Marine fish consumption in medieval Britain: the isotope perspective from human skeletal remains

Book or Report Section

Published Version

COD AND HERRING

AN OFFPRINT FROM

COD AND HERRING

THE ARCHAEOLOGY AND HISTORY OF MEDIEVAL SEA FISHING

Edited by

JAMES H. BARRETT AND DAVID C. ORTON

Paperback Edition: ISBN 978-1-78570-239-6
Digital Edition: ISBN 978-1-78570-240-2 (epub)

OXBOW | books

Oxford & Philadelphia
www.oxbowbooks.com

Published in the United Kingdom in 2016 by
OXBOW BOOKS
10 Hythe Bridge Street, Oxford OX1 2EW

and in the United States by
OXBOW BOOKS
1950 Lawrence Road, Havertown, PA 19083

Paperback Edition: ISBN 978-1-78570-239-6
Digital Edition: ISBN 978-1-78570-240-2 (epub)

A CIP record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Names: Barrett, James H. (James Harold), editor. | Orton, David C. (David Clive), editor.
Title: Cod and herring : the archaeology and history of medieval sea fishing
/ edited by James H. Barrett and David C. Orton.
Description: Oxford; Philadelphia: Oxbow Books, 2016. | Includes
bibliographical references.
Identifiers: LCCN 2016013177| ISBN 9781785702396 (softcover) | ISBN
9781785702402 (digital)
Subjects: LCSH: Fish remains (Archaeology) | Saltwater fishing–History–To
1500.
Classification: LCC CC79.5.A5 C63 2016 | DDC 930.1–dc23 LC record available at http://lccn.loc.gov/2016013177

Printed in the United Kingdom by Latimer Trend

For a complete list of Oxbow titles, please contact:

UNITED KINGDOM
Oxbow Books
Telephone (01865) 241249, Fax (01865) 794449
Email: oxbow@oxbowbooks.com
www.oxbowbooks.com

UNITED STATES OF AMERICA
Oxbow Books
Telephone (800) 791-9354, Fax (610) 853-9146
Email: queries@casemateacademic.com
www.casemateacademic.com/oxbow

Oxbow Books is part of the Casemate Group

Front cover: Design by Katie Gabriel Allen using a woodcut image from *Historia de Gentibus Septentrionalibus* by Olaus Magnus (used by permission of University of Glasgow Library, Special Collections)
Back cover: Medieval fish bones from Blue Bridge Lane, York (Photo: James Barrett)

Contents

Contributors

JAMES H. BARRETT, McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, England

COLIN BREEN, School of Geography and Environmental Sciences, Ulster University, Coleraine, Northern Ireland

INGE BØDKER ENGHOFF, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

ANTON ERVYNCK, Flemish Heritage Agency, Brussels, Belgium

MARK GARDINER, Archaeology, School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Belfast, Northern Ireland

SHEILA HAMILTON-DYER, SH-D ArchaeoZoology, Southampton, England

JENNIFER HARLAND, Archaeology Institute, University of the Highlands and Islands, Orkney College, Kirkwall, Orkney, Scotland

POUL HOLM, School of Histories and Humanities, Trinity College Dublin, Dublin, Ireland

ANNE KARIN HUFTHAMMER, Department of Natural History, The University Museum, University of Bergen, Bergen, Norway

ANDREW K. G. JONES, Department of Archaeology, University of York, York, England

MARYANNE KOWALESKI, Department of History, Fordham University, Bronx, New York, USA

ALISON LOCKER, Escaldes-Engordany, Andorra

LEMBI LÕUGAS, Archaeological Research Collection, Tallinn University, Tallinn, Estonia

DANIEL MAKOWIECKI, Laboratory for Natural Environment Reconstruction, Institute of Archaeology, Nicolaus Copernicus University, Toruń, Poland

JAMES MORRIS, School of Forensic and Applied Sciences, University of Central Lancashire, Preston, Lancashire, England

GUNDULA MÜLDNER, Department of Archaeology, University of Reading, Reading, England

ARNVED NEDKVITNE, Department of Archaeology and History, University of Oslo, Oslo, Norway

ALF RAGNAR NIELSSEN, University of Nordland, Bodø, Norway

DAVID C. ORTON, BioArCh, Department of Archaeology, University of York, York, England

REBECCA REYNOLDS, Department of Archaeology, University of Nottingham, Nottingham, England

HELGE SØRHEIM, Museum of Archaeology, University of Stavanger, Stavanger, Norway

WIM VAN NEER, Royal Belgian Institute of Natural Sciences, Brussels, Belgium; Laboratory of Biodiversity and Evolutionary Genomics, University of Leuven, Leuven, Belgium

ORRI VÉSTEINSSON, Department of Archaeology, University of Iceland, Reykjavík, Iceland

Preface and Acknowledgements

The analysis of fish bones from archaeological sites is a highly specialised and painstaking task, requiring an abundance of the time that is so rarely available in either academic or commercial archaeology. Moreover, study of fish remains has seldom been at the top of archaeological research priorities. Nevertheless, over the last 40 years a few specialists across Europe have dedicated themselves to work of this kind, and thus to discovering the outlines of medieval fishing history around the North Atlantic, and the Irish, North and Baltic seas. Although mutually informed in terms of methodology, this fundamental research has often been carried out in the framework of national institutions and agendas. Concurrently, historians have independently striven to systematise and analyse complex corpora of textual evidence regarding medieval fishing and fish trade. Once again this work has sometimes occurred within national or regional schools of research. The results of these zooarchaeological and historical efforts have often proven surprising and important, revealing remarkable evidence of continuity and change. Archaeologists of medieval coastal settlements have also contributed much to our understanding of the relationship between people and the sea.

The present volume is an effort to enhance the value of this past work by crossing boundaries – between regions and between disciplines. It also emerges from a time when traditional zooarchaeology (the identification, quantification and interpretation of skeletal remains) has increasingly benefited from integration with biomolecular approaches, such as stable isotope analysis and the study of ancient DNA. These latter methods are not the main focus of the book – they are changing far too quickly for this to have been helpful. Nevertheless, they inform many of its chapters and Gundula Müldner has taken up the challenge of surveying the extant stable isotope evidence regarding human skeletal remains from medieval Britain. Even in the fields of zooarchaeology and history it is recognised, even hoped, that this volume will quickly become outdated. It is our aspiration that the collaborative process of consolidating what is known and unknown may already have accelerated the pace of current research on medieval sea fishing.

The idea behind the book emerged from an interdisciplinary conference organised by one of us (JHB) in Westray, Orkney, Scotland, in June of 2008. It was several years, however, before the groundwork could be laid – including finishing the analysis of major collections and the synthesis of decades of fish-bone and historical research. The initial practicalities were skilfully managed by Cluny Johnstone, then a postdoctoral research fellow on the 'Medieval Origins of Commercial Sea Fishing' project funded by the Leverhulme Trust. After a period of maternity leave Cluny decided to be a full-time parent and editing became our responsibility. DCO began the process while a postdoctoral research fellow on the Leverhulme Trust project 'Ancient DNA, Cod and the Origins of Commercial Trade in Medieval Europe'. JHB was then able to see it through to completion. This book is also based upon work from the COST Action Oceans Past Platform, supported by COST (European Cooperation in Science and Technology).

We are grateful to Julie Gardiner of Oxbow Books for her helpfulness and patience during the book's long gestation. Jennifer Harland (also a postdoctoral research fellow on the 'Medieval Origins of Commercial Sea Fishing' project) and Christine Harcus assisted with the original conference in Orkney, which was funded by the Leverhulme Trust, the McDonald Institute for Archaeological Research and the History of Marine Animal Populations project (supported by the Alfred P. Sloan Foundation). Many thanks are owed to Suzanne Needs-Howarth, who copy-edited the volume and helped compile Appendix 1.1, and to the McDonald Institute for Archaeological Research, which contributed to the cost of her work. Dora Kemp also kindly assisted with copy-editing. The cover was designed by Katie Gabriel Allen using a woodcut image from *Historia de Gentibus Septentrionalibus* by Olaus Magnus (used by permission of University of Glasgow Library, Special Collections) and a photograph of medieval fish bones from York taken by JHB. Other image credits are given in the figure captions, and each chapter includes its own acknowledgements section when appropriate. Most importantly, we thank the contributors to this volume for the many years of careful research that their chapters represent.

James H. Barrett
University of Cambridge
David C. Orton
University of York

COST is supported by the EU Framework Programme Horizon 2020

COST (European Cooperation in Science and Technology) is a pan-European intergovernmental framework. Its mission is to enable break-through scientific and technological developments leading to new concepts and products and thereby contribute to strengthening Europe's research and innovation capacities. It allows researchers, engineers and scholars to jointly develop their own ideas and take new initiatives across all fields of science and technology, while promoting multi- and interdisciplinary approaches. COST aims at fostering a better integration of less research intensive countries to the knowledge hubs of the European Research Area. The COST Association, an International not-for-profit Association under Belgian Law, integrates all management, governing and administrative functions necessary for the operation of the framework. The COST Association has currently 36 Member Countries. www.cost.eu

20

Marine Fish Consumption in Medieval Britain: The Isotope Perspective from Human Skeletal Remains

Gundula Müldner

Introduction

When considering the archaeological evidence for the early history of marine fishing, we need to accord a central role to isotope data. While zooarchaeological studies of fish-bone assemblages reflect the availability of marine resources in greater detail – to the level of individual species – carbon and nitrogen stable isotope analysis of human skeletal remains is the only direct method for reconstructing the actual level of human consumption of marine foods. Stable isotope analysis thus enables us to explore if, when and where marine fish became a dietary staple and by whom such fish were preferentially consumed. Therefore a comprehensive approach to the question of the early fishing industries should always combine zooarchaeological and isotopic methods (see Barrett *et al*. 2001).

Although some of the earliest applications of stable isotope analysis in European archaeology included skeletons of medieval date (Bocherens *et al*. 1991; Johansen *et al*. 1986; Tauber 1981), it was only in the late 1990s that Mays (1997) published a study with the explicit aim of exploring variation in marine food use in the medieval and post-medieval periods. The size of Mays' sample, 67 individuals from five sites in northeastern England, was very large for the time and allowed for differences between populations to be observed, both geographically, between coastal and inland locations, and socially, between different social groups buried in the same cemetery. Since Mays' study, the amount of stable isotope data available from medieval and post-medieval sites both in Britain and continental Europe has increased greatly. This dataset enables us to draw at least preliminary conclusions about the impact of the expanding fisheries on everyday subsistence. This paper aims to review the currently available carbon and nitrogen stable isotope evidence for marine fish consumption in medieval England and southern Scotland with a special emphasis on chronology – at what point in time did marine fish begin to make a regular contribution to human diet? – and on characterising the groups in society that were preferentially involved in its consumption. As will become apparent in this chapter, the available evidence is still patchy and leaves much to be desired in terms of our ability to address specific questions. Nevertheless, it is derived from a sufficient variety of site types and chronological phases to allow us to begin to outline some wider trends and formulate agendas for future research. Isotope data offer a different perspective on the history of the early sea fisheries and their effects on society than do the more traditional, zooarchaeological methods.

Carbon and nitrogen stable isotope data as a reflection of marine food consumption

There is now abundant evidence from field studies and controlled-feeding experiments to demonstrate that the carbon and nitrogen stable isotope composition of bone collagen, the main organic constituent of bone, reliably reflects that of the main protein sources in an individual's diet (see Ambrose 1993; Kelly 2000; Schwarcz and Schoeninger 1991).

Isotopes are atoms of the same element with slightly different atomic masses. Carbon has two stable isotopes, C-12 (^{12}C), with an atomic mass of 12, and the heavier C-13 (^{13}C). In contrast to the widely known radiocarbon (C-14), these two carbon isotopes do not decay radioactively over time; in other words, they are stable. The relative abundance of the stable isotopes of carbon in nature, or the ratio of

C-13 to C-12 ($^{13}C/^{12}C$, usually expressed as $\delta^{13}C$ or delta-13-C), varies significantly between different environments, especially between plants of different photosynthetic pathways (so-called C_3 and C_4 plants) as well as between C_3 plant-dominated terrestrial and marine ecosystems. These differences are preserved in all foods produced in these environments, and they can also be traced in the body tissues of their human consumers. In temperate northwestern Europe, where C_4 plants were largely absent until modern times, carbon stable isotope analysis is therefore the method of choice for distinguishing between the terrestrial and marine components in past human diet (Chisholm *et al*. 1982; Tauber 1981).

Nitrogen also has two stable isotopes, N-14 and N-15. The abundance of the 'heavy' N-15 in relation to N-14 (i.e. the $^{15}N/^{14}N$ ratio, or $\delta^{15}N$) in consumer tissues increases by 3–5‰ with each step up the food chain – a mechanism called the trophic level effect. $\delta^{15}N$ values are therefore useful to assess the trophic position of an organism and hence the importance of plant versus animal protein in human diet (DeNiro and Epstein 1981; Hedges and Reynard 2007). Nitrogen isotope ratios of marine animals are usually several per mil higher than those of terrestrial organisms, mainly because of the longer food-chains in aquatic ecosystems. The bone collagen of consumers of marine fish should consequently be enriched, not only in 'heavy' ^{13}C but also in ^{15}N. Both the $\delta^{13}C$ and $\delta^{15}N$ values of consumers of marine fish are therefore normally higher than those of organisms consuming an exclusively terrestrial diet (Richards and Hedges 1999; Schoeninger and DeNiro 1984).

It has to be understood that stable isotope data give only very general information about diet. Bone collagen, the preferred material for archaeological investigations, reflects a long-term average of foods eaten over at least several years to several decades of an individual's life (Hedges *et al* 2007; Sealy *et al*. 1995). The isotopic signal obtained from collagen is heavily biased towards the protein component of the diet, meaning that foods with relatively little protein, such as plants, fats or carbohydrate-rich foods will be underrepresented or even invisible in comparison with protein-rich items, such as lean meat or fish (see Ambrose 1993; Jim *et al*. 2006). For this reason, and especially where the varied diets eaten by humans are concerned, stable isotope values are often best interpreted in relative terms, i.e. whether an individual consumed relatively more or less marine protein than other individuals, rather than truly quantitatively, even if stable isotope mixing models that seek to fully quantify consumption are becoming continuously more sophisticated (see Phillips *et al*. 2014).

Stable isotope data reflect only very broadly defined groups of foods, especially terrestrial and marine and plant or animal protein. They do not, for example, allow us to distinguish among different products of the same animal, such as meat or dairy; nor do they easily allow us to detect the consumption of different species of marine fish (O'Connell and Hedges 1999; Richards and Hedges 1999). The method is also not particularly sensitive to small variations in dietary intake. Even though the large isotopic differences between C_3 terrestrial and marine foods make these foods particularly suitable for this type of analysis, humans still have to derive a substantial (≥~20%) portion of their dietary protein from marine resources (a figure which may increase further in certain low-protein diets) before these can be traced with certainty (see Hedges 2004; Schwarcz 2000). Even then, it is usually essential to establish local 'baseline' values typical for the different foods available to a population, by processing bone from fish and terrestrial animals from a site alongside the human samples, before small contributions of marine protein can be inferred with confidence (Figure 20.1; see Müldner and

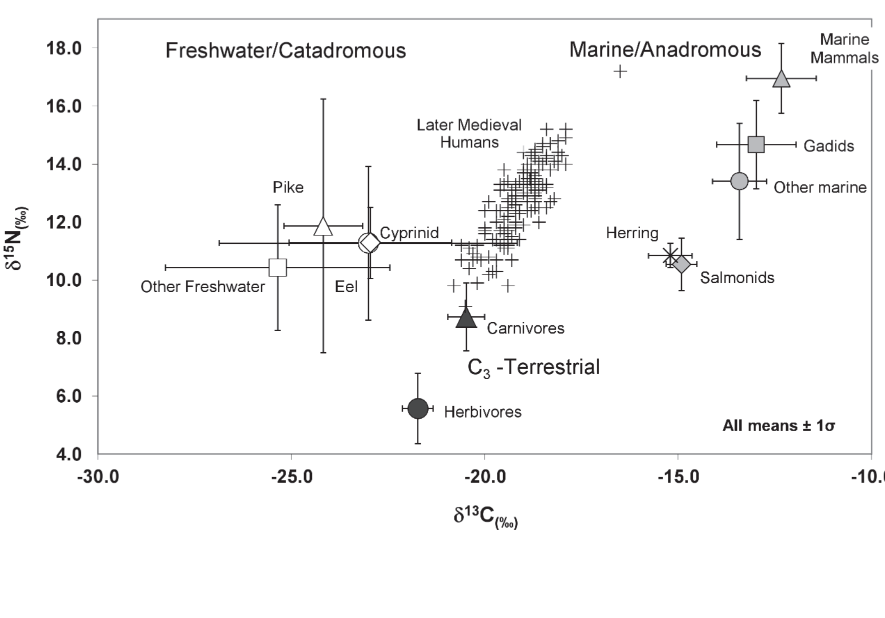

Figure 20.1. Carbon and nitrogen stable isotope ratios for fauna from northern England, illustrating the differences in isotope values between terrestrial, marine and freshwater animals as well as by trophic level. Also shown are human stable isotope data from the later medieval (thirteenth–early sixteenth-century AD*) Gilbertine priory at Fishergate in York, which reflect a range of diets with varying proportions of marine protein (Data: Müldner and Grimes 2007, 201–2; Müldner and Richards 2005; 2007a,b).*

Richards 2007b). Small-scale or irregular consumption of marine foods by humans may well go undetected.

Finally, some consideration must be given to our ability to distinguish between freshwater and marine fish by means of stable isotope analyses. The nitrogen isotope ratios of freshwater animals are similar to those of marine organisms of comparable trophic level, at least where there is no heavy load of sewage or other pollutants (France 1995). $\delta^{15}N$ values therefore have little potential for distinguishing between freshwater and marine foods in the diet. Carbon stable isotope values of freshwater fauna, on the other hand, are notoriously variable and can show significant overlap with the ranges of both terrestrial and marine habitats (Dufour *et al*. 1999; Katzenberg and Weber 1999). Nevertheless, especially in rivers and shallow lakes where there is a large input of terrestrial plant material to the nutrient pool, animal $\delta^{13}C$ values often resemble or are more negative than those of terrestrial fauna (Fry 1991).

Numerous isotope measurements on fish-bone collagen from medieval contexts in northern England allow us to characterise the ranges of freshwater and marine species relatively well (Figure 20.1; Müldner and Grimes 2007, 201–2; Müldner and Richards 2005; 2007b). They demonstrate that the two are completely separated by their carbon stable isotope signatures. Contributions of freshwater and marine protein to human diet should therefore not normally be confused; however, if both are being eaten in some quantity, a 'mixing effect' might obscure the isotopic signals of either (Müldner and Richards 2005). Also, recognising small contributions of freshwater foods to an otherwise terrestrial diet is even more difficult than for marine protein, as they may not be distinguishable from a number of other (terrestrial) foods that have high $\delta^{15}N$ values (Müldner and Richards 2007b; Privat *et al*. 2002). Importantly, the isotope values of migratory fish reflect those of the ecosystems where they spend most of their life-cycle (and do most of their feeding) (Kline *et al*. 1998). While life-cycles are species-specific and may also vary geographically (see Fuller *et al*. 2012), anadromous species (mainly salmonids [Salmonidae]) from British medieval contexts have been shown to have $\delta^{13}C$ most similar to marine fish, while catadromous fish (especially eel [*Anguilla anguilla*]) plot with the freshwater taxa (see Figure 20.1). When human consumption of 'marine' or 'freshwater' foods are referred to in this paper, it should therefore be understood that these categories may include migratory species.

An isotope perspective on the 'fish event horizon'

One of the key questions regarding England's early maritime economy is when the sea fisheries became suitably commercialised to supply fish in large numbers to the English markets. Historical evidence pre-dating the later medieval period is relatively scarce, although the Domesday Book indicates that productive herring fisheries were established in southeastern England, and especially East Anglia, by the later eleventh century (Campbell 2002; Kowaleski 2003; Chapter 3). Barrett and colleagues' (2004) survey of the English fish-bone evidence suggested that a landmark change occurred somewhat earlier, in the decades around AD 1000, when marine species, initially herring (*Clupea harengus*) and later increasingly cod (*Gadus morhua*) and similar species, began to dominate the assemblages. So how is this 'fish event horizon' (Barrett *et al*. 2004, 621) reflected in the human stable isotope data?

The stable isotope evidence certainly suggest a dietary change on a significant scale. Available isotope data from Anglo-Saxon England and early medieval southern Scotland suggest that marine protein contributed very little, if anything, to the diet (Hull and O'Connell 2011; Lightfoot *et al*. 2009; Lucy *et al*. 2009; Mays and Beavan 2012; Modzelewski 2008; Privat *et al*. 2002), while isotope values for most later medieval humans are visibly different from those of earlier time periods and indicate that marine protein was a regular part of subsistence (Lakin 2010; Lamb *et al*. 2012; Müldner and Richards 2005; 2007a,b; Müldner *et al*. 2009). Although the contribution to the diet made by marine protein was arguably still only minor in absolute terms – the medieval isotope values are entirely different from those of coastal hunter-gathers, for example (Coltrain *et al*. 2004; Richards and Hedges 1999) – consumption of sea-fish in medieval Britain must have been much more substantial than in preceding periods in order to effect such clear isotopic differences between early and later medieval populations.

Differences between late/post-medieval and earlier populations, which probably reflect a shift towards increased marine consumption, can also be observed in isotope data from other European countries. Apart from northern Scotland, which is relatively well researched (Barrett and Richards 2004; Barrett *et al*. 2000; 2001; Richards *et al*. 2006; Curtis-Summer *et al*. 2014), changes through time have also been suggested based on palaeodietary data from Belgium (Polet and Katzenberg 2003), northeastern Germany (Peitel 2006; Schäuble 2006) and Italy (Salamon *et al*. 2007). Nevertheless, in other isotopic data sets no diachronic trend appears to register, even where it might be expected based on other archaeological sources (Yoder 2010; Ervynck *et al*. 2013). More detailed investigations are therefore needed before any general European trends can be postulated.

Pinning down when the transition in England occurred in absolute chronological terms is more difficult, for two reasons. First, as noted above, only a limited number of populations have been analysed. Second, dating later Anglo-Saxon and medieval cemeteries to a meaningful precision is notoriously difficult, as accompanying dateable artefacts are scarce. The time-frames that can be assigned to different phases of a cemetery are therefore often quite wide, even where additional stratigraphic information is available (e.g. Hadley 2001; Kemp and Graves 1996). Although direct dating of human remains by radiocarbon analysis is carried out more and more frequently (e.g. Bayliss *et al*. 2013; Pollard *et al*. 2012), interpreting the results for the specific question of early fish consumption is complicated by the 'marine reservoir effect', which makes individuals with marine foods in their diet appear chronologically older than those with a terrestrial diet (Stuiver *et al*. 1998; see Barrett *et al*. 2000). While a number of different methods for marine reservoir effect correction are available, these unavoidably introduce additional error, especially since the exact contribution of marine protein cannot necessarily easily be quantified (Ambrose *et al*. 1997; Arneborg *et al*. 1999; Barrett and Richards 2004). The dating programme on human skeletal remains from the medieval Timberhill cemetery in Norwich (Bayliss *et al*. 2004) illustrates the potentially significant consequences of the marine reservoir effect for dating burials in and around the 'fish event horizon'. Although Bayesian statistics were employed to improve the precision of the dates, application of different algorithms for calculating marine contributions to the diet resulted in archaeologically very significant variation in the absolute dates assigned to the burials. Possible dates ranged from a short pre-Conquest sequence (without reservoir correction) to the later twelfth and thirteenth centuries (with correction) (Bayliss *et al*. 2004). Even though the chronological resolution of the evidence discussed below could therefore no doubt be significantly improved by a number of strategically placed radiocarbon dates, it would probably take a much larger programme to settle the questions of chronology.

Starting with the early Anglo-Saxon period, isotope data are now available from a significant number of sites in southern England and East Anglia (Hull and O'Connell 2011; Lightfoot *et al*. 2009; Lucy *et al*. 2009; Mays and Beavan 2012; Privat *et al*. 2002). These data indicate that marine foods played a role in supplementing human diet in coastal settlements, where they could easily be obtained (Mays and Beavan 2012); however, at the overwhelming majority of fifth–seventh-century AD sites, marine protein made no measurable contribution to subsistence. Evidence from the remainder of the Anglo-Saxon period is much scarcer, but several publications either report no measurable marine-fish consumption (Buckberry *et al*. 2014; Müldner and Richards 2007b) or use a possible marine component in the diet as further evidence to identify Scandinavian incomers on British soil (Chenery *et al*. 2014; Pollard *et al*. 2012). Still, Hull and O'Connell (2011) note a significant shift in carbon and nitrogen isotope ratios between their large sample of early Anglo-Saxons and individuals at three later Anglo-Saxon sites in Norfolk which very likely reflect marine consumption. Two of the sites, Caister-on-Sea and Burgh Castle, are in the immediate vicinity of Great Yarmouth. They would date the beginning of the East-Anglian fisheries to the eighth to tenth centuries AD, and possibly even as far back as the seventh century, although it is unclear whether relatively early radiocarbon dates obtained on the human remains from Burgh Castle are in need of reservoir correction (Hull and O'Connell 2011; see Johnson 1983, 111–12; Rodwell 1993, 252).

This early evidence from Norfolk is of great interest. However, there seems to be significant regional variation in the introduction of marine fish to the diet, just as the historical evidence for the development of the fisheries suggests (Kowaleski 2003; Chapter 3). Results of the palaeodietary analysis of eighth–late ninth-century burials from Bishopstone, near Brighton in East Sussex, suggest that any contribution of marine foods to the diet of these individuals was below the threshold where it can be confidently identified in the stable isotope signal (Thomas 2010). This threshold is commonly assumed to be 20% of the dietary protein, but it may be higher in certain low-protein diets (see above). The results from Bishopstone are surprising, given the large proportion of marine species in Bishopstone's fish-bone assemblage (Reynolds 2011; Chapter 17), which makes the site one of the few Anglo-Saxon estates in England known to have actively exploited marine resources (Thomas 2013, see Chapter 17 and references therein). A considerable number of the recovered fish bones showed signs of digestion, and stable isotope values for the bones of a cat, radiocarbon dated to the same horizon as the human burials, suggest that marine fish waste was lying around openly in the settlement for animals to scavenge (Reynolds 2010; Thomas 2010).

For the northeast, stable isotope evidence from the later seventh–eighth-century cemetery at Belle Vue House/ Lamel Hill in York equally shows no indication of marine consumption on a measurable scale (Müldner and Richards 2007b), and neither do a small number of human values from ninth-century Coppergate (York). Palaeodietary data of seventh–eleventh-century date from rural Masham, near Ripon in North Yorkshire, and from the coastal cemetery of Lundin Links, in Fife in southeast Scotland, which has been dated to the fifth–seventh centuries, also allow for only small marine components, below the detection limits of the method (Buckberry *et al*. 2014; Modzelewski 2008). York is the only site in England for which we have a long-term diachronic sequence of isotope data, from the Roman to the post-medieval period, although, regrettably, the important ninth–tenth centuries are so far represented by only three samples from Coppergate (Buckberry *et al*. 2014; Müldner and Richards 2007b). Isotope evidence from the parish cemetery of St Andrew, Fishergate, suggests that a shift towards the consumption of marine fish in measurable quantities was only just in progress in Period 4b, dated to the mid-/late eleventh or early twelfth centuries (Kemp and Graves 1996). A significant minority of the people who were eventually buried in this cemetery (all young males) seem to have adopted marine foods, while the majority continued to eat the terrestrial diet that had been characteristic of the Anglian period (Figure 20.2; Müldner 2009; Müldner and Richards 2007a). By the thirteenth century (Period 6a/b), represented by the large sample from the Gilbertine priory at Fishergate, the situation had completely reversed. The great majority of the population now consumed marine protein on a regular basis, with only few individuals registering little or no marine protein in their bones (Müldner and Richards 2007b).

Finally, an example from southern Scotland allows us to glimpse the chronology on the west coast of Britain. A small group of radiocarbon-dated burials from Whithorn Cathedral Priory on the Machars Peninsula (Dumfries and Galloway) suggests a transition to measurable quantities of marine protein in the diet as late as the thirteenth century (Montgomery *et al*. 2009). However, the isotope data also demonstrate large differences in diet according to social status, which is likely to have biased the results (see Müldner *et al*. 2009, and below). Unfortunately, few identifiable fish-bone fragments were retrieved during the excavations at Whithorn, and the faunal assemblage therefore has extremely limited value for deducing temporal trends (Hamilton-Dyer 1997, 602–3). The observation that most marine species are not present before Period V/1–3 (from *c*. AD 1260) must therefore be treated with caution, although it may support the relatively late date for dietary change suggested by the isotope data.

In summary, the English and southern-Scottish isotope evidence, although still very incomplete, suggests significant regional variation in the adoption of marine fish into the diet. The currently available data span from mid-/late Anglo-Saxon beginnings in East Anglia, to a probably post-Conquest transition in York and an even later dietary shift on the southwest coast of Scotland.

When trying to reconcile these results with the fish-bone record, it is apparent that there are several instances when the isotope evidence for marine consumption post-dates the arrival of marine species in the fish-bone assemblages by some time. At Anglo-Saxon Bishopstone, marine fish has been recorded in significant numbers throughout the occupation sequence (Thomas 2010; see Chapter 17), and in York, the relative abundance of herring increased from the mid-tenth century (Harland *et al*. 2008; O'Connor 1991, 263–7; see Chapter 15).

These data are of course not irreconcilable. A certain lag of time between zooarchaeological and isotopic evidence is actually to be expected, since fish-bone assemblages register more subtle trends and will pick up intensification of marine exploitation earlier than will stable isotope data. The latter will register major change and will therefore only reflect when sea-fish became a significant part of human diet. With this in mind, a transition in York from the eleventh century onwards, as can be argued from the Fishergate isotope data (assuming an early mid-eleventh-century date for Period 4b and taking into account that the individuals with marine diets were all between *c*. 20 and 30 years old when they died; see Müldner 2009), actually fits well with the fish-bone evidence, as it is only then that marine species began to truly dominate the assemblages (Barrett *et al*. 2004; see Chapter 15).

An additional factor for seeming disagreement between isotope and fish-bone data may be that the most abundant species in the early 'fish event horizon' is herring (Barrett *et al*. 2004). Herring occupy a relatively low trophic level in the marine food chain, and their carbon and nitrogen isotope values are therefore generally lower (and less distinct from

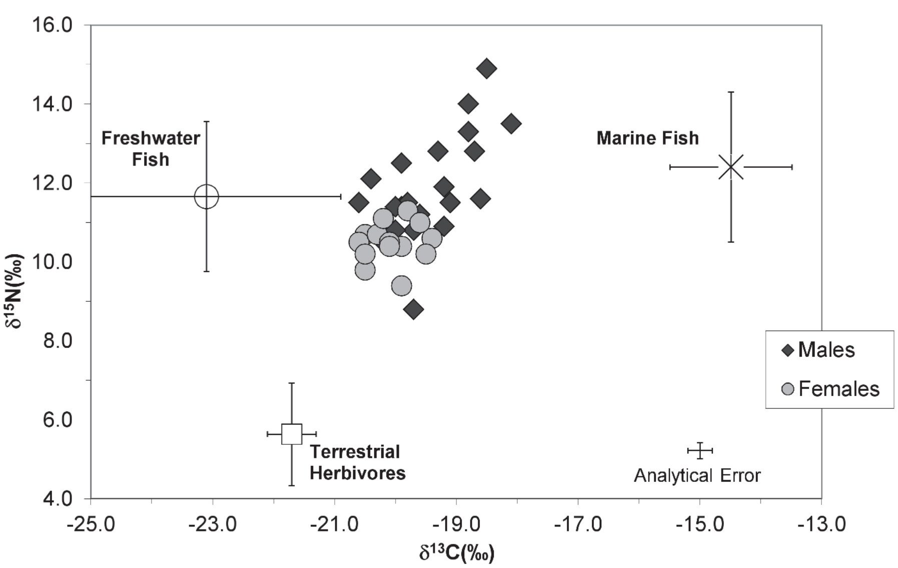

Figure 20.2. Stable isotope data from Period 4b (mid-eleventh–twelfth century) of the parish cemetery of St Andrew Fishergate in York, showing a population in transition between the 'traditional' terrestrial diet that appears to have been typical of the Anglo-Saxon period and the mixed marine-terrestrial diet that would become characteristic for Fishergate in the later medieval phase. For discussion of gender differences see below and Müldner (2009) (Data: Müldner and Richards 2007b).

terrestrial foods) than are those of top predators, such as cod (Figure 20.1). Consumption of herring in smaller quantities will therefore not register as strongly in consumer collagen; in other words, it would take relatively more herring protein in the diet to effect a clearly recognisable 'marine' signature in humans than it would cod protein. This issue is yet to be fully explored, especially since the isotope values of different fish species can vary significantly according to their geographical origin (see Barrett *et al*. 2008). Nevertheless, cod and related taxa appearing in greater numbers from the eleventh century onwards (Barrett *et al*. 2004; Serjeantson and Woolgar 2006) may have made any marine component become more visible in the human isotope data.

These technical issues aside, we also have to consider social variation as a reason for any seeming divergence of fish-bone evidence and isotope data. An important difference between the two methods is that animal-bone assemblages are unspecific regarding the identity of the human consumers behind them. Their associations can rarely even be narrowed down further than to a single household. In contrast, stable isotope values are specific to individuals, and allow levels of consumption to be assessed at least in relative terms (see Gumerman 1997). They therefore enable us to investigate in much more detail the different groups in society that partook in fish consumption, and how this consumption may have changed over time. The social dynamics of marine food use in medieval England will be explored in the next section.

Social variation in fish consumption in medieval England

Fish, its substantial nutritional value aside, had special significance in medieval diet as a fasting food. It could be eaten during Lent and on the numerous other days in the Church calendar on which the faithful were to abstain from meat as a sign of penitence and religious worship. References to the numerous associations of Christ and the Apostles with fish and fishing illustrate that fish consumption was indeed more than just a convenient 'loophole' in the Rule of St Benedict (which, strictly speaking, forbade only the 'flesh of quadrupeds'); it was imbued with spiritual value in itself (Serjeantson and Woolgar 2006; Woolgar 2000). Possibly fuelled by this attitude, fish in large quantities or species that were particular costly to produce or obtain became signs of social distinction. They were exchanged as gifts and adorned the tables of the rich as items of conspicuous consumption (Dyer 1988; Woolgar 2001). The value attributed to different fish species changed over time according to how readily available they were. While in the later Anglo-Saxon period any type of marine fish, including herring, may have carried special status (Fleming 2000, 5–6), it was larger or exotic specimens and costly pond-reared freshwater fish which were most highly regarded and priced in later medieval England (Dyer 1988; Woolgar 2000; see also Gardiner 1997). Because of the special qualities attributed to fish – qualities that go beyond its nutritional value – investigating variation in fish consumption in medieval society is a particularly fruitful approach towards understanding the success of the early fishing industries.

The timing of when fish became common in monastic and lay fasts is a subject of special significance for the early history of medieval sea fishing. The key question is whether the obligation to abstain from meat created great demand for fish early on in the medieval period and was therefore a significant driving force behind the rapid expansion of the marine fisheries (see Barrett *et al*. 2004). While numerous references to fasting regulations are found in Anglo-Saxon documents, especially of the tenth century AD, it is disputed whether fish was widely accepted as appropriate for consumption on fast days prior to the Norman Conquest (Barrett *et al*. 2004, 629–30; Frantzen 2014, 232–45; Serjeantson and Woolgar 2006, 104; Woolgar 2000: 36; see Hagen 1992, 393–408).

It has been suggested that the marine signal in the majority of later-medieval isotope data can be seen as a reflection of how the fasting requirements had transformed diet on a large scale (Müldner and Richards 2005). If this interpretation is accepted, then the absence of an obvious marine (or freshwater) component in the pre-Conquest isotope data could indicate that fish was not yet a regular substitute for meat on fast days. Unfortunately, however, although work on later Anglo-Saxon populations to date has not found much evidence for marine fish consumption (with the notable exception of the sites from Norfolk discussed above), stable isotope data from the crucial ninth to early eleventh centuries are currently too sparse to infer any bigger picture.

The possibility of profound social variation in diet, at a time when marine fish were not yet widely available, is a key issue in this respect. The main consumers of fish in later Anglo-Saxon England may simply elude us, since isotope evidence from monastic communities, early towns and high-status contexts of such an early medieval date is still sparse or missing entirely. Interestingly, both Burgh Castle and Caister-on-Sea, two of the Norfolk sites with early, pre-Conquest evidence of marine foods consumption, have been discussed as possible monastic settlements – although in both cases the main argument is the suggested identification with Cnobheresburgh, a religious house mentioned by Bede in the eighth century (Darling and Gurney 1993; Hull and O'Connell 2011; Johnson 1983). Similarly, it is currently unclear whether the cemetery of Belle Vue House/Lamel Hill in York, where no evidence of marine food consumption was found, was serving the population of the Anglian town, an important ecclesiastical and economic centre at the time, or rather that of an agricultural settlement nearby (Tweddle *et al*. 1999, 176). Moreover, the three individuals with a terrestrial diet sampled from ninth-century Coppergate, York's proto-urban Anglo-Scandinavian settlement, are arguably unusual, having been deposited in pits rather than afforded a proper burial (Buckberry *et al*. 2014). At Bishopstone in East Sussex, only the periphery of the Anglo-Saxon churchyard has been excavated. Burials of the highest-ranking members of the community, which were often situated inside or in close proximity to the church, may therefore have been missed. If marine fish was at the time indeed mainly served at the tables of the elite, we would therefore not necessarily see its consumption reflected in the Bishopstone isotope data (Reynolds 2010). The chronologically later case-study from Whithorn Cathedral Priory in Scotland illustrates this point well. Here, isotope data for a number of very high-ranking individuals, including several bishops of Galloway, were contrasted with data for a group of lower-status burials. The results demonstrate significant differences in diet between the two groups. In fact, any contributions from marine foods to the diet of the lower-status individuals were too small to be detectable (Müldner *et al*. 2009).

While the Whithorn data provide excellent evidence that the quantities of fish consumed indeed increased with socio-economic status, this is not necessarily a universal trend. At the later medieval Gilbertine Priory at Fishergate, there were no systematic differences between individuals buried in designated high- and low-status areas or those reserved for the monastic community. However, a group of men and women buried in the church crossing, one of the most prestigious locations for lay burial the house offered, stood out by having consumed significantly *less* marine protein than individuals from other areas (Figure 20.3; Müldner and Richards 2007a). These results correspond to observations of unusually low counts of fish-bone at a number of medieval high-status sites (Serjeantson and Woolgar 2006, 128–9; Sykes 2007, 60–1). They suggest that some aristocratic families sought to distinguish themselves by avoiding what was by now a popular and widely available food, rather than by the conspicuous consumption of it. A closer look at the documentary evidence indicates that preference for fish and its acceptance as suitable fare on fast days was indeed often a matter of personal choice, at least among those who could afford it (Woolgar 1995; 2006).

In several instances, stable isotope data have been able to demonstrate gender differences in the consumption of marine food. These are discussed in detail elsewhere (Müldner 2009) and shall only be briefly touched upon here. The differences between males and females among the early consumers of sea-fish at pre-monastic St Andrew, Fishergate, in York are particularly striking (Figure 20.2). Here, only males ate marine protein in measurable quantities. Given the associations of the Fishergate area with the fishing trade, it seems that the first regular consumers of marine fish, at least in a relatively low-status parish like St Andrew, were those directly involved in its production (Kemp and Graves 1996, 95–6; Müldner 2009).

Finally, let us now briefly consider the isotope evidence for variation between town and country. The large isotopic differences between the peasant population of Wharram Percy in the Yorkshire Wolds and other medieval assemblages have been discussed before (Müldner and Richards 2005; 2006). The Wharram Percy humans exhibit slightly elevated carbon isotope ratios, which could be interpreted as evidence for marine food consumption (Mays 1997; 2007, 94–5). However, the lack of correlation between $\delta^{13}C$ and $\delta^{15}N$ values, a correlation that is expected if a group of individuals is consuming marine protein in

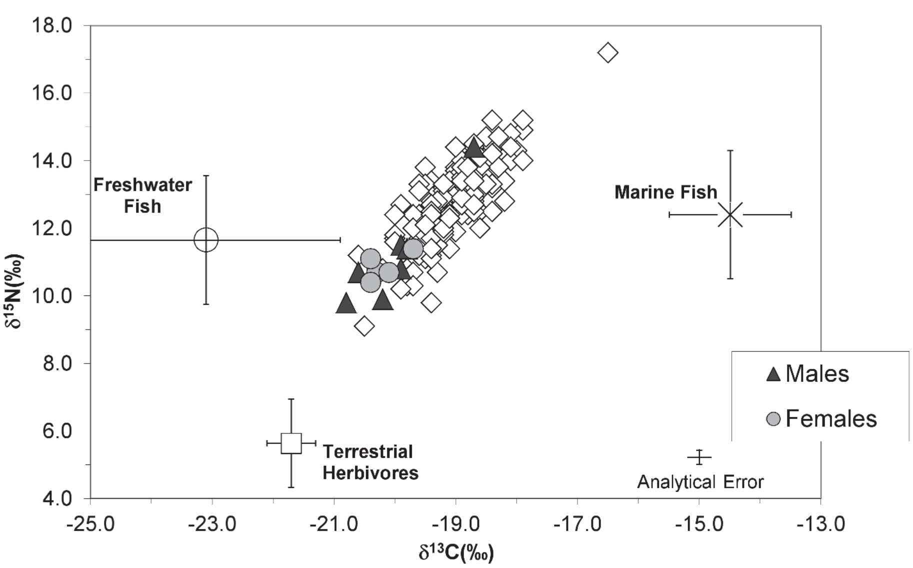

Figure 20.3. Stable isotope data for humans buried at the later medieval (thirteenth– early sixteenth-century AD) Gilbertine priory at Fishergate in York. A group of males and females buried in prominent position in the crossing of the priory church, probably in the early thirteenth century, stands out by having consumed significantly less marine protein than usual for the time (Data: Müldner and Richards 2007a).

varying quantities, and also the uncharacteristically low $\delta^{15}N$ values, suggest that diet at Wharram Percy was very different than at the other medieval sites, where a marine contribution is more evident. Nevertheless, being in the countryside and having limited economic means alone did not mean that there could not be a regular supply of fish for the table. This is evidenced by the isotope data from the small rural hospital of St Giles, near Richmond in North Yorkshire (Müldner and Richards 2005). As a hospital, St Giles was effectively a monastic institution. Again, social context is likely the key to understanding patterns of fish consumption at different sites. In this context and more generally, the fact that most available isotope data from the later medieval period are from monastic sites, and may therefore be skewed towards higher fish consumption, is a problem that future research will have to address (Müldner 2009; Quintelier *et al*. 2014).

Conclusions

The current survey of the stable isotope evidence for fish consumption in medieval England has shown that the expansion of the marine-fishing industry was accompanied by a significant change in the diet of large segments of the population. The isotope evidence is still sketchy and, at the moment, only affords spotlights on individual cemeteries from across England and southern Scotland. Still, many of the available data resonate with evidence from other sources. They suggest substantial geographical variation in the introduction of marine fish as a dietary staple. So far, only the results from East Anglia give convincing isotopic evidence for recognisable marine-food consumption before the turn of the first millennium AD (Hull and O'Connell 2011). They correspond to historical sources for the early development of the eastern fisheries, especially in the Great Yarmouth area (Kowaleski 2003; Chapter 3). Elsewhere, major changes do not seem to occur until the mid-eleventh century or later. In some areas this may have been as late as the thirteenth century, as is suggested by the small data set from Whithorn in southwest Scotland (Müldner *et al*. 2009). Nevertheless, stable isotope data from the ninth to eleventh centuries, which would be critical for exploring when and for whom sea-fish first became available in significant quantities, are still woefully scarce. These results should therefore be seen as preliminary. Social variation in fish consumption has been shown to be clearly reflected in the stable isotope data, especially those from the later medieval period. This observation reminds us that the socio-economic context of each cemetery has to be considered before stable isotope values can be interpreted in terms of continuity and change of medieval diet in general. Context is all-important, and in this respect stable isotope data are no different from any other archaeological evidence.

Future research should therefore seek not only to increase the number of samples available from the later Anglo-Saxon period, but also to deliberately target different settlement types, such as high and low status, urban and monastic, in order to establish which groups in society first made use of sea-fish as a new resource. Exploring geographic variation in the prominence of marine foods in the diet of medieval humans seems another fruitful avenue for future work. Stable isotope data for the bishops of Whithorn in the thirteenth and fourteenth centuries indicate that they ate significantly more fish than their local contemporaries, a special diet befitting their high office (Müldner *et al*. 2009). However, if their isotope values are compared with those of humans from later medieval York, the bishops' consumption of marine protein appears no more than average, hinting that substantial regional diversity existed irrespective of social status (Montgomery *et al*. 2009).

Overall, stable isotope studies on diet in the medieval period are still in their early stages. In time, they will hopefully be considered to be as important as more traditional archaeological approaches to the early history of marine fishing in medieval Europe.

References

Ambrose, S. H. 1993. Isotopic analysis of paleodiets: methodological and interpretive considerations, in M. K. Sandford (ed.) *Investigations of Ancient Human Tissue: chemical analyses in anthropology*: 59–130. Langthorne: Gordon & Breach.

Ambrose, S. H., B. M. Butler, D. B. Hanson, R. L. Hunter-Anderson & H. W. Krueger. 1997. Stable isotopic analysis of human diet in the Marianas Archipelago, western Pacific. *American Journal of Physical Anthropology* 104: 343–61.

Arneborg, J., J. Heinemeier, N. Lynnerup, H. L. Nielsen, N. Rud & A. E. Sveinbjörnsdóttir. 1999. Change of diet of the Greenland Vikings determined from stable carbon isotope analysis and ^{14}C dating of their bones. *Radiocarbon* 41(2): 157–68.

Barrett, J. H. & M. P. Richards. 2004. Identity, gender, religion and economy: new isotope and radiocarbon evidence for marine resource intensification in early historic Orkney, Scotland, UK. *European Journal of Archaeology* 7(3): 249–71.

Barrett, J. H., R. P. Beukens & D. R. Brothwell. 2000. Radiocarbon dating and marine reservoir correction of Viking Age Christian burials from Orkney. *Antiquity* 74: 537–43.

Barrett, J. H., R. P. Beukens & R. A. Nicholson. 2001. Diet and ethnicity during the Viking colonization of northern Scotland: evidence from fish bones and stable carbon isotopes. *Antiquity* 75: 145–54.

Barrett, J. H., A. M. Locker & C. M. Roberts. 2004. 'Dark Age economics' revisited: the English fish bone evidence AD 600–1600. *Antiquity* 78: 618–36.

Barrett, J. H., C. Johnstone, J. Harland, W. Van Neer, A. Ervynck, D. Makowiecki, D. Heinrich, A. K. Hufthammer, I. B. Enghoff, C. Amundsen, J. S. Christiansen, A. K. G. Jones, A. Locker, S. Hamilton-Dyer, L. Jonsson, L. Lõugas, C. Roberts & M. Richards. 2008. Detecting the medieval cod trade: a new method and first results. *Journal of Archaeological Science* 35(4): 850–61.

Bayliss, A., E. Shepherd Popescu, N. Beavan-Athfield, C. Bronk Ramsey, G. T. Cook & A. Locker. 2004. The potential significance of dietary offsets for the interpretation of radiocarbon dates: an archaeologically significant example from medieval Norwich. *Journal of Archaeological Science* 31(5): 563–75.

Bayliss, A., J. Hines, K. Hoilund Nielsen, G. McCormac & C. Scull. 2013. *Anglo-Saxon Graves and Grave Goods of the 6th and 7th centuries AD: a chronological framework*. London: Society for Medieval Archaeology.

Bocherens, H., M. Fizet, A. Mariotti, C. Olive, G. Bellon & D. Billiou. 1991. Application de la biogéochimie isotopique (^{13}C, ^{15}N) a la détermination du régime alimentaire des populations humaines et animales durant les périodes antique et médiévale. *Archives des Sciences (Geneva)* 44(3): 329–40.

Buckberry, J., J. Montgomery, J. Towers, G. Müldner, M. Holst, J. Evans, A. Gledhill, N. Neale & J. Lee-Thorp. 2014. Finding Vikings in the Danelaw. *Oxford Journal of Archaeology* 33: 413–34.

Campbell, J. 2002. Domesday herrings, in C. Harper-Bill, C. Rawcliffe & R. G. Wilson (eds) *East Anglia's History: studies in honour of Norman Scarfe*: 5–17. Woodbridge: Boydell Press.

Chenery, C. A., J. A. Evans, D. Score, A. Boyle & S. R. Chenery 2014. A boat load of Vikings? *Journal of the North Atlantic, Special Volume* 7: 43–53.

Chisholm, B. S., D. E. Nelson & H. P. Schwarcz. 1982. Stable-carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets. *Science* 216: 1131–2.

Coltrain, J. B., M. G. Hayes & D. H. O'Rourke. 2004. Sealing, whaling and caribou: the skeletal isotope chemistry of Eastern Arctic foragers. *Journal of Archaeological Science* 31(1): 39–57.

Curtis-Summer, S., J. Montgomery & M. Carver. 2014. Stable isotope evidence for dietary contrast between Pictish and medieval populations at Portmahomack, Scotland. *Medieval Archaeology* 58: 21–43.

Darling, M. J. & D. Gurney. 1993. *Caister-on-Sea, excavations by Charles Green 1951–1955*. (East Anglian Archaeology 60). Dereham: Norfolk Archaeological Unit/Norfolk Museums Service.

DeNiro, M. J. & S. Epstein. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et Cosmochimica Acta* 45(3): 341–51.

Dufour, E., H. Bocherens & A. Mariotti. 1999. Palaeodietary implications of isotopic variability in Eurasian lacustrine fish. *Journal of Archaeological Science* 26(6): 617–27.

Dyer, C. C. 1988. The consumption of freshwater fish in medieval England, in M. Aston (ed.) *Medieval Fish, Fisheries and Fishponds in England:* 27–38 (British Archaeological Report 182). Oxford: British Archaeological Reports.

Ervynck, A., M. Boudin, T. Van den Brande & M. Van Strydonck. 2013. Dating human remains from the historical period in Belgium: diet changes and the impact of marine and freshwater reservoir effects. *Radiocarbon* 56(2): 779–88.

Fleming, R. 2000. The new wealth, the new rich and the new political style in late Anglo-Saxon England. *Anglo-Norman Studies* 23: 1–22.

France, R. 1995. Stable nitrogen isotopes in fish: literature synthesis on the influence of ecotonal coupling. *Estuarine, Coastal and Shelf Science* 41(6): 737–42.

Frantzen, A. J. 2014. *Food, Eating and Identity in Early Medieval England*. Woodbridge: Boydell Press.

Fry, B. 1991. Stable isotope diagrams of freshwater food webs. *Ecology* 72(6): 2293–7.

Fuller, B. T., G. Müldner, W. Van Neer, A. Ervynck & M. P. Richards. 2012. Carbon and nitrogen stable isotope ratio analysis of freshwater, brackish and marine fish from Belgian archaeological sites (1st and 2nd millennium AD). *Journal of Analytical Atomic Spectrometry* 27: 807–20.

Gardiner, M. 1997. The exploitation of sea-mammals in medieval England: bones and their social context. *Archaeological Journal* 154: 173–95.

Gumerman, G. 1997. Food and complex societies. *Journal of Archaeological Method & Theory* 4(2): 105–39.

Hadley, D. M. 2001. *Death in Medieval England*. Stroud: Tempus.

Hagen, A. 1992. *A Handbook of Anglo-Saxon food: processing and consumption*. Frithgard: Anglo-Saxon Books.

Hamilton-Dyer, S. 1997. The bird and fish bones, in P. Hill (ed.) *Whithorn and St Ninian: the excavation of a monastic town 1984–91*: 601–05. Stroud: Whithorn Trust/Sutton.

Harland, J., C. Johnstone & A. Jones. 2008. A case study from the medieval origins of commercial sea fishing project: zooarchaeological results from York (UK), in P. Béarez, S. Grouard & B. Clavel (eds) *Archéologie du poisson: 30 ans d'archéo-ichtyologie au CNRS*: 15–26. Antibes: Éditions APDCA.

Hedges, R. E. M. 2004. Isotopes and red herrings: comments on Milner *et al*. and Lidén *et al. Antiquity* 78: 34–7.

Hedges, R. E. M. & L. M. Reynard. 2007. Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science* 34: 1240–51.

Hedges, R. E. M., J. G. Clement, C. D. L. Thomas & T. C. O'Connell. 2007. Collagen turnover in the adult femoral mid-shaft: modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* 133(2): 808–16.

Hull, B. D. & T. C. O'Connell. 2011. Diet: recent evidence from analytical chemical techniques, in H. Hamerow, D. A. Hinton & S. Crawford (ed.) *The Oxford Handbook of Anglo-Saxon Archaeology*: 667–87. Oxford: Oxford University Press.

Jim, S., V. Jones, S. H. Ambrose & R. P. Evershed. 2006. Quantifying dietary macronutrient sources of carbon for bone collagen synthesis using natural abundance stable carbon isotope analysis. *British Journal of Nutrition* 95(6): 1055–62.

Johansen, O. V., S. Gulliksen & R. Nydal. 1986. $\delta^{13}C$ and diet: analysis of Norwegian human skeletons. *Radiocarbon* 28: 754–61.

Johnson, S. 1983. *Burgh Castle: excavations by Charles Green, 1958–61* (East Anglian Archaeology 20). Dereham: Norfolk Archaeological Unit/Norfolk Museums Service.

Katzenberg, M. A. & A. W. Weber. 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. *Journal of Archaeological Science* 26(6): 651–9.

Kelly, J. F. 2000. Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. *Canadian Journal of Zoology* 78(1): 1–27.

Kemp, R. L. & C. P. Graves. 1996. *The Church and Gilbertine Priory of St. Andrew, Fishergate*. (Archaeology of York 7/1). York: Council for British Archaeology.

Kline, T. C., W. J. Wilson & J. J. Goering. 1998. Natural isotope indicators of fish migration at Prudhoe Bay, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 55(6): 1494–502.

Kowaleski, M. 2003. The commercialization of the sea fisheries in medieval England and Wales. *International Journal of Maritime History* 15(2): 177–231.

Lakin, K. E. 2010. Diet in Medieval London: Stable Isotope Analysis of Human and Faunal Remains. Unpublished PhD dissertation, University of Reading.

Lamb, A. L., M. Melikian, R. Ives & J. Evans. 2012. Multi-isotope analysis of the population of the lost medieval village of Auldhame, East Lothian, Scotland. *Journal of Analytical Atomic Spectrometry* 27(5): 765–77.

Lightfoot, E., T. C. O'Connell, R. E. Stevens, J. Hamilton, G. Hey & R. E. M. Hedges. 2009. An investigation into diet at the site of Yarnton, Oxfordshire, using stable carbon and nitrogen isotopes. *Oxford Journal of Archaeology* 28(3): 301–22.

Lucy, S., R. Newman, N. Dodwell, C. Hills, M. Dekker, T. O'Connell, I. Riddler & P. Walton Rogers. 2009. The burial of a princess? The later seventh-century cemetery at Westfield Farm, Ely. *Antiquaries Journal* 89: 81–141.

Mays, S. A. 1997. Carbon stable isotope ratios in mediaeval and later human skeletons from northern England. *Journal of Archaeological Science* 24(6): 561–7.

Mays, S. A. 2007. The human remains, in S. Mays, C. Harding & C. Heighway (eds) *Wharram: a study of settlement on the Yorkshire Wolds. Volume 11: the churchyard*: 77–192. (York University Archaeological Publications 13). York: University of York.

Mays, S. & N. Beavan. 2012. An investigation of diet in early Anglo-Saxon England using carbon and nitrogen stable isotope analysis of human bone collagen. *Journal of Archaeological Science* 39(4): 867–74.

Modzelewski, K. 2008. Palaeodietary analysis of an early medieval coastal community in southern Scotland: the cemetery of Lundin Links, Fife. Unpublished MA dissertation, University of Reading.

Montgomery, J., G. Müldner, G. Cook, A. Gledhill & R. Ellam. 2009. Isotope analysis of bone collagen and tooth enamel, in C. Lowe (ed.) *'Clothing for the soul divine': burials at the tomb of St Ninian: excavations at Whithorn Priory 1957–67*: 63–80. Edinburgh: Historic Scotland: Edinburgh.

Müldner, G. 2009. Investigating medieval diet and society by stable isotope analysis of human bone, in R. Gilchrist & A. Reynolds (eds) *Fifty Years of Medieval Archaeology*: 327–46. Leeds: Maney.

Müldner, G. & V. Grimes. 2007. Stable isotope analysis of cetaceans and fish from Flixborough, in K. Dobney, D. Jaques, J. Barrett & C. Johnstone (eds) *Farmers, Monks and Aristocrats: the environmental archaeology of Anglo-Saxon Flixborough*: 201–6 (Excavations at Flixborough 3). Oxford: Oxbow Books.

Müldner, G. & M. P. Richards. 2005. Fast or feast: reconstructing diet in later medieval England by stable isotope analysis. *Journal of Archaeological Science* 32(1): 39–48.

Müldner, G. & M. P. Richards. 2006. Diet in medieval England: the evidence from stable isotopes, in C. M. Woolgar, D. Serjeantson & T. Waldron (eds) *Food in Medieval England: diet and nutrition*: 228–38. Oxford: Oxford University Press.

Müldner, G. & M. P. Richards. 2007a. Diet and diversity at later medieval Fishergate: the isotopic evidence. *American Journal of Physical Anthropology* 134(2): 162–74.

Müldner, G. & M. P. Richards. 2007b. Stable isotope evidence for 1500 years of human diet at the City of York, U. K. *American Journal of Physical Anthropology* 133(1): 682–97.

Müldner, G., J. Montgomery, G. Cook, R. Ellam, A. Gledhill & C. Lowe. 2009. Isotopes and individuals: diet and mobility among the medieval bishops of Whithorn. *Antiquity* 83: 1119–33.

O'Connell, T. C. & R. E. M. Hedges. 1999. Investigations into the effect of diet on modern human hair isotopic values. *American Journal of Physical Anthropology* 108(4): 409–25.

O'Connor, T. P. 1991. *Bones from 46–54 Fishergate*. (Archaeology of York 15/4). York: Council for British Archaeology.

Peitel, D. 2006. Rekonstruktion der Ernährung und weiterer Subsistenzgrundlagen dreier frühneuzeitlicher Bevölkerungen anhand der Analyse stabiler Isotope und Spurenelemente. Unpublished PhD dissertation, Freie Universität Berlin.

Phillips, D. L., R. Inger, S. Bearhop, A. L. Jackson, J. W. Moore, A. C. Parnell, B. X. Semmens & E. J. Ward. 2014. Best practices for use of stable isotope mixing models in food-web studies. *Canadian Journal of Zoology* 92: 823–35.

Polet, C. & M. A. Katzenberg. 2003. Reconstruction of the diet in a mediaeval monastic community from the coast of Belgium. *Journal of Archaeological Science* 30(5): 525–33.

Pollard, A. M., P. Ditchfield, E. Piva, S. Wallis, C. Falys & S. Ford. 2012. 'Sprouting like cockle amongst the wheat': The St Brice's Day Massacre and the isotopic analysis of human bones from St John's College, Oxford. *Oxford Journal of Archaeology* 31(1): 83–102.

Privat, K. L., T. C. O'Connell & M. P. Richards. 2002. Stable isotope analysis of human and faunal remains from the Anglo-Saxon cemetery at Berinsfield, Oxfordshire: dietary and social implications. *Journal of Archaeological Science* 29(7): 779–90.

Quintelier, K., A. Ervynck, G. Müldner, W. Van Neer, M. P. Richards & B. T. Fuller. 2014. Isotopic examination of links between diet, social differentiation, and DISH at the post-medieval Carmelite Friary of Aalst, Belgium. *American Journal of Physical Anthropology* 153: 203–13.

Reynolds, R. 2010. Fish remains, in G. Thomas (ed.) *The Later Anglo-Saxon Settlement at Bishopstone: a downland manor in the making*: 157–64. (Council for British Archaeology Research Report 163). York: Council for British Archaeology.

Reynolds, R. 2011. Anglo-Saxon fish remains from Lyminge, Kent. Report on file, Reading University. http://www.reading.ac.uk/web/FILES/archaeology/LymingeReynolds2011.pdf.

Richards, M. P. & R. E. M. Hedges. 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* 26(6): 717–22.

Richards, M. P., B. T. Fuller & T. I. Molleson. 2006. Stable isotope palaeodietary study of humans and fauna from the multi-period (Iron Age, Viking and Late Medieval) site of Newark Bay, Orkney. *Journal of Archaeological Science* 33(1): 122–31.

Rodwell, K. 1993. The cemetery, in M. J. Darling & D. Gurney (eds) *Caister-on-Sea: excavations by Charles Green 1951–1955*:

252–55. (East Anglian Archaeology 60). Dereham: Norfolk Archaeological Unit/Norfolk Museums Service.

Salamon, M., A. Coppa, M. McCormick, M. Rubini, R. Vargiu & N. Tuross. 2007. The consilience of historical and isotopic approaches in reconstructing the medieval Mediterranean diet. *Journal of Archaeological Science* 35(6): 1667–72.

Schäuble, A. 2006. Ernährungsrekonstruktion dreier mittelalterlicher Bevölkerungen anhand der Analyse stabiler Isotope und Spurenelemente. Unpublished PhD dissertation, Freie Universität Berlin.

Schoeninger, M. J. & M. J. DeNiro. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* 48: 625–39.

Schwarcz, H. P. 2000. Some biochemical aspects of carbon isotopic palaeodiet studies, in S. H. Ambrose and M. A. Katzenberg (ed.) *Biogeochemical Approaches to Palaeodietary Analysis*: 189–209. New York: Kluwer Academic/Plenum.

Schwarcz, H. P. & M. J. Schoeninger. 1991. Stable isotope analyses in human nutritional ecology. *Yearbook of Physical Anthropology* 34(S13): 283–321.

Sealy, J., R. Armstrong & C. Schrire. 1995. Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. *Antiquity* 69: 290–300.

Serjeantson, D. & C. M. Woolgar. 2006. Fish consumption in medieval England, in C. M. Woolgar, D. Serjeantson & T. Waldron (eds) *Food in Medieval England: diet and nutrition*: 102–30. Oxford: Oxford University Press.

Stuiver, M., P. J. Reimer & T. F. Braziunas. 1998. High-precision radiocarbon age calibration for terrestrial and marine samples. *Radiocarbon* 40(3): 112–51.

Sykes, N. 2007. *The Norman Conquest: a zooarchaeological perspective*. (British Archaeological Report S1656). Oxford: Archaeopress.

Tauber, H. 1981. ^{13}C evidence for dietary habits of prehistoric man in Denmark. *Nature* 292: 332–3.

Thomas, G. 2010. *The Later Anglo-Saxon Settlement at Bishopstone: a downland manor in the making* (Council for British Archaeology Research Report 163). York: Council for British Archaeology.

Thomas, G. 2013. Life before the Minster: the social dynamics of monastic foundation at Anglo-Saxon Lyminge, Kent. *Antiquaries Journal* 93: 109–45.

Tweddle, D., J. Moulden & E. Logan. 1999. *Anglian York: a survey of the evidence* (Archaeology of York 7/2). York: Council for British Archaeology.

Woolgar, C. M. 1995. Diet and consumption in gentry and noble households: a case study from around the Wash, in R. E. Archer & S. Walker (eds) *Rulers and Ruled in Late Medieval England: essays presented to Gerald Harriss*: 17–31. London: Hambledon Press.

Woolgar, C. M. 2000. 'Take this penance now, and afterwards the fare will improve': seafood and late medieval diet, in D. J. Starkey, C. Reid & N. Ashcroft (eds) *England's Sea Fisheries: the commercial sea fisheries of England and Wales since 1300*: 36–44. London: Chatham.

Woolgar, C. M. 2001. Fast and feast: conspicuous consumption and the diet of the nobility in the fifteenth century, in M. Hicks (ed.) *Revolution and Consumption in Late Medieval England*: 7–25. Woodbridge: Boydell Press.

Woolgar, C. M. 2006. Group diets in late medieval England, in C. M. Woolgar, D. Serjeantson & T. Waldron (eds) *Food in Medieval England: diet and nutrition*: 191–200. Oxford: Oxford University Press.

Yoder, C. 2010. Diet in medieval Denmark: a regional and temporal comparison. *Journal of Archaeological Science* 37: 2224–36.