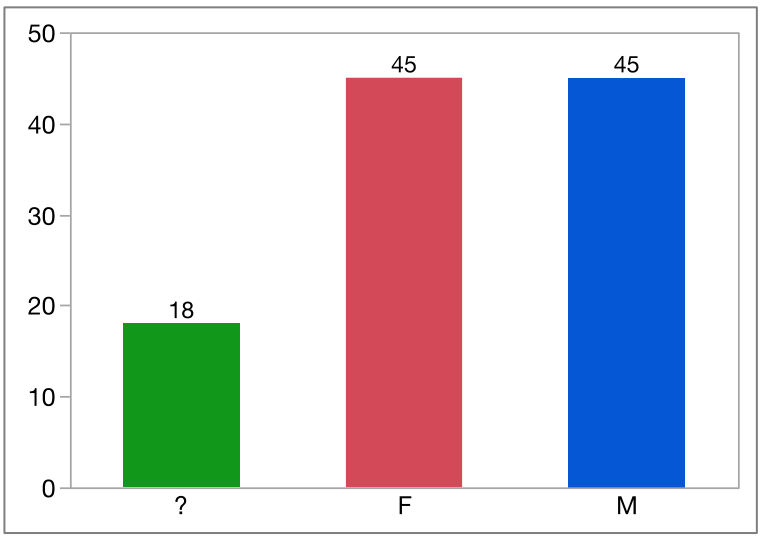


Figure 7.4. Sex distribution for Medieval bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis (n = 108).

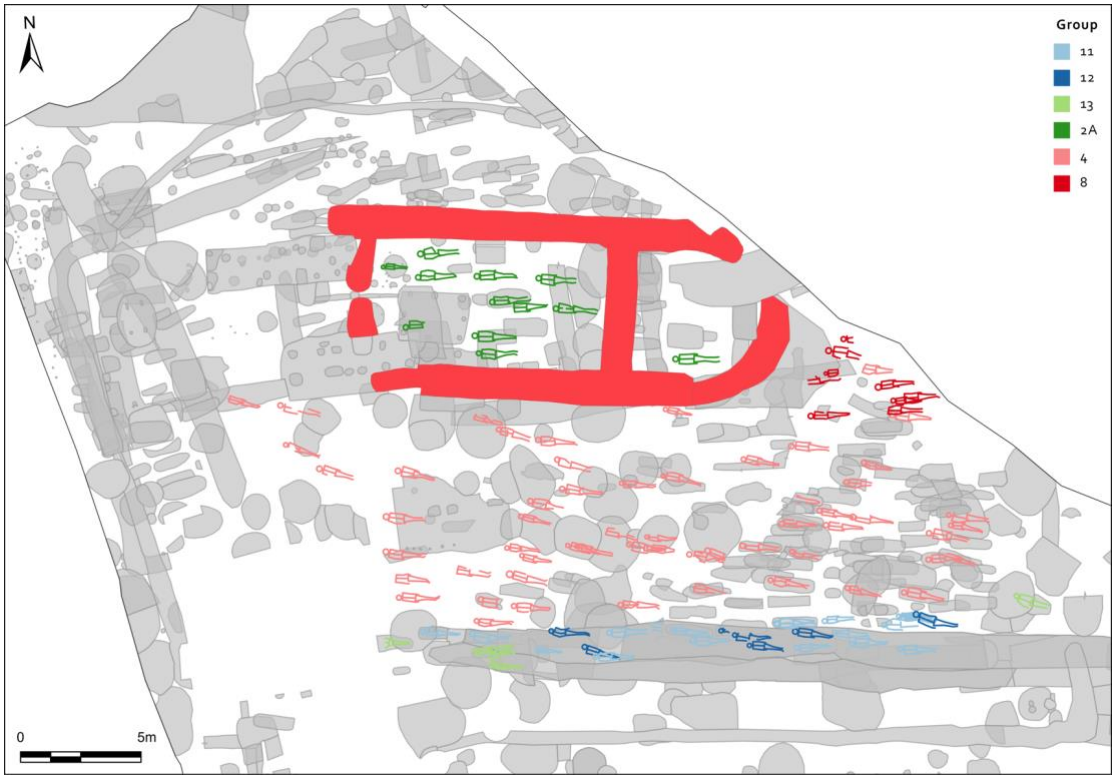


Figure 7.5. Map of Medieval skeletons sampled bone collagen $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by Cemetery Group.

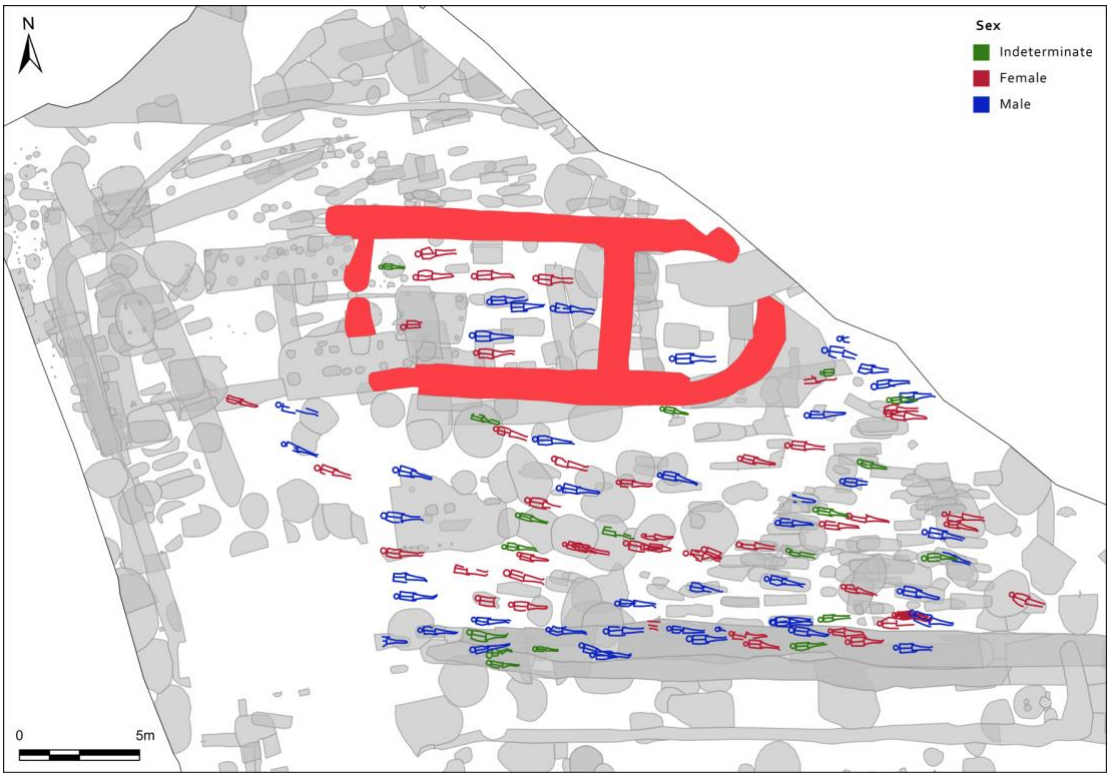


Figure 7.6. Map of Medieval skeletons sampled for $\delta^{13}C$ and $\delta^{15}N$ analysis, coloured by sex.



Figure 7.7. Map of Medieval skeletons sampled for $\delta^{13}C$ and $\delta^{15}N$, coloured by age.

7.3.3 Samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis

Tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was performed on 18 Medieval individuals. The sampled skeletons are listed in Table 7.3 with the reasons for selection. Age and sex distributions are shown in Figure 7.8.

Sk ID	Age	Sex	Ancestry	Selection Reason	CG	Tooth
5699	13-17	?	Caucasoid	Unusual diet	4	L mand. M2
*5931	18-25	M		-	11	R mand. M2
6473	06-12	?		Unusual diet	11	L max. M2
*8532	26-35	F	Mixed/?	Pathology (TB)	4	R max. M2
20116	36-45	F	Caucasoid	Unusual diet	4	L max. M2
20177	18-25	F	Caucasoid	Unusual diet	12	R max. M2
20192	45+	F		Average diet	11	L mand. M2
20381	26-35	F		Pathology (TB)	11	L max. M2
20560	45+	M	Caucasoid	Average diet	8	R mand. M2
21032	26-35	M	Caucasoid	Unusual diet	2A	L max. M2
*21217	36-45	M	Mixed/?	Ancestry	11	L mand. P4
*21289	60+	M	Caucasoid	Trauma	2A	L mand. C
*21348	18+	F	Caucasoid	-	4	R max. P4
22418	26-35	M		Trauma	4	R max. M2
22646	18-25	F		Average diet	4	L mand. M2
*22739	45+	M		Trauma	4	L mand. M2
*22989	26-35	F	Mixed/?	Path (TB), ancestry	4	L mand. C
23141	45+	M	Caucasoid	Unusual diet	8	L max. M2

Table 7.3. Medieval $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ sample, with demographics, reason for selection, and tooth sampled (n = 18). * Included in pilot study (Farber & Lee-Thorp, in press).

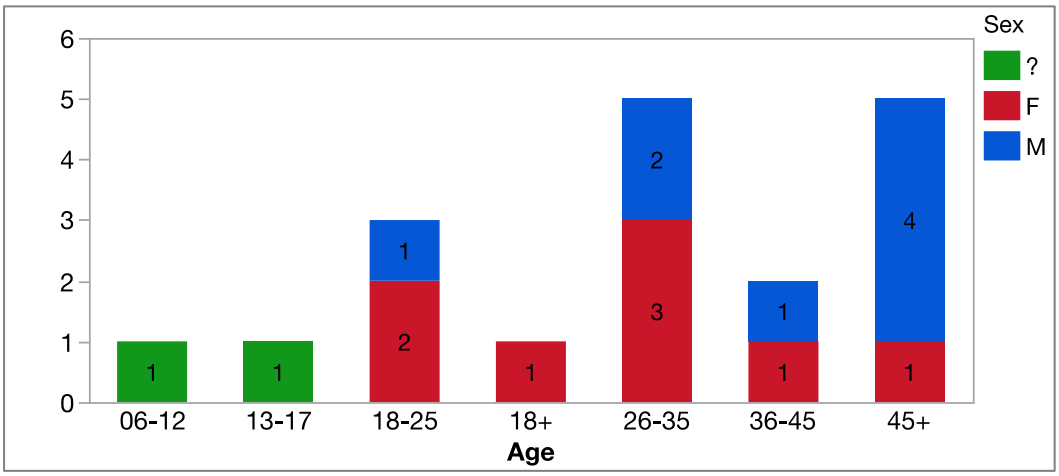


Figure 7.8. Age and sex distribution for Medieval individuals sampled for enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis (n = 18).

7.4 Results

This section presents the Medieval $\delta^{13}C$ and $\delta^{15}N$ results, followed by the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results. Interpretations and a discussion of the significance of these results are provided in Section 7.5.

7.4.1 $\delta^{13}C$ and $\delta^{15}N$ results

Of the 108 individuals sampled, 107 yielded acceptable collagen (see Section 2.2 for quality indicators). It should be noted that the isotopic values for two individuals, Sk 7527 and Sk 22418, are based on singular not duplicate analyses as per the conventional method, because of the small amount of collagen produced. Individual results are reported in Appendix 2. Summary statistics for subadults, adults, and all 107 individuals are shown in Table 7.4.

The group $\delta^{13}C$ mean is -18.8‰ (±0.6, 1σ), ranging from -20.2 to -17.2‰, and the $\delta^{15}N$ mean is 12.7‰ (±1.5, 1σ), ranging from 7.5 to 16.1‰. The $\delta^{13}C$ values are normally distributed, so they are analysed with parametric tests (Shapiro-Wilk W Test, W = 0.9878, p = 0.4414). The $\delta^{15}N$ values are not normally

distributed, so further analyses are performed with nonparametric tests (Shapiro-Wilk W Test, W= 0.9680, p = 0.0111).

The $\delta^{13}C$ and $\delta^{15}N$ data are plotted in Figure 7.9. Based on a line of best fit there is a highly statistically significant relationship between $\delta^{13}C$ and $\delta^{15}N$ (r^2 = 0.71, p < 0.0001). The $\delta^{13}C$ and $\delta^{15}N$ results are plotted separately when testing relationships between isotopic values and non-numerical factors such as age, sex, burial location, or pathology.

Group	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Subadults	18	11.1	1.5	7.5	13.0	-19.2	0.7	-20.2	-17.8
Adults	89	13.0	1.3	9.0	16.1	-18.7	0.6	-20.0	-17.2
All	107	12.7	1.5	7.5	16.1	-18.8	0.6	-20.2	-17.2

Figure 7.4. Summary statistics by general age category for Medieval bone collagen $\delta^{13}C$ and $\delta^{15}N$ results (n = 107).

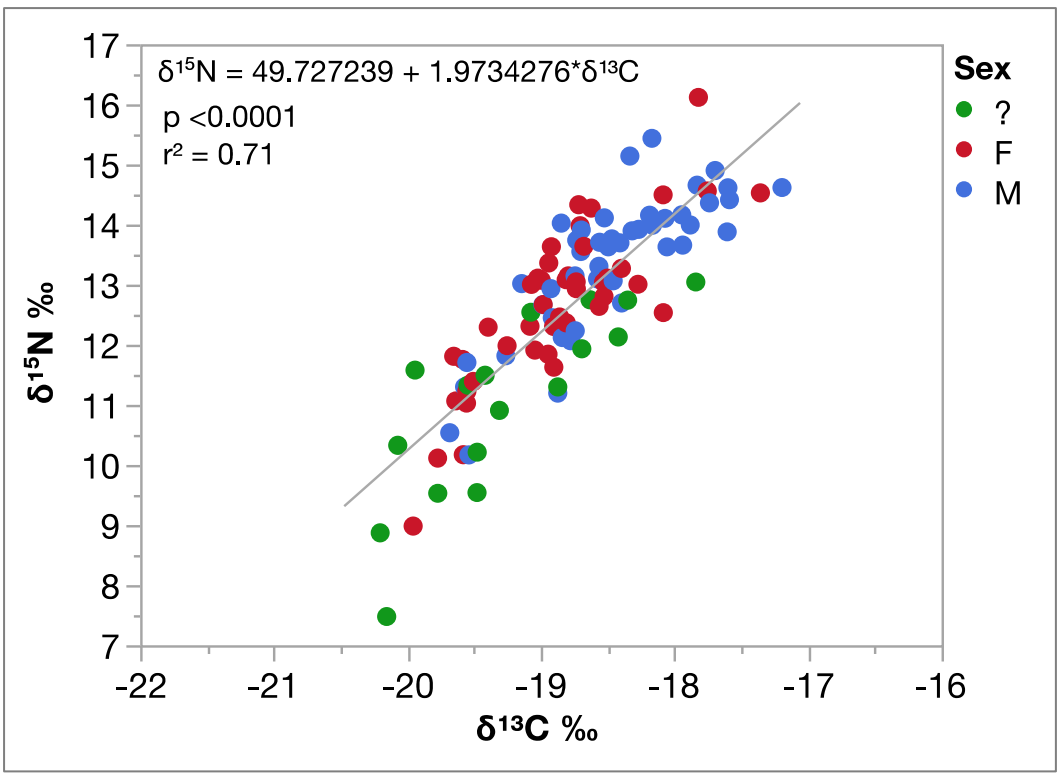


Figure 7.9. Scatterplot of Medieval bone collagen $\delta^{13}C$ and $\delta^{15}N$ results (n = 107). A line of best fit shows a statistically significant correlation between $\delta^{13}C$ and $\delta^{15}N$ (p < 0.0001, r^2 = 0.71).

7.4.2 $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results

All 18 individuals selected for $^{87}Sr/^{86}Sr$ analysis yielded results, ranging from 0.708695 to 0.710286 (mean 0.709351 ± 0.000388). The $^{87}Sr/^{86}Sr$ results are not normally distributed, requiring nonparametric tests for further statistical analyses (Shapiro-Wilk W Test, W= 0.8947, p = 0.0465).

Only 15 of the 18 individuals sampled for $\delta^{18}O$ analysis yielded acceptable results (see Chapter 2 Section 2.3.3 for details). Summary statistics for $\delta^{18}O_{VPDB}$ and calculated $\delta^{18}O_P$ results are given in Table 7.5. The $\delta^{18}O$ distributions are normal, so parametric tests are appropriate for additional statistical analyses.

Figure 7.10 shows the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results. A line of best fit shows a weak, positive, statistically insignificant correlation between the datasets (r^2 = 0.04, p = 0.5; Figure 7.10). Individual results are given in Appendix 3.

$\delta^{18}O$	n	Mean	1σ	Min	Max
$^{87}Sr/^{86}Sr$	18	0.709351	0.000388	0.708695	0.710286
$\delta^{18}O_{C\text{-}VPDB}$	15	-4.8	0.6	-5.6	-3.4
$\delta^{18}O_{P\text{-}VSMOW}$	15	17.1	0.6	16.2	18.6

Table 7.5. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ summary statistics, with carbonate values relative to VPDB, and calculated phosphate values relative to VSMOW (Chenery et al. 2012).

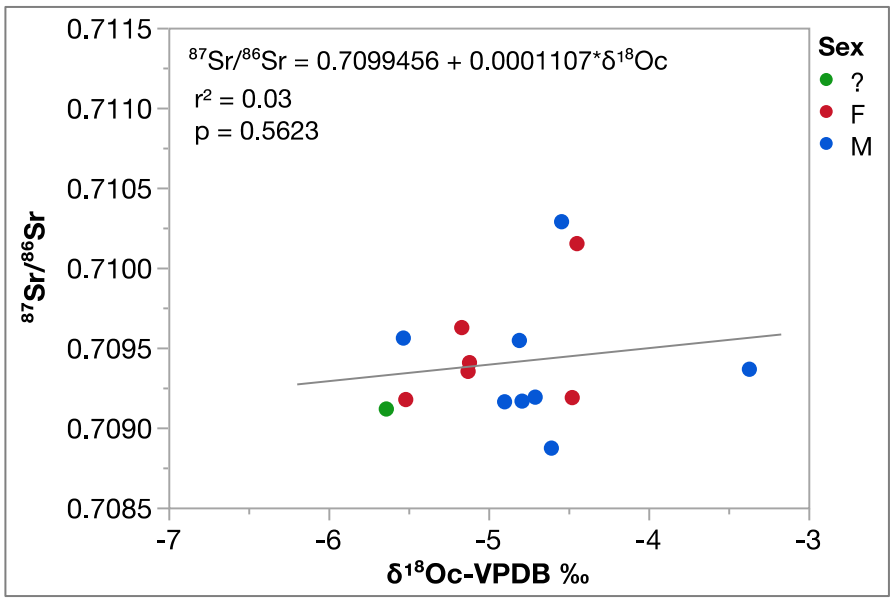


Figure 7.10. Scatterplot of Medieval $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results coloured by sex. A line of best fit shows very weak correlation between $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ (p = 0.5, r^2 = 0.04).

7.5 Discussion

This section aims to address the research questions outlined in Section 7.2. The $\delta^{13}C$ and $\delta^{15}N$ results are discussed in relation to the impact of marine fish on the Medieval diet at Stoke Quay, particularly regarding the consumption of gadids, and the data are analysed for potential dietary differences by sex, age group, and status. Individuals with evidence for high and low marine fish consumption are evaluated for possible correlations with skeletal stress indicators and stature. The $\delta^{13}C$ and $\delta^{15}N$ results are also compared to those from contemporary Fishergate, York, and St Mary Spital, London, to investigate potential differences in diet for urban populations.

Next, the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results are discussed, and interpretations are made regarding 'local' and 'nonlocal' origins using the expected baseline values from Chapter 2. The 'local' and 'nonlocal' groups are compared based on evidence for disease to test whether those with infectious disease and nonspecific stress indicators were more or less likely to come from outside Ipswich. Isotopic interpretations of diet and evidence for trauma are also compared between the groups, to address whether the violence against foreigners attested to in the historical records can be seen in the skeletal record.

7.5.1 Diet

Overall interpretations of diet and fish consumption

The first question addressed in this discussion is whether the consumption of gadids and other marine fish rises at Medieval Stoke Quay, in correspondence with the growing importance of the cod fisheries and continued

expansion in the international trade of preserved fish (Barrett et al. 2004a, b; Barrett 2018; Kowaleski 2016).

The Medieval $\delta^{13}C$ and $\delta^{15}N$ are plotted in Figure 7.11 with the expected terrestrial carnivore range and mean values (±1σ) obtained from the literature for fish from different habitats (Müldner & Richards 2005; Jay 2008; Barrett et al. 2011). As established in Chapter 3, Section 3.3.5, individuals consuming an omnivorous terrestrial-based diet would be expected to yield $\delta^{13}C$ between -20.6‰ and -19.6‰, and $\delta^{15}N$ between 10.3‰ and 12.3‰.

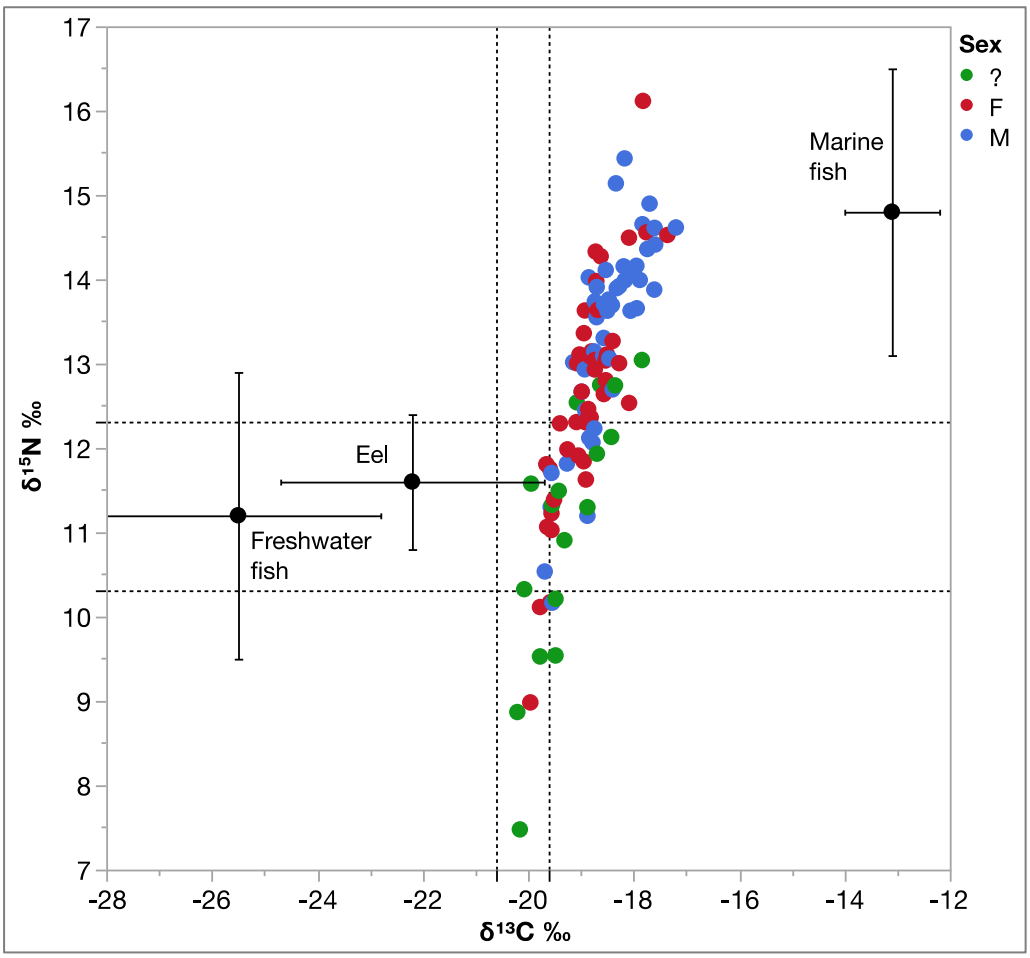


Figure 7.11. Scatterplot of Medieval $\delta^{13}C$ and $\delta^{15}N$ coloured by sex, with expected terrestrial carnivore values shown as dotted lines.

As shown in Figure 7.11, only six out of 107 individuals yielded both $\delta^{13}C$ and $\delta^{15}N$ within the expected terrestrial carnivore range, with a majority

trending toward the marine fish range. The five individuals with the lowest values, two females and three children aged 6-12 years, appear to have consumed a C_3 diet but with little animal protein, at least compared to the rest of the group (see below for subadult diet). A majority of the samples (63%, or 68/107) yielded $\delta^{13}C$ and $\delta^{15}N$ above the expected terrestrial carnivore range, an increase from the previous period. Few subadults are included in this group with high $\delta^{13}C$ and $\delta^{15}N$. In a marked change from the Anglo-Norman results, the group with the highest values is largely male but no longer exclusively so, instead including several females. This group is examined in greater detail further below, while age-related differences are explored next.

Overall age patterns

As shown in Figure 7.11, there is a large range in isotopic values for the Medieval assemblage, with $\delta^{13}C$ and $\delta^{15}N$ ranges of 3‰ and 8.6‰, respectively. To characterise the variability in the data and evaluate the presence of age-related dietary differences, the Medieval human $\delta^{13}C$ and $\delta^{15}N$ results are compared by age group (Table 7.6, Figure 7.12a,b).

Mean $\delta^{13}C$ increases with age, with statistically significant differences (Table 7.6; $p = 0.0041$, ANOVA). One exception is the single 18+ year-old (Sk 21348) with slightly lower $\delta^{13}C$ than 13-17 year-olds. Means comparisons reveal statistically significant differences between children aged 6-12 years and all adults except for Sk 21348 (see Figure 7.12a caption for p-values).

The pattern is similar for the mean $\delta^{15}N$ values, which rise with age, again with statistically significant differences ($p < 0.0001$, ANOVA). For $\delta^{15}N$, Sk 21348 falls above the mean for the 18-25 year-olds. Means comparisons show the same

pattern for $\delta^{15}N$ as for $\delta^{13}C$, with statistically significant differences between 6-12 year-olds and all adults except Sk 21348 (see Figure 7.12b for p-values).

Based on these results, it appears that age-related dietary differences existed between children and adults in this period, and that adult marine fish consumption increased with age. Among adults, increased $\delta^{13}C$ and $\delta^{15}N$ with higher age-at-death may indicate better overall nutrition and health as a result of eating marine fish. Access to fish could be influenced by status or occupation as well (see Section 7.2.2), and these potential explanations are discussed further below, while the subadults are discussed in the following section.

Age (years)	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
6-12	10	10.3	1.6	7.5	12.7	-19.5	0.6	-20.2	-18.3
13-17	8	12.0	0.6	11.3	13.0	-18.8	0.6	-19.9	-18.7
18-25	19	12.4	1.5	9.0	14.6	-18.8	0.6	-20.0	-17.6
18+	1	12.7	-	-	-	-19.0	-	-	-
26-35	25	13.1	1.3	10.1	15.4	-18.6	0.6	-19.8	-17.7
36-45	23	13.2	1.2	11.1	16.1	-18.6	0.6	-19.6	-17.4
45+	21	13.2	1.2	10.2	15.1	-18.6	0.6	-19.6	-17.2

Table 7.6. Summary statistics for Medieval bone collagen $\delta^{13}C$ and $\delta^{15}N$ by age (n = 107).

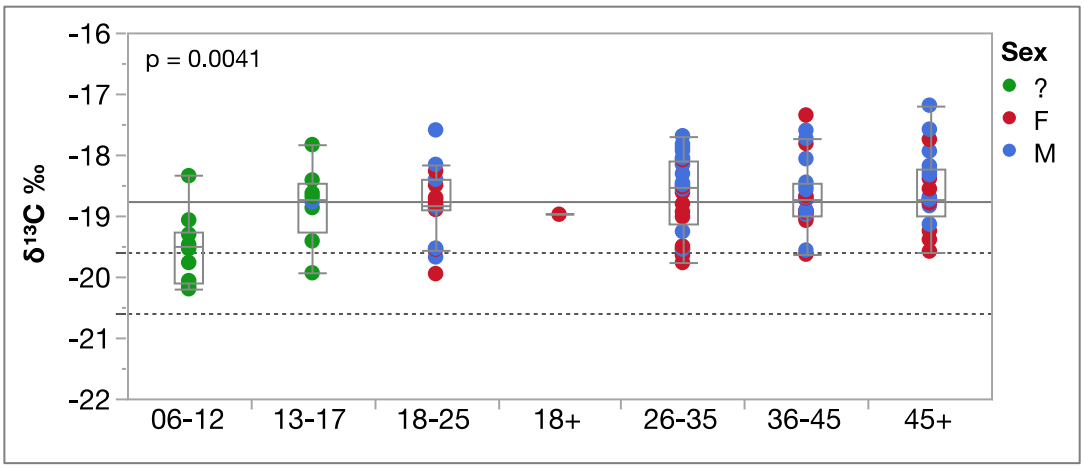


Figure 7.12a. $\delta^{13}C$ boxplots by age for Medieval Stoke Quay, with statistically significant differences (p = 0.0041, ANOVA). Means comparisons show significant differences between the 6-12 year and 18-25 (p = 0.0423), 26-35 (p = 0.0021), 36-45 (p = 0.0034), and 45+ year-olds (p = 0.0017; Tukey-Kramer HSD). Dotted grey lines: expected terrestrial carnivore range; solid line: group mean.

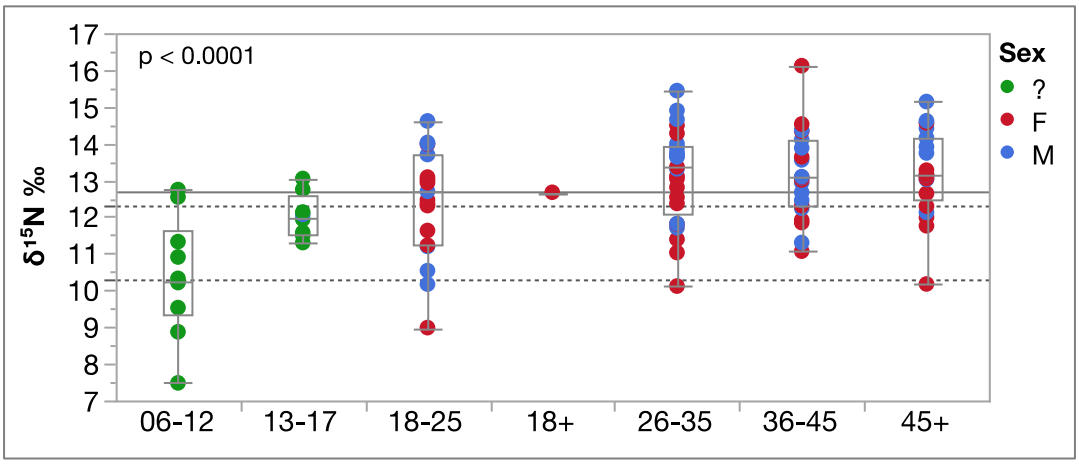


Figure 7.12b. $\delta^{15}N$ boxplots by age for Medieval Stoke Quay, with statistically significant differences ($p < 0.0001$, ANOVA). Means comparisons show significant differences between the 6-12 year and 18-25 ($p = 0.0013$), 26-35 ($p < 0.0001$), 36-45 ($p < 0.0001$), and 45+ year-olds ($p < 0.0001$; Tukey-Kramer HSD). Dotted grey lines: expected terrestrial carnivore range; solid line: group mean.

Subadult diet and health

Based on the statistical analyses shown in Figures 7.12a,b, childhood isotopic values stand out clearly from those of adults. This difference is particularly clear for $\delta^{15}N$, with much lower values for the 6-12 year-olds compared to adolescents, and even greater differences compared to adults. The 6-12 year-old $\delta^{15}N$ fall mainly within and below the terrestrial range, with several individuals showing very little animal protein intake. This can be attributed to the effect of the well-established dip in $\delta^{13}C$ and $\delta^{15}N$ that occurs shortly after weaning (e.g. Mays et al. 2002; Fuller et al. 2003).

The $\delta^{13}C$ and $\delta^{15}N$ for adolescents cluster together much more tightly than do those of the younger children, with $\delta^{13}C$ values very similar to those of 18-25 year-olds, and $\delta^{15}N$ values falling roughly within the central two quartiles of the 18-25 year-olds. It is possible that by adolescence, these individuals were already consuming a more adult diet, and as shown by Lewis (2016) they may have even been employed as apprentices and labourers by this age.

To visualise isotopic patterns in the Medieval subadult sample, the $\delta^{13}C$ and $\delta^{15}N$ values are plotted by age (mean value from estimated age-at-death ranges). The plots reveal a statistically significant relationship between age and both $\delta^{13}C$ and $\delta^{15}N$, and a line of best fit for each isotopic system shows fairly weak but statistically significant correlations between the datasets. Cubic polynomial curves fitted to the data show slightly higher correlations, but no statistical significance ($r^2 = 0.36$ for both isotopes; see captions, Figures 7.13a,b).

In contrast to the Anglo-Norman plots (Chapter 6, Figures 6.13a,b), the Medieval subadult polynomial curves follow a more typical weaning pattern. However, the lack of young children in this sample means the curve may not be truly representative of the assemblage. This could be clarified in the future if it is possible to add young children (1-5 years old) to the analyses.

The higher $\delta^{13}C$ and $\delta^{15}N$ for one 8 year-old, and lower values for one 7 year-old, are of potential interest. The divergent values could indicate wide variation in childhood diets, with some including marine fish and others involving very little. Complicating these interpretations is the issue of selective mortality. These individuals died young, so their bone collagen $\delta^{13}C$ and $\delta^{15}N$ may have been influenced by illness, growth spurts, and starvation, and it is not possible to differentiate between physiological and dietary causes (Sandberg et al. 2014; Fuller et al. 2004; Beaumont & Montgomery 2016). Therefore, these individuals may not reflect wider dietary trends.

Serial dentine sampling would allow for a more detailed view of diet and health for Medieval children at Stoke Quay, while palaeopathological data can provide further contextual information about childhood health and diet. Childhood palaeopathology is considered below.

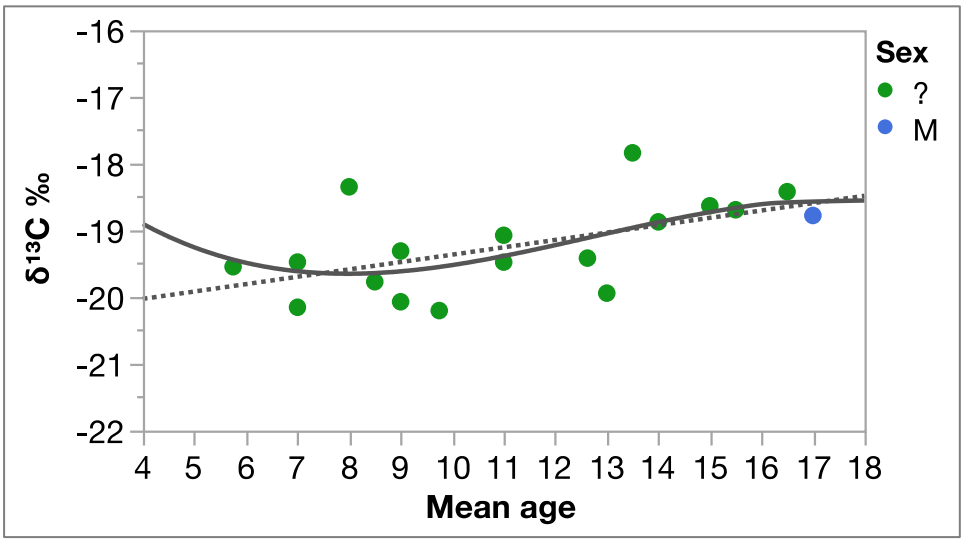


Figure 7.13a. Medieval subadult $\delta^{13}C$ by age (n = 18). A line of best fit (dotted grey) shows statistically significant correlation ($r^2 = 0.32$, p = 0.0148); a cubic polynomial curve (solid grey) shows higher correlation but no statistical significance ($r^2 = 0.36$, p = 0.0940).

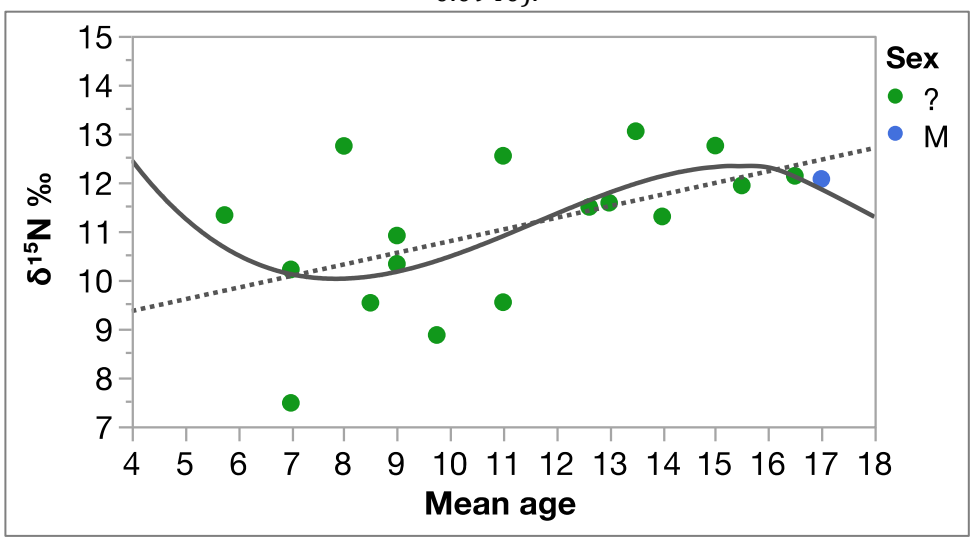


Figure 7.13b. Medieval subadult $\delta^{15}N$ by age (n = 18). A line of best fit (dotted grey) shows statistically significant correlation ($r^2 = 0.30$, p = 0.0178); a cubic polynomial curve (solid grey) shows higher correlation but no statistical significance ($r^2 = 0.36$, p = 0.0893).

As noted above, when analysing individuals from the archaeological record, the sample we have available may be inherently biased due to the fact that these are individuals who did not survive into adulthood. Therefore, it must be considered that this group of subadults may not completely reflect the healthier individuals that did survive. One manner of testing this hypothesis is to

examine the incidence of skeletal stress markers among different age groups to determine whether there are any links between age and disease or stress.

To better understand the effect of stress on age at death, the incidence of dental enamel hypoplasia (DEH) is compared amongst the different age groups represented in the Medieval Stoke Quay assemblage (Table 7.7). Just over 50% of the adults aged over 25 years have DEH, with higher frequencies for young adults (18-25 years) and subadults. The 6-12 year-olds have the highest frequency, with 100% exhibiting DEH, followed by young adults aged 18-25 years, then adolescents aged 13-17 years.

Age Group	# with DEH	Total	% with DEH
6-12	10	10	100 %
13-17	4	6	66.67 %
18+	1	1	100 %
18-25	11	15	73.3 %
26-35	13	25	52 %
36-45	11	20	55 %
45+	10	19	52.6 %

Table 7.7. Frequency of DEH by age group at Medieval Stoke Quay.

Using a Chi Square test, the frequency of DEH by age group can be tested against the null hypothesis that DEH is not independent of age-at-death (excluding the 13-17 and 18+ age groups because of their low sample numbers). The Chi Square results do not satisfy the null hypothesis, instead showing a relationship between DEH incidence and age-at-death (Likelihood Ratio $p = 0.0137$, Pearson $p = 0.0584$). These findings suggest that those who died young, especially before reaching adolescence, had been previously weakened by illness or systemic stressors that had impacted on tooth formation, forming the hypoplasias.

The prevalence rates for *cribra orbitalia* and *cribra femoralis* also support the hypothesis that children who died young had dietary deficiencies and prolonged poor health. The 6-12 year-olds in this sample have a crude prevalence rate of 70% for *cribra orbitalia*, and of 80% for *cribra femoralis*. The 13-17 year-olds have a slightly higher prevalence of *cribra orbitalia*, at 75%, but a lower prevalence of only 50% for *cribra femoralis*. *Cribra femoralis* may heal with age, but the high prevalence of *cribra orbitalia* in these subadults, which can last into adulthood, is a useful indication of the health status of these children.

Finally, two adolescents have probable tuberculosis, and one of these, Sk 21983, aged approximately 12.65 years, also has skeletal lesions indicative of scurvy. Clearly, childhood at Medieval Stoke Quay was a perilous time, with threats from infectious disease, malnutrition, and systemic stress taking their toll on these vulnerable members of society. Whether this was also the case for adults is explored in the next section, along with sex-based differences in diet.

Sex-based differences in diet

Sex-based differences are evaluated for adults to test whether males have statistically significantly higher $\delta^{13}C$ and $\delta^{15}N$ compared to females, as in the previous two periods. As shown in Figure 7.14, there are indeed statistically significant differences between males and females for both $\delta^{13}C$ and $\delta^{15}N$ ($\delta^{13}C$ $p = 0.0013$, $\delta^{15}N$ $p = 0.0065$, ANOVA). Mean $\delta^{13}C$ and $\delta^{15}N$ for both sexes are higher than for the previous period, indicating a population-wide increase in marine fish consumption (see discussion in Chapter 8).

The broad increase in $\delta^{13}C$ and $\delta^{15}N$ correlates well with current narratives regarding the 'fish event horizon,' discussed in Section 7.2 and

Chapter 6, indicating increased consumption of high trophic-level fish such as gadids, and/or increased overall fish consumption. As described above, males generally have more positive values for both isotopic systems, though as in the previous period there is considerable overlap between the sexes. Despite these similarities, some important differences are evident in the distribution and range of $\delta^{13}C$ and $\delta^{15}N$ by sex. Notably, the highest $\delta^{15}N$ value belongs to a probable female (Sk 20116), and the second-highest $\delta^{13}C$ value also belongs to a probable female (Sk 21335).

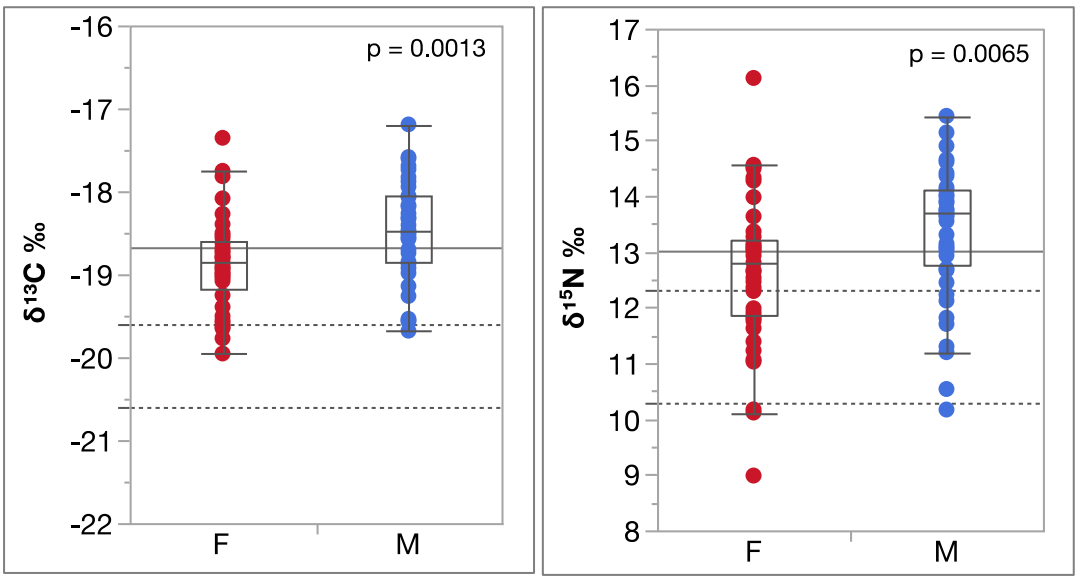


Figure 7.14. Boxplots by sex for Medieval adult $\delta^{13}C$ (left) and $\delta^{15}N$ (right), with statistically significant differences between sexes ($\delta^{13}C$ p = 0.0013, $\delta^{15}N$ p = 0.0065, ANOVA). Dotted grey: expected terrestrial carnivore values; solid grey: group mean.

As shown in Table 7.8, the male and female isotope values have wider ranges than in the previous periods. For the first time at the site, Medieval females exhibit a wider range for both $\delta^{13}C$ and $\delta^{15}N$ than males, the opposite trend from that seen in the Late Saxon and Anglo-Norman assemblages. The $\delta^{13}C$ differences between sexes are subtle, with ranges of 2.6‰ for females and 2.5‰

for males, but the difference the $\delta^{15}N$ are more pronounced, with a range of 7.1‰ for females and 5.2‰ for males.

Sex	n	Mean $\delta^{15}N$	1σ	$\delta^{15}N$ Range	Mean $\delta^{13}C$	1σ	$\delta^{13}C$ Range
Female	45	12.6	1.3	9.0-16.1 (7.1)	-18.9	0.5	-20.0 to -17.4 (2.6)
Male	44	13.4	1.2	10.2-15.4 (5.2)	-18.5	0.6	-19.7 to -17.2 (2.5)

Table 7.8. Summary statistics for $\delta^{13}C$ and $\delta^{15}N$ analysis of Stoke Quay Medieval adults (n = 89). Values are in ‰.

The boxplots in Figure 7.14 and ranges in Table 7.8 help illustrate differences between males and females for each isotopic system, but $\delta^{13}C$ and $\delta^{15}N$ are more instructive when used together. The $\delta^{13}C$ and $\delta^{15}N$ for adult males and females are plotted in Figure 7.15 with 95% density ellipses by sex and the maximum expected terrestrial carnivore values. There is substantial overlap between the sexes.

As in the Late Saxon and Anglo-Norman periods, the $\delta^{13}C$ and $\delta^{15}N$ for most males but also a majority of females fall above the maximum expected terrestrial carnivore range. However, as noted above, there is a major change in the distribution and range of female values, which are far more dispersed than in previous periods and substantially overlap with the male values. Only three males have combined $\delta^{13}C$ and $\delta^{15}N$ beyond the female 95% ellipse.

The change in the number of females with $\delta^{13}C$ and $\delta^{15}N$ indicative of intensive marine fish consumption from the Anglo-Norman to Medieval period indicates that by the late 12th-late 15th centuries, fish were available to both sexes in port towns.

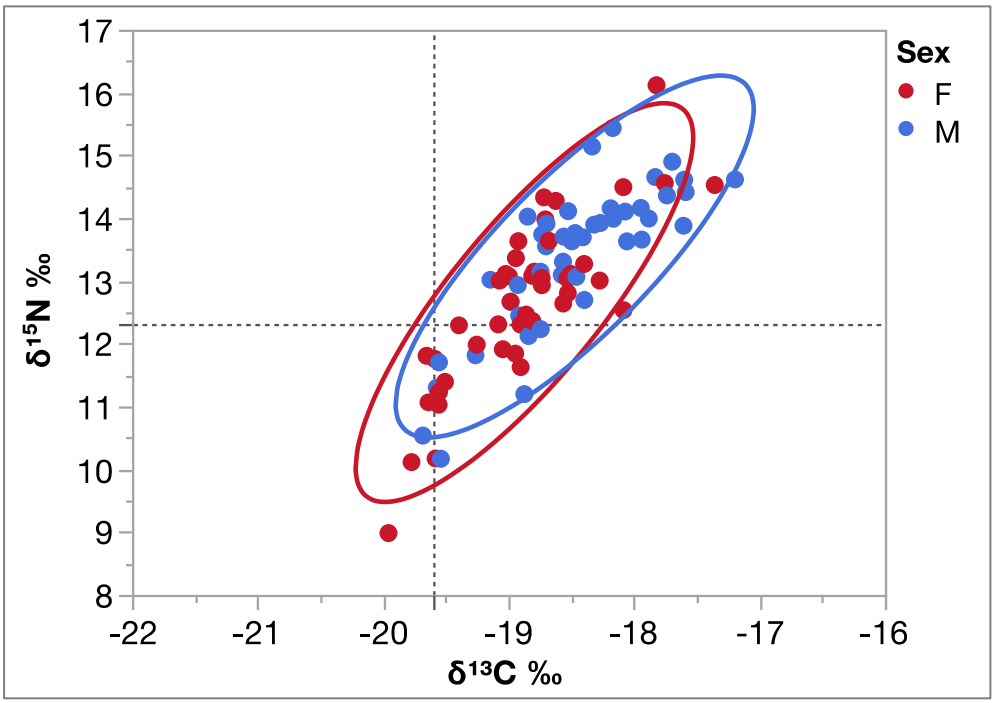


Figure 7.15. Medieval adult male and female $\delta^{13}C$ and $\delta^{15}N$, with 95% density ellipses around each group. Dotted grey lines: maximum expected terrestrial carnivore ranges.

With women moving to urban areas in increasing numbers to participate in the workforce (Lewis 2016), it is not necessarily surprising that the diets of at least some women would also begin to resemble those of men (at least isotopically). In Chapter 6, the high isotopic values for Anglo-Norman males, and their distinction from the female values, were interpreted as evidence for men's participation in the fishing and seafaring trades. However, it is unlikely that women would have been directly taking part in seafaring, so another cause for the overlap in Medieval male and female values must be sought.

It is important to note that the three females with $\delta^{13}C$ and $\delta^{15}N$ in or beyond the upper reaches of the male density ellipse are outliers, and that most females cluster more densely in the same general range as the Anglo-Norman females. This suggests that most females consumed either less marine fish overall than males, or that they consumed less of the high trophic level fish such as gadids (Müldner 2016). A potential explanation for the range in female values

could be that during this period, factors other than sex, such as status, were the primary characteristics defining diet at Stoke Quay.

Adult diet and status

The wide ranges in both male and female $\delta^{13}C$ and $\delta^{15}N$ and the presence of some females in the group of individuals consuming the most fish indicates that factors such as status may have influenced diet at Medieval Stoke Quay.

Despite the presumed low to middling status of this population, the church of St. Augustine was remodelled during the Medieval period, so the parish must have had some wealthier patrons to help pay for the work (Breen, in press). Furthermore, the Medieval burials at Stoke Quay provide evidence for differentiation in manner and location of burial. As described in Section 7.3.1, 18 burials were recovered from within the church (Cemetery Group 2A), a location normally reserved for the elite. As another indicator of status, the burials inside the church were almost all in coffins, as opposed to burials near the southern cemetery boundary, which were primarily without coffins (Teague, in press).

To investigate potential relationships between diet and status, the Medieval adult $\delta^{13}C$ and $\delta^{15}N$ are compared by Cemetery Group in Figure 7.16a,b. There are statistically significant differences for $\delta^{15}N$ ($p = 0.0079$, ANOVA) but not for $\delta^{13}C$ ($p = 0.1163$, ANOVA).

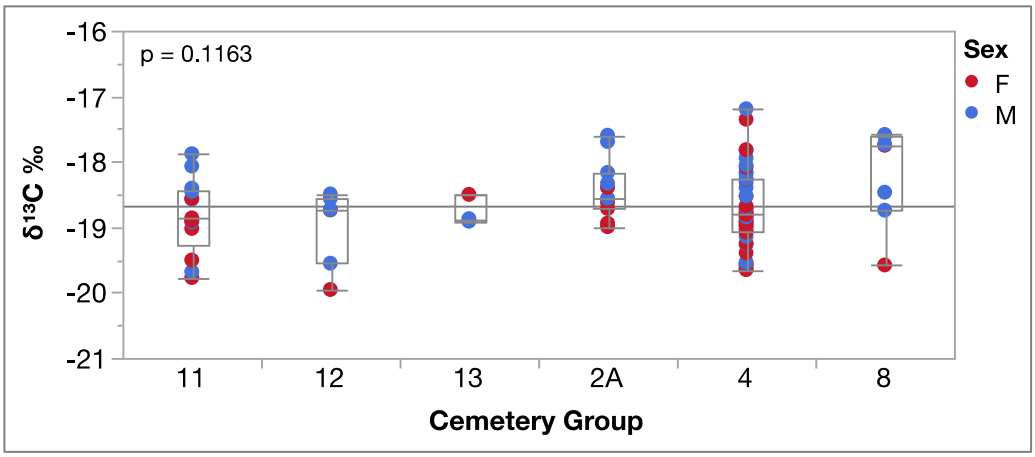


Figure 7.16a. Boxplots of $\delta^{13}C$ by Cemetery Group for Medieval Stoke Quay adults (n = 89), with no statistically significant differences between groups (ANOVA, p = 0.1163). Grey line: group mean.

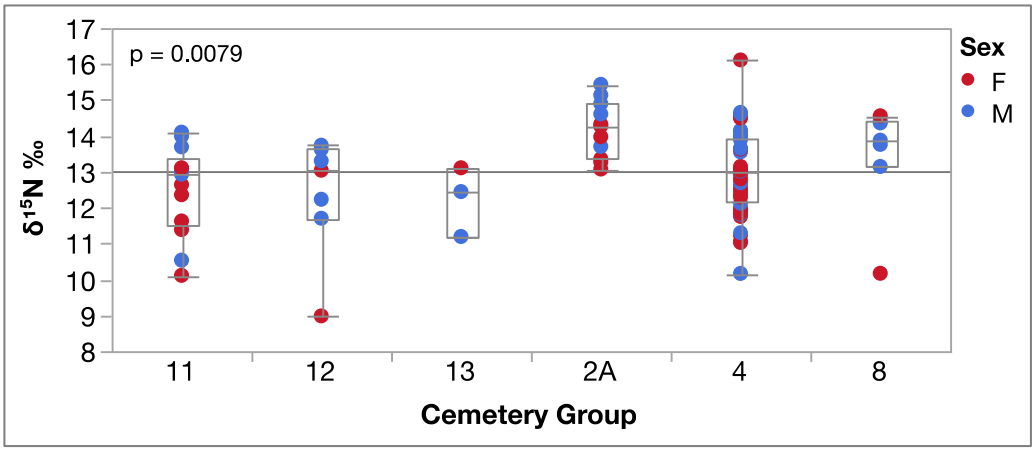


Figure 7.16b. Boxplots of $\delta^{15}N$ by Cemetery Group for Medieval Stoke Quay adults (n = 89), with statistically significant differences (p = 0.0079, ANOVA). Means comparisons show significant differences between group 2A and groups 11 (p = 0.0149) and 4 (p = 0.0142; Steel-Dwass). Grey line: group mean.

Cemetery Group 2A (individuals buried within the church) exhibits the highest mean $\delta^{15}N$, with all values falling above the overall sample mean. A means comparison (Steel-Dwass, nonparametric) shows $\delta^{15}N$ differences between Cemetery Group 2A and Cemetery Group 11 (p = 0.0149), which includes graves clustered near to and later than the first southern cemetery ditch (12^{th}-14^{th} centuries; Brown, in press). Statistically significant differences are also present between Cemetery Group 2A and Cemetery Group 4 (p = 0.0142), the

main group mostly located to the south of the church and containing the largest number of individuals (n = 156; 13th-15th centuries).

It would thus appear that, while there is overlap in isotopic values amongst the burial groups, the more elite individuals (as indicated by burial in coffins inside the church of St. Augustine) exhibit statistically significantly higher $\delta^{13}C$ and $\delta^{15}N$, indicating a status-based difference in diet at Stoke Quay during this time. Additionally, with consistently high $\delta^{15}N$ values but variable $\delta^{13}C$ values in the 2A group, it may be the case that some of these elite individuals were consuming freshwater fish, which would result in high $\delta^{15}N$ but lower $\delta^{13}C$ than would be expected for a diet high in marine fish.

Comparative assemblages

In addition to potential differences in the consumption of higher trophic level fish by age group or sex, another primary research question for this chapter is how diet at Medieval Stoke Quay compares to contemporary urban sites engaged in trade by land and sea. In this section, the adult dietary isotopes are compared with contemporary assemblages from St. Andrew's, Fishergate in York, and St. Mary Spital in London, both located in non-prosperous neighbourhoods. Osteological reports have also been published for these assemblages, so health at these sites can be compared as well. Palaeopathological comparisons between sites are shown following the isotopic comparisons.

As the largest urban centre in later medieval England, London provides a suitable comparison for Stoke Quay. The samples considered here are from St Mary Spital, an Augustinian priory and hospital in east London in use from c. 1120-1539 AD. As a hospital, the population buried at St Mary Spital is biased

towards the lower classes and the sick. Excavations at the site from 1999-2002 revealed over 10,500 individuals, of which nearly 4,000 were interred in mass burials. Osteological analysis was conducted on a sample of 5387 individuals (Connell et al. 2012). A sample of 127 individuals have been analysed for $\delta^{13}C$ and $\delta^{15}N$, including 97 adults from the late 12th-16th centuries (Walter 2017).

As a town of similar importance to Ipswich (Dyer 2000), York is another natural comparison for Stoke Quay. In Chapter 6, Fishergate, York provided a comparative assemblage for Stoke Quay Anglo-Norman dietary isotope results (Section 6.5.1), so a comparison of samples from the subsequent period might indicate temporal trends in urbanisation and diet at both sites. The 154 adult comparative samples derive from 13th-early 16th century St. Andrew, Fishergate, a Gilbertine priory cemetery that appears to have included both lay burials and members of the monastic community (Müldner & Richards 2007).

The comparative adult $\delta^{13}C$ and $\delta^{15}N$ are plotted with the Stoke Quay adults in Figures 7.17a,b, with statistically significant differences for both $\delta^{13}C$ ($p < 0.0001$) and $\delta^{15}N$ ($p = 0.0133$, ANOVA). Means comparisons show highly statistically significant differences in $\delta^{13}C$ between Stoke Quay and both sites ($p < 0.0001$ for both sites, Steel-Dwass). Stoke Quay has the highest $\delta^{15}N$ mean and highest values, but statistically significant differences are only observed between Stoke Quay and St Mary Spital ($p = 0.0042$, Steel-Dwass)(Table 7.9).

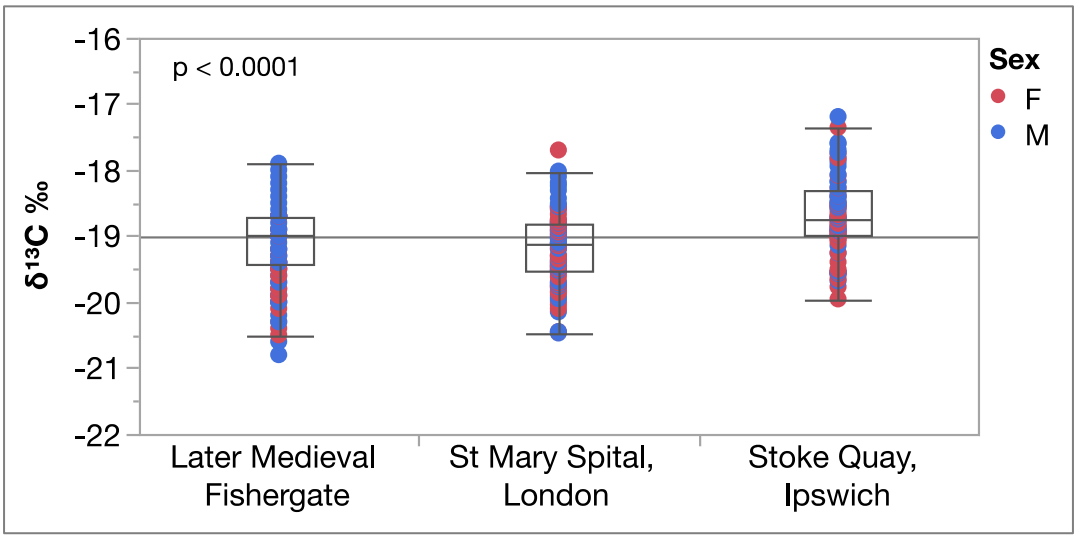


Figure 7.17a. Comparative site $\delta^{13}C$, with significant differences ($p < 0.0001$, ANOVA). Means comparisons show significant differences between Stoke Quay and Fishergate, York ($p < 0.0001$), and St. Mary Spital, London ($p < 0.0001$, Steel-Dwass). Grey line: group mean.

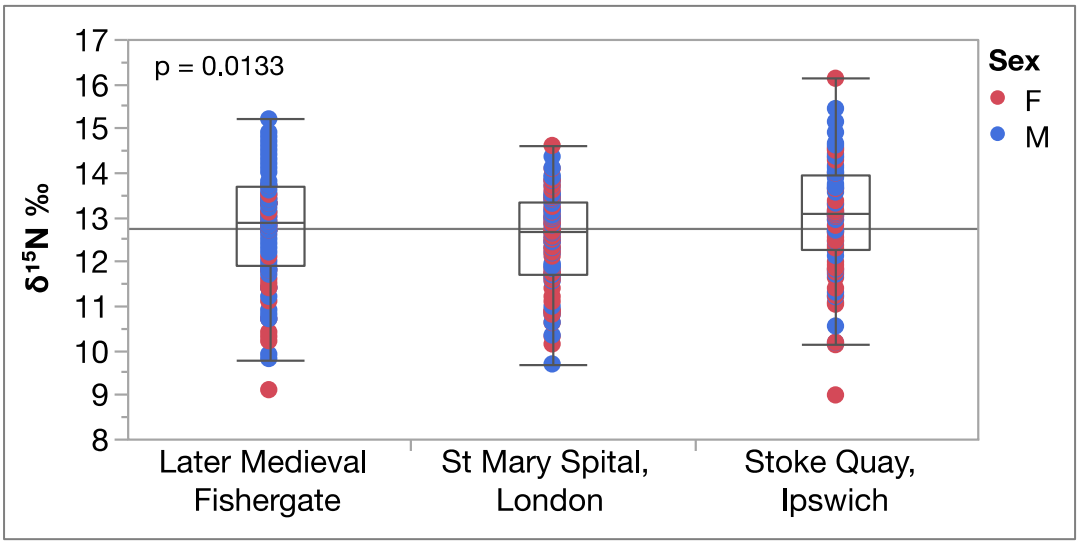


Figure 7.17b. Comparative site $\delta^{15}N$, with significant differences ($p = 0.0133$, ANOVA). Means comparisons only show significant differences between Stoke Quay and St. Mary Spital, London ($p = 0.0042$, Steel-Dwass).

Site	n	Mean $\delta^{15}N$	1σ	Min	Max	Mean $\delta^{13}C$	1σ	Min	Max
Fishergate	154	12.7	1.2	9.1	15.2	-19.1	0.6	-20.8	-17.9
St Mary Spital	97	12.5	1.1	9.7	14.6	-19.2	0.5	-20.5	-17.7
Stoke Quay	89	13.0	1.3	9.0	16.1	-18.7	0.6	-20.0	-17.2

Table 7.9. Summary statistics for adult $\delta^{13}C$ and $\delta^{15}N$ at Stoke Quay, St. Andrew's Fishergate, York, and St. Mary Spital, London.

These results indicate that overall, Stoke Quay adults consumed significantly higher proportions of marine fish than their contemporaries in

London and York. The trophic levels of marine fish eaten at Stoke Quay appear to have varied most, with a $\delta^{15}N$ range of 7.1‰ compared to narrower ranges of 6.1‰ at Fishergate and only 4.9‰ at St Mary Spital. However, the $\delta^{13}C$ ranges were very similar across all three sites, at 2.8-2.9‰. Therefore, while all three sites were engaged in international trade, and London had by this time gained primacy as a centre of trade and commerce (Britnell 2008; Kowaleski 2008), it appears that fish were not as central to urban diets at these other sites as they were at Stoke Quay. This would support the hypothesis that the members of St Augustine's parish, Ipswich, were taking part directly in the fishing industry.

Comparative health

Ipswich was urban environment by the medieval period, but evidence is sparse regarding the degree of urbanisation in the parish of St Augustine's. Given the association between urban living environments and the health issues described in Section 7.2 and previous chapters, indicators of urban living environments are compared between Medieval Stoke Quay and contemporary urban sites (Table 7.10). Crude prevalence rates (CPR; number of individuals with the pathology out of the total number of individuals) at Medieval Stoke Quay (Loe et al., in press) are compared to those from St. Andrew's, Fishergate, York, and St. Mary Spital, London, as well as mean CPR from later Medieval Britain, compiled by Roberts and Cox (2003).

As shown in the table, the Medieval Stoke Quay assemblage has much higher rates of periostitis and cribra orbitalia compared to both St. Mary Spital and St. Andrew's Fishergate. While the total CPR of maxillary sinusitis at Stoke Quay is lower than the contemporary British mean, the adult CPR at Stoke Quay

is higher than the contemporary British average. Furthermore, the total CPR for tuberculosis at Stoke Quay is lower than many other sites, but the rate for the Medieval Stoke Quay assemblage is much higher than elsewhere.

Pathology	Medieval Stoke Quay, Ipswich[1]	St. Andrew's, Fishergate, York[2]	St. Mary Spital, London[2]	Survey[2] of late medieval sites (# of sites)
Maxillary sinusitis	Total: 10.8% (28/259) Adults: 15.1% (28/185) Males: 12.9% (11/85) Females: 18.7% (17/91)	-	-	13.3% (276/2076) (9 sites)
Periostitis	Total: 51% (132/259) Adults: 62.7% (117/185) Males: 63.5% (54/85) Females: 61.5% (56/91)	24% (59/402)	44.1% (30/126)	14.1% (631/4479) (16 sites)
Cribra orbitalia	Total: 55.2% (143/259) Adults: 58.9% (109/185) Males: 62.4% (53/85) Females: 59.3% (54/91)	6.7% (27/402)	28.6% (36/126)	10.8% (640/5752) (33 sites)
Tuberculosis	All periods: 1.7% (19/1142) Medieval: 4.6% (12/259)	1.5% (6/402)	-	0.9% (60/6796) (15 sites)

Table 7.10. Crude prevalence rates (CPR) for pathologies related to living environment at Medieval Stoke Quay and comparative sites. [1] Loe et al., in press, Appendix 5; [2]Roberts & Cox 2003 (Fishergate: Stroud & Kemp 1993; St Mary Spital: Conheeney 1992).

Taken together, the high rates of pathological lesions at Stoke Quay suggest that this population lived in crowded, unhealthy conditions, typical of a fully urbanised environment. Yet, because they survived long enough to develop skeletal indicators of these pathologies, the inhabitants of St Augustine's parish may have actually been more robust than many of their contemporaries, possibly due to a diet high in marine fish.

Given the association between adequate nutrition and final achieved height (Waldron 2009; Roberts & Manchester 2010), the relationship between diet and health at Stoke Quay may be clarified somewhat by comparing mean

estimated adult stature at Medieval Stoke Quay to means for later medieval British sites (Roberts & Cox 2003).

As shown in Table 7.11, mean female and male stature at Stoke Quay are slightly above average for this period. As in the previous period, the range of stature for both sexes at Stoke Quay is broader than the mean range for Britain. This is particularly evident for Stoke Quay males, with a maximum estimated stature over 10cm above the maximum mean stature for Britain. The male minimum estimated stature is also almost 10cm below the minimum mean for Britain, indicating a wide range of male stature at Stoke Quay. Some of this variation could be due to the presence of foreigners in the Stoke Quay population, addressed in the following section.

Sex	Medieval Stoke Quay		Late Medieval Britain[1]			
	mean (cm)	range (cm)	mean (cm)	mean range (cm)	# of sites	n
Female	159.7	149.2-172.4	159	154-165	7929	26
Male	172.0	158.2-184.9	171	167-174	8494	34

Table 7.11. Mean female and male stature at Medieval Stoke Quay and for late medieval British sites. [1] Roberts & Cox 2003.

7.5.2 Evidence for mobility

As discussed in Chapter 3 (Section 3.4), interpretations of mobility in this thesis are based on the expected 'local' bioavailable $^{87}Sr/^{86}Sr$ range of 0.709-0.710 (Evans et al. 2010), and the English 'low rainfall' $\delta^{18}O_P$ range of 15.9-18.5‰ (Evans et al. 2012). Individuals with results outside of one or both ranges are interpreted as 'Nonlocals'.

Tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis was performed on 18 individuals from the Medieval skeletal assemblage (see Section 7.3.3, 7.4.2). The

$^{87}Sr/^{86}Sr$ results (n = 18) are shown in Figure 7.18 with the expected local bioavailable $^{87}Sr/^{86}Sr$ range. Four individuals fall outside this range.

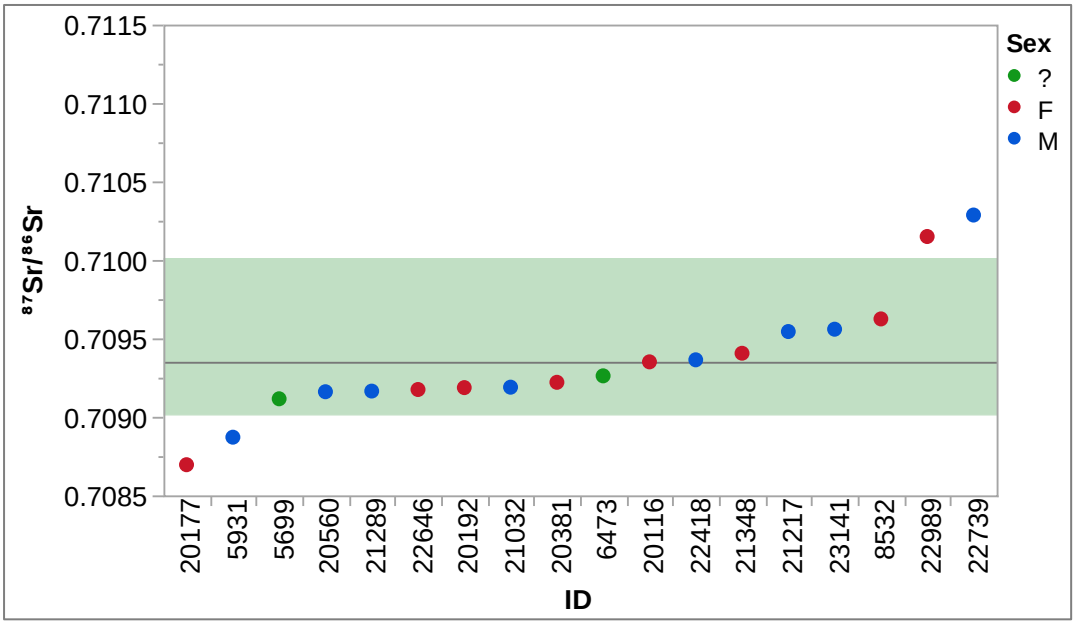


Figure 7.18. Medieval Stoke Quay $^{87}Sr/^{86}Sr$ results. Green band shows the expected local bioavailable $^{87}Sr/^{86}Sr$ range (Evans et al. 2010); grey line shows group mean.

The $^{87}Sr/^{86}Sr$ and calculated $\delta^{18}O_P$ values for individuals yielding results for both isotopic systems are shown in Figure 7.19 (n = 14; see Chapter 2, Section 2.3.3 for issues with $\delta^{18}O$ analysis), along with the expected 'local' ranges for both isotopes.

As shown in Figure 7.19, of the 15 individuals yielding results for both isotopic systems, the paired $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ values for 11 individuals fall within the combined expected local range, and four have values outside of the expected local ranges. In combination with the $^{87}Sr/^{86}Sr$ results for individuals that did not yield $\delta^{18}O_P$, five individuals are interpreted as 'Nonlocals', and include two females and three males. Individual interpretations are shown in Table 7.12.

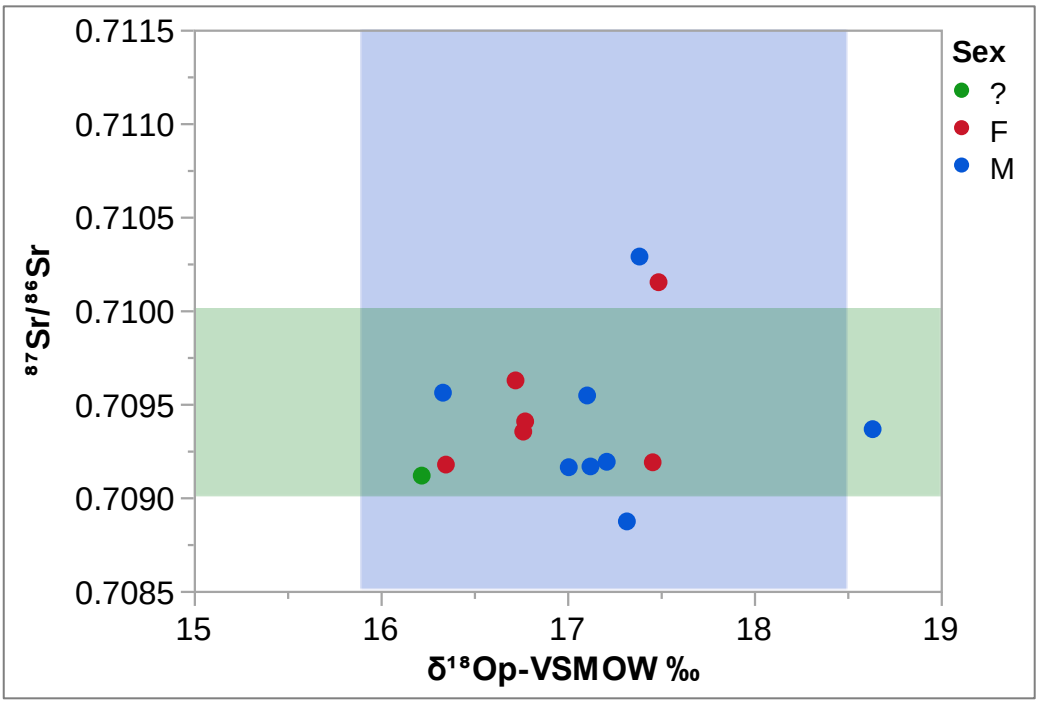


Figure 7.19. Medieval Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results. Expected local ranges shown in green ($^{87}Sr/^{86}Sr$, Evans et al. 2010) and blue ($\delta^{18}O_P$, Evans et al. 2012).

Sk ID	Age	Sex	Reason for Selection	Cemetery Group	Interpretation: $^{87}Sr/^{86}Sr$	Interpretation: $\delta^{18}O$
5699	13-17	?	Unusual diet	4	Local	Local
*5931	18-25	M	-	11	Nonlocal	Local
6473	06-12	?	Unusual diet	11	Local	-
*8532	26-35	F	Pathology (TB)	4	Local	Local
20116	36-45	F	Unusual diet	4	Local	Local
20177	18-25	F	Unusual diet	12	Nonlocal	-
20192	45+	F	Average diet	11	Local	Local
20381	26-35	F	Pathology (TB)	11	Local	-
20560	45+	M	Average diet	8	Local	Local
21032	26-35	M	Unusual diet	2A	Local	Local
*21217	36-45	M	Ancestry	11	Local	Local
*21289	60+	M	Trauma	2A	Local	Local
*21348	18+	F	-	4	Local	Local
22418	26-35	M	Trauma	4	Local	Nonlocal
22646	18-25	F	Average diet	4	Local	Local
*22739	45+	M	Trauma	4	Nonlocal	Local
*22989	26-35	F	Path (TB), ancestry	4	Nonlocal	Local
23141	45+	M	Unusual diet	8	Local	Local

Table 7.12. Medieval Stoke Quay $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ interpretations with demographic information and reason for selection (n = 18). *Included in the pilot study.

Looking at the interpretations more closely, the two subadults aged 6-12 and 13-17 years are both interpreted as 'Locals'. The 6-12 year old, Sk 6473, is

discussed earlier in this chapter and has the lowest $\delta^{13}C$ and $\delta^{15}N$ of the subadult group. The 'local' interpretation based on $^{87}Sr/^{86}Sr$ supports the argument put forth above that ill health, possibly in combination with poor diet, affected this child's $\delta^{13}C$ and $\delta^{15}N$, rather than for example, migration from an inland location.

Two of the three individuals selected for analysis because of skeletal trauma are interpreted as 'Nonlocals', whereas only one of the three individuals chosen for skeletal evidence of tuberculosis is interpreted as 'Nonlocal.' Six individuals were selected because of atypical $\delta^{13}C$ and $\delta^{15}N$, and of these, only one is interpreted as 'nonlocal.' It therefore appears that, proportionally, trauma is a more indicative of 'nonlocal' origins than these other methods used to predict mobility in this period. Trauma is discussed in further detail below.

The sample size for the interpreted 'Nonlocal' group is too small for reliable Chi Square tests, but Table 7.13 shows the percentage of individuals for the 'local' and 'nonlocal' groups with skeletal evidence of maxillary sinusitis, *cribra orbitalia*, periostitis, infectious disease, and trauma. There are some differences between the percentages of 'locals' and 'nonlocals' with each type of pathology, but the largest difference is for *cribra orbitalia*, which is present in 5/5 'nonlocals' (100%) and 9/13 'locals' (69.2%). However, both groups show high frequencies of these lesions, and as shown in Table 7.10, more than half of the Medieval Stoke Quay assemblage has this pathology.

Pathology	Locals (% of total)	Comparison	Nonlocals (% of total)
Maxillary sinusitis	3/13 (23.1%)	>	1/5 (20%)
Cribra orbitalia	9/13 (69.2%)	<	5/5 (100%)
Periostitis	9/13 (69.2%)	>	3/5 (60%)
Trauma	4/13 (30.8%)	<	2/5 (40%)
Infectious disease	2/13 (15.4%)	<	1/5 (20%)

Table 7.13. Comparison of percentages of Medieval 'locals' and 'nonlocals' with skeletal evidence for pathology and trauma.

As discussed in Section 7.2, historical records for Medieval Ipswich show that interpersonal violence was widespread and could be deadly. One guiding question for this chapter's analyses was whether violence against foreigners is evident in this period at Stoke Quay. As noted above, three individuals were selected for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis specifically because of trauma, and a total of six individuals have some sort of skeletal trauma, described in Table 7.14.

Sk ID	Local/Nonlocal	Age	Sex	Trauma
21348	Local	18+	F	Healed fractured TV8 (possible compression fracture)
20560	Local	45+	M	Healed transverse fractures on 2 L ribs at midshaft
21217	Local	36-45	M	Healed fractures to R scapula acromial process, R clavicle lateral end (ununited), L tibia distal shaft, L medial cuneiform
21289	Local	60+	M	Perimortem sharp-force trauma to cranium, 3 R ribs (possible stab wounds); entire spine sliced through (possible early post-mortem anatomisation)
20177	Nonlocal	18-25	F	Possible healed L talus fracture
22418	Nonlocal	26-35	M	Perimortem blunt force trauma to R parietal (possible stellate fracture)

Table 7.14. 'Local' and 'nonlocal' trauma and demographics at Medieval Stoke Quay.

The perimortem injuries in the group speak to the sometimes-violent nature of life at medieval Ipswich, and involve one individual (Sk 21289) interpreted as 'local' and one (Sk 22418) interpreted as 'nonlocal.' Sk 22418, a male aged 26-35 years whose combination of high $\delta^{18}O$ and 'local' $^{87}Sr/^{86}Sr$ is not likely to be found in Britain (Evans et al. 2018), has perimortem blunt-force trauma to the right parietal. The force of this trauma resulted in a radiating (stellate) fracture to the cranium, and the lack of healing to the wound indicates that this occurred around the time of death. Given the force of the trauma, and the fact that the head is the region most commonly targeted in violent assaults (Brickley & Smith 2006), it is likely that this man suffered a violent death.

A more gruesome end was met by Sk 21289, a Caucasoid male estimated to be over 60 years old at the time of his death, radiocarbon dated to 1245-1400 cal AD at 95.4% confidence (SUERC-59359, 31% marine correction ±10%). This was likely a man of high status, buried in an important position beneath the church nave (Teague, in press; Figure 7.20). In addition to Paget's disease, which causes thickened bones (which may not have been outwardly visible), this man had numerous perimortem sharp-force injuries including at least three fully penetrating blade wounds through his frontal and right parietal, three v-shaped notches (likely penetrating wounds) to the top of the cranium, and three right ribs with cut marks possibly caused by stabbing (Loe et al., in press).

Likely shortly after death, this man's entire spine from cervical vertebrae to sacrum was sliced longitudinally from behind. These injury patterns were interpreted as consistent with post-mortem anatomisation to access the internal structures of the spine following a possibly violent death (Loe et al., in press, Ch. 6). No contemporary parallels of this type of dissection have been found, so this case is seemingly unique.



Figure 7.20. Photograph of grave 21287 with Sk 21289, a 60+ year-old male buried in the nave of the church with extensive perimortem sharp-force injuries. From Teague, in press, Figure 3.59.

The two cases of perimortem trauma discussed here are indications that Medieval Ipswich was violent, and that this violence reached St Augustine's. This is supported by the observation that nearly 20% of the trauma in the Stoke Quay assemblage was potentially the result of violence, indicated by multiple injuries to anatomically unrelated elements in the skeleton (Loe et al., in press; Judd 2002). The skeletal evidence at Stoke Quay, in addition to the historical examples discussed in Section 7.2, indicate that 'nonlocals' may have faced significant prejudice and even assault, particularly toward the end of the medieval period, but that violence was not necessarily isolated to foreigners at Ipswich.

7.6 Conclusions

As shown in the preceding sections, the late 12th-15th centuries were a time of instability and profound changes in English demographics, health, mobility, and trade. The productivity of the previous period led to crowded urban areas and a larger population, which exacerbated the effects of crop failures, animal moraines, and epidemic diseases. Urban centres such as London and Norwich grew, while others went into sharp decline or disappeared entirely.

During the same period, many rural settlements were abandoned due to changes in climate that affected agriculture and animal husbandry, and the epidemics that swept through the country. Rural folk looking for employment in urban areas would have benefitted from the availability of work, but movement to towns also brought increased risk of disease from pathogens to which rural people had no immunity (Dyer 2000; Roberts & Cox 2003). Urban environments also presented dangers in the form of pollution, accidental injuries, and violence—particularly against foreigners (Kowaleski 2008).

Along with changes in public health and demographics, diet was also changing. The booming fishing trade, which had previously been dominated by the herring fishery, was expanding to encompass deep-sea fish such as cod and other gadids, many of which were fished in distant seas (Kowaleski 2008, 2016). The increasing stockfish trade and active market economy resulted in wider access to foods previously only available to elites, including offshore fish and imported foods from the Continent and beyond.

The isotopic analyses presented this chapter demonstrate the degree to which Medieval Ipswich had become urbanised, as well as its complex social and economic environment. Children who died young may have been predisposed to ill health due to poor diets, while adolescents may have had more 'adult' diets through their apprenticeships. In contrast to the previous period at Stoke Quay, and to contemporary English sites, female diet at Stoke Quay varied widely, with many consuming large amounts of marine fish that included gadids and other high trophic level species. Men at Stoke Quay also consumed a high proportion of marine foods, in most cases higher than local females and also above the levels seen at contemporary Fishergate, York and St Mary Spital, London.

From the small sample of individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, and from the documentary evidence, it is apparent that migration to Ipswich was not uncommon during this period. Males and females of different ages were among those raised outside Ipswich, and the number of interpreted 'nonlocals' (28%) in a relatively small sample indicates that a sizeable proportion of St Augustine's parish may have been foreigners. Some of these nonlocals appear to have suffered violent ends, highlighting the perils that many foreigners faced as the journeyed to urban areas in search of employment.

Chapter 8: Temporal trends in diet, mobility, and health at Stoke Quay

8.1 Introduction

The skeletal assemblage from Stoke Quay, Ipswich, spans approximately 900 years, and thus provides a rare opportunity to evaluate long-term trends in diet, mobility, and health in a single location. Moreover, the location is of prime importance to our understanding of urbanisation in England, the growth and strengthening of overseas trade networks, and the impact of marine resources on medieval diet and health.

Each of the preceding chapters have explored specific periods within this timespan, focusing on three main issues: 1) diet, as revealed through bone collagen $\delta^{13}C$ and $\delta^{15}N$, 2) health and disease, as observed through osteological evaluations of pathological lesions and trauma, and 3) mobility, as interpreted from tooth enamel $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$. This chapter takes a more synthetic approach, comparing the results across all periods represented in this thesis to evaluate how diet, health, and mobility changed over time at Stoke Quay. The observations generated by these comparisons reflect the character and growth of Ipswich as well as the processes of urbanisation and trade development in England and Western Europe.

8.2 Fish and access to food at Mid Saxon to Medieval Stoke Quay

As discussed in Chapter 1, a primary focus of this thesis is the timing and extent of the 'fish event' at Ipswich. This study is the first of its kind to evaluate the impact of marine fish on a medieval port town, and includes the largest sample size for isotopic analysis of any single site in Britain. The long duration of

burial at Stoke Quay makes it an ideal assemblage for this purpose. Comparing the $\delta^{13}C$ and $\delta^{15}N$ values for each time period illustrates how and when marine fish began to be heavily exploited in this important port.

8.2.1 The timing of the 'Fish Event' at Stoke Quay

Each previous chapter approached the timing of the 'fish event' from specific periods, while this section compares the results across periods to obtain a more holistic view of changing habits of fish consumption at Stoke Quay.

As discussed in Chapter 3, Section 3.3.5, the mean $\delta^{13}C$ and $\delta^{15}N$ for the Mid Saxon faunal assemblage were shown to be statistically significantly different than the means from the Late Saxon, Anglo-Norman, and Medieval fauna. For this reason, two separate faunal baselines were created, one for the Mid Saxon period and one for the remaining periods. The expected terrestrial carnivore range during the Mid Saxon period was thus estimated at -20‰ to -19‰ for $\delta^{13}C$, and 11.1‰ to 13.1‰ for $\delta^{15}N$, while for the remaining periods it was estimated at -20.6‰ to -19.6‰ for $\delta^{13}C$ and 10.3‰ to 12.3‰ for $\delta^{15}N$. Any individuals with $\delta^{13}C$ and $\delta^{15}N$ above these ranges are interpreted as likely consumers of marine fish, with more intensive or higher trophic level fish consumption inferred from higher isotopic values.

The human $\delta^{13}C$ and $\delta^{15}N$ values for each time period are presented in Figures 8.1a and 8.1b, along with the expected terrestrial carnivore ranges. Because of the difference between the faunal baselines at Mid Saxon Stoke Quay and the later periods at the site, the Mid Saxon humans are graphed separately. The Mid Saxon group shows a markedly different level of marine fish consumption from the other groups. While the Mid Saxon assemblage is by far

the smallest, c. 10% the size of the other groups, all 10 samples fall within or below the expected terrestrial carnivore $\delta^{13}C$ range. Occasional consumption of marine or freshwater fish by this group would not be visible isotopically due to blending effects from lengthy bone collagen turnover times (Hedges et al. 2007), but it is nevertheless unlikely that this group regularly consumed marine fish.

The Late Saxon group includes a large number of individuals with $\delta^{13}C$ and $\delta^{15}N$ above the modelled terrestrial carnivore range, though there are also several individuals with $\delta^{15}N$ below the range. The terrestrial $\delta^{13}C$ values for this low-$\delta^{15}N$ group suggest that these individuals could have eaten negligible amounts of freshwater fish or terrestrial animal products, but consumption of marine fish is unlikely and their diets may have been largely plant-based. This group is mostly comprised of children, so it is possible that they largely consumed a typical post-weaning diet heavy in cereals, and this is explored further in Section 8.2.2 (Tsutaya 2017; Buikstra et al. 1986).

Notably, men dominate the highest values for both isotopes, indicating that a transition to greater fish consumption had occurred by the Late Saxon period. These results show that the typical diet at Ipswich underwent a major shift sometime between the early 8th century when Mid Saxon burial practice ceased, and the late 9th century, when Late Saxon cemetery burials began.

The dramatic shift from Mid Saxon to Late Saxon $\delta^{13}C$ and $\delta^{15}N$, and the presence of mostly males in the group with the highest values, indicate that the 'fish event' took place with at an early date at Ipswich. The fish event may have therefore begun at Stoke Quay as early as the late 9th century.

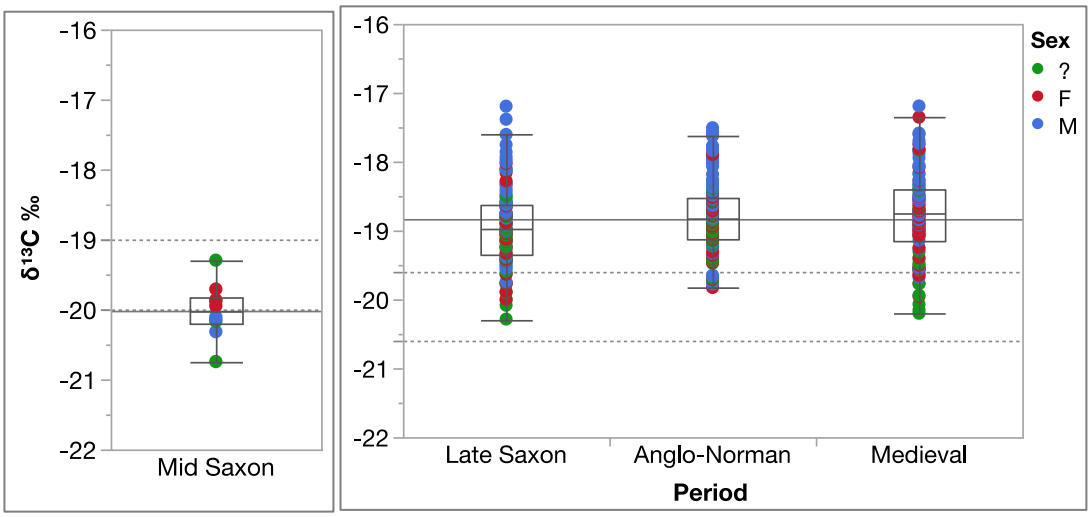


Figure 8.1a. Stoke Quay $\delta^{13}C$ boxplots by period. Dotted grey lines show the expected terrestrial carnivore range, and solid grey lines show the group mean.

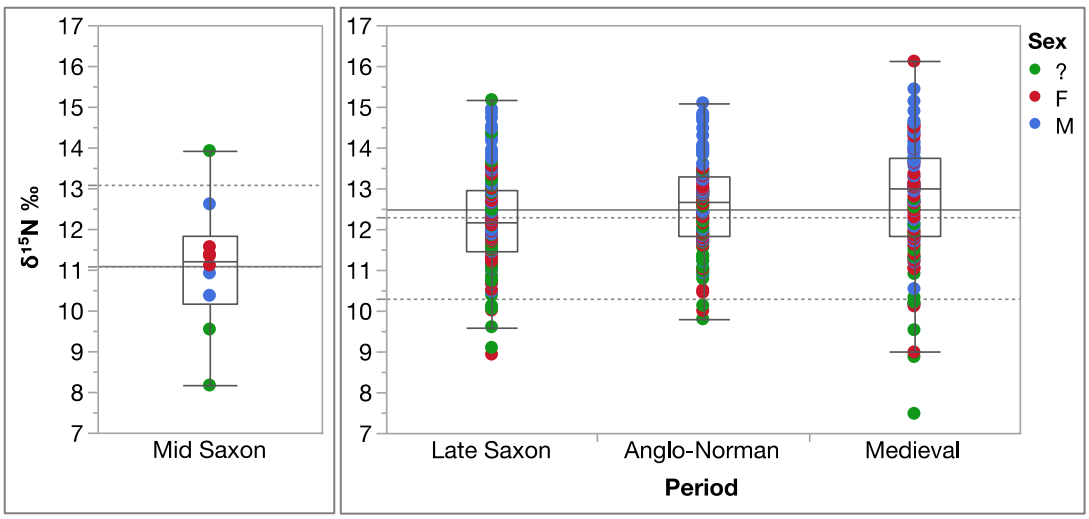


Figure 8.1b. Stoke Quay $\delta^{15}N$ boxplots by period. Dotted grey lines show the expected terrestrial carnivore range, and solid grey lines show the group mean.

The results shown in Figures 8.1a and 8.1b also suggest differential consumption of marine fish within the Stoke Quay population for each period. Late Saxon males comprise the majority of the group with isotopic values above the terrestrial carnivore range, which is particularly clear in the $\delta^{13}C$ results (Figure 8.1a). Values for Late Saxon females and subadults are generally more consistent with terrestrial omnivore diets, but a few individuals appear in the high $\delta^{13}C$ and $\delta^{15}N$ group. Sex-based differences in $\delta^{13}C$ and $\delta^{15}N$ are evaluated in the following section. Subadults are considered separately due to the known

effects of breastfeeding and rapid growth on the $\delta^{13}C$ and $\delta^{15}N$ of infants and young children (Fuller et al. 2006a; Jay 2009; Sandberg et al. 2014).

8.2.2 Differential consumption of marine fish

Another central question addressed in this thesis is whether differences in diet, particularly fish consumption, are evident between age groups and sexes at Stoke Quay. This question is addressed first for subadults, and then for adults. No subadults were present in the Mid Saxon skeletal assemblage, so the following discussion is restricted to the Late Saxon through Medieval periods.

Differential marine fish consumption in subadults

The subadult $\delta^{13}C$ and $\delta^{15}N$ for the Late Saxon to Medieval periods are presented in Figures 8.2a-c, with lines of best fit and associated p-values and r^2 values. Summary statistics are given in Table 8.1. There is only a 0.1‰ difference in mean $\delta^{13}C$ between periods, but the Medieval group has a lower mean $\delta^{15}N$, likely caused by the absence of young children aged 1-5 years in the sample.

Period	n	$\delta^{15}N$ mean	1σ	min	max	$\delta^{13}C$ mean	1σ	min	max
Late Saxon	37	11.8	1.3	9.1	15.2	-19.1	0.5	-20.3	-18.1
Anglo-Norman	37	11.9	0.9	9.8	13.8	-19.0	0.3	-19.7	-18.3
Medieval	18	11.1	1.5	7.5	13.0	-19.2	0.7	-20.2	-17.8

Table 8.1. $\delta^{13}C$ and $\delta^{15}N$ summary statistics for Stoke Quay subadults by period.

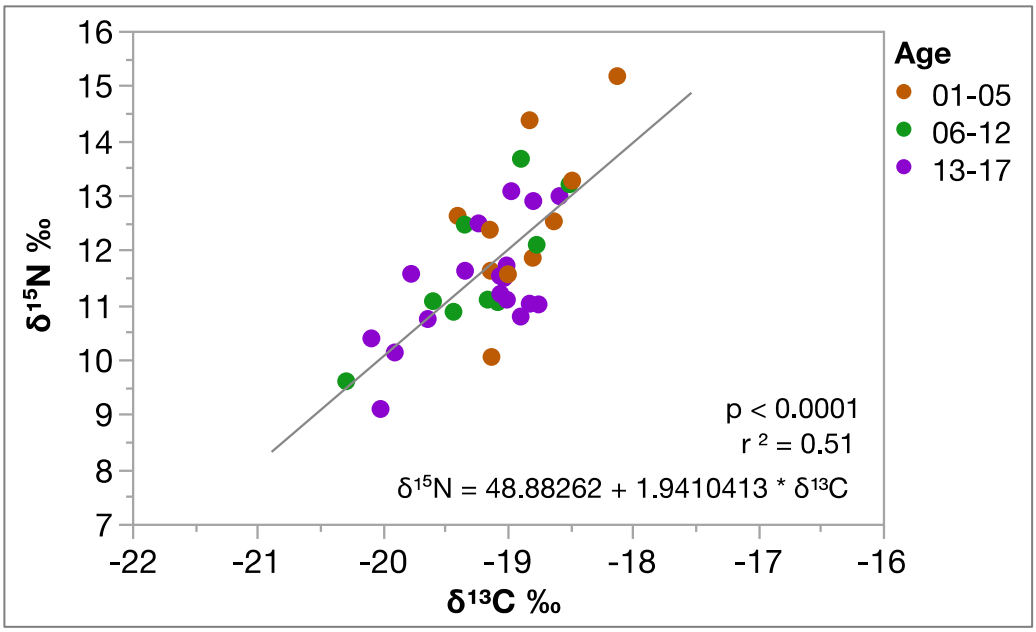


Figure 8.2a. Late Saxon subadult $\delta^{13}C$ and $\delta^{15}N$ coloured by age, with a line of best fit and basic statistics (n = 37).

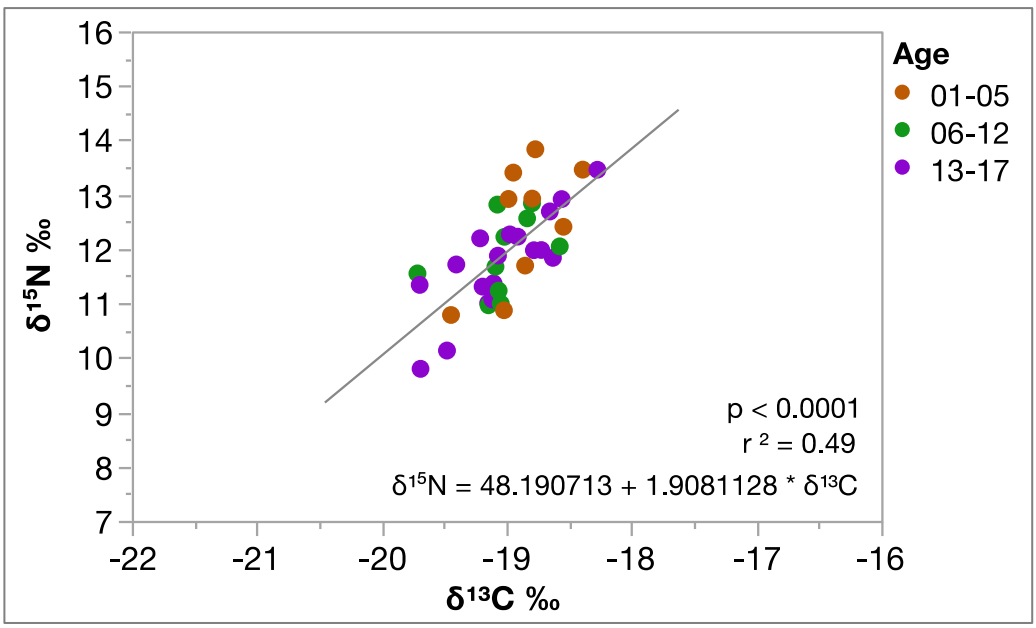


Figure 8.2b. Anglo-Norman subadult $\delta^{13}C$ and $\delta^{15}N$ coloured by age, with a line of best fit and basic statistics (n = 37).

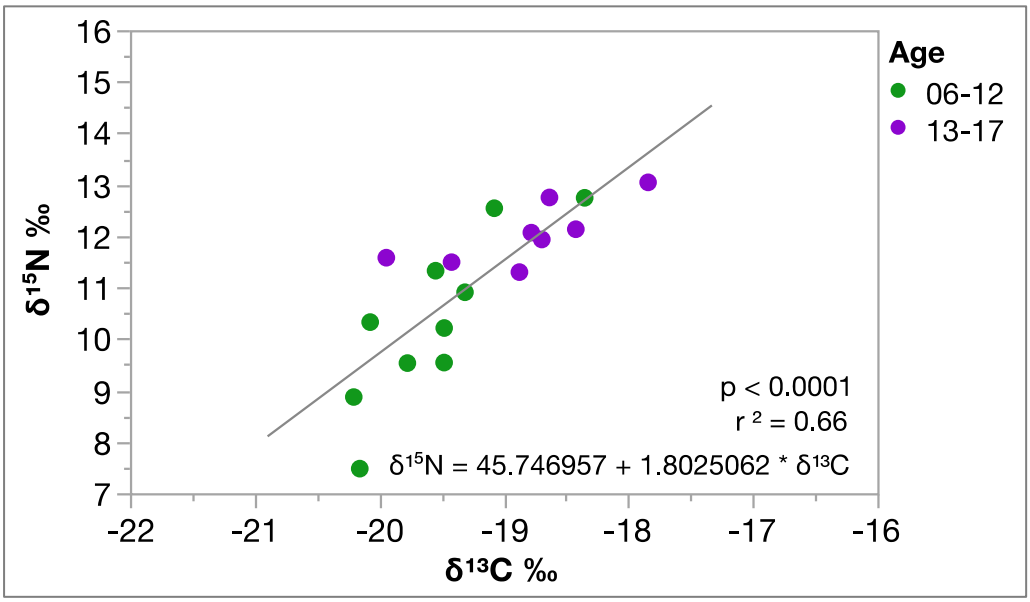


Figure 8.2c. Medieval subadult $\delta^{13}C$ and $\delta^{15}N$ coloured by age, with a line of best fit and basic statistics (n = 18).

When the young children (aged 1-5 years) are removed from the subadult dataset to eliminate any influence of breastfeeding signals, there are no statistically significant differences over time, suggesting that overall, childhood diet did not change substantially between the Late Saxon and Medieval periods (Figures 8.3a,b). However, the predominance of older children in the lower $\delta^{15}N$ range for the Medieval group (Fig 8.3b) warrants further study.

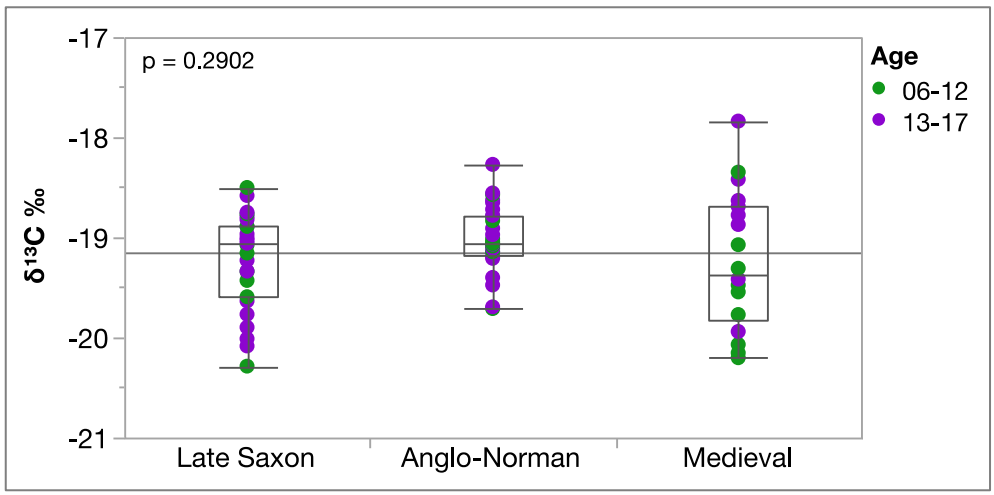


Figure 8.3a. $\delta^{13}C$ by period for Stoke Quay children (6-12 years) and adolescents (13-17 years), with no statistically significant differences (p = 0.2902, ANOVA).

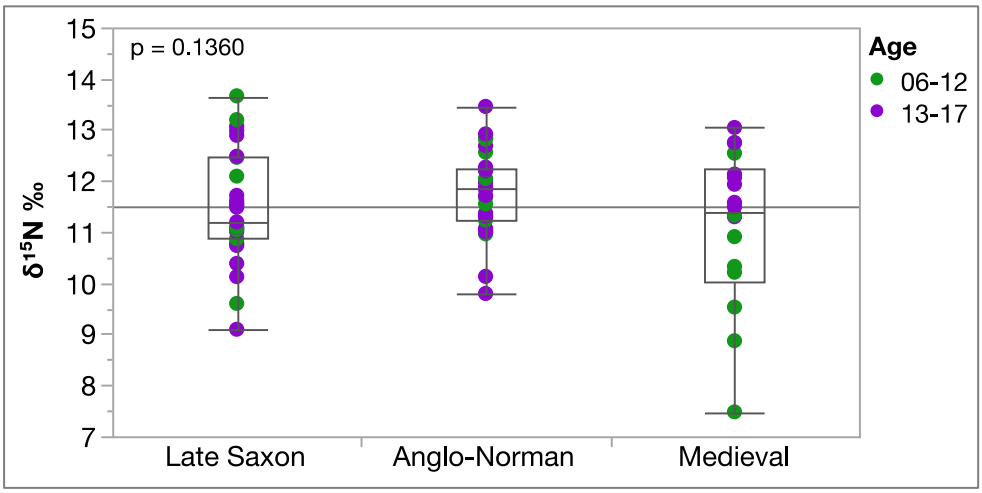


Figure 8.3b. $\delta^{15}N$ by period for Stoke Quay older children (6-12 years) and adolescents (13-17 years), with no statistically significant differences (p = 0.1360, ANOVA).

Looking at the 6-12 year-old $\delta^{15}N$ more closely, nearly all Medieval 6-12 year-olds yield $\delta^{15}N$ below their Anglo-Norman peers, with significant differences between groups (Figure 8.4). These results may suggest that those who died during older childhood in the Medieval period consumed less protein than their peers from other periods, and this diet may have contributed to poor health and early death. This hypothesis is supported by the palaeopathological data from the 6-12 year-olds.

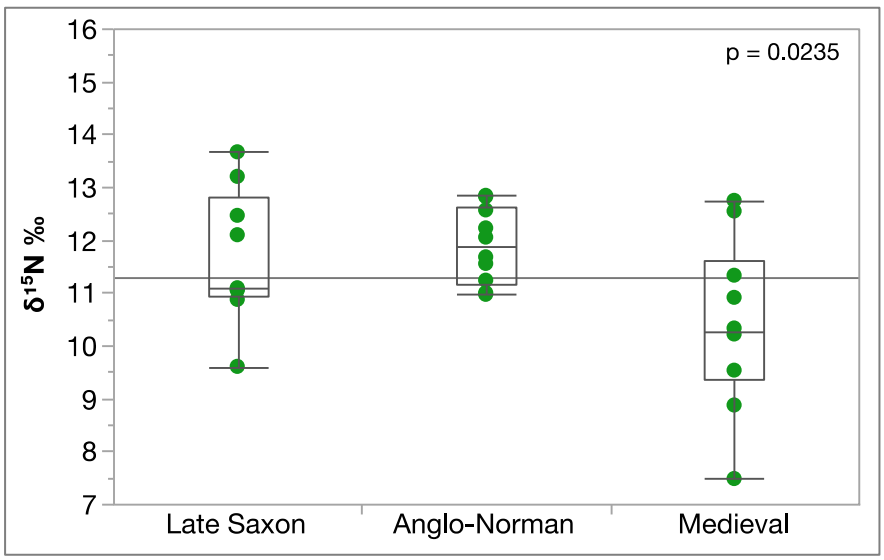


Figure 8.4. $\delta^{15}N$ by period for Stoke Quay 6-12 year-olds, with statistically significant differences by period (p= 0.0235). Means comparisons show significant differences between Anglo-Norman and Medieval groups (p = 0.0287, Tukey-Kramer HSD).

A comparison of the incidence of different pathologies by time period for 6-12 year-olds shows statistically significant differences between groups for dental enamel hypoplasia, disruptions in enamel growth due to periods of acute stress or illness (Hillson 1996; Waldron 2009)(Likelihood ratio p = 0.0090; Pearson p = 0.0154, Chi-Square). Due to low sample numbers, the Chi-Square results may be suspect. However, a trend is also seen in the crude prevalence rates (CPR) for this condition in older children: 88.9% (8/9) for Late Saxons, 50% (5/10) for Anglo-Normans, and 100% (10/10) for the Medieval group.

The Anglo-Norman older children thus have the lowest CPR for dental enamel hypoplasia and the highest mean $\delta^{15}N$, while the Medieval group has the highest CPR and the lowest mean $\delta^{15}N$. These correlations indicate a possible relationship between low $\delta^{15}N$ and early childhood stress, despite small samples.

Differential marine fish consumption in adults

Disparities in consumption of marine fish and other foods can reveal a great deal about social roles and their relationship to diet. As seen in the previous section, the late childhood diet at Stoke Quay may have been different for those who died young compared to those who lived to adolescence or later. In this section, differences in adult marine fish consumption are explored by comparing isotopic values by sex and age groups.

Male and female diets are first compared via 95% density ellipses for each period, to establish the degree of overlap between the sexes over time (Figure 8.5). As shown, the Mid Saxon diets for both sexes look very different from later diets, with an extremely tight range particularly for females. Males show a range in $\delta^{13}C$ but there is very little variation overall in $\delta^{13}C$ for either sex. Though the

Mid Saxon sample is much smaller than the later assemblages, there is nevertheless a clear pattern with little variation.

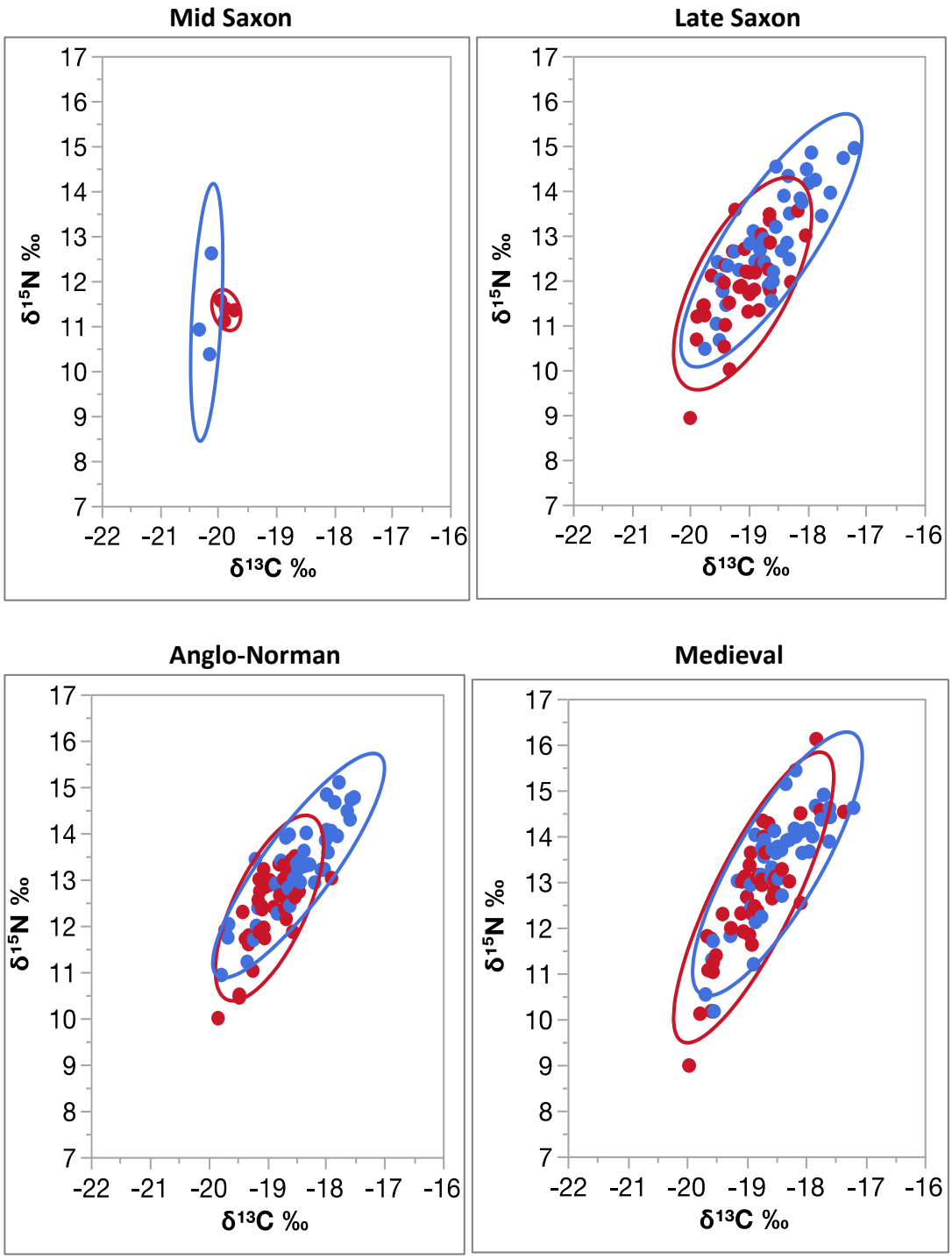


Figure 8.5. Stoke Quay adult male (blue) and female (red) $\delta^{13}C$ and $\delta^{15}N$ by period. 95% density ellipses for each sex show different diets for Mid Saxon males and females, overlapping diets but with higher male ranges for Late Saxon and Anglo-Norman groups, and largely overlapping Medieval diets with only slightly higher male values.

A different pattern is shown for the Late Saxons, with much greater variation for both sexes, but especially for males, while the Anglo-Norman plot shows a similar but more condensed pattern. The Medieval plot has the same degree of overlap in the lower $\delta^{13}C$ and $\delta^{15}N$ ranges, but the female ellipse overlaps almost completely with the male ellipse even at the upper limit. It would thus appear that adult diet at Stoke Quay from the Late Saxon period onward included marine fish for some males and also, to a lesser extent, females. Some females began to consume higher trophic level fish in the Medieval period, though males continue to dominate the upper limit of $\delta^{13}C$ and $\delta^{15}N$ values.

Clear sex-based differences in diet at Stoke Quay can be seen by comparing male and female $\delta^{13}C$ and $\delta^{15}N$ values for each period using ANOVA. The degree of marine input for both sexes can be inferred based on relative distance from the terrestrial carnivore ranges established in Chapter 2.

Figure 8.6 presents plots for $\delta^{13}C$ and $\delta^{15}N$ by sex (summary statistics in Table 8.2), with statistically significant differences between male and female diets for all periods. The greatest statistical significance for both $\delta^{13}C$ and $\delta^{15}N$ occurs in the Anglo-Norman period. It appears that from the beginning of the shift to marine fish exploitation at Stoke Quay, despite considerable overlap between the sexes, a group of males consistently has isotopic values indicative of intensive marine fish consumption.

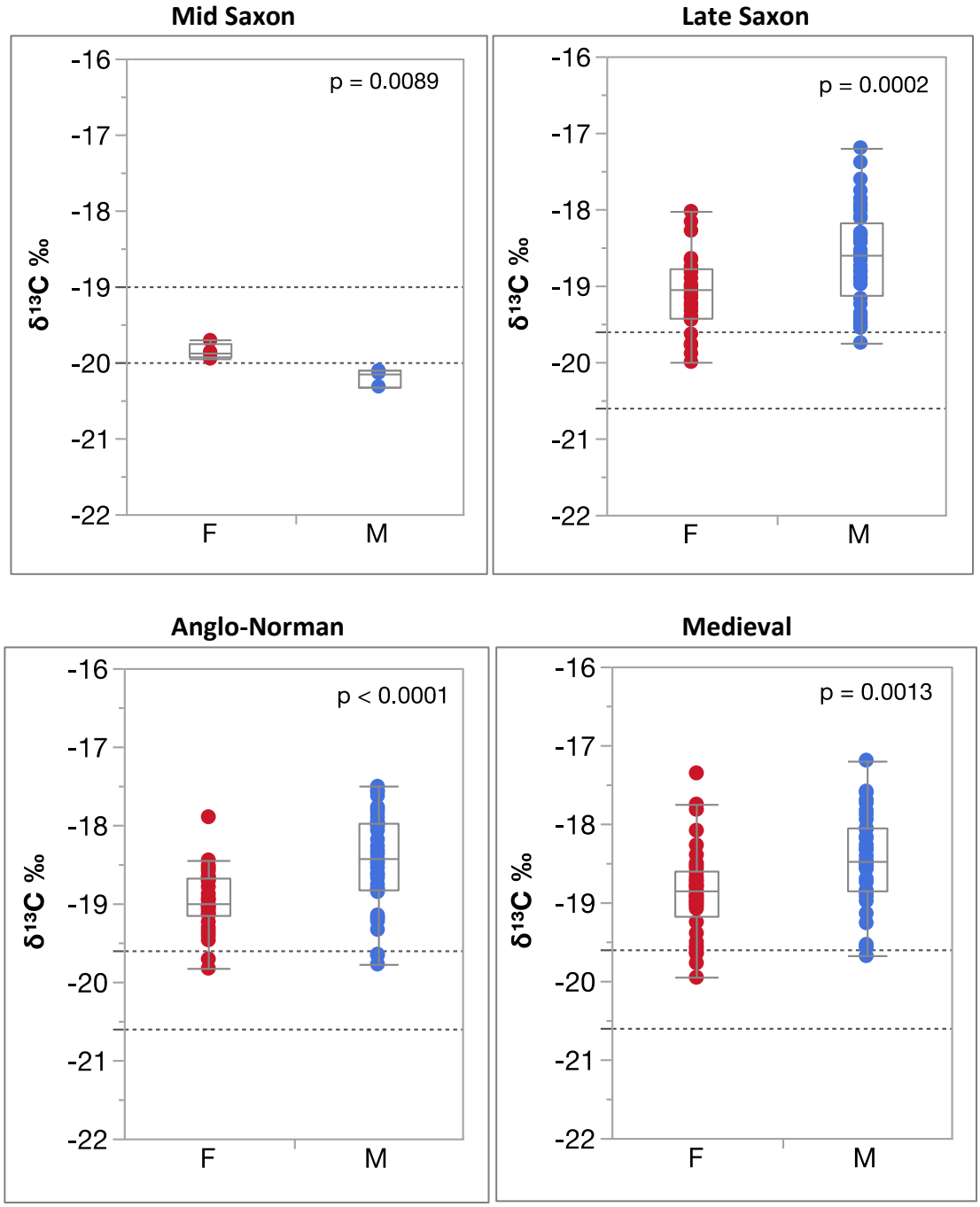


Figure 8.6a. Female (red) and male (blue) $\delta^{13}C$ by period, with modelled terrestrial carnivore range shown by dashed lines. There are statistically significant differences between sexes for all periods, with the highest significance for the Anglo-Norman period.

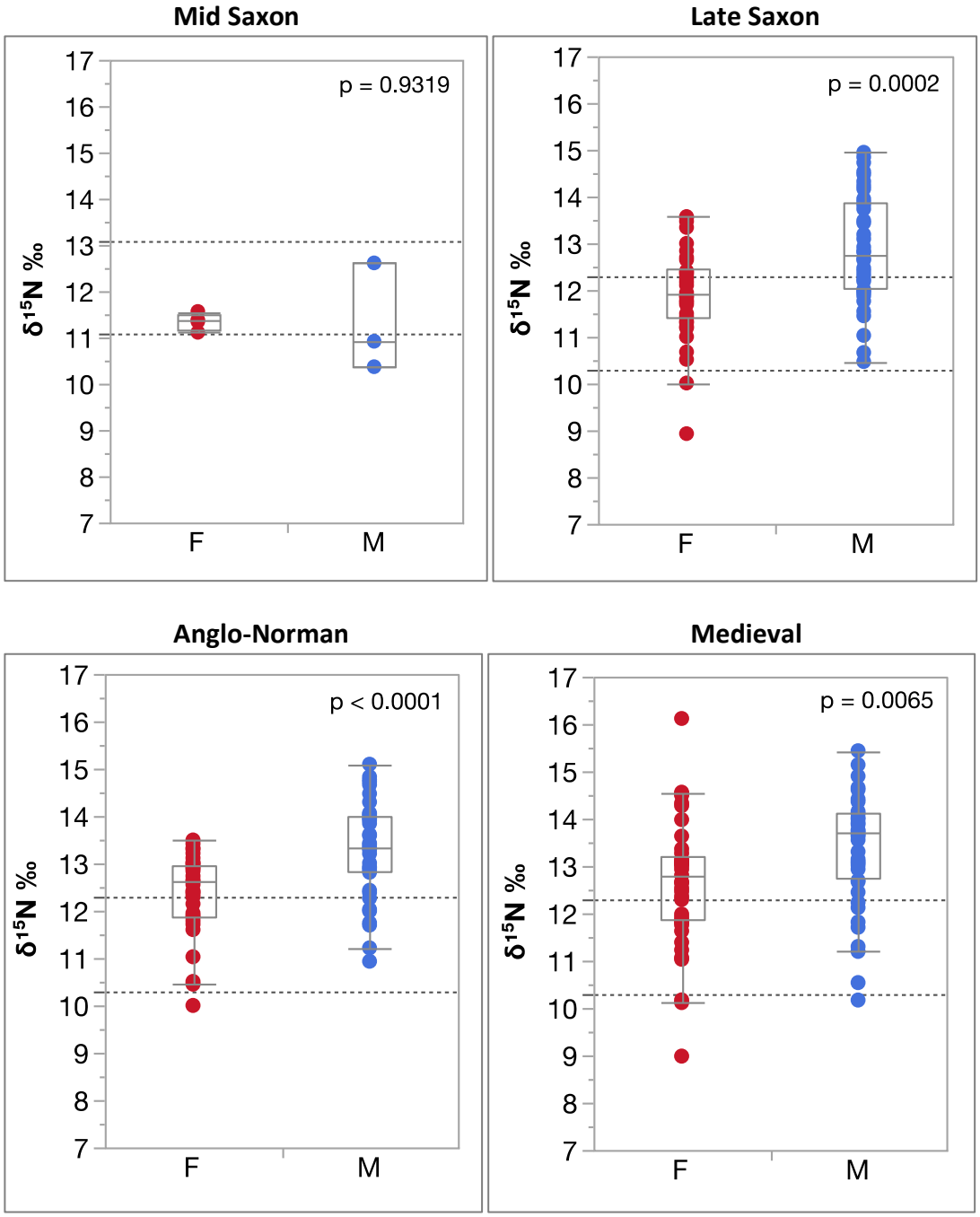


Figure 8.6b. Female (red) and male (blue) $\delta^{15}N$ by period, with modelled terrestrial carnivore range shown by dashed lines. There are statistically significant differences between sexes for all periods, with the highest significance for the Anglo-Norman period.

FEMALES									
Period	**n**	**$\delta^{15}N$ mean**	**1σ**	**min**	**max**	**$\delta^{13}C$ mean**	**1σ**	**min**	**max**
Mid Saxon	4	11.3	0.2	11.1	11.6	-19.8	0.1	-19.9	-19.7
Late Saxon	38	11.9	1.0	8.9	13.6	-19.1	0.5	-20.0	-18.0
Anglo-Norman	40	12.4	0.8	10.0	13.5	-18.9	0.4	-19.8	-17.9
Medieval	45	12.6	1.3	9.0	16.1	-18.9	0.5	-20.0	-17.3
MALES									
Period	**n**	**$\delta^{15}N$ mean**	**1σ**	**min**	**max**	**$\delta^{13}C$ mean**	**1σ**	**min**	**max**
Mid Saxon	3	11.3	1.2	10.4	12.6	-20.2	0.1	-20.3	-20.1
Late Saxon	40	12.9	1.1	10.5	14.9	-18.6	0.6	-19.7	-17.2
Anglo-Norman	41	13.3	1.0	10.9	15.1	-18.5	0.6	-19.8	-17.5
Medieval	44	13.4	1.2	10.2	15.4	-18.5	0.6	-19.7	-17.2

Table 8.2. Summary statistics for Stoke Quay female and male δ13C and δ15N by time period.

The lowest male $\delta^{13}C$ values throughout the Late Saxon to Medieval periods fall within the terrestrial carnivore range, but the vast majority in each period show ^{13}C enrichment beyond what would be expected for terrestrial foods. Men appear to have obtained much of their dietary protein from fish, with those at the upper end of the $\delta^{13}C$ range likely consuming high trophic level fish such as gadids beginning in the Late Saxon period (see Müldner 2016 and previous chapters). The minimum and maximum $\delta^{13}C$ for males remain remarkably similar from the Late Saxon to Medieval periods, with minimum values only varying by 0.1‰, and maximum values varying by 0.3‰. This consistency over time suggest more fundamental underlying influences than mere food preferences, with a possible explanation being male occupation in the fishing and seafaring industries.

Male $\delta^{15}N$ shows more variation in both minimum and maximum values, with varying numbers within and beyond the terrestrial carnivore range. As seen in Figure 8.6, most of the bottom two quartiles for the Late Saxon $\delta^{15}N$ values fall within the terrestrial carnivore range, which, paired with $\delta^{13}C$ values, indicate

terrestrial diets with low-trophic level fish consumption, or limited consumption of higher trophic level fish. By the Medieval period, less than half of the bottom quartile overlaps with the omnivore range, pointing to a major shift in the proportion of marine fish consumption over time.

The minimum $\delta^{13}C$ values for females, though slightly lower than for males, also remain very consistent, varying by only 0.2‰ over the same period. Greater temporal differences in female $\delta^{13}C$ occur in the maximum values, but these still vary by only 0.7‰ over time. The maximum female $\delta^{13}C$ increases steadily over time, though the means plateau between the Anglo-Norman and Medieval periods. The rise in maximum female $\delta^{13}C$, but relatively stable mean values over time suggest that the majority of women at Stoke Quay consumed a fairly consistent diet across periods, but that some Medieval women consumed more marine, and possibly freshwater, fish than their earlier counterparts.

The shift to greater marine resource consumption among females can be clearly seen when comparing the $\delta^{15}N$ distribution from the Late Saxon period to that from the Medieval period. Only the upper quartile of Late Saxon women have $\delta^{15}N$ above the terrestrial carnivore range, but by the Medieval period, the upper two quartiles and some of the third quartile fall above that range. The mean $\delta^{15}N$ for females also increases steadily over time. Notably, the lowest $\delta^{15}N$ values for the Late Saxon and Medieval periods are only 0.1‰ apart, and both are outliers falling well below the minimum for the terrestrial carnivore range, so women consuming low protein or mostly plant-based diets were atypical.

Taken together, these data suggest that women experienced a major shift in marine food consumption over time. While it is possible that some of this shift could be explained by women gaining greater access to marine resources

through occupations in fish processing, thus far this has not been shown in the Ipswich historical record.

Another explanation for the female dietary shift could be that while access to cod and other high trophic level fish in the Late Saxon period may have been restricted to those engaged in fishing or seafaring, by the Medieval period the market for traded and imported fish had expanded enough to allow all members of society access to this food (Kowaleski 2016; Barrett 2018).

Summary

The preceding paragraphs have shown that there was a major shift from largely terrestrial omnivorous diets in the Mid Saxon period, to significant marine resource consumption in the Late Saxon period. From the Late Saxon through Medieval periods, both males and females consumed increasing amounts of marine fish, with some at the upper limit of the isotopic range consuming high trophic level fish, likely including offshore species from the gadid family (Müldner 2016).

Though specific occupations for the population buried at St. Augustine's Church are unknown, historical parish documents such as wills and tallage rolls mention the occupation of mariner (Breen, in press). The combination of isotopic and historical evidence supports the hypothesis presented here, that significant numbers of the members of St. Augustine's parish must have been involved in fishing and seafaring to account for the high levels of marine fish consumption in the community as a whole. This would be particularly important for access to marine fish in the Late Saxon period, prior to the expansion in the trade of

preserved and fresh fish that occurred after the 11th century (Barrett et al. 2004a,b; Müldner & Richards 2007; Kowaleski 2016).

Along with changing patterns of fish consumption at Stoke Quay, other temporal changes are also evident. As discussed in Chapters 1 and 4-7, the process of urbanisation would have had a major impact life in Ipswich. The following section examines how health may have changed over time at Stoke Quay, as urbanisation progressed.

8.3 Urbanisation and health

The living environment can have a profound impact on health, particularly if it is crowded, unsanitary, and polluted (Roberts & Cox 2003). Medieval urbanisation led to greater economic opportunities and social mobility for some, but it could also lead to unhealthy living conditions, especially among the lower social strata. As one of the less prosperous parishes, the population at St. Augustine's may have been particularly susceptible to the hazards of urban living. Evaluating potential changes in prevalence rates for certain diseases over time can elucidate the effect of the shift to urban living on the population.

In examining the effect of urbanisation on health at Stoke Quay in this thesis, a number of pathological lesions are considered, each pertaining to different aspects of the living environment (see Chapter 2, Section 2.4). Total crude prevalence rates (n/N) for Late Saxon to Medieval Stoke Quay (Loe et al., in press; Gibson et al., in press) are used for comparison with prevalence rates from contemporary assemblages compiled by Roberts and Cox (2003). The links between these pathologies, dietary isotopes, and evidence for mobility in the Stoke Quay sample group are explored further in section 7.4.

8.3.1 Indicators of urban living at Stoke Quay over time

This thesis primarily uses four conditions to evaluate the effect of urbanisation on the population buried at Stoke Quay: maxillary sinusitis, periostitis, *cribra orbitalia*, and tuberculosis. Figure 8.7 shows total crude prevalence rates for these pathologies at Late Saxon to Medieval Stoke Quay, and Table 8.3 shows the overall rates and those for males, females, adults, and subadults.

Pathology	Late Saxon (9^{th}-\$11^{th}$ c.)	Anglo-Norman (11^{th}-12^{th} c.)	Medieval (13^{th}-15^{th} c.)
Maxillary sinusitis[1]	Total: 8.2% (26/316) Adult: 13.3% (23/173) Male: 14.9% (11/74) Female: 14.8% (12/81) Subadult: 2.1% (3/143)	Total: 9.9% (55/558) Adult: 13.5% (41/304) Male: 17.7% (22/124) Female: 14.6% (18/123) Subadult: 5.5% (14/254)	Total: 10.8% (28/259) Adult: 15.1% (28/185) Male: 12.9% (11/85) Female: 18.7% (17/91) Subadult: 0% (0/74)
Periostitis[2]	Total: 35.1% (111/316) Adult: 49.7% (86/173) Male: 59.5% (44/74) Female: 46.9% (38/81) Subadult: 17.5% (25/143)	Total: 40.1% (224/558) Adult: 58.2% (177/304) Male: 68.5% (85/124) Female: 57.7% (71/123) Subadult: 19.3% (47/254)	Total: 51% (132/259) Adult: 62.7% (117/185) Male: 63.5% (54/85) Female: 61.5% (56/91) Subadult: 23% (16/74)
Cribra orbitalia[3]	Total: 42.7% (135/316) Adult: 39.3% (68/173) Male: 44.6% (33/74) Female: 42% (34/81) Subadult: 46.9% (67/143)	Total: 38.5% (215/558) Adult: 37.2% (113/304) Male: 49.2% (61/124) Female: 41.5% (51/123) Subadult: 40.2% (102/254)	Total: 55.2% (143/259) Adults: 58.9% (109/185) Males: 62.4% (53/85) Females: 59.3% (54/91) Subadult: 45.9% (34/74)
TB[4]	Total: 1.5% (5/316)	Total: 0.4% (2/558)	Medieval: 4.6% (12/259) All periods: 1.7% (19/1142)

Table 8.3. Crude prevalence rates by period for maxillary sinusitis, periostitis, cribra orbitalia, and tuberculosis for Late Saxon to Medieval Stoke Quay. From Gibson et al., in press, Appendix A5: [1] Table A5.50, [2] Table A5.59, [3] Table A5.66, [4] Loe et al., in press, Ch. 6:17.

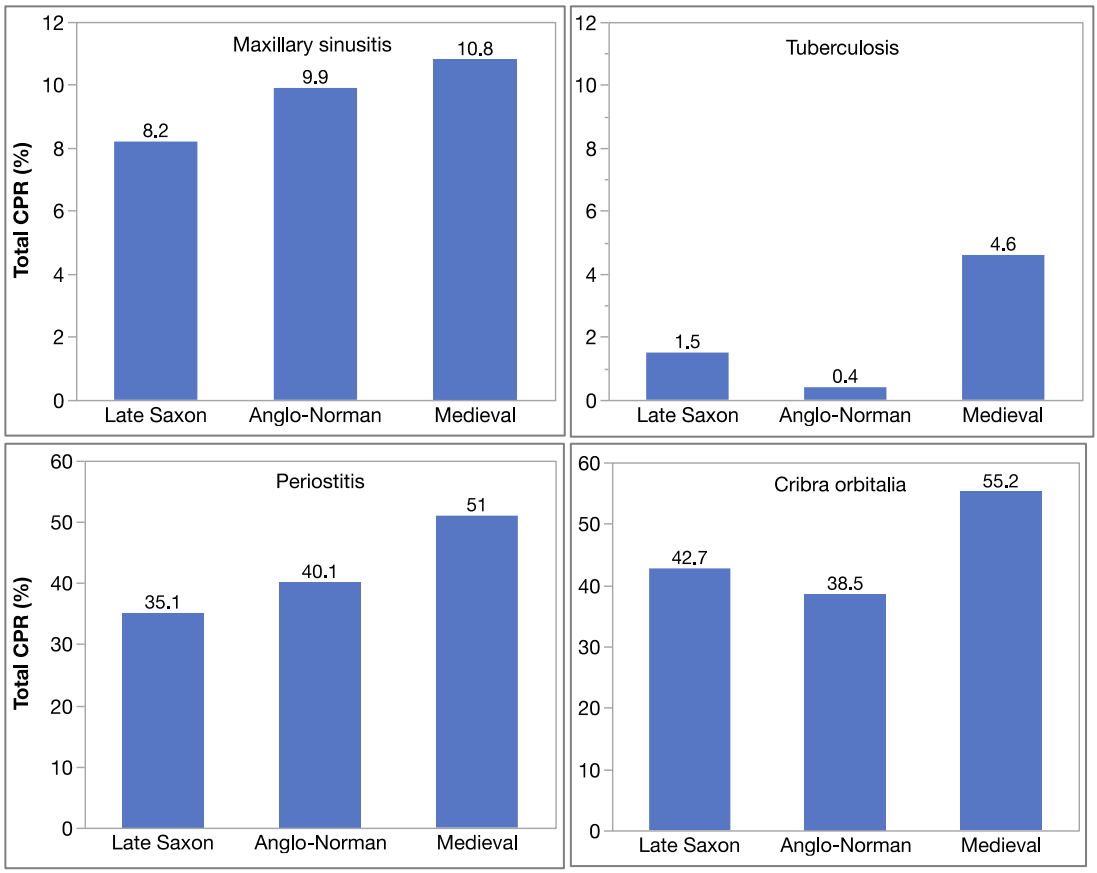


Figure 8.7. Stoke Quay pathology by period. Crude prevalence rates (n/N, each period) are shown as percentages).

As shown in Figure 8.7, the Medieval period has the highest rates for all conditions. The Late Saxon assemblage has the lowest rates for maxillary sinusitis and periostitis, while the Anglo-Norman period has the lowest rates for tuberculosis and cribra orbitalia.

From these results, a number of inferences can be made about St. Augustine's parish during the period in question. Firstly, the rising rates of maxillary sinusitis indicate that exposure to airborne irritants increased over time, particularly for females. Women may have been spending more time cooking indoors with poor ventilation during the Medieval period, or perhaps they were exposed to irritants from occupations in industries such as cloth-dying (Lewis et al 1995).

Secondly, overall disease burden may have increased over time, as suggested by the steady rise in periostitis, with the largest increase between the Anglo-Norman and Medieval periods. All groups show increasing prevalence over time except for males, who instead reach a peak in the Anglo-Norman period. This trend indicates that living conditions and disease burdens worsened over time, with men showing a spike in periostitis prevalence during the Anglo-Norman period. However, it is important to note that most cases of periostitis at Stoke Quay were either healed or in the process of healing, indicating that this population was often able to fight off infections (Loe et al., in press). This suggests a population with relatively robust immune responses, which may have been strengthened by readily accessible sources of protein such as marine fish.

Third, total prevalence of cribra orbitalia is highest in the Medieval and lowest in the Anglo-Norman period. The prevalence rates for adults, subadults, and females follow this pattern, while the lowest male prevalence rates are in the Late Saxon period. The increase in total cribra orbitalia prevalence from the Late Saxon to Medieval period is in keeping with the generally poorer health shown by the maxillary sinusitis and periostitis rates. However, the Anglo-Norman dip in prevalence is more difficult to characterise. It is possible that the relative prosperity of the Anglo-Norman period allowed the inhabitants of St. Augustine's access to higher quality foods and better hygiene, reducing the rates of parasitic infection and perhaps anaemia or other metabolic disorders.

Fourth, the Anglo-Norman group has the lowest CPR for tuberculosis, with only 2 out of 558 individuals exhibiting skeletal evidence for the disease (0.4%). The Late Saxon group has higher rates, affecting 5 out of 316 skeletons (1.5%), but these rates more than triple in the Medieval group, with 12 out of

259 individuals affected (4.6%). This is strong evidence for crowded living conditions in St. Augustine's parish, with transmission rates likely worsened by overall poor health as indicated by the previously mentioned pathologies.

This section has shown that as urbanisation increased at Ipswich, so too did crude prevalence rates for several pathological conditions. As shown in Chapters 5-7, the rates for periostitis, cribra orbitalia, and tuberculosis at Stoke Quay were in many cases higher than at contemporary urban sites across Britain, and this may have been largely due to urbanisation at Ipswich. However, the high disease burden observed at Stoke Quay may have also been related to other factors such as occupation and mobility.

The following section examines mobility at the site over time, exploring the power of different characteristics for predicting interpretations of non-local origins, as well as demographics and potential links between mobility and vulnerability to violence.

8.4 Evidence for mobility at Stoke Quay

This section examines the overall evidence for mobility at Stoke Quay, as interpreted from $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analyses of tooth enamel carbonate from 45 individuals dating to the Mid Saxon to Medieval periods. It begins with an overview of the results and interpretations by period, with evaluations of how mobility interpretations correspond to the reasons for sample selection described in Section 2.3.2. This is followed by a discussion of demographics and mobility over time, and finally, the treatment of interpreted 'Nonlocals' and 'Locals' is evaluated using osteological and isotopic data.

8.4.1 Overview of mobility over time at Stoke Quay

The $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results are shown in Figure 8.8, coloured by period. Summary statistics are given in Table 8.4 and a full list of results (including all $\delta^{18}O_{C\text{-}VPDB}$ values) and demographics is provided in Appendix 3.

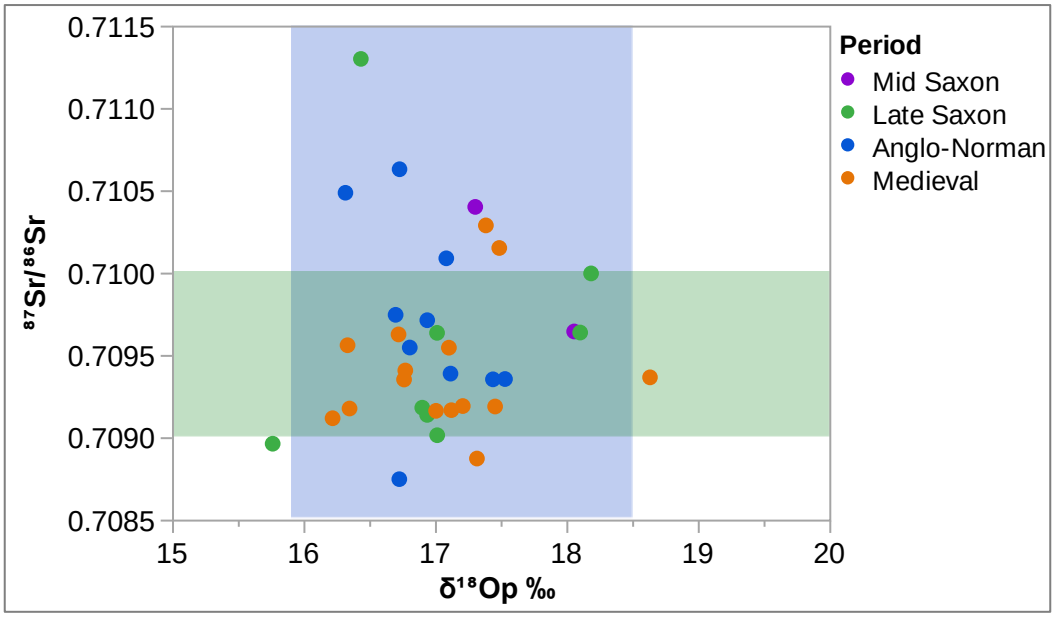


Figure 8.8. Paired $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ results from Mid Saxon to Medieval Stoke Quay, coloured by period (n = 33). Grey dotted lines: expected 'local' bioavailable $^{87}Sr/^{86}Sr$ (Evans et al. 2010) and expected British 'low rainfall' $\delta^{18}O_P$ (Evans et al. 2012).

Period	$^{87}Sr/^{86}Sr$			$\delta^{18}O_P$		
	n	Mean	σ	n	Mean	σ
Mid Saxon	2	0.710020	0.000535	2	17.7	0.5
Late Saxon	11	0.709483	0.000685	8	17.0	0.8
Anglo-Norman	14	0.709603	0.000521	10	16.9	0.4
Medieval	18	0.709351	0.000389	15	17.1	0.6
Total	45	0.709491	0.000526	35	17.1	0.6

Table 8.4. $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ (Chenery et al. 2012) summary statistics for all Stoke Quay samples (n = 45).

As shown in Figure 8.8, there is little pattern to the distribution of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ over time, with overlap in the ranges of both isotopic systems for all time periods. The $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ means are also similar between each period, with the exception of the Mid Saxon period, which has higher means for both isotopic systems than the other periods (Table 8.4). A different view of the

distribution of values for both isotopes is presented in Figures 8.9a,b. Despite the ranges for both $^{87}Sr/^{86}Sr$ and $\delta^{18}O_P$ over time, ANOVA show no statistically significant differences.

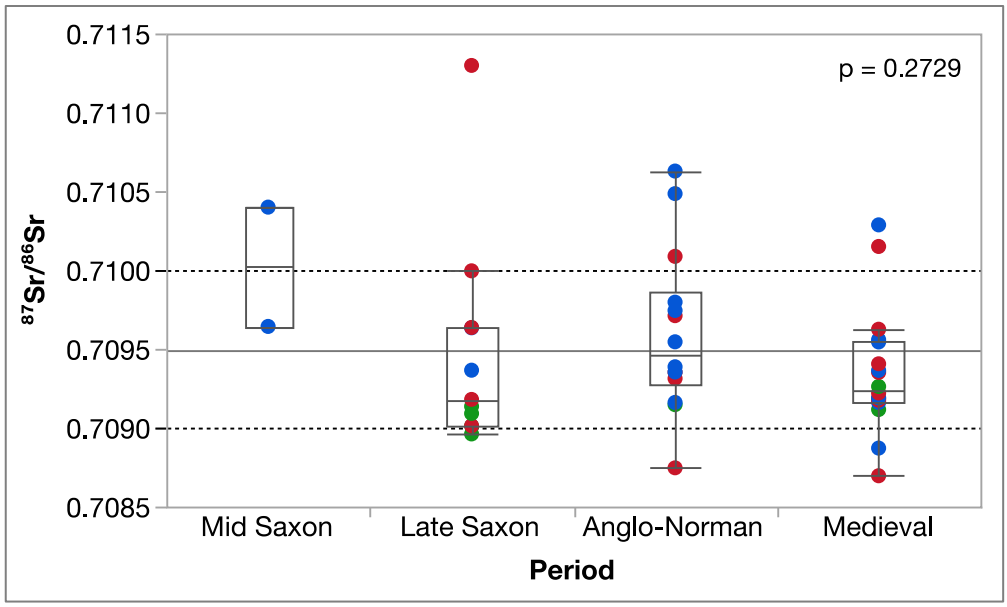


Figure 8.9a. $^{87}Sr/^{86}Sr$ boxplots by period for Mid Saxon to Medieval Stoke Quay, with no statistically significant differences by period (p = 0.2729, ANOVA). Grey dotted lines: expected 'local' $^{87}Sr/^{86}Sr$ range (Evans et al. 2010); solid line: group mean.

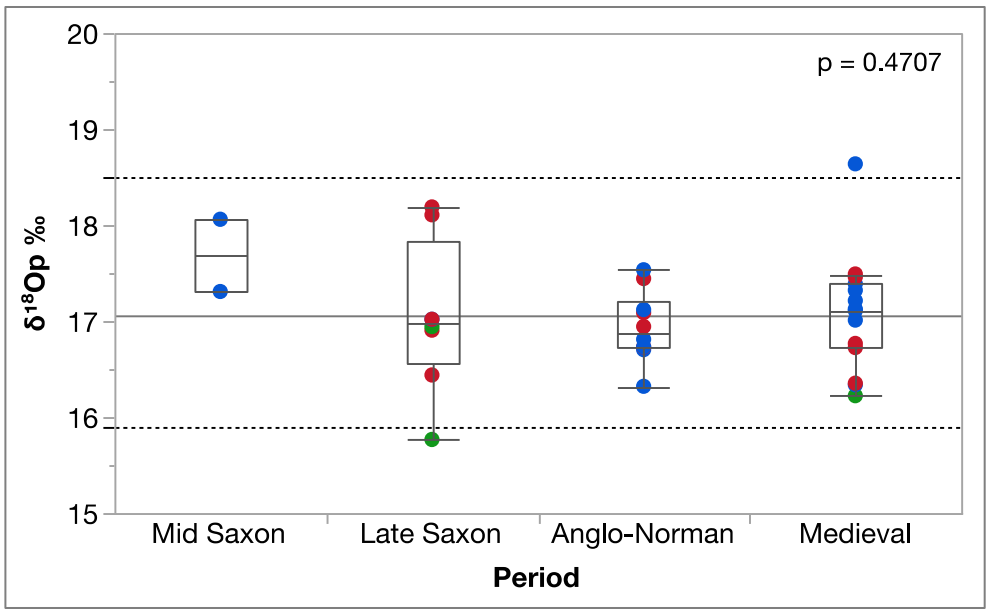


Figure 8.9b. $\delta^{18}O_P$ boxplots by period for Mid Saxon to Medieval Stoke Quay, with no statistically significant differences by period (p = 0.4707, ANOVA). Grey dotted lines: expected 'low rainfall' British $\delta^{18}O_P$ range (Evans et al. 2012); solid line: group mean.

Out of 33 individuals yielding $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results, 12 have $^{87}Sr/^{86}Sr$ or $\delta^{18}O_P$ outside the expected 'local' ranges. A thirteenth individual has $^{87}Sr/^{86}Sr$ at the very top of the 'local' range and high $\delta^{18}O_P$ (but within the 'local' range). These 13 individuals have been interpreted as 'nonlocals' in Chapters 4-7, and one is Mid Saxon, three are Late Saxon, four are Anglo-Norman, and five are Medieval in date. If these interpretations are considered as correct, it would appear that St. Augustine's parish saw visitors from abroad beginning in the Mid Saxon period, and potentially increasing over time.

Interestingly, this group of possible 'nonlocals' is comprised of one adolescent, six females, and six males, with adults of both sexes in every age category from 18-25 to 45+ years. The age and sex distributions indicate that overseas travel was not limited to men. Whether the adolescents and females would have travelled on their own or with families cannot be assessed with the current data, but serial micro-sampling of teeth might help elucidate the age at which these individuals moved from their place of origin, if they were in fact bone elsewhere. Given the complexity in human behaviour, including the preparation of food (Brettell et al. 2012), the 'local' versus 'nonlocal' designations discussed here are not certainties, merely interpretations of the data, and therefore they must be taken with some caution.

In addition to the confounding factors of human behaviour, the high percentage of individuals interpreted as potentially 'nonlocal' based on $^{87}Sr/^{86}Sr$ or $\delta^{18}O_P$ may not be an accurate reflection of the entire population of St. Augustine's, since some of these individuals were selected precisely because they appeared to be atypical (see below, and Section 2.3.2). Nevertheless, as discussed in the following section (8.4.2), the difficulty encountered in predicting nonlocal

origins for this assemblage indicates that there very well may be large numbers of 'nonlocals' buried at the site, but they might be hard to detect by these geochemical methods. Future studies could pursue these questions using a larger sample size, in order to better gauge the amount of normal variability in the isotopic values of the population.

8.4.2 Predicting 'Local' and 'Nonlocal' interpretations at Stoke Quay

The 45 individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in this study include 15 selected by the Burials Department at Oxford Archaeology for a pilot study (Farber & Lee-Thorp, in press), and 30 selected by the author for this thesis. Of the 30 individuals selected for the thesis, 20 were chosen because of atypical $\delta^{13}C$ and $\delta^{15}N$ results or evidence of disease, trauma, or non-Caucasoid features, and 10 were chosen because of their average $\delta^{13}C$ and $\delta^{15}N$ results and unremarkable skeletal characteristics (Section 2.3.2).

Ten individuals were selected for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis because of their average $\delta^{13}C$ and $\delta^{15}N$ results and skeletal characteristics. These individuals were hypothesised to be likely 'locals' based on observations of a relationship between unusual diet and 'nonlocal' interpretations in the pilot study (see Section 2.3.2). As shown in Figure 8.10, 100% of the 'average' individuals were interpreted as 'locals' (10/10). This result indicates that $\delta^{13}C$ and $\delta^{15}N$ values around the group means, paired with unremarkable skeletal traits, may be a good indication of 'local' origins for this site. Alternatively, this observed correlation could be a result of 'average' diets at the site all incorporating the same general types of foods and food processing methods, thus influencing the human isotopic values.

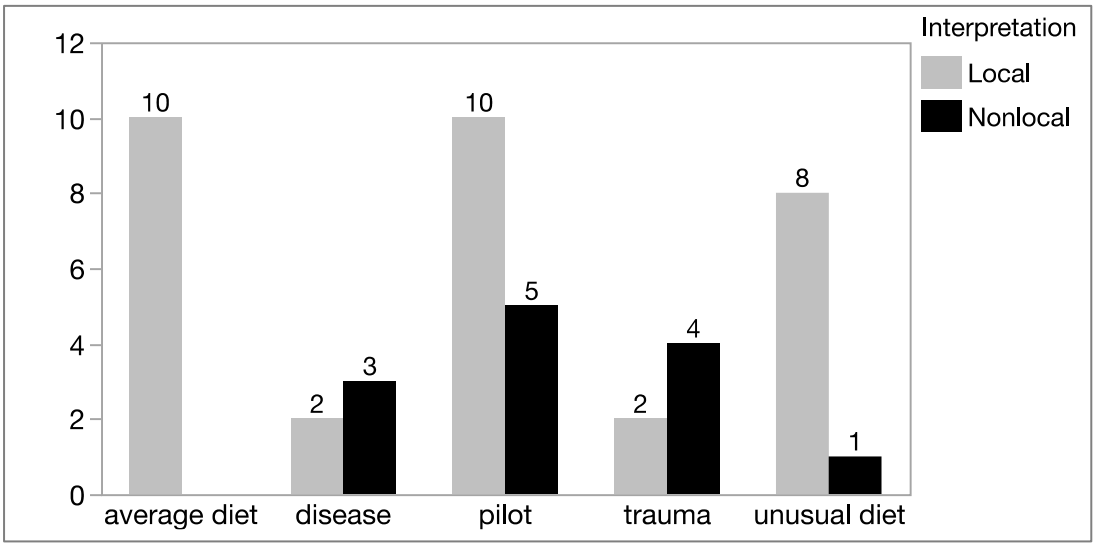


Figure 8.10. Sample selection criteria for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis, marked by 'local'/'nonlocal' interpretation of origin (n = 45). Interpreted 'locals' shown in grey, 'nonlocals' in black.

The other categories used when selecting samples for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis had mixed success at predicting interpretations of mobility. Four of the six individuals selected because of skeletal trauma were interpreted as 'Nonlocal', suggesting that the presence of skeletal trauma may be correlated with place of origin (see Section 8.4.3). Evidence for specific diseases was only marginally more successful at predicting interpretations, with three out of five individuals with skeletal indicators of specific disease (tuberculosis and syphilis) interpreted as 'nonlocals.' Interestingly, despite the correlations seen in the pilot study between unusual diet and possible 'nonlocal' origins, only one out of eight individuals selected for atypical dietary isotope results was interpreted as 'Nonlocal'.

The difficulty in predicting interpretations of mobility, if indeed mobility can be predicted, may be partly due to the diverse nature of Ipswich throughout the period addressed in this study. As a port town with international trade contacts and visiting merchants, sailors, fishermen, and townspeople from the

hinterland, it is perhaps not surprising that a variety of traits can be found in those seemingly born locally and also those who appear to be from elsewhere.

The following section discusses the treatment of those individuals interpreted as 'nonlocals.'

8.4.3 The treatment of 'nonlocals' vs. 'locals' at Stoke Quay

The manner in which a society treats visitors and migrants is often a reflection of that society's own values. Fear and the desire to protect those values can lead to discrimination against those perceived as 'Other', sometimes even resulting in violence. This phenomenon can be seen today in nationalist backlashes against rising numbers of displaced persons, and it was visible in Medieval London in the form of violence against foreign traders (Kowaleski 2008). The previous chapters include several cases of violence against individuals interpreted as 'nonlocals' based on $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results, and this subject is returned to here, this time including individuals from all time periods at Stoke Quay.

Of the 45 individuals analysed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, 19 show evidence for skeletal trauma, a rate of 42%. This is high compared to the percentage of healed fractures in the entire skeletal assemblage, 18.2% (208/1142), but similar to the percentages for adult males (39.2%, 111/283) and higher than the percentage for adult females (25.9%, 78/301) (Loe et al., in press).

The types of trauma on each skeleton are examined in more detail in this section, relying on assessments recorded by Oxford Archaeology osteologists in their database, and interpreted here by the author following the methods described in Chapter 2, Section 2.4. Based on the type of trauma, element

involved, and degree of healing, the 19 individuals are categorised by whether their skeletal trauma is consistent with interpersonal violence ('Yes', 'No', and '?'). These results are shown in Figure 8.11 and described in Table 8.5.

Trauma to the feet and lower limbs were categorised as 'No', as these elements are prone to accidental injuries. Trauma to the cranium, especially the top and back of the cranial vault (above the 'hat brim line') and the face, were categorised as 'Yes', as the head is amongst the most common locations injured during interpersonal violence (see Krakowka 2017, Manchester & Roberts 2010). Fractures to the distal ulna can be defensive wounds, or 'parry fractures' (Judd 2008) so these are categorised as 'Yes'.

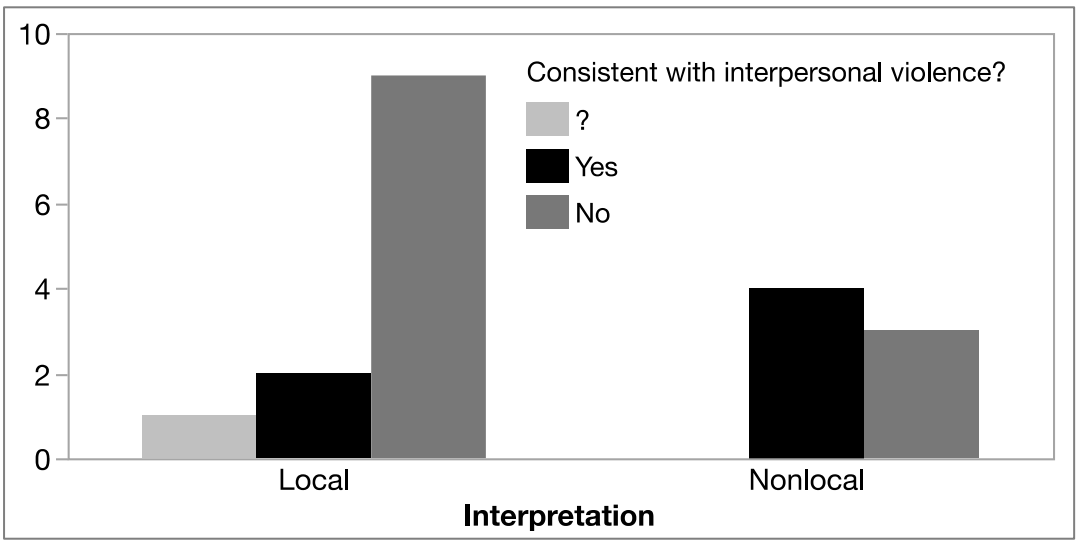


Figure 8.11. Individuals interpreted as 'local' and 'nonlocal' with skeletal trauma categorised by whether it is consistent with interpersonal violence.

As shown in Figure 8.11, six individuals have trauma categorised as consistent with interpersonal violence, including one Mid Saxon male, a Late Saxon female and adolescent, one Anglo-Norman male, and two Medieval men. Of these six individuals, four are interpreted as 'Nonlocals'. A seventh individual shows possible signs of interpersonal violence in the form of a transverse rib

fracture, but this type of injury is difficult to assess with certainty. Furthermore, two of the four individuals with perimortem injuries are interpreted as 'Nonlocals', while a third with perimortem injuries falls near the upper extreme for $\delta^{18}O_P$, and may possibly be nonlocal to the Ipswich area.

These results suggest that individuals born outside of the Ipswich area were somewhat more likely to have experienced some sort of interpersonal violence than those who were born locally, and that this violence could be deadly. Further $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of additional individuals with trauma consistent with interpersonal violence could help clarify whether the trend seen in this sample is reflective of the population as a whole.

Sk	Age	Sex	Period	Origin?	Trauma	Violence?
20207	36-45	F	Late Saxon	Nonlocal	Cranial (R parietal) depression fracture	Yes
20748	26-35	F	Late Saxon	Local	Talus avulsion(?) fracture	No
20894	45+	F	Late Saxon	Local	Elbow trauma (probable traumatic dislocation)	No
7968	36-45	M	Anglo-Norman	Local	Avulsion(?) fracture L patella/R ulna, L calcaneus fracture, R rib 8 oblique fracture	No
21079	13-17	M	Anglo-Norman	Local	Dislocation R MT1-PP1	No
21776	45+	F	Anglo-Norman	Local	Soft tissue trauma L femur (greater trochanter)	No
22114	26-35	M	Anglo-Norman	Local	R rib 2/3 midshaft oblique fracture, soft tissue trauma(?) L femur	No
22727	45+	M	Anglo-Norman	Local	R & L talus (Shepherd's?) fractures (posterior tubercle), R foot PP oblique fracture, transverse rib fracture	No
20560	45+	M	Medieval	Local	2 L rib midshaft transverse fractures	?
21348	18+	F	Medieval	Local	TV8 compression fracture	No
20808	36-45	M	Mid Saxon	Local?	Perimortem sharp force cranial trauma x2; R nasal/maxilla fracture (healed)	Yes
20292	13-17	?	Late Saxon	Nonlocal	Perimortem sharp force trauma to neck, TV 7 fracture (healing) likely from hyperextension	Yes
21166	36-45	F	Late Saxon	Local	R distal radius (Colles') fracture, R distal ulna crush fracture, ossified haematoma R humerus posterior shaft	No
6443	36-45	M	Anglo-Norman	Nonlocal	R MT transverse (Jones) fracture	No
22219	26-35	M	Anglo-Norman	Nonlocal	R ulna oblique (parry?) fracture, TV2 possible compression fracture	Yes
20177	18-25	F	Medieval	Nonlocal	L talus fracture (posterior tubercle, Shepherd's fracture)	No
21217	36-45	M	Medieval	Local	R scapula fracture (acromial process), L tibia fracture (malleolus), L MT2 fracture, R clavicle fracture	No
21289	60+	M	Medieval	Local	Perimortem sharp force trauma to cranium, ribs, entire spine	Yes
22418	26-35	M	Medieval	Nonlocal	Perimortem blunt force trauma to cranium (R parietal)	Yes

Table 8.5. Interpersonal violence categorisation and mobility interpretations for Stoke Quay individuals with skeletal evidence of trauma.

8.5 Conclusions

This chapter has evaluated the evidence for temporal changes in diet, health, and mobility at Stoke Quay. Section 8.1 introduced the period and the importance of this site for enhancing our understanding of long-term developments in medieval English diet and ways of life. Section 8.2 compared the $\delta^{13}C$ and $\delta^{15}N$ results from 354 individuals covering a period of nearly 900 years.

These comparisons demonstrated that the 'fish event' at Ipswich occurred within the 100-150 years between the Mid Saxon and Late Saxon burials, with intense marine fish exploitation beginning perhaps as early as the late 9th century, somewhat earlier than predicted based on zooarchaeological evidence at Stoke Quay and elsewhere (Barrett et al. 2004a,b; Nicholson, in press).

This early marine resource consumption is most visible in male $\delta^{13}C$ and $\delta^{15}N$, with generally higher values than females who appear to have consumed more modest amounts of marine fish. In the Medieval period some female isotopic values approach the top of the male range, suggesting a shift toward high trophic level fish such as gadids in the latest phase of burial at Stoke Quay.

Section 8.3 evaluated trends in skeletal indicators of pathologies associated with urbanisation, finding an overall increase in periostitis, cribra orbitalia, maxillary sinusitis, and tuberculosis over time at Stoke Quay. The crude prevalence rates for these conditions at Stoke Quay were found to be higher in most cases than averages for contemporary British sites, and in some cases the Stoke Quay prevalence rates were above those at any other site.

This trend suggests that St. Augustine's parish was significantly urbanised from the Late Saxon period, with living conditions growing increasingly hazardous over time. However, the population survived long enough to develop

skeletal reactions to these hazards, and in many cases the lesions were healed or healing at the time of death. Therefore, it may be the case that the population of St. Augustine's, though carrying a heavy disease burden, may have been relatively robust in terms of immune response, perhaps as a result of the amounts of dietary protein gained from fish consumption.

Finally, Section 8.4 analysed mobility at Stoke Quay over time through comparisons of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis of 45 individuals from the Mid Saxon to Medieval periods. These comparisons showed that nearly 30% of the sampled individuals may have had origins outside of Ipswich, including males, females, and adolescents. Section 8.4.2 assessed the correlations between traits used for sample selection and interpretations of 'local' or 'nonlocal' origins, showing that 100% of those selected as likely 'locals' because of their 'average' diets were interpreted as such. Correlations for 'nonlocal' origins were less clear, with mixed interpretations for samples selected for unusual diet, disease, and trauma.

Section 8.4.3 examined the treatment of interpreted 'nonlocals' versus 'locals', finding an association between interpersonal violence and interpreted 'nonlocal' origins; in several cases, this violence was likely the cause of death.

The overall picture that emerges of St. Augustine's parish during the Mid Saxon to Medieval periods is of an increasingly urbanised environment with a diverse and cosmopolitan population of varied backgrounds and geographical origins. This population may have traded and mixed more freely than those from inland locations, with increased access to imports and marine fish facilitated by proximity to the busy port of Ipswich. However, in some cases, the mixing of people led to violent ends, underlining the hazards of life in a busy medieval port town.

Chapter 9: Conclusions

9.1 Overview

This thesis has utilised multiple forms of evidence to assess long-term trends in diet, mobility and health in eastern England during the period of urbanisation and economic expansion from the late 6th through late 15th centuries. During this time, the inhabitants of England experienced significant changes to nearly every facet of life. At the beginning of the period, new power structures were taking shape and strengthening, as Anglo-Saxon kingdoms filled the void left by the Roman Empire. In this new socio-political landscape, overseas trade began to flourish, facilitated by the newly formed *emporia* or *wics*, including Ipswich, which arose on the eastern and southern coasts of Britain and in other coastal and riverine locations around the North Sea. Aside from these trading centres, the English economy was based primarily on rural production, with the average diet comprised of cereals and animal products from the three main domesticate species.

By the end of the period, England was a single nation state, with a large proportion of the population living in towns and cities. Developments in shipping technology and food preservation methods enabled long-distance travel overseas, allowing for a greater variety and volume of foods and products, including a wide variety of marine fish, to be traded overseas and distributed via regional networks. Imported products were received at coastal ports, with London dominating the economic sphere. These urban centres provided employment opportunities for both men and women in a wide variety of occupations and trades, drawing migrants from the countryside and abroad. At

the same time, the pressures of urbanisation and the impact of epidemics and famines led to a worsening of health and hygiene for many urban dwellers.

The complexities of studying changes in diet, health and mobility over this long period required a multi-faceted approach utilising multiple analytical techniques applied to a large dataset. The large and well-preserved skeletal assemblage from Stoke Quay provided what was in many ways an ideal sample through which to investigate these trends. The results from this thesis add to the corpus of isotopic and osteological information available to scholars of the medieval period, and provide a detailed analysis of the effects of changing food sources and urbanisation on diet, health, and mobility in medieval period.

9.2 Conclusions

9.2.1. Diet and the timing of the 'fish event horizon'

One of the primary research objectives in this thesis was to investigate long-term trends in diet in medieval England, particularly with reference to the impact of marine fish. Based on zooarchaeological and historical evidence, a rapid shift to increased marine fish consumption appears to have occurred around the turn of the 11th century, likely starting with coastal sites and spreading inland over the following centuries (Barrett et al. 2004a, b). However, until now, the only unambiguous evidence of marine fish consumption based on human bone collagen $\delta^{13}C$ and $\delta^{15}N$ came from a small number of males buried at mid-late 11th to early 12th century St. Andrew, Fishergate in York (Müldner 2009; Barrett 2018).

Through $\delta^{13}C$ and $\delta^{15}N$ analysis of human bone collagen, this thesis has uncovered new evidence for earlier exploitation of marine fish at Ipswich. As

shown in Chapter 4, there was little evidence for marine fish consumption at Stoke Quay during the Mid Saxon period, based on a sample of 10 individuals. However, by the late 9th to late 11th centuries, $\delta^{13}C$ and $\delta^{15}N$ analysis of 115 individuals at Stoke Quay demonstrated that considerable numbers of males, but also some females, were consuming marine fish in high enough quantities to raise their $\delta^{13}C$ and $\delta^{15}N$ well above the expected terrestrial carnivore range (Chapter 5). Radiocarbon analyses indicating a pre-11th century date for several individuals in the Late Saxon assemblage (Teague, in press) suggest that results from this thesis could provide evidence for the earliest unambiguous exploitation of marine fish in medieval England.

Throughout the Late Saxon through Medieval periods at Stoke Quay, males as a group have statistically significantly higher $\delta^{13}C$ and $\delta^{15}N$ than females, though there is considerable overlap between the sexes, particularly in the Medieval period (Chapters 4-7). Coupled with historical and archaeological evidence for Ipswich's involvement in shipbuilding and fishing, the $\delta^{13}C$ and $\delta^{15}N$ data suggest that many males in St. Augustine's parish were employed as fishermen or mariners. Occupation in these industries would give men increased access to marine fish, which would support the high levels of fish consumption evident in their bone collagen $\delta^{13}C$ and $\delta^{15}N$.

Access to fish in this population could have also been enabled by proximity to the quays of the busy port of Ipswich, which may help to explain some of the high $\delta^{13}C$ and $\delta^{15}N$ values seen in some Medieval females. These women may have found employment processing or selling fish, either with their husbands or families or on their own. Alternatively, if some of these women were

of higher status, as indicated by their burial in coffins, they may have been able to afford fresh fish such as cod and other gadids, or even marine mammals.

The considerable overlap between male and female $\delta^{13}C$ and $\delta^{15}N$ from the Late Saxon through Medieval periods indicates that diet at this time was the result of a number of social and economic factors that are difficult to isolate. The results also indicate that large sample numbers are needed to capture the breadth and variety of $\delta^{13}C$ and $\delta^{15}N$ even in a single population, particularly one as potentially diverse as that of a port town. The faunal $\delta^{13}C$ and $\delta^{15}N$ results demonstrate the need for comprehensive dietary baselines including a number of species in order to interpret human diet.

9.2.2 Health and urbanisation

Historical and archaeological evidence shows that the process of urbanisation, which accelerated around the 11th and 12th centuries, led to increased economic opportunities for many, but also increased the risk of exposure to communicable diseases and the potential for illness from pollution, poor diet, and poor hygiene (Dyer 2000; Roberts & Cox 2003). At many medieval sites, particularly those from the highly urbanised and densely populated city of London, temporal comparisons show a rise in 'urban' pathologies concomitant with rises in urbanisation (Walter 2017; Connell et al. 2012).

These pathologies include general stress indicators such as periostitis and dental enamel hypoplasia, as well as evidence for dietary deficiencies and parasitic illnesses (*cribra orbitalia*, rickets, scurvy), and evidence of pollution and upper respiratory infections (maxillary sinusitis)(Roberts & Cox 2003). Studies have also found high rates of interpersonal violence in London, especially

from the later 14th century (Krakowka 2017a, b). There has been a relative dearth of osteological analyses on long-term impacts of urbanisation at other English towns, likely due to the fairly short duration of burial at many urban cemeteries.

The large skeletal assemblage at Stoke Quay, coupled with the duration of burial at the site, enabled osteological observations of a host of pathological and demographic indicators at an urbanised site over an exceptionally long time period. Palaeopathological information recorded by osteologists at Oxford Archaeology was analysed and adapted for this thesis to focus on skeletal indicators of urban living conditions and how they may have changed over time.

The skeletal assemblage from Stoke Quay exhibits a wide variety of pathological conditions, including comparatively high crude prevalence rates for periostitis, *cribra orbitalia*, and infectious diseases such as tuberculosis, all of which were more prevalent than at most contemporary urban sites (Chapter 8). Maxillary sinusitis crude prevalence rates also rose over time, though these were lower than the national averages (based on Roberts & Cox 2003, Table 5.3). These conditions all increased at Stoke Quay from the Late Saxon to Medieval periods, though tuberculosis and cribra orbitalia crude prevalence rates dipped in the Anglo-Norman period, perhaps as a result of the relative prosperity of the period leading to better hygiene and improved nutrition.

The high rates of periostitis and *cribra orbitalia* in this assemblage suggest a high disease burden for this population. However, adult age-at-death for the Late Saxon and Anglo-Norman periods peaked at 36-45 years, later than at contemporary St. Mary Spital, where adult age-at-death peaked at 26-35 years (Connell et al. 2012; Loe et al., in press). Medieval age-at-death profiles at Stoke

Quay also show a peak at 26-35 years, indicating lower life expectancy toward the end of the period, perhaps unsurprisingly, given the famines and plagues that swept through Britain during this time. Though there were comparatively low numbers of adults over 45 years of age at Stoke Quay for all periods, the survival of many Late Saxon and Anglo-Norman adults to at least middle age, despite their high probable disease burdens, indicates that they must have been a relatively robust population. Their ability to survive prolonged infections and chronic ill health may have been aided by consumption of marine fish, a nutritionally rich food source (Barrett 2018; Hagen 2006).

The combination of dietary and osteological information presented in this thesis, generated through paired $\delta^{13}C$ and $\delta^{15}N$ analyses and osteological assessments, demonstrates the importance of interrogating more than one data source when studying past populations. Without the demographic and health backgrounds provided by osteological analyses and historical sources, interpretations of $\delta^{13}C$ and $\delta^{15}N$ values might lead to different conclusions about the population buried at Stoke Quay. Notably, without understanding the socioeconomic status of these individuals and their overall poor health, one might conclude, based solely on the high $\delta^{13}C$ and $\delta^{15}N$ values, that this was a high status population. Combining isotopic analyses with in-depth osteological assessments not only enriches our understanding of past diet and life-ways, it also allows for a more informed and nuanced interpretation of the data.

9.2.3 Mobility and the treatment of 'nonlocals'

As highlighted in Chapters 2 and 3, there are a number of complicating issues that make interpretation of 'local' versus 'nonlocal' origins difficult,

despite the fact that isotopic distributions in Britain are relatively well mapped. Of central importance here, the geology and climate of southeastern England is in many cases isotopically indistinguishable from locations in France, southern Scandinavia, and the Netherlands, all areas likely to have engaged in trade with Ipswich over the course of the medieval period (Chapter 8). Added to this are factors related to food preservation and cooking practices, the uncertainties regarding the fractionation of oxygen from drinking water to human body water, as well as the impact of imported foods on $^{87}Sr/^{86}Sr$ ratios.

The difficulty in defining parameters for 'local' isotopic values, and of ascribing potential places of origin to those interpreted as 'nonlocals,' suggests the limited power of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analysis for studies of medieval mobility in southeastern England, at least during the Medieval time period. This thesis has therefore utilised a method for $\delta^{18}O$ interpretations based on archaeological human $\delta^{18}O_P$, paired with a broad range for expected bioavailable $^{87}Sr/^{86}Sr$. With the caveat that these interpretations may be biased by the ranges and methods used, the focus was largely shifted to potential differences *between* these groups, rather than possible places of origin.

Unlike other studies, which found a correlation between diet and interpreted 'nonlocal' origins (Müldner et al. 2011, in a study of Roman York), this study found only a weak correlation between the two variables. A better indicator was found in skeletal indicators of interpersonal violence, which were more prevalent amongst individuals interpreted as 'nonlocals'. Of the six individuals in the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ sample with injuries consistent with interpersonal violence, five were interpreted as 'nonlocals.' Most strikingly, three out of four individuals with perimortem injuries were in this 'nonlocal' group. A

fifth 'nonlocal' with injuries related to interpersonal violence had an antemortem fracture to the ulna known as a 'parry fracture' because it often occurs as a result of defensively parrying a blow by raising the arm over the face (Judd 2008). Injuries were common in this assemblage (Loe et al., in press), but it may be the case that 'nonlocals' suffered a higher proportion of perimortem injuries. One should therefore look carefully at these individuals when trying to establish if whether 'nonlocals' are present in the population.

Medieval towns could be dangerous places, with high numbers of injuries resulting from interpersonal violence seen in London and in towns abroad such as Västerhus, Sweden (Krakowka 2017; Kjellström 2014). There is some documentary evidence that individuals with 'nonlocal' or 'foreign' origins feared for their safety in the Medieval period. As referenced in Chapter 7, the Medieval inhabitants of Ipswich were advised to carry weapons for personal protection, and in the late 14th century, 449 letters of protection were obtained for immigrants living and working in England (Brown et al., in press; Amor 2011; England's Immigrants Database). Combined with the historical evidence, the skeletal and isotopic evidence for violence against foreigners at Stoke Quay contributes to our understanding of social tensions and violence in this period.

The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data also suggest, based on subtle outliers, that both males and females were among the potential 'nonlocals' for the Late Saxon through Medieval periods at Stoke Quay. The presence of males with relatively high $\delta^{13}C$ and $\delta^{15}N$ in the potential 'nonlocal' group could indicate that some of the men were sailors or fishermen from overseas; indeed, written accounts tell us that hundreds of foreign fishermen flocked each year to the productive herring fisheries off the coast of East Anglia (Kowaleski 2016). Potential

'nonlocal' females raise intriguing possibilities; the tentative finding is consistent with documentary evidence for young women moving to urban areas from the countryside in search of apprenticeships and other employment (Goldberg 1992; Dyer 2000). Alternatively, they might be women travelling with their husbands or families.

9.3 Future work

The sampling strategy for the human $\delta^{13}C$ and $\delta^{15}N$ analyses in this thesis was designed to provide a representative view of diet over time at Stoke Quay, while also acting as a pilot study for future research. The results from this thesis point to a number of potentially fruitful areas for future work.

Despite the large numbers of animal bones sampled to establish a baseline for terrestrial animal protein, interpretations of human diet would benefit greatly from $\delta^{13}C$ and $\delta^{15}N$ analysis of fish bones from the site. These samples and results were obtained too late for inclusion in the thesis, but I have already begun a pilot study to determine the best collagen extraction methods for these samples, given the generally poor collagen preservation in archaeological fish bones (Nicholson 1996b; Szpak 2011; Tsutaya et al. 2018). Following this pilot study, I will use the results to extract fish bone collagen from a number of species in order to characterise the range of $\delta^{13}C$ and $\delta^{15}N$ for fish consumed at the site. This will allow firmer conclusions to be drawn regarding the role of fishing practices, and fish in human diets.

Another area for future research that has already begun is to identify occupational injuries associated with different modes of transportation by water, to then evaluate whether these injuries are present in individuals at Stoke Quay

with high $\delta^{13}C$ and $\delta^{15}N$ values. Significant advances in shipbuilding and ship powering technology developed from the Late Saxon to Medieval periods, moving from oared and single masted clinker-built ships to cogs and hulcs, eventually culminating in the three-masted sailing ships of the later Medieval period (Greenhill 1988). While it is difficult, if not impossible, to securely identify occupational injuries in skeletal populations, the added osteological analyses could provide some clarity to the question of whether the men at Stoke Quay with high $\delta^{13}C$ and $\delta^{15}N$ were employed in fishing and seafaring.

The results of this study show that the 'fish event horizon', if indeed it was a horizon, began earlier at Stoke Quay than at other, more inland, sites, but the precise timing of this change at Stoke Quay is unclear due to the limited numbers of radiocarbon dates obtained for the 9th-11th century burials. Due to the approximately 100-150-year gap in burial practice at Stoke Quay, it is difficult to assess whether fish consumption increased gradually or more suddenly at this site. Better resolution for the timing of the 'fish event horizon' could be produced from additional targeted radiocarbon dating of Late Saxon individuals at Stoke Quay with high $\delta^{13}C$ and $\delta^{15}N$ values indicative of marine fish consumption.

Following on the work of Mary Lewis on adolescence in the medieval period, the adolescents in the Stoke Quay assemblage could be assessed for skeletal indicators of reaching the age of menarche. Additionally, micro-sampling of enamel and dentine from adolescents could elucidate the timing of movement to urban areas for apprenticeships. This would add much needed information to our currently limited understanding of adolescence during the medieval period.

9.4 Significance of this study

Ipswich has long been considered an important early medieval trading centre and later medieval town, but it is often given only a cursory acknowledgement in historical narratives of trade, urbanisation, and fishing in medieval England. Indeed, while much scholarly attention has been paid to the *emporia* of *Hamwic* (Southampton), *Eoforwic* (York), and *Lundenwic* (London), far less attention is paid to *Gippeswic* (Ipswich), likely due to a lack of published excavations and a relative dearth of documentary materials. With the results from this thesis and the forthcoming Stoke Quay site monograph, the situation may begin to change.

This thesis contributes to the corpus of research on medieval diet and, to the best knowledge of the author, has analysed more skeletons for $\delta^{13}C$ and $\delta^{15}N$ than at any other single site in England. In addition to the sheer number of individuals sampled, this is also the first large-scale isotopic study of diet at a medieval English port. This research is instrumental to furthering our understanding of the character and living conditions of medieval towns in general, and of Ipswich in particular. It also contributes to the growing body of evidence for the timing of the 'fish event horizon', pointing to an early adoption of marine fish exploitation at Ipswich compared to other medieval sites.

The strontium and oxygen isotope results in this thesis highlight the complexity involved in detecting 'nonlocals' in a large unmarked medieval cemetery, and indicate that larger sample sizes are needed in order to characterise the scale and nature of medieval mobility. The combined $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analyses, in conjunction with osteological analyses, point to the utility of multifaceted approaches for understanding past lives.

In addition to the human isotopic results, this thesis also involves a large number of faunal $\delta^{13}C$ and $\delta^{15}N$ analyses, with a sample size among the largest yet analysed for any human dietary study in medieval England. The results for major domesticates from Mid Saxon to Medieval contexts provide a data source that can inform studies of changing medieval English animal husbandry and urban food sourcing. Additionally, the inclusion of a number of chicken and goose bones in the faunal sample contributes to our understanding of the consumption of animals in the medieval period, showing that relatively high $\delta^{15}N$ can be obtained from a diet high in domestic poultry. This could have important implications for future studies of medieval human diet.

This study has also shown a potential link between mobility and violence-related trauma in the medieval period, previously only hinted at as potential explanations in studies of either trauma or mobility. The combined approach used here further demonstrates the utility in using multiple sources of data and lines of evidence when investigating the experience of past peoples.

The wide range of dietary practices evident in the $\delta^{13}C$ and $\delta^{15}N$ at Stoke Quay, paired with diverse burial practices, stature, and skeletal morphology throughout the Mid Saxon to Medieval periods, highlights the diversity that has characterised many English towns since their formation. More broadly speaking, this study contributes to our understanding of the busy trading and fishing economy of the regions abutting the North Sea, and hints at the potentially high degree of mobility between these areas from an early date. Particularly in the current climate of increasingly isolationist policies and nationalism around Europe, this study serves to illustrate the cross-sea connections that have characterised the North Sea region and its people for well over 1000 years.

Appendix 1: Faunal $\delta^{13}C$ and $\delta^{15}N$ Results

ID	Species	Period	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N
5432-CH2	Chicken	Mid Saxon	-19.7	8.5	41.4	14.8	3.3
5432-CH3	Chicken	Mid Saxon	-20.5	11.5	43.7	15.7	3.3
5432-CH4	Chicken	Mid Saxon	-20.3	11.5	43.8	15.5	3.3
5432-CH5	Chicken	Mid Saxon	-18.9	11.2	44.1	15.7	3.3
5432-CH6	Chicken	Mid Saxon	-19.8	9.3	44.7	16.0	3.3
5432-CH8	Chicken	Mid Saxon	-19.6	12.5	45.5	16.2	3.3
5432_B1	Cow	Mid Saxon	-22.0	6.4	42.9	15.3	3.3
5432_B2	Cow	Mid Saxon	-21.9	7.5	32.5	11.3	3.4
5432_B3	Cow	Mid Saxon	-22.2	6.4	42.7	15.3	3.3
5432_B4	Cow	Mid Saxon	-21.9	7.7	42.2	14.8	3.3
5432-G1	Goose	Mid Saxon	-22.4	8.0	43.3	15.4	3.3
5432-G2	Goose	Mid Saxon	-23.6	6.7	41.2	14.9	3.2
5432-G3	Goose	Mid Saxon	-14.7	11.5	44.7	16.2	3.2
5432-G4	Goose	Mid Saxon	-21.8	12.1	45.2	16.2	3.2
5432-G5	Goose	Mid Saxon	-22.2	10.7	47.0	17.0	3.2
5432-G6	Goose	Mid Saxon	-21.8	7.5	44.7	16.2	3.2
5432_S1	Pig	Mid Saxon	-20.4	6.4	43.2	15.2	3.3
5432_S2	Pig	Mid Saxon	-20.3	7.4	42.4	14.6	3.4
5432_S3	Pig	Mid Saxon	-21.3	6.6	41.8	14.5	3.4
5432_S4	Pig	Mid Saxon	-21.7	6.6	34.9	12.3	3.3
5432_S5	Pig	Mid Saxon	-21.6	6.0	40.4	14.1	3.3
5432_S6	Pig	Mid Saxon	-20.5	5.4	42.0	14.9	3.3
5432_S7	Pig	Mid Saxon	-21.1	6.7	42.5	14.6	3.4
5432_OC1	Sheep/goat	Mid Saxon	-20.8	4.8	40.2	14.1	3.3
5432_OC1	Sheep/goat	Mid Saxon	-20.9	7.1	41.2	14.7	3.3
5432_OC3	Sheep/goat	Mid Saxon	-19.3	6.7	35.6	12.7	3.3
5432_OC4	Sheep/goat	Mid Saxon	-22.4	6.8	23.7	8.0	3.5
5432-OC4-2	Sheep/goat	Mid Saxon	-22.4	8.4	41.9	14.9	3.3
5432_OC5	Sheep/goat	Mid Saxon	-18.5	9.4	42.5	15.1	3.3
5434-CH1	Chicken	Late Saxon	-20.1	11.4	45.1	16.2	3.2
5434-CH2	Chicken	Late Saxon	-19.9	11.0	43.3	15.4	3.3
5434_B1	Cow	Late Saxon	-22.4	7.2	42.2	15.1	3.3
7308_B1	Cow	Late Saxon	-23.6	7.3	34.9	12.0	3.4
7308-B1-2	Cow	Late Saxon	-22.5	7.5	41.2	14.8	3.3
7308_B2	Cow	Late Saxon	-22.6	5.7	36.7	12.3	3.5
7308-B2-2	Cow	Late Saxon	-22.2	5.6	40.0	14.2	3.3
5434-G1	Goose	Late Saxon	-21.6	9.9	42.2	15.4	3.2
5434_S1	Pig	Late Saxon	-21.3	8.2	41.0	14.5	3.3
5434_S2	Pig	Late Saxon	-20.6	5.9	33.6	11.8	3.3
7308_S1	Pig	Late Saxon	-22.0	6.7	41.2	14.6	3.3
7308_S2	Pig	Late Saxon	-23.4	6.4	34.8	12.2	3.3
7308-S2-2	Pig	Late Saxon	-22.4	6.7	42.5	15.1	3.3
7308_S3	Pig	Late Saxon	-21.9	5.3	43.1	14.4	3.5
7308-S3-2	Pig	Late Saxon	-21.1	4.7	44.5	15.8	3.3
7308_S4	Pig	Late Saxon	-21.9	5.3	27.3	9.4	3.4

ID	Species	Period	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N
7308_S5	Pig	Late Saxon	-21.6	5.4	38.1	13.5	3.3
7308_S6	Pig	Late Saxon	-21.1	7.8	38.6	13.9	3.2
5434_OC1	Sheep/goat	Late Saxon	-22.1	7.6	41.0	14.6	3.3
5434-OC1-2	Sheep/goat	Late Saxon	-22.0	7.6	44.0	15.9	3.2
5434_OC2	Sheep/goat	Late Saxon	-21.3	9.2	40.0	13.7	3.4
7308_OC1	Sheep/goat	Late Saxon	-21.3	6.5	37.6	13.4	3.3
7308_OC2	Sheep/goat	Late Saxon	-23.3	7.1	22.2	7.7	3.4
7308-OC2-2	Sheep/goat	Late Saxon	-22.4	8.1	40.0	14.4	3.2
7308_OC3	Sheep/goat	Late Saxon	-22.5	5.9	38.4	13.8	3.2
7308_OC4	Sheep/goat	Late Saxon	-22.3	7.2	36.7	12.4	3.5
7308-OC4-2	Sheep/goat	Late Saxon	-21.9	7.1	38.5	13.5	3.3
7308_OC5	Sheep/goat	Late Saxon	-22.1	5.9	35.6	12.8	3.2
5752-F1	Cat	Anglo-Norman	-18.9	12.0	45.8	16.7	3.2
1061-CH2	Chicken	Anglo-Norman	-20.6	9.7	45.8	16.4	3.3
1061-CH3	Chicken	Anglo-Norman	-20.8	8.9	41.1	14.9	3.2
1061-CH4	Chicken	Anglo-Norman	-20.4	9.5	44.1	16.1	3.2
5752-CH10	Chicken	Anglo-Norman	-20.6	8.6	46.4	16.8	3.2
5752-CH2	Chicken	Anglo-Norman	-19.8	9.8	41.4	14.8	3.3
1061_B1	Cow	Anglo-Norman	-22.8	6.1	37.9	13.4	3.3
1061-B1-2	Cow	Anglo-Norman	-22.7	6.3	42.3	15.4	3.2
1061_B2	Cow	Anglo-Norman	-21.5	7.6	31.9	11.4	3.3
1061_B3	Cow	Anglo-Norman	-21.6	7.7	39.0	13.6	3.3
1061_B5	Cow	Anglo-Norman	-21.5	6.8	35.5	12.6	3.3
5752_B1	Cow	Anglo-Norman	-22.6	6.3	39.2	13.8	3.3
5752_B3	Cow	Anglo-Norman	-21.9	7.0	41.5	14.6	3.3
5752_B4	Cow	Anglo-Norman	-22.2	6.4	36.4	12.6	3.4
5752-C1	Dog	Anglo-Norman	-19.2	12.3	43.1	15.5	3.2
5752-G2	Goose	Anglo-Norman	-22.3	8.5	44.4	15.3	3.4
1061_E1	Horse	Anglo-Norman	-22.3	6.3	30.8	10.8	3.3
5752-M1	Mallard	Anglo-Norman	-22.6	7.5	39.2	14.0	3.3
1061_S1	Pig	Anglo-Norman	-21.1	8.6	43.6	15.5	3.3
1061_S2	Pig	Anglo-Norman	-20.8	6.4	39.8	14.1	3.3
1061_S3	Pig	Anglo-Norman	-20.8	5.5	37.9	13.4	3.3
1061_S4	Pig	Anglo-Norman	-21.4	6.9	33.9	12.0	3.3
1061_S5	Pig	Anglo-Norman	-21.5	6.3	42.1	14.7	3.3
5752_S1	Pig	Anglo-Norman	-21.9	6.4	28.3	10.1	3.3
5752_S2	Pig	Anglo-Norman	-22.1	6.7	36.4	12.6	3.4
5752_S3	Pig	Anglo-Norman	-21.6	7.8	41.3	14.7	3.3
5752_S4	Pig	Anglo-Norman	-20.5	7.4	41.6	14.7	3.3
5752_S5	Pig	Anglo-Norman	-20.9	5.4	39.2	13.4	3.4
5752_S6	Pig	Anglo-Norman	-22.6	8.2	23.3	7.9	3.5
5752-S1-2	Pig	Anglo-Norman	-21.7	6.1	32.5	11.5	3.3
5752-S2-2	Pig	Anglo-Norman	-21.7	6.7	41.1	14.5	3.3
5752-S6-2	Pig	Anglo-Norman	-22.0	8.5	41.8	14.8	3.3
1061_OC1	Sheep/goat	Anglo-Norman	-20.8	4.1	40.0	14.1	3.3
1061_OC2	Sheep/goat	Anglo-Norman	-22.2	4.4	34.6	12.2	3.3
1061_OC3	Sheep/goat	Anglo-Norman	-21.4	7.3	39.3	14.1	3.3
5752_OC1	Sheep/goat	Anglo-Norman	-20.6	8.1	42.2	15.1	3.3

ID	Species	Period	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N
5752_OC2	Sheep/goat	Anglo-Norman	-21.6	4.6	41.1	14.7	3.3
5752_OC3	Sheep/goat	Anglo-Norman	-22.1	7.9	34.1	11.9	3.4
5752_OC4	Sheep/goat	Anglo-Norman	-21.5	4.8	28.7	10.1	3.3
5752_OC5	Sheep/goat	Anglo-Norman	-21.2	5.6	41.7	14.8	3.3
5752_OC6	Sheep/goat	Anglo-Norman	-22.0	7.3	38.3	13.2	3.4
5752_OC7	Sheep/goat	Anglo-Norman	-21.4	4.7	36.1	12.1	3.5
8490_B1	Cow	Medieval	-22.1	6.3	29.4	10.3	3.3
8490_B2	Cow	Medieval	-22.4	5.6	40.1	14.5	3.2
8490-B2-2	Cow	Medieval	-22.2	5.6	42.3	15.5	3.2
8566_B1	Cow	Medieval	-22.8	6.1	16.7	5.6	3.5
8566-B1-2	Cow	Medieval	-22.3	6.9	39.6	14.1	3.3
8490-G1	Goose	Medieval	-22.2	10.6	43.9	15.7	3.3
8490-G2	Goose	Medieval	-23.1	9.4	44.9	16.3	3.2
8490_S1	Pig	Medieval	-21.4	6.8	40.7	14.3	3.3
8490_S2	Pig	Medieval	-22.0	6.4	36.8	12.6	3.4
8490-S2-2	Pig	Medieval	-21.7	5.8	44.0	15.7	3.3
8490_S3	Pig	Medieval	-21.6	7.1	41.1	14.5	3.3
1104_OC1	Sheep/goat	Medieval	-21.8	5.7	39.9	13.9	3.3
1104_OC2	Sheep/goat	Medieval	-21.5	8.7	41.5	14.6	3.3
1104_OC3	Sheep/goat	Medieval	-21.8	5.6	43.9	15.8	3.2
5432-CH2	Chicken	Mid Saxon	-19.7	8.5	41.4	14.8	3.3

Appendix 2: Human $\delta^{13}C$ and $\delta^{15}N$ Results

Results from single analysis; * Part of the pilot study

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
1045	26-35	?F	Mid Saxon	-19.7	11.3	44.7	15.5	3.4	7.9
7948	26-35	?	Mid Saxon	-	-	-	-	-	0.0
7993	18+	?	Mid Saxon	-20.2	9.5	35.5	12.6	3.3	1.9
8343	36-45	?M	Mid Saxon	-20.1	10.4	25.4	8.9	3.3	1.0
8661	26-35	?	Mid Saxon	-	-	-	-	-	1.4
9073	18-25	?	Mid Saxon	-	-	-	-	-	0.2
*20109	36-45	?M	Mid Saxon	-20.3	10.9	40.4	14.6	3.2	10.6
20136	26-35	?	Mid Saxon	-20.7	8.2	16.4	5.5	3.4	4.9
20148	26-35	?	Mid Saxon	-	-	-	-	-	0.0
20413	36-45	??M	Mid Saxon	-	-	-	-	-	4.2
20512	26-35	F	Mid Saxon	-19.9	11.1	42.6	15.2	3.3	8.9
*20808	36-45	M	Mid Saxon	-20.1	12.6	30.6	10.7	3.3	9.5
20899	18-25	??M	Mid Saxon	-	-	-	-	-	0.3
21036	26-35	??F	Mid Saxon	-	-	-	-	-	0.0
21707	18+	?	Mid Saxon	-19.3	13.9	45.0	16.0	3.3	6.9
21975	18-25	??F	Mid Saxon	-	-	-	-	-	3.2
22032	18-25	F	Mid Saxon	-20.0	11.6	31.1	11.0	3.3	5.0
22480	18-25	F	Mid Saxon	-19.9	11.4	43.9	15.7	3.3	6.3
5028	13-17	?	Late Saxon	-19.0	11.7	42.6	15.1	3.3	5.4
5096	13-17	?	Late Saxon	-19.0	11.5	43.2	15.2	3.3	5.3
5260	13-17	?	Late Saxon	-19.8	11.6	37.6	13.3	3.3	9.4
5347	06-12	?	Late Saxon	-19.4	10.9	40.5	14.3	3.3	5.3
5406	45+	??M	Late Saxon	-19.4	11.4	36.3	12.6	3.4	4.6
+ 5909	45+	F	Late Saxon	-19.4	11.0	-	-	-	-
6370	45+	M	Late Saxon	-18.4	12.7	31.2	11.1	3.3	5.0
6500	06-12	?	Late Saxon	-20.3	9.6	35.8	12.5	3.3	3.4
6528	18-25	F	Late Saxon	-19.0	11.3	42.9	15.3	3.3	5.5
6564	13-17	?	Late Saxon	-19.9	10.1	40.1	13.9	3.4	6.0
6610	36-45	?M	Late Saxon	-17.4	14.7	41.9	14.8	3.3	6.5
6630	18-25	M	Late Saxon	-19.0	12.8	43.3	15.4	3.3	4.7
7037	13-17	?	Late Saxon	-18.8	11.0	43.8	15.4	3.3	5.1
7279	13-17	?	Late Saxon	-18.6	13.0	42.0	14.5	3.4	4.9
*7327	45+	M	Late Saxon	-18.5	14.5	43.2	15.2	3.3	6.2
7440	45+	?F	Late Saxon	-19.9	10.7	41.5	14.7	3.3	5.5
7517	45+	F	Late Saxon	-18.8	13.0	42.8	15.1	3.3	5.2
7849	36-45	F	Late Saxon	-18.9	12.2	44.1	15.5	3.3	4.4
7952	01-05	?	Late Saxon	-19.1	11.6	44.0	15.6	3.3	9.2

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
*8104	36-45	?M	Late Saxon	-18.6	12.0	39.4	14.1	3.3	11.3
8193	13-17	M	Late Saxon	-19.0	11.1	42.3	15.0	3.3	4.5
8241	13-17	?	Late Saxon	-18.9	10.8	42.2	15.0	3.3	3.4
8348	06-12	?	Late Saxon	-	-	-	-	-	-
8357	01-05	?	Late Saxon	-18.8	14.4	41.2	14.4	3.3	4.0
8433	45+	?F	Late Saxon	-18.3	12.0	45.7	15.9	3.4	8.3
8439	13-17	?	Late Saxon	-20.0	9.1	43.1	15.4	3.3	16.2
8485	13-17	?	Late Saxon	-19.3	11.6	36.2	13.2	3.2	8.9
*8517	36-45	M	Late Saxon	-18.8	12.9	41.3	14.8	3.3	4.7
8547	06-12	?	Late Saxon	-19.2	11.1	41.9	14.7	3.3	5.1
8582	01-05	?	Late Saxon	-19.1	12.4	44.5	15.1	3.4	4.9
8587	36-45	?F	Late Saxon	-18.8	11.3	43.4	15.4	3.3	4.1
8590	06-12	?	Late Saxon	-19.6	11.1	41.4	14.5	3.3	3.4
8785	13-17	?	Late Saxon	-18.8	11.0	42.7	15.2	3.3	5.3
20052	36-45	F	Late Saxon	-19.3	11.5	46.8	15.9	3.4	3.1
20058	26-35	?M	Late Saxon	-19.6	11.0	43.7	15.4	3.3	3.8
20068	18-25	?M	Late Saxon	-19.4	11.8	44.2	15.6	3.3	5.7
20096	26-35	M	Late Saxon	-18.3	13.5	44.4	15.5	3.3	3.3
20207	36-45	F	Late Saxon	-19.0	11.7	44.2	15.6	3.3	9.2
20222	13-17	?	Late Saxon	-19.2	12.5	42.8	15.0	3.3	3.9
20280	13-17	?	Late Saxon	-19.1	11.2	46.4	16.4	3.3	5.6
*20292	13-17	?	Late Saxon	-19.1	11.5	41.4	14.7	3.3	4.6
20307	36-45	M	Late Saxon	-18.6	11.5	36.7	13.1	3.3	3.0
20352	06-12	?	Late Saxon	-18.8	12.1	35.1	12.5	3.3	5.0
20392	01-05	?	Late Saxon	-19.4	12.6	41.4	14.7	3.3	6.4
20548	26-35	F	Late Saxon	-19.4	10.5	42.2	14.8	3.3	5.5
20617	18-25	F	Late Saxon	-19.2	11.8	27.2	9.8	3.2	3.6
20641	45+	?F	Late Saxon	-18.6	12.8	27.9	10.1	3.2	5.0
20657	13-17	?	Late Saxon	-19.0	13.1	41.8	14.7	3.3	5.1
20665	36-45	F	Late Saxon	-18.6	13.5	44.0	15.6	3.3	4.6
20669	26-35	F	Late Saxon	-18.7	12.4	41.5	14.6	3.3	4.7
20708	45+	M	Late Saxon	-18.3	14.3	37.4	13.2	3.3	3.1
*20748	26-35	F	Late Saxon	-20.0	8.9	44.7	16.1	3.2	13.0
20790	06-12	?	Late Saxon	-19.1	11.0	37.4	12.7	3.4	2.6
20798	26-35	F	Late Saxon	-19.1	11.9	41.1	14.2	3.4	4.0
20825	06-12	?	Late Saxon	-18.9	13.7	39.9	13.8	3.4	6.7
20834	01-05	?	Late Saxon	-18.1	15.2	43.8	15.1	3.4	4.1
20839	01-05	?	Late Saxon	-19.0	11.6	37.6	13.2	3.3	9.0
20894	45+	F	Late Saxon	-18.6	13.3	35.2	12.3	3.3	7.4
20919	13-17	?	Late Saxon	-20.1	10.4	40.5	14.2	3.3	6.9
20952	13-17	?	Late Saxon	-19.6	10.7	32.2	11.5	3.3	5.0
21014	01-05	?	Late Saxon	-18.5	13.3	43.1	15.2	3.3	5.1
21087	36-45	F	Late Saxon	-19.4	11.9	43.2	14.5	3.5	4.9

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
21124	36-45	M	Late Saxon	-18.4	13.9	41.6	14.8	3.3	7.3
21136	18-25	M	Late Saxon	-18.9	12.4	41.6	14.5	3.4	4.5
21160	36-45	M	Late Saxon	-18.1	13.8	41.9	14.8	3.3	3.4
21166	36-45	?F	Late Saxon	-19.0	12.2	44.0	15.6	3.3	8.4
21202	26-35	?F	Late Saxon	-19.3	10.0	44.4	15.3	3.4	5.0
21209	26-35	?M	Late Saxon	-19.2	12.6	42.7	14.8	3.4	6.7
21226	26-35	M	Late Saxon	-19.4	12.3	45.4	15.8	3.4	7.9
21237	06-12	?	Late Saxon	-19.3	12.5	45.4	15.7	3.4	6.9
21243	36-45	M	Late Saxon	-18.7	12.9	33.7	11.9	3.3	8.0
21255	60+	M	Late Saxon	-18.7	11.9	43.7	15.7	3.3	6.5
21267	45+	M	Late Saxon	-18.0	14.2	39.1	14.2	3.2	11.4
21324	18-25	??M	Late Saxon	-19.5	10.7	34.3	12.2	3.3	3.5
*21338	36-45	M	Late Saxon	-18.0	14.5	22.7	7.9	3.4	4.3
21371	06-12	?	Late Saxon	-18.5	13.2	41.0	14.5	3.3	6.2
21441	26-35	M	Late Saxon	-19.5	12.0	38.6	13.4	3.4	7.8
21516	26-35	F	Late Saxon	-19.8	11.4	43.0	15.0	3.3	5.2
21820	45+	??M	Late Saxon	-19.5	12.4	41.5	14.9	3.3	12.0
21833	18-25	??M	Late Saxon	-17.8	13.4	42.3	15.0	3.3	3.7
21871	18-25	M	Late Saxon	-18.3	12.8	42.2	15.0	3.3	5.3
*21946	26-35	??F	Late Saxon	-18.8	12.4	39.7	14.4	3.2	6.8
*21957	36-45	?F	Late Saxon	-19.9	11.2	39.9	13.5	3.4	1.6
22049	26-35	F	Late Saxon	-18.0	13.0	43.6	15.1	3.4	4.5
22118	45+	M	Late Saxon	-19.2	12.2	42.2	14.7	3.4	4.6
22131	01-05	?	Late Saxon	-18.6	12.5	40.5	14.3	3.3	15.3
22162	36-45	?M	Late Saxon	-18.3	12.5	42.8	15.2	3.3	8.3
22191	26-35	M	Late Saxon	-17.2	14.9	42.0	15.1	3.2	15.3
*22215	36-45	F	Late Saxon	-19.8	11.4	43.3	15.3	3.3	4.0
*22272	36-45	?M	Late Saxon	-18.9	13.1	32.1	11.3	3.3	6.0
22284	01-05	?	Late Saxon	-18.8	11.9	39.9	13.9	3.3	4.5
22300	45+	M	Late Saxon	-18.6	11.9	42.0	14.9	3.3	14.1
22370	36-45	F	Late Saxon	-19.1	12.7	43.8	15.4	3.3	12.6
*22376	36-45	?F	Late Saxon	-19.8	11.2	40.3	14.4	3.3	10.3
22385	45+	M	Late Saxon	-17.9	14.8	43.5	15.3	3.3	4.8
22400	01-05	?	Late Saxon	-19.1	10.0	41.3	14.8	3.3	9.4
22404	45+	?F	Late Saxon	-19.0	12.2	40.2	13.9	3.4	7.8
22467	26-35	?F	Late Saxon	-19.6	12.1	42.0	14.7	3.3	4.7
22531	36-45	?M	Late Saxon	-18.8	12.7	43.4	15.2	3.3	-
22580	45+	F	Late Saxon	-18.9	11.8	40.8	14.6	3.3	15.0
22633	36-45	?M	Late Saxon	-17.6	13.9	39.5	13.8	3.3	6.3
22652	26-35	??M	Late Saxon	-18.6	12.2	42.7	15.1	3.3	6.2
22664	26-35	?F	Late Saxon	-18.6	11.8	43.2	15.3	3.3	4.4
*22785	36-45	F	Late Saxon	-19.2	13.6	43.9	15.4	3.3	4.7
22815	26-35	M	Late Saxon	-18.1	13.7	40.6	14.1	3.4	7.7

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
22872	26-35	?F	Late Saxon	-18.2	13.5	44.0	15.8	3.3	10.1
22914	36-45	?M	Late Saxon	-17.9	14.2	44.3	15.4	3.4	5.2
22952	13-17	?	Late Saxon	-18.8	12.9	42.6	14.8	3.4	4.4
22973	45+	F	Late Saxon	-19.0	11.7	43.5	15.0	3.4	5.7
23014	18-25	?M	Late Saxon	-19.7	10.5	44.5	15.9	3.3	6.3
23040	18-25	F	Late Saxon	-19.3	12.6	41.9	14.4	3.4	4.3
23133	26-35	?M	Late Saxon	-18.5	13.2	31.9	11.4	3.3	6.5
23150	18-25	F	Late Saxon	-19.4	11.8	43.6	15.1	3.4	4.2
23170	36-45	?M	Late Saxon	-18.7	12.4	44.2	15.6	3.3	5.4
*23218	18-25	??F	Late Saxon	-18.7	12.2	43.2	15.2	3.3	5.5
23235	45+	?F	Late Saxon	-19.4	12.3	43.1	15.1	3.3	5.0
5158	06-12	?	Anglo-Norman	-18.6	12.0	33.6	12.2	3.2	4.4
#5269	01-05	?	Anglo-Norman	-19.7	8.2	20.4	7.2	3.3	6.1
5423	18-25	F	Anglo-Norman	-19.0	11.7	25.1	8.9	3.3	2.7
5427	45+	F	Anglo-Norman	-18.6	13.4	42.0	14.9	3.3	6.0
5507	13-17	?	Anglo-Norman	-19.5	10.1	43.3	15.4	3.3	4.0
5547	18-25	F	Anglo-Norman	-18.6	11.9	41.7	14.8	3.3	5.3
5632	45+	M	Anglo-Norman	-18.4	12.9	43.9	15.7	3.3	6.7
5683	13-17	?	Anglo-Norman	-19.1	11.9	45.6	16.3	3.3	6.7
5794	18-25	M	Anglo-Norman	-18.4	13.3	43.8	15.5	3.3	4.8
5867	13-17	?	Anglo-Norman	-19.1	11.0	41.1	14.5	3.3	4.1
*5968	06-12	?	Anglo-Norman	-19.7	11.5	44.9	15.9	3.3	4.7
5999	18-25	F	Anglo-Norman	-18.9	13.0	41.9	14.8	3.3	6.1
6058	01-05	?	Anglo-Norman	-18.9	13.4	41.5	14.8	3.3	4.3
6220	18-25	M	Anglo-Norman	-18.5	13.0	43.1	15.4	3.3	3.8
6311	01-05	?	Anglo-Norman	-18.8	12.9	38.9	13.9	3.3	6.8
#6359	13-17	?	Anglo-Norman	-18.9	11.8	43.8	15.7	3.3	4.9
6380	45+	?F	Anglo-Norman	-19.1	11.9	40.6	14.6	3.2	7.9
6396	26-35	M	Anglo-Norman	-19.8	10.9	33.3	11.9	3.3	3.3
6400	26-35	M	Anglo-Norman	-19.2	12.0	42.7	14.9	3.4	8.1
6443	36-45	?M	Anglo-Norman	-18.8	12.9	42.8	15.0	3.3	4.7

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
6560	18-25	??F	Anglo-Norman	-19.1	12.4	41.0	14.5	3.3	4.5
6646	26-35	M	Anglo-Norman	-19.3	11.2	41.7	14.7	3.3	5.4
6749	13-17	?	Anglo-Norman	-19.2	11.3	40.2	14.2	3.3	4.6
6783	36-45	F	Anglo-Norman	-19.8	10.0	30.7	10.8	3.3	4.0
6819	45+	?M	Anglo-Norman	-19.2	11.7	41.9	14.9	3.3	10.6
*6907	45+	M	Anglo-Norman	-18.0	13.6	37.2	13.5	3.2	6.0
6912	18-25	?F	Anglo-Norman	-18.8	13.3	35.9	12.8	3.3	8.7
6955	06-12	?	Anglo-Norman	-19.1	12.8	41.4	14.6	3.3	6.4
6994	18-25	??F	Anglo-Norman	-19.0	12.9	39.9	14.0	3.3	4.9
7044	36-45	M	Anglo-Norman	-18.5	13.3	42.6	15.0	3.3	4.7
7183	36-45	?F	Anglo-Norman	-18.7	12.7	38.7	13.6	3.3	8.3
7223	18-25	F	Anglo-Norman	-19.4	11.7	39.1	13.7	3.3	3.5
*7268	36-45	M	Anglo-Norman	-18.5	13.2	31.1	10.8	3.4	5.4
7335	13-17	?	Anglo-Norman	-18.3	13.5	46.3	16.5	3.3	9.9
7365	01-05	?	Anglo-Norman	-19.4	10.8	47.3	16.3	3.4	9.9
7588	26-35	M	Anglo-Norman	-18.0	14.8	45.6	16.0	3.3	11.7
*7599	26-35	M	Anglo-Norman	-18.4	13.3	40.7	14.4	3.3	6.6
7696	06-12	?	Anglo-Norman	-19.1	11.2	44.1	15.6	3.3	5.6
7769	18-25	M	Anglo-Norman	-18.4	13.4	44.2	15.4	3.3	4.1
7932	01-05	?	Anglo-Norman	-19.0	12.9	37.2	12.9	3.4	4.1
7968	36-45	M	Anglo-Norman	-17.6	14.7	37.2	13.2	3.3	2.7
8170	26-35	F	Anglo-Norman	-19.1	11.9	42.2	14.8	3.3	5.0
8303	36-45	F	Anglo-Norman	-19.1	12.7	41.5	14.6	3.3	3.6
8387	36-45	M	Anglo-Norman	-18.4	13.6	41.8	14.6	3.3	8.1
8678	45+	??F	Anglo-Norman	-19.5	10.5	35.3	12.6	3.3	6.3
8759	36-45	?M	Anglo-Norman	-18.9	12.9	24.8	9.0	3.2	3.8
8805	45+	F	Anglo-Norman	-18.9	12.4	41.6	14.4	3.4	4.5

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
*8866	36-45	??F	Anglo-Norman	-17.9	13.0	34.1	12.2	3.3	4.1
20040	26-35	F	Anglo-Norman	-19.3	11.6	46.7	16.4	3.3	4.5
*20060	45+	??F	Anglo-Norman	-19.1	13.0	36.4	12.7	3.3	6.9
20080	45+	M	Anglo-Norman	-17.8	15.1	44.7	15.8	3.3	8.0
20120	26-35	M	Anglo-Norman	-18.0	13.2	46.5	16.3	3.3	5.2
20201	18-25	??M	Anglo-Norman	-19.2	12.4	29.7	10.5	3.3	3.7
20243	13-17	?	Anglo-Norman	-18.7	12.0	41.4	14.9	3.2	7.7
20271	01-05	?	Anglo-Norman	-18.8	13.8	42.4	15.2	3.3	10.6
20295	26-35	F	Anglo-Norman	-18.9	12.9	48.0	17.2	3.3	11.8
20319	36-45	F	Anglo-Norman	-19.1	13.2	36.3	12.8	3.3	6.6
20322	45+	M	Anglo-Norman	-18.2	12.9	47.6	16.6	3.3	7.8
20368	13-17	??M	Anglo-Norman	-18.6	11.8	24.7	8.8	3.3	3.4
*20394	06-12	?	Anglo-Norman	-18.8	12.6	33.0	11.9	3.2	5.1
20416	36-45	F	Anglo-Norman	-19.3	11.8	42.8	15.3	3.3	15.8
20421	36-45	??F	Anglo-Norman	-18.8	12.7	30.1	10.8	3.3	4.5
20425	36-45	M	Anglo-Norman	-18.6	12.4	42.1	14.8	3.3	4.0
20428	06-12	?	Anglo-Norman	-19.0	11.0	37.5	13.1	3.3	9.4
20437	13-17	?	Anglo-Norman	-18.9	12.2	42.8	14.9	3.3	4.7
20569	06-12	?	Anglo-Norman	-19.1	11.7	26.6	9.7	3.2	3.1
20572	18-25	??F	Anglo-Norman	-18.7	12.1	25.2	8.9	3.3	5.6
*20580	26-35	M	Anglo-Norman	-18.0	14.1	41.5	15.3	3.2	7.3
20602	13-17	?	Anglo-Norman	-19.2	12.2	35.5	12.4	3.3	7.9
*20633	36-45	?M	Anglo-Norman	-18.8	13.4	23.6	8.3	3.3	4.4
20649	06-12	?	Anglo-Norman	-18.8	12.8	43.2	15.2	3.3	2.8
20677	26-35	F	Anglo-Norman	-18.7	12.6	22.5	8.1	3.2	4.5
20703	01-05	?	Anglo-Norman	-18.5	12.4	36.4	13.0	3.3	3.6
*20801	60+	F	Anglo-Norman	-19.5	10.4	32.1	11.4	3.3	2.4

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
20817	13-17	?	Anglo-Norman	-19.7	9.8	40.6	14.6	3.2	14.1
*20820	36-45	M	Anglo-Norman	-18.7	13.9	25.3	8.9	3.3	1.4
20879	06-12	?	Anglo-Norman	-19.1	11.0	38.5	13.5	3.3	7.8
20970	36-45	M	Anglo-Norman	-18.0	13.8	33.7	11.7	3.4	6.9
20993	45+	M	Anglo-Norman	-18.6	14.0	38.2	13.2	3.4	5.1
21019	13-17	?	Anglo-Norman	-18.7	12.7	44.6	15.1	3.5	4.2
21079	13-17	?M	Anglo-Norman	-18.6	12.9	46.0	16.2	3.3	8.7
21099	26-35	?F	Anglo-Norman	-19.7	11.9	43.3	15.3	3.3	4.7
21116	26-35	M	Anglo-Norman	-19.7	12.0	43.6	14.7	3.4	4.7
21180	36-45	F	Anglo-Norman	-18.7	12.4	41.0	14.8	3.2	14.9
21343	45+	?F	Anglo-Norman	-19.0	12.9	44.7	15.3	3.4	8.0
21479	01-05	?	Anglo-Norman	-18.4	13.5	42.3	14.9	3.3	4.5
#21496	18-25	M	Anglo-Norman	-19.6	12.8	20.4	7.3	3.2	3.7
21639	18-25	F	Anglo-Norman	-18.5	12.6	43.0	15.4	3.3	6.1
21678	18-25	M	Anglo-Norman	-18.3	14.0	43.5	14.8	3.4	4.8
21759	45+	F	Anglo-Norman	-18.4	12.7	42.7	15.2	3.3	5.3
21776	45+	?F	Anglo-Norman	-18.5	13.5	38.9	13.3	3.4	6.7
21798	01-05	?	Anglo-Norman	-18.9	11.7	40.6	14.4	3.3	5.2
21867	13-17	?	Anglo-Norman	-19.0	12.3	37.8	13.0	3.4	7.9
21879	45+	M	Anglo-Norman	-17.8	13.9	43.3	15.0	3.4	3.9
21913	36-45	?M	Anglo-Norman	-18.8	12.3	41.9	14.8	3.3	4.5
*21930	45+	?F	Anglo-Norman	-19.2	11.0	35.2	12.7	3.2	2.1
21934	18-25	?M	Anglo-Norman	-17.6	14.5	43.5	15.3	3.3	3.1
21996	36-45	?F	Anglo-Norman	-18.7	12.6	41.1	14.5	3.3	4.8
22000	45+	M	Anglo-Norman	-17.6	14.3	41.2	14.4	3.3	8.4
22109	36-45	F	Anglo-Norman	-18.7	13.3	39.3	14.0	3.3	3.2
*22114	26-35	M	Anglo-Norman	-19.7	11.7	36.2	12.6	3.4	3.1

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
22139	13-17	?	Anglo-Norman	-19.1	11.4	41.1	14.5	3.3	10.8
22166	26-35	?F	Anglo-Norman	-19.1	12.4	44.4	15.5	3.3	6.9
22186	18-25	?M	Anglo-Norman	-18.1	13.2	41.9	14.6	3.3	7.0
22219	26-35	M	Anglo-Norman	-19.2	13.4	41.4	14.1	3.4	10.1
22292	06-12	?	Anglo-Norman	-19.0	12.2	41.6	14.5	3.4	4.1
22344	26-35	F	Anglo-Norman	-18.7	13.0	38.8	13.7	3.3	6.2
*22356	13-17	?	Anglo-Norman	-19.7	11.3	45.0	16.0	3.3	9.1
22414	01-05	?	Anglo-Norman	-19.0	10.9	43.6	15.3	3.3	7.5
22471	13-17	?	Anglo-Norman	-18.8	12.0	40.6	14.4	3.3	10.8
22477	45+	F	Anglo-Norman	-19.1	12.5	29.5	10.4	3.3	3.2
*22527	36-45	?M	Anglo-Norman	-18.6	12.8	41.9	14.4	3.4	9.3
22617	13-17	?	Anglo-Norman	-19.1	11.1	40.4	14.3	3.3	6.6
22620	18-25	M	Anglo-Norman	-18.3	13.3	42.1	14.9	3.3	5.7
22699	13-17	?	Anglo-Norman	-19.4	11.7	42.6	14.7	3.4	5.5
22727	45+	?M	Anglo-Norman	-17.9	14.0	45.5	15.8	3.4	6.4
22882	45+	M	Anglo-Norman	-17.8	14.7	41.1	14.3	3.4	8.6
*22942	26-35	?F	Anglo-Norman	-19.0	12.8	40.1	14.2	3.3	6.7
*23166	45+	M	Anglo-Norman	-17.5	14.8	41.3	14.7	3.3	4.5
23207	36-45	?F	Anglo-Norman	-18.6	13.1	40.0	14.3	3.3	4.1
23213	45+	F	Anglo-Norman	-19.4	12.3	37.5	13.0	3.4	7.2
5458	06-12	?	Medieval	-19.3	10.9	41.2	14.7	3.3	6.1
5645	45+	M	Medieval	-18.3	13.9	42.8	15.0	3.3	4.8
5698	45+	M	Medieval	-17.9	14.2	44.1	15.9	3.2	16.5
*5699	13-17	?	Medieval	-18.4	12.1	38.8	13.9	3.2	3.6
5871	36-45	F	Medieval	-19.0	11.9	40.1	14.1	3.3	6.4
*5931	18-25	?M	Medieval	-19.7	10.5	38.0	13.4	3.3	7.0
5949	06-12	?	Medieval	-19.5	9.5	44.6	15.4	3.4	6.1
5957	18-25	F	Medieval	-18.9	12.5	37.8	13.3	3.3	4.9
*6038	26-35	??M	Medieval	-18.6	13.3	43.0	15.1	3.3	5.0
6187	36-45	??M	Medieval	-18.5	13.1	44.3	15.7	3.3	4.7
6223	26-35	M	Medieval	-17.9	14.0	42.7	15.3	3.3	8.5

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
*6249	45+	F	Medieval	-19.4	12.3	44.0	15.4	3.3	5.1
6374	06-12	?	Medieval	-19.8	9.5	42.1	14.8	3.3	8.8
6473	06-12	?	Medieval	-20.2	7.5	31.8	11.2	3.3	2.3
6550	06-12	?	Medieval	-20.2	8.9	36.9	13.1	3.3	7.0
6579	45+	F	Medieval	-18.7	13.0	41.0	14.5	3.3	7.2
6729	06-12	?	Medieval	-19.1	12.5	44.3	15.4	3.3	3.8
6765	45+	F	Medieval	-18.8	13.1	43.4	15.4	3.3	2.8
7031	18-25	??M	Medieval	-18.8	14.0	39.9	14.2	3.3	5.4
7072	45+	M	Medieval	-18.2	14.2	45.1	15.5	3.4	8.4
7092	18-25	F	Medieval	-18.9	11.6	44.2	15.3	3.4	6.2
7097	26-35	M	Medieval	-17.8	14.7	43.9	15.6	3.3	8.7
7251	18-25	??M	Medieval	-19.5	10.2	41.5	14.5	3.3	4.4
7257	36-45	F	Medieval	-19.6	11.1	40.9	14.3	3.3	3.8
7527	36-45	??M	Medieval	-18.9	12.4	42.9	15.3	3.3	5.6
7626	45+	?F	Medieval	-19.6	11.8	44.7	15.5	3.4	5.4
7700	26-35	M	Medieval	-18.3	13.9	43.4	15.0	3.4	8.2
7914	06-12	?	Medieval	-19.5	10.2	28.5	10.3	3.2	3.7
7929	18-25	?F	Medieval	-18.9	12.3	42.6	14.8	3.4	6.3
8052	45+	M	Medieval	-19.1	13.0	44.6	15.3	3.4	8.1
8078	18-25	M	Medieval	-18.9	11.2	41.7	15.2	3.2	8.9
8164	36-45	??M	Medieval	-19.6	11.3	40.8	14.4	3.3	2.6
8259	26-35	F	Medieval	-18.5	12.8	42.5	14.9	3.3	7.0
8267	45+	??F	Medieval	-18.8	13.1	42.1	14.7	3.3	4.3
8493	18-25	?F	Medieval	-18.5	13.1	32.9	11.8	3.3	4.8
8506	26-35	M	Medieval	-18.2	15.4	41.2	14.5	3.3	6.2
*8532	26-35	F	Medieval	-19.6	11.0	31.8	11.3	3.3	3.6
8637	36-45	?F	Medieval	-19.0	13.1	44.4	15.5	3.3	5.7
8690	06-12	?	Medieval	-19.5	11.3	44.8	16.1	3.2	5.9
20026	26-35	F	Medieval	-18.9	13.4	43.4	15.3	3.3	6.2
20116	36-45	?F	Medieval	-17.8	16.1	44.4	15.1	3.4	8.2
20132	45+	?F	Medieval	-19.6	10.2	41.4	14.7	3.3	4.3
20144	13-17	?	Medieval	-17.8	13.0	44.1	15.3	3.4	4.0
20177	18-25	?F	Medieval	-20.0	9.0	42.4	14.7	3.4	4.8
20192	45+	?F	Medieval	-18.6	12.6	41.1	14.3	3.3	7.4
20214	18-25	M	Medieval	-17.6	14.6	35.6	12.6	3.3	4.4
20235	26-35	?F	Medieval	-19.8	10.1	43.0	14.9	3.4	3.0
20251	06-12	?	Medieval	-18.3	12.7	45.5	16.2	3.3	6.8
20344	13-17	?	Medieval	-	-	-	-	-	-
*20348	26-35	?F	Medieval	-18.1	14.5	44.6	15.8	3.3	-
20372	36-45	?F	Medieval	-18.7	14.3	43.6	15.3	3.3	4.2
20377	26-35	F	Medieval	-19.0	13.1	48.2	16.8	3.4	3.2
20381	26-35	F	Medieval	-19.5	11.4	29.5	10.5	3.3	4.7
20445	26-35	?M	Medieval	-19.6	11.7	42.6	15.0	3.3	4.2

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
20493	36-45	??M	Medieval	-18.6	13.1	40.4	14.4	3.3	3.3
20560	45+	M	Medieval	-18.7	13.1	42.0	14.6	3.3	4.9
20611	36-45	M	Medieval	-18.7	13.5	41.9	14.8	3.3	6.0
20717	26-35	M	Medieval	-18.5	13.6	41.4	14.5	3.3	3.8
20765	18-25	?F	Medieval	-18.9	12.4	40.9	14.1	3.4	7.4
20863	45+	M	Medieval	-18.7	13.7	39.4	13.8	3.3	6.3
20867	13-17	?	Medieval	-18.6	12.7	44.3	15.5	3.3	7.1
*21032	26-35	M	Medieval	-17.7	14.9	23.7	8.2	3.4	6.5
21040	45+	?M	Medieval	-18.8	12.1	42.0	14.9	3.3	4.3
21083	45+	?M	Medieval	-17.2	14.6	45.0	16.3	3.2	10.8
21172	18-25	F	Medieval	-18.7	14.0	43.1	15.1	3.3	4.9
*21217	36-45	M	Medieval	-18.1	14.1	31.6	11.0	3.4	4.4
21247	18-25	?M	Medieval	-18.4	13.7	43.1	15.0	3.4	4.6
21274	36-45	M	Medieval	-18.7	12.2	44.5	15.6	3.3	4.2
*21289	60+	M	Medieval	-18.3	15.1	39.9	14.2	3.3	10.1
21318	45+	?F	Medieval	-18.4	13.3	30.6	11.1	3.2	5.4
21335	36-45	?F	Medieval	-17.4	14.5	44.5	16.2	3.2	9.5
*21348	18+	F	Medieval	-19.0	12.7	30.4	10.9	3.3	3.9
21383	36-45	F	Medieval	-18.9	11.8	42.1	14.7	3.3	5.0
21404	36-45	F	Medieval	-18.7	13.6	37.8	13.3	3.3	9.8
21418	26-35	F	Medieval	-18.1	12.5	43.9	15.7	3.3	11.0
*21421	26-35	M	Medieval	-18.6	13.7	33.1	12.0	3.2	5.0
21453	26-35	?F	Medieval	-18.6	14.3	42.3	14.7	3.4	5.4
21463	13-17	?	Medieval	-18.7	11.9	42.9	14.8	3.4	4.6
21610	36-45	F	Medieval	-18.9	13.6	43.5	14.8	3.4	6.2
21634	18-25	??M	Medieval	-18.2	14.0	42.3	15.0	3.3	4.6
21668	26-35	F	Medieval	-18.8	12.4	43.3	15.3	3.3	5.4
21675	26-35	M	Medieval	-19.3	11.8	39.7	13.5	3.4	7.1
*21686	26-35	M	Medieval	-18.1	13.6	27.7	9.7	3.3	4.5
*21699	18-25	?F	Medieval	-18.8	13.1	30.9	11.0	3.3	5.7
21892	45+	F	Medieval	-19.3	12.0	41.2	14.5	3.3	11.7
21983	13-17	?	Medieval	-19.4	11.5	39.7	13.7	3.4	8.7
22017	13-17	?	Medieval	-18.9	11.3	43.9	15.5	3.3	3.0
22255	18-25	?M	Medieval	-18.4	12.7	38.3	13.8	3.2	8.4
22296	18-25	?F	Medieval	-18.3	13.0	33.2	11.8	3.3	16.0
#22418	26-35	M	Medieval	-17.9	13.7	35.3	12.8	3.2	6.3
22436	13-17	?	Medieval	-19.9	11.6	41.0	14.5	3.3	6.8
22488	26-35	F	Medieval	-18.5	13.0	43.3	15.4	3.3	10.5
22514	36-45	?M	Medieval	-19.0	12.7	40.6	14.3	3.3	16.0
22646	18-25	?F	Medieval	-18.7	12.9	37.9	13.7	3.2	4.0
*22739	45+	M	Medieval	-18.7	13.9	22.2	7.5	3.5	9.5
22791	36-45	M	Medieval	-18.9	12.9	42.2	14.6	3.4	4.4
22956	13-17	??M	Medieval	-18.8	12.1	42.1	14.7	3.3	3.2

Sk ID	Age	Sex	Period	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C:N	%Coll
22968	36-45	M	Medieval	-17.6	13.9	40.4	14.3	3.3	10.2
*22989	26-35	?F	Medieval	-19.7	11.8	26.6	9.2	3.4	6.5
*23017	36-45	F	Medieval	-19.1	13.0	44.1	15.2	3.4	5.6
23097	06-12	?	Medieval	-20.1	10.3	42.5	14.5	3.4	7.9
23125	36-45	?F	Medieval	-19.1	12.3	43.7	15.4	3.3	6.6
*23141	45+	?M	Medieval	-17.6	14.4	41.1	14.5	3.3	3.9
23203	18-25	F	Medieval	-19.6	11.2	42.2	14.7	3.3	4.0
23209	45+	?F	Medieval	-17.8	14.6	42.8	15.1	3.3	9.2
23265	26-35	?M	Medieval	-18.5	13.8	41.6	14.7	3.3	8.5
*23273	36-45	M	Medieval	-18.5	14.1	42.8	15.0	3.3	8.9
23285	36-45	?M	Medieval	-17.7	14.4	41.5	14.5	3.3	4.3

Results from single analysis; * Part of the pilot study

Appendix 3: $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ Results

+ Analysed by Peter Ditchfield; * Part of pilot study

Sk ID	$^{87}Sr/^{86}Sr$	$\delta^{18}O_{C\text{-}VPDB}$ ‰	$\delta^{18}O_{P\text{-}VSMOW}$ ‰	Sex	Age	Period
*20109	0.710398	-4.6	17.3	?M	36-45	Mid Saxon
*20808	0.709642	-3.9	18.1	M	36-45	Mid Saxon
5347	0.709090	-	-	?	06-12	Late Saxon
+ 5909	0.709635	-3.9	18.1	F	45+	Late Saxon
6500	0.709135	-5.0	16.9	?	06-12	Late Saxon
7279	0.709011	-	-	?	13-17	Late Saxon
*8104	0.709633	-4.9	17.0	?M	36-45	Late Saxon
20207	0.709994	-3.8	18.2	F	36-45	Late Saxon
*20292	0.708960	-6.1	15.8	?	13-17	Late Saxon
*20748	0.709012	-4.9	17.0	F	26-35	Late Saxon
20894	0.709179	-5	16.9	F	45+	Late Saxon
21166	0.711297	-5.4	16.4	?F	36-45	Late Saxon
23133	0.709364	-	-	?M	26-35	Late Saxon
6443	0.710484	-5.5	16.3	?M	36-45	Anglo-Norman
6783	0.708745	-5.2	16.7	F	36-45	Anglo-Norman
6955	0.709146	-	-	?	06-12	Anglo-Norman
*7599	0.709386	-4.8	17.1	M	26-35	Anglo-Norman
7968	0.709544	-5.1	16.8	M	36-45	Anglo-Norman
*8866	0.709710	-5.0	16.9	??F	36-45	Anglo-Norman
*20580	0.709353	-4.4	17.5	M	26-35	Anglo-Norman
21079	0.709160	-	-	?M	13-17	Anglo-Norman
21759	0.710086	-4.8	17.1	F	45+	Anglo-Norman
21776	0.709312	-	-	?F	45+	Anglo-Norman
21996	0.709351	-4.5	17.4	?F	36-45	Anglo-Norman
*22114	0.709743	-5.2	16.7	M	26-35	Anglo-Norman
22219	0.710627	-5.2	16.7	M	26-35	Anglo-Norman
22727	0.709796	-	-	?M	45+	Anglo-Norman
*5699	0.709115	-5.6	16.2	?	13-17	Medieval
*5931	0.708870	-4.6	17.3	?M	18-25	Medieval
6473	0.709261	-	-	?	06-12	Medieval
*8532	0.709624	-5.2	16.7	F	26-35	Medieval
20116	0.709350	-5.1	16.8	?F	36-45	Medieval
20177	0.708695	-	-	?F	18-25	Medieval
20192	0.709186	-4.5	17.5	?F	45+	Medieval
20381	0.709220	-	-	F	26-35	Medieval
20560	0.709160	-4.9	17.0	M	45+	Medieval
*21032	0.709189	-4.7	17.2	M	26-35	Medieval
*21217	0.709543	-4.8	17.1	M	36-45	Medieval
*21289	0.709164	-4.8	17.1	M	60+	Medieval
*21348	0.709405	-5.1	16.8	F	18+	Medieval
22418	0.709363	-3.4	18.6	M	26-35	Medieval
22646	0.709174	-5.5	16.4	?F	18-25	Medieval
*22739	0.710286	-4.5	17.4	M	45+	Medieval
*22989	0.710149	-4.4	17.5	?F	26-35	Medieval
*23141	0.709558	-5.5	16.7	?M	45+	Medieval

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