1 **Investigating dietary patterns and organisational structure by using stable isotope analysis: a pilot**
2 **study of the Danish medieval leprosy hospital at Næstved**

3 **Anastasia Brozou[1], Niels Lynnerup[2], Marcello A. Mannino[1], Andrew R. Millard[3], Darren R. Gröcke[4]**
4 [1]Department of Archaeology and Heritage Studies, School of Culture and Society, Aarhus University,
5 Aarhus, Denmark
6 ana.brozou@cas.au.dk
7 [2]Department of Forensic Medicine, University of Copenhagen, Denmark
8 [3]Department of Archaeology, Durham University, United Kingdom
9 [4]Department of Earth Sciences, Durham University, United Kingdom

10

11 With 3 figures and 5 tables

12

13 **Summary:** During the 12th and 13th centuries, numerous leprosy hospitals were founded in Europe.
14 Given that leprosy was not considered infectious, this may reflect social dimensions of the disease.
15 Aiming at exploring the impact of leprosy on medieval people and the organisation of the Danish
16 *leprosarium* at Næstved, we reconstructed the diet of twenty patients using stable isotopes, and
17 compared our results with relevant historical data. The isotope results revealed a terrestrial C_3 diet with
18 a small contribution of aquatic foods. Contrary to historical evidence of daily fish consumption in the
19 leprosy hospital, only six individuals consumed relatively large amounts of freshwater fish. *Leprosaria*
20 have been considered monastic institutions, and thus a varied diet, poor in aquatic protein, questions
21 the monastic nature of the hospital and points to a social stratification. A multi-isotope analysis of a
22 larger sample set would add to our understanding of the diet of the leprosy patients, as well as their
23 treatment in the *leprosarium*.

24

25 **Key words:** leprosy, diet, carbon isotopes, nitrogen isotopes, medieval Denmark

26

27 Leprosy is a severely debilitating and crippling disease, which changes the physical appearance of its
28 sufferers and stigmatises them physically, psychologically and socially. The disease affects the skin and
29 the peripheral nerves, leading to paralysis of muscle groups in the extremities and subsequent
30 deformity of bones (Job et al. 1966; Lockwood et al. 2012); as well as secondary infection that is
31 facilitated by loss of sensitivity to pain, ulceration of the skin and invasion by environmental pathogens
32 (Roberts and Manchester 2005). Initial skin changes may be quite visible, as is also the involvement of
33 the eyelids, which leads to loss of eye function and blindness (Daniel et al. 1997; Lynnerup and Boldsen
34 2012). Sufferers may thus exhibit pronounced, visible signs that may lead to stigmatisation with
35 immense social and psychological implications (Heijnders 2004; Rafferty 2005; Lusli et al. 2015). The
36 social stigmatisation of medieval leprosy sufferers has been widely debated by modern scholars (cf.
37 Brody 1974; Touati 2000; Rawcliffe 2006; Boldsen 2009).

38

39 Influenced by socioeconomic, cultural and moral determinants, the social dimensions of the disease are
40 closely related to, and thus reflect, the cultural traditions of each society (Bainson and van den Borne
41 1998). The establishment, therefore, of leprosy hospitals was a reaction to the disease during the High
42 Medieval period when the notion of contagion was not yet established (Rawcliffe 2006). Because
43 leprosy was considered more as a disease of the soul (Roberts and Manchester 2005), this gives an
44 insight into the medieval mentality towards diseases and social relations. The investigation of the link
45 between leprosy and leprosy hospitals (*leprosaria*) is thus essential for improving our knowledge on
46 how the disease affected institutionalised individuals and society as a whole. This paper aims to explore
47 this link through an isotopic investigation of the dietary patterns and behaviours of medieval leprosy
48 sufferers, complemented further by information from historical sources.

49

50 The reconstruction of past human diets is important for understanding how communities were
51 organised, revealing for example distinctions between different sex, age and social groups, as well as

the level of health (e.g. Kjellström 2005; Yoder 2012; Beaumont and Montgomery 2016). Our knowledge of diets in medieval *leprosaria* derives mainly from regulation documents of the institutions. The amount and types of foods consumed by the patients of the *leprosaria* depended on the availability of goods and the economic status of each institution. Richards (1977) and Rawcliffe (2006) present several examples for Scandinavian and English *leprosaria* respectively. However, evidence of corrupt administration at *leprosaria* raises doubts about the implementation of the regulations mentioned in the historical texts. For example, according to a document dated to 1492, every morning the patients of the Danish *leprosarium* at Næstved were provided with porridge, fish and beer, but on meat days with either pork, beef or just cabbage, depending on availability (Richards 1977). The same document, however, reveals that the leprosy patients lodged a complaint to the king concerning their warden, who withheld their income, a condition that could have further influenced their diet. A similar event occurred at the *leprosarium* at Hedon in England, when, in 1334, the administrative body proceeded in the reduction of the daily dietary allowances (Rawcliffe 2006). Examples of corruption are also known from other medieval *leprosaria*, such as those at Kronoby, Finland and Svendborg, Denmark (Richards 1977).

Unlike historical sources, however, which may provide debatable information about past diets, the method of carbon and nitrogen stable isotope analysis not only provides a means for determining what people were actually eating, but may also provide information to reconstruct the issue of stigma attached to the disease. For example, Taylor et al. (2013) isotopically analysed rib and femur samples from three skeletons excavated from the cemetery of the medieval *leprosarium* of St. Mary Magdalen in Winchester (England), and revealed that the carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope ratios were enriched in the rib compared to the femur samples in all three individuals. Since bone material undergoes replacement at a faster rate in ribs than it does in femora, Taylor et al. (2013) interpreted this as indicating an increased consumption of marine foods during the last years of life, when these individuals were probably living in the *leprosarium*. Taylor et al. (2013) further suggested that this implied a monastic diet was imposed on the leprosy patients. The present study will conduct an isotopic dietary reconstruction of twenty leprosy patients from the Danish medieval *leprosarium* at Næstved, that will be compared with dietary information from historical sources. This study hopes to further explore the organisational structure of this *leprosarium*.

Materials and methods

The samples analysed in this study are from the medieval *leprosarium* at Aaderup, a suburb of the town of Næstved in Denmark (**Figure 1**). The *leprosarium* was first commemorated in a will that is dated to 1261 (Madsen 1990:8) and functioned for almost 300 years until 1542, when it was allocated to the House of the Holy Ghost (Helligåndshuset) in Næstved (Michelsen 1954).

Twenty skeletons (ten male and ten female) were selected, all aged between 20 and 45 years at death. The determination of sex was based on the morphological features of the pelvis and the skull (Phenice 1969; Ferembach et al. 1980; Buikstra and Ubelaker 1994; Loth and Henneberg 1996) as well as metrical methods (Bass 2005), while age was estimated, when applicable, by the morphological changes of the auricular surface (Lovejoy et al. 1985), the pubic symphysis (Brooks and Suchey 1990), the sternal rib end (Işcan et al. 1984) and the closure of ectocranial sutures (Meindl and Lovejoy 1985).

Rib fragments were sampled, since collagen in ribs remodels faster than in any other skeletal element, allowing us to gain dietary information for the last 3 to 5 years of life (Jørkov et al. 2009). We do not know how long the sampled individuals had been in the Næstved *leprosarium*, but sampling ribs maximises the chance of obtaining dietary information for the time of internment. Ribs with pathological lesions were avoided, because the effect of pathological changes on isotope ratios is not sufficiently understood (Katzenberg and Lovell 1999). The samples were taken from the mid-shaft using a low-speed drill, and the first, second, eleventh and twelfth ribs were not included (Jørkov et al. 2009).

102 All samples weighed up to 200 mg and grinding was avoided, as this would damage proteins and other
103 bone biopolymers (Collins and Galley 1998).
104
105 **[>>> Figure 1 <<<]**
106
107 Collagen extraction was based on a modification of the Longin (1971) method by Brown et al. (1988)
108 that includes an additional ultrafiltration step. The isotopic measurements were run in duplicate at the
109 Stable Isotope Biogeochemistry Laboratory (SIBL) at Durham University. Total carbon and nitrogen
110 content, and stable isotope analysis were performed using a Costech Elemental Analyser (ECS 4010)
111 connected to a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer. Isotopic accuracy
112 was monitored through routine analyses of in-house standards and international standards (e.g.,
113 USGS40, USGS24, IAEA-600, IAEA-N-1, IAEA-N-2): Analytical uncertainty in carbon and nitrogen isotope
114 analysis was typically <±0.1 ‰ for replicate analyses of the international standards and <0.2 ‰ on
115 replicate sample analysis. Total organic carbon and nitrogen data was obtained as part of the isotopic
116 analysis using an internal standard (Glutamic Acid, 40.82 % C, 9.52 % N).
117
118 The non-parametric Kolmogorov-Smirnov two-sample test was performed in order to explore potential
119 dietary differences between the two sexes (Siegel and Castellan 1988). Instead of a parametric, a non-
120 parametric, test was preferred because the size of the samples tested is small (under twenty) (Madrigal
121 2012).
122
123 **Results**
124 **Table 1** presents in detail the quality indicators and the isotopic values obtained from each sample.
125 Except for a single outlier (371), all samples fall within the suggested range of atomic C/N ratio (2.9–3.6)
126 for well-preserved collagen (DeNiro 1985; Ambrose 1990). Thus, the isotopic values of sample 371 were
127 not considered. The collagen yield and carbon and nitrogen percentages of all samples fall within the
128 range proposed by van Klinken (1999). The δ^{13}C values range from -20.8‰ to -19.2‰ (mean = -20‰),
129 while the δ^{15}N values range from 9.9‰ to 12.9‰ (mean = 11.7‰). Males have δ^{13}C values ranging from
130 -20.3‰ to -19.2‰ (mean = -19.8‰) and δ^{15}N values ranging from 11.3‰ to 12.6‰ (mean = 11.9‰).
131 Females have δ^{13}C values ranging from -20.8‰ to -19.6‰ (mean = -20.2‰) and δ^{15}N values ranging
132 from 9.9‰ to 12.9‰ (mean = 11.6‰).
133
134 The narrow range of the δ^{13}C values suggest that the individuals from Næstved had a diet dominated
135 by terrestrial C_3 based foods (Johansen et al. 1986). The majority of the analysed individuals had δ^{13}C
136 values around -20‰, corresponding to a diet with little or no marine protein (Richards and Hedges
137 1999; Olsen et al. 2018). The δ^{15}N values exhibit a range from 9.9‰ to 12.9‰, suggesting that animal
138 protein may have contributed significantly to the diet, since a diet consisting of protein from both plants
139 and animals would give lower δ^{15}N, around 6–9‰ (Jørkov et al. 2010). The consumption of omnivores,
140 for example, pigs feeding on slops (Müldner and Richards 2005) has been connected with the
141 combination of an entirely terrestrial δ^{13}C signal with high δ^{15}N values. However, Halley and Rosvold
142 (2014) indicate through δ^{13}C and δ^{15}N that domestic pigs from medieval sites of northern Europe had a
143 wide range of diets in different areas. Furthermore, the study of a single pig from the Danish medieval
144 site of Øm Kloster gave a δ^{15}N of 6‰ corresponding to an herbivorous diet (Yoder, 2010). The
145 consumption of manured plants, as well as freshwater and suckling animals may also explain the
146 combination of high δ^{15}N with terrestrial δ^{13}C (Müldner and Richards 2005; Jay and Richards 2006;
147 Jørkov et al. 2010).
148
149 The Kolmogorov-Smirnov tests revealed no significant difference between the diets of men and women
150 ($Z = 1.06$, $p = 0.21$ for δ^{13}C and $Z = 0.75$, $p = 0.63$ for δ^{15}N).
151
152 **[>>> Table 1 <<<]**

153
154 **Discussion**
155 During the medieval period, cereals constituted the main food consumed, with barley and winter rye
156 being the main crops, while wheat was considered as a luxury food source (Stone 2006a). According to
157 Yoder (2012), sheep, pigs and cattle provided the highest proportions of protein intake, while before
158 the later 14th century and the intensification of cattle production in Denmark, dairy products and eggs
159 were also an important source of protein. Rawcliffe (2006) further mentions that eggs and fresh milk,
160 among other products, were considered beneficial for leprosy. In antithesis to fresh fruit and vegetables
161 that were considered inappropriate food for the upper class (Dyer 1983), the consumption of birds was
162 a privilege of the aristocracy and the clergy; a concept that rose to prominence during the late 14th
163 century (Stone 2006b).
164
165 The δ^{13}C and δ^{15}N values in this study reveal a diet based on C_3 plants and various amounts of terrestrial
166 and aquatic protein for both male and female leprosy patients. For a better interpretation of the human
167 isotope data, it is important to have data from a variety of faunal samples from the same period and
168 location. It was not possible, however, to obtain animal bones from the area of the *leprosarium*. **Figure**
169 **2** depicts the δ^{13}C and δ^{15}N values of the leprosy patients, as well as the values of terrestrial and aquatic
170 animals mentioned by Yoder (2010, Table 1). This data comes from the Danish medieval monastery at
171 Øm Kloster (Yoder 2010), the English medieval sites of St. Giles and Beverley (a Dominican priory)
172 (Müldner and Richards 2005), as well as from Neolithic sites in Denmark (Fischer et al. 2007) and
173 medieval sites in northern Europe (Barrett et al. 2008).
174
175 All the marine fish (ling, haddock, cod and herring) have more positive δ^{13}C and δ^{15}N than the humans,
176 while the herbivores (goat, cow, sheep and pig) have more depleted values. There is a progressive
177 enrichment of δ^{13}C (1‰ to 2‰; Bocherens and Drucker 2003; Brown & Brown 2011:84) and δ^{15}N (3‰
178 to 5‰; Schoeninger et al. 1983; Bocherens and Drucker 2003) from the lower to higher trophic levels
179 in the food chain. The enrichment of ^{15}N enables the differentiation between animal and plant resources
180 (Schoeninger et al. 1983), while carbon stable isotopes distinguish between plants that follow different
181 photosynthetic pathways (C_3 *versus* C_4), as well as between terrestrial and marine resources (Tauber
182 1981; DeNiro 1985). The lower δ^{15}N of the herbivores indicates that they could have been a staple food
183 source for the leprosy patients. Only one pike sample (pike 2) could possibly contribute to the diet (pike
184 is a freshwater fish). δ^{13}C values that indicate a terrestrial C_3 diet and are combined with δ^{15}N values
185 over 12‰, reflect a significant contribution of freshwater fish (Jørkov et al. 2010, based on Bonsall et
186 al. 1997). The daily consumption of fish by the patients of the *leprosarium* at Næstved is recorded in a
187 15th century document (Richards 1977). However, from a total of nineteen samples, only six have
188 nitrogen values greater than 12‰. Relative dating, in the form of the arrangement in the grave of the
189 arms in relation to the rest of the body, is available for four of these samples (**Figure 3**).
190
191 **[>>> Figure 2 <<<]**
192
193 The arm-position method is used widely in Denmark for medieval contexts until the Reformation in
194 1536 (after this period older positions came into use again), as it provides a broad, but rather consistent
195 method for dating. The four arm positions (Position A, AD 1000–1300, arms next to the body; Position
196 B, AD 1300–1350, forearms over the lower parts of the abdomen and hands over the pelvic region;
197 Position C, AD 1350–1400, forearms over the upper part of the abdomen, with elbows flexed at
198 approximately 90˚; Position D, 1400–1536, forearms crossed over the chest and hands on the shoulders)
199 have been described by Kieffer-Olsen (1993), and the dates are assigned by Jantzen et al. (1994) based
200 on the dominant arm position for each period. No chronological pattern can be observed in the diet of
201 the sampled individuals.
202
203 **[>>> Figure 3 <<<]**

In medieval England, as fishing rights in local streams and rivers were a privilege of the aristocracy, freshwater fish were regarded to be an expensive foodstuff (Dyer 1988; Hoffman 1996). Rawcliffe (2006), however, mentions the individuals with leprosy from Boughton, England, who owned the right of keeping a boat and fishing in the river Dee. Suså, the longest river in southern Zealand, flows through Næstved and was probably the source of the freshwater fish for the population of the surrounding area. The high cost of freshwater fish is emphasised by the frequency of ponds found in relation to land owned by aristocrats (Dyer 1994; Serjeantson and Woolgar 2006). Eel, bream, perch, pike, roach and tench were the most common fish consumed by the upper class, and they could be found in both ponds, rivers and streams (Dyer 1988). Hybel and Poulsen (2007) mention that fishponds are frequently encountered in Danish sources that date after the late 14th century. The *leprosarium* at Næstved owned an area of forest and at least one farm (Richards 1960), although the existence of a pond remains unknown.

Compared to freshwater fish, marine fish were possibly more affordable due to their greater availability, which lowered their market value (Hoffmann 1996). In northern Europe there was a wide trade of herring and cod during the Medieval period (Enghoff 1996; Barrett et al. 2008; 2011). The establishment of major marine fisheries, combined with the fasting rules that prohibited the consumption of meat, eggs and dairy products for a large number of days of the year (Dyer 1988; Müldner and Richards 2005) would suggest that marine fish were an important component of the Danish medieval diet. A zooarchaeological study focusing on herring bones that date between the 8th and 13th centuries uncovered large scale activity on Zealand (Enghoff 1996). Moreover, bones from marine fish, such as ling, cod, dab and salmon, as well as from freshwater fish, such as pike, perch, bream and sturgeon, have also been discovered at medieval sites (Arcini 1999).

Yoder (2012) claims that due to the high cost of meat, the lower class probably ate fish more frequently than the upper class. On the contrary, based on historical documents, Dyer (1983) suggests that the upper class was more likely to follow the fasting rules, and therefore consumed larger quantities of fish. Even though the drying and salting of marine fish for preservation was common, Hoffmann (1996) suggests that difficulties of transporting fresh marine fish to the mainland for immediate consumption probably made freshwater fish more desirable even after the expansion of the marine fish trade. Although Næstved´s close proximity to the sea suggests access to marine resources, there is no evidence of significant consumption of marine food in the population from the nearby *leprosarium*. This has also been noted for other coastal sites, such as the late Anglo-Saxon site in Bishopstone, England, where stable isotope analysis revealed a terrestrial-based diet with only a small input of marine protein (Marsall et al. 2010) – here, too, in contrast to the large amount of recovered marine fish bones (Reynolds 2010). A diet that is completely dependant on marine resources is expected to have δ^{13}C values of approximately -12‰, while a diet that is based on purely C$_3$ plants and terrestrial animals is expected to have values of around -20‰ (Richards and Hedges 1999). Several studies have produced carbon and nitrogen stable isotope values that indicate either a mixed diet or purely terrestrial/marine diets (e.g. Schulting et al. 2008; Keenleyside et al. 2009; Schwarcz et al. 2014; Müldner 2016). **Table 2** provides the mean carbon and nitrogen values of various populations from northern Europe. Noteworthy is the progressive enrichment of δ^{13}C values from purely terrestrial to mixed and marine diets, as well as the fact that, in some cases, coastal populations had a minimal dietary contribution of marine protein (e.g. a late Anglo-Saxon population from England; Marsall et al. 2010 and a medieval population from Sweden; Linderholm and Kjellström 2011).

[>>> Table 2 <<<]

The limited contribution of marine resources in the diet of the leprosy patients, in combination with the fact that only six of them have δ^{15}N values indicative of some contribution of freshwater fish to the diet

255 (greater than 12‰; Jørkov et al. 2010, based on Bonsall et al. 1997), suggests that the information
256 provided by the 15th century historical source (i.e, daily consumption of fish by the leprosy patients)
257 from Næstved (Richards 1977) is incorrect. Furthermore, this may indicate that less than half of the
258 individuals included in our study followed the fasting rules. Taking into account that the total number
259 of fasting days covered approximately half of a year's duration (Yoder 2012), it remains uncertain to
260 what extent leprosy patients from Næstved followed the religious food restrictions.

261

262 Isotopic analysis for the dietary reconstruction of individuals with bone lesions of leprosy has also been
263 conducted in three other sites: the medieval *leprosarium* of St. Mary Magdalen in Winchester, England
264 (Roffey et al. 2017); a medieval cemetery in Norwich, England (Bayliss et al. 2004); and a medieval
265 cemetery in Sigtuna, Sweden (Linderholm and Kjellström 2011) (**Table 3**). δ^{13}C and δ^{15}N values indicate
266 a diet based on C_3 plants and various amounts of terrestrial and aquatic protein for all four sites. It is
267 noteworthy however, that all samples from the *leprosarium* at Winchester and the cemetery in Norwich
268 (probably also related to a *leprosarium*) have slightly higher δ^{15}N and more positive δ^{13}C than the
269 samples from Næstved, indicating a higher consumption of marine protein. All four samples from
270 Sigtuna have similar δ^{13}C values to Næstved, but higher δ^{15}N, indicating more consumption of
271 freshwater fish; however, these skeletons come from a regular, parish cemetery and are not linked to
272 a *leprosarium*.

273

274 A similar diet to that recorded for the leprosy patients from Næstved is also evident for another four,
275 Danish cemeteries, contemporary to the *leprosarium* (**Table 4**). These are located at the town of Holbæk
276 (Jørkov et al. 2009), which is approximately 63 km north of Næstved, at the rural Cistercian monastery
277 at Øm Kloster, at the important administrative, ecclesiastical and mercantile city of Viborg and at Ribe,
278 one of the largest cities in medieval Denmark (Yoder 2010).

279

280 **[>>> Table 3 <<<]**

281

282 **[>>> Table 4 <<<]**

283

284 Small variations between the mean δ^{13}C and δ^{15}N values of these sites suggest that the diet of the
285 individuals from Holbæk and Øm Kloster consisted of C_3 plants and animals, such as pigs, sheep and
286 cows, as well as a relatively small amount of freshwater fish, whereas the diet of the individuals from
287 the larger urban site, Ribe, included large amounts of fish, both marine and freshwater (Yoder 2010).
288 The diet of the individuals from Viborg, seems to be intermediate between the diets from the other
289 sites. The mean values of the individuals from the *leprosarium* appear to be closer to the mean δ^{13}C and
290 δ^{15}N values of the individuals from Øm Kloster. However, when taking into consideration the different
291 social groups from the monastery, the mean values of the leprosy patients are closer to the values of
292 the peasants (**Table 5**). Yoder (2006) explores the status-based differences in the diet of the peasants,
293 the monks and the elites from Øm Kloster, with the social class being distinguished by the location of
294 the burial in relation to the church. The diet of the leprosy patients seems to be more closely related to
295 that of the peasant group, which consisted of C_3 plant and terrestrial animal proteins with only a small
296 contribution of aquatic foods.

297

298 **[>>> Table 5 <<<]**

299

300 **Dietary variation in the *leprosarium* and possible interpretations**
301 It has been proposed that medieval leprosy hospitals were monastic institutions, and that the leprosy
302 patients had to follow a monastic life of daily prayers and a uniform diet defined by the fasting rules
303 (Rawcliffe 2001; 2006). The δ^{13}C and δ^{15}N values of the leprosy patients from Næstved, however, do
304 show some variation, suggesting a homogeneous diet was not prevalent. Since people from the entire
305 social spectrum were admitted at Danish *leprosaria* (Dahl 2001), and due to bone turnover rates, this

306 could partially reflect social status variation of the pre-*leprosarium* period. Nevertheless, it may also
307 indicate a social inequality among the patients of the *leprosarium*, which could further be related to the
308 organisational structure of the institution.
309
310 In contrast to British *leprosaria* that depended heavily on endowments, gifts and alms provided by
311 wealthy individuals (Richards 1977; Roberts 1986), *leprosaria* in Scandinavia mainly acquired their
312 income through taxes paid by local communities (Richards 1960). The dependence of the Danish
313 *leprosaria* on the taxes paid by the local communities, from which they further had the obligation to
314 receive infected individuals (Ehlers 1898), reveals a direct correlation between *leprosaria* and the
315 economic state of the communities that supported them. The economic situation of each community,
316 therefore, which might have varied over time, must have had a considerable impact on the organisation
317 of the leprosy institutions, and thus on the diet of the patients. As we do not have precise information
318 on the dating of our samples, the variation we see could simply reflect the changing ability of the local
319 community to support the *leprosarium*.
320
321 Unlike the main economic source (a tax-collection system) for the *leprosaria* in Denmark, that could
322 have been independent of religious guidelines for equality and sharing, the religious motives of the
323 benefactors of British *leprosaria* may have constituted the stimulus for the hospitals to turn to a
324 monastic lifestyle, aiming at attracting more donations. Rawcliffe (2001:250) mentions that punishment
325 with the imposition of strict fasting and public repentance was not only frequent, but also a means by
326 which a leprosy patient would become "a more potent intercessor for benefactors and patrons".
327 However, Rawcliffe (2001:233) also refers to high status patients in British *leprosaria*, "whose rank
328 merited more solicitous treatment". Nevertheless, the benefits of a higher social status within the
329 leprosy community could have been restricted to differences in the type of accommodation and burial
330 location (cf. Roffey and Tucker 2012), without further encompassing a more varied diet.
331

Conclusions
333 The isotopic study of the *leprosarium* at Næstved has generated a better reconstruction of dietary
334 patterns and behaviours . The δ^{13}C and δ^{15}N values reveal a diet based dominantly on C$_3$ plants, meat
335 (very likely also eggs and dairy products) and fish for both men and women. However, the contribution
336 of marine proteins to the diet of most of the leprosy patients was limited, and only six individuals had a
337 diet that was significantly enriched by freshwater fish (combination of low δ^{13}C values with δ^{15}N higher
338 than 12‰). This contradicts the 15th century historical source that refers to a daily consumption of fish
339 by the patients of the Næstved leprosy hospital (Richards 1977), something that emphasises the
340 importance of approaching the study of past diets through a combination of different methods.
341 Furthermore, a diet poor in aquatic protein raises questions regarding the adherence to the fasting
342 rules, and consequently to the monastic nature of the hospital. Finally, the diet of the patients was
343 similar to that consumed by the non-leprous individuals from surrounding areas to the institution,
344 especially to the diet of the peasant group from Øm Kloster, as well as to the diet of leprous individuals
345 from other leprous and non-leprous contexts.
346
347 This study highlights the importance and value of stable isotope analysis in understanding diet in ancient
348 hospitals and *leprosaria*. It is however, a pilot study and the number of analysed skeletons is rather
349 small. An expansion of the research, with the inclusion of individuals from additional Danish medieval
350 *leprosaria*, would provide a more complete picture of medieval diets in the region, including our
351 knowledge and understanding of the organisational structure of such institutions.
352

360 **References**

361 Ambrose, S.H. (1990): Preparation and characterisation of bone and tooth collagen for isotopic analysis.
362 – J. Archaeol. Sci. **17**: 431–451.
363 Arcini, C. (1999): Health and disease in early Lund, Osteo-pathologic studies of 3,305 individuals buried
364 in the cemetery area of Lund 990-1536. – Lund University Publications, Lund.
365 Bainson, K.A. & Borne, B. van den (1998): Dimensions and process of stigmatization in leprosy. – Lepr.
366 Rev. **69**: 341–350.
367 Barrett, J. et al. (2008): Detecting the medieval cod trade: a new method and first results. – J. Archaeol.
368 Sci. **35**: 850–861.
369 Barrett, J. et al. (2011): Interpreting the expansion of sea fishing in medieval Europe using stable isotope
370 analysis of archaeological cod bones. – J. Archaeol. Sci. **38**: 1516–1524.
371 Bass, W.M. (2005): Human Osteology: A Laboratory and Field Manual (fifth edition). – Special
372 Publication No. 2 of the Missouri Archaeological Society, Springfield.
373 Bayliss, A. et al. (2004): The potential significance of dietary offsets for the interpretation of radiocarbon
374 dates: an archaeologically significant example from medieval Norwich. – J. Archaeol. Sci. **31**: 563–575.
375 Beaumont, J. & Montgomery, J. (2016): The Great Irish Famine: Identifying Starvation in the Tissues of
376 Victims Using Stable Isotope Analysis of Bone and Incremental Dentine Collagen. – PLoS ONE **11**:
377 e0160065.
378 Bocherens, H. & Drucker, D. (2003): Trophic level isotopic enrichment of carbon and nitrogen in bone
379 collagen: case studies from recent and ancient terrestrial ecosystems. – Int. J. Osteoarchaeol. **13**: 46–
380 53. Boldsen, J.L. (2009): Leprosy in Medieval Denmark: Osteological and epidemiological analyses. –
381 Anthrop. Anz. **67**: 407–425.
382 Bonsall, C. et al. (1997): Mesolithic and early Neolithic in the Iron Gates: a palaeodietary perspective. –
383 J. Europ. Archaeol. **5**: 50–92.
384 Brody, S.N. (1974): The Disease of the Soul: Leprosy in Medieval Literature. – Cornell University Press,
385 Ithaca, New York and London.
386 Brooks, S. & Suchey, J.M. (1990): Skeletal age determination based on the os pubis: A comparison of
387 the Acsádi-Nemeskéri and Suchey-Brooks methods. – Hum. Evol. **5**: 227–238.
388 Brown, T.A. et al. (1988): Improved collagen extraction by modified Longin method. – Radiocarbon **30**:
389 171–177.
390 Brown, T. & Brown, K. (2011): Biomolecular Archaeology. An introduction. – Wiley-Blackwell,
391 Oxford.Buikstra, J.E. & Ubelaker, D.H. (eds.) (1994): Standards for Data Collection from Human Skeletal
392 Remains: Proceedings of a Seminar at the Field Museum of Natural History organized by Jonathan Haas.
393 – Arkansas Archeological Survey (Research Series **44)**, Fayetteville.
394 Collins, M.J. & Galley, P. (1998): Towards an optimal method of archaeological collagen extraction: The
395 influence of pH and grinding. – Ancient Biomolecules **2**: 209–222.
396 Dahl, S. C. (2001): Næstved i Middelalderen. Købstadens oprindelse, dens udseende og indbyggernes
397 tro, levevilkår og dagligdag. – Suså-Komiteen, Næstved.
398 Daniel, E. et al. (1997): Pathology of iris in leprosy. – Br. J. Ophthalmol. **81**: 490–492.
399 DeNiro, M.J. (1985): Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in
400 relation to palaeodietary reconstruction. – Nature **317**: 806–809.
401 Dyer, C. (1983): English Diet in the Later Middle Ages. – In: Aston, T.H. et al. (eds.): Social Relations and
402 Ideas: Essays in Honour of R. H. Hilton. – Cambridge University Press, Cambridge, pp. 191–216.
403 Dyer, C. (1988): The consumption of fresh-water fish in medieval England. – In: Aston, M. (ed.): Medieval
404 fish, fisheries and fishponds in England. – BAR British Series **182**: 27–38.
405 Dyer, C. (1994): Everyday Life in Medieval England. – Hambledon Press, London.
406 Ehlers, E. (1898): Danske St. Jørgensgaarde i Middelalderen. Særtryk af Bibliotek for Læger. Udarbejdet
407 med understøttelse af det Classenske Fideicommis. – Fr. Baggesbogtrykkeri, Kjøbenhavn.

408 Enghoff, I.B. (1996): A medieval herring industry in Denmark and the importance of herring in eastern
409 Denmark. – Archaeofauna **5**: 43–47.
410 Ferembach, D. et al. (1980): Recommendation for Age and Sex Diagnoses of Skeletons. – J. Hum. Evol.
411 **9**: 517–549.
412 Halley, D.J. & Rosvold, J. (2014): Stable isotope analysis and variation in medieval domestic pig
413 husbandry practices in northwest Europe: absence of evidence for a purely herbivorous diet. – J.
414 Archaeol. Sci. **49**: 1–5.
415 Heijnders, M.L. (2004): The Dynamics of Stigma in Leprosy. – Int. J. Lepr. Other Mycobact. Dis. **72**: 437–
416 447.
417 Hoffmann, R.C. (1996): Economic Development and Aquatic Ecosystems in Medieval Europe. – Am. Hist.
418 Rev. **101**: 631–669.
419 Hybel, N. & Poulsen, B. (2007): The Danish Resources c. 1000-1550: Growth and Recession. – Brill (The
420 Northern World Series **34**), Leiden and Boston.
421 Işcan, M.Y. et al. (1984): Age estimation from the rib by phase analysis: white males. – J. Forensic Sci.
422 **29**: 1094–1104.
423 Jantzen, C. et al. (1994): De små brødres hus i Ribe. – Mark og montre **30**: 26–36.
424 Jay, M. & Richards, M.P. (2006): Diet in the Iron Age cemetery population at Wetwang Slack, East
425 Yorkshire, UK: carbon and nitrogen stable isotope evidence. – J. Archaeol. Sci. **33**: 653–662.
426 Job, C.K. et al. (1966): The histopathological appearance of leprous rhinitis and pathogenesis of septal
427 perforation in leprosy. – J. Laryngol. Otol. **80**: 718–732.
428 Johansen, O.S. et al. (1986): δ^{13}C and Diet: Analysis of Norwegian Human Skeletons. – Radiocarbon **28**:
429 754–761.
430 Jørkov, M.L.S. et al. (2009): The petrous bone: a new sampling site for identifying early dietary patterns
431 in stable isotopic studies. – Am. J. Phys. Anthropol. **138**: 199–209.
432 Jørkov, M.L.S. et al. (2010): Uniform diet in a diverse society. Revealing new dietary evidence of the
433 Danish Roman Iron Age based on stable isotope analysis. – Am. J. Phys. Anthropol. **143**: 523–533.
434 Katzenberg, M.A. & Lovell, N.C. (1999): Stable isotope variation in pathological bone. – Int. J.
435 Osteoarchaeol. **9**: 316–324.
436 Keenleyside, A. et al. (2009): Stable isotopic evidence for diet in a Roman and Late Roman population
437 from Leptiminus, Tunisia. – J. Archaeol. Sci. **36**:51–63.Kieffer-Olsen, J. (1993): Grav og gravskik i det
438 middelalderlige Danmark: 8 kirkegårdsudgravninger. – PhD thesis, submitted at Aarhus University,
439 Aarhus.
440 Kjellström, A. (2005): The Urban Farmer: Osteoarchaeological Analysis of Skeletons from Medieval
441 Sigtuna Interpreted in a Socioeconomic Perspective. – PhD thesis, submitted at Stockholm University,
442 Stockholm.
443 Klinken, G.J. van (1999): Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon
444 Measurements. – J. Archaeol. Sci. **26**: 687–695.
445 Kosiba, S.B., Tykot, R.H. & Carlsson, D. (2007): Stable isotopes as indicators of change in the food
446 procurement and food preference of Viking Age and Early Christian populations on Gotland (Sweden).
447 – J. Anthrop. Archaeol. **26**:394–411.
448 Linderholm, A. & Kjellström, A. (2011): Stable isotope analysis of a medieval skeletal sample indicative
449 of systemic disease from Sigtuna Sweden. – J. Archaeol. Sci. **38**: 925–933.
450 Lockwood, D.N. & Saunderson, P.R. (2012): Nerve damage in leprosy: a continuing challenge to
451 scientists, clinicians and service providers. – Int. Health **4**: 77–85.
452 Longin, R. (1971): New Method of Collagen Extraction for Radiocarbon Dating. – Nature **230**: 241–242.
453 Loth, S.R. & Henneberg, M. (1996): Mandibular ramus flexure: a new morphologic indicator of sexual
454 dimorphism in the human skeleton. – Am. J. Phys. Anthropol. **99**: 473–485.
455 Lovejoy, C.O. et al. (1985): Chronological metamorphosis of the auricular surface of the ilium: a new
456 method for the determination of adult skeletal age at death. – Am. J. Phys. Anthropol. **68**: 15–28.
457 Lusli, M. et al. (2015): Dealing with Stigma: Experiences of Persons Affected by Disabilities and Leprosy.
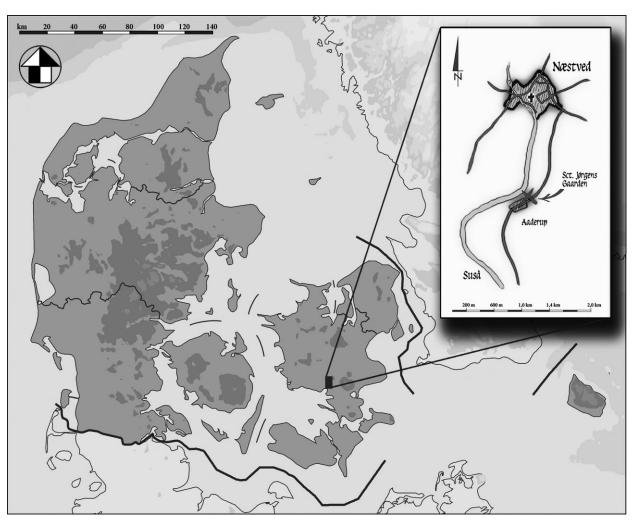458 – BioMed Research International: 1–9.

459 Lynnerup, N. & Boldsen, J. (2012): Leprosy (Hansen's disease). In: Grauer, A.L. (ed.): A Companion to
460 Paleopathology. – Wiley-Blackwell, Chichester, pp. 458–471.
461 Madrigal, L. (2012): Statistics for Anthropology. – Cambridge University Press, Cambridge.
462 Madsen, K. (1990): Spedalskhed og Sct. Jørgensgård (second edition). – Næstved Museum, Næstved.
463 Marsall, P. et al. (2010): Scientific dating evidence – In: Thomas, G. (ed.): The Later Anglo-Saxon
464 Settlement at Bishopstone: a downland manor in the making. – Council for British Archaeology (Council
465 for British Archaeology Report 163), York, pp. 157–164.
466 Meindl, R.S. & Lovejoy, C.O. (1985): Ectocranial suture closure: a revised method for the determination
467 of skeletal age at death based on the lateral-anterior sutures. – Am. J. Phys. Anthropol. **68**: 57–
468 66.Michelsen, F. (1954): St. Jørgensgården i Aaderup ved Næstved. – Historisk Samfund for Præstø
469 (Årbog, Ny række **4**), Præstø, pp. 72–85.
470 Müldner, G. & Richards, M.P. (2005): Fast or feast: reconstructing diet in later medieval England by
471 stable isotope analysis. – J. Archaeol. Sci. **32**: 39–48.
472 Müldner, G. (2016): Marine fish consumption in medieval Britain: the isotope perspective from human
473 skeletal remains. – In: Barrett, J. and Orton, D. (eds.): Cod and herring: the archaeology and history of
474 medieval sea fishing. – Oxbow Books, Oxford, pp. 239-249.Olsen, K.C., White, C.D., Longstaffe, F.J. &
475 Rühli, F.J. (2018): Isotopic anthropology of rural German medieval diet: intra- and inter-population
476 variability. – Archaeol. Anthropol. Sci. **10**:1053-1065.
477 Phenice, T.W. (1969): A newly developed visual method of sexing the os pubis. – Am. J. Phys. Anthropol.
478 **30**: 297–302.
479 Rafferty, J. (2005): Curing the stigma of leprosy. – Lepr. Rev. **76**: 119–126.
480 Rawcliffe, C. (2001): Learning to Love the Leper: Aspects of Institutional Charity in Anglo Norman
481 England. – In: Gillingham, J. (ed.): Proceedings of the Battle Conference 2000. – The Boydell Press
482 (Anglo-Norman Studies XXIII), Woodbridge, pp. 231–250.
483 Rawcliffe, C. (2006): Leprosy in Medieval England. – The Boydell Press, Woodbridge.
484 Reynolds, R. (2010): Fish remains. – In: Thomas, G. (ed.): The Later Anglo-Saxon Settlement at
485 Bishopstone: a downland manor in the making. – Council for British Archaeology (Council for British
486 Archaeology Report 163), York, pp. 157–164.
487 Richards, M.P. & Hedges, R.E.M. (1999): Stable Isotope Evidence for Similarities in the Types of Marine
488 Foods Used by Late Mesolithic Humans at Sites Along the Atlantic Coast of Europe. – J. Archaeol. Sci.
489 **26**: 717–722.
490 Richards, P. (1960): Leprosy in Scandinavia. – Centaurus **7**: 101–131.
491 Richards, P. (1977): The Medieval Leper and his Northern Heirs. – Boydell and Brewer, Woodbridge.
492 Roberts, C. & Manchester, K. (2005): The Archaeology of Disease (third edition). – The History Press,
493 Stroud.
494 Roberts, C. (1986): Leprosy and Leprosaria in Medieval Britain. – MASCA Journal **4**: 15–21.
495 Roffey, S. & Tucker, K. (2012): A contextual study of the medieval hospital and cemetery of St Mary
496 Magdalen, Winchester, England. – Int. J. Palaeopathol. **2**: 170–180.
497 Roffey, S. et al. (2017): Investigation of a Medieval Pilgrim Burial Excavated from the *Leprosarium* of St
498 Mary Magdalen Winchester, UK. – PLoS Negl. Trop. Diseases **11**: 1–27.
499 Schoeninger, M.J., DeNiro, M.J. & Tauber, H. (1983): Stable nitrogen ratios of bone collagen reflect
500 marine and terrestrial components of prehistoric human diet. – Science **220**:1381–1383.
501 Schulting, R.J. et al. (2008): Stable carbon and nitrogen isotope analysis on human remains from the
502 Early Mesolithic site of La Vergne (Charente-Maritime, France). – J. Archaeol. Sci. **35**:763–772.
503 Schwarcz, H.P., Chisholm, B.S. & Burchell, M. (2014): Isotopic Studies of the Diet of the People of the
504 Coast of British Columbia. – Am. J. Phys. Anthropol. **155**:460–468.
505 Serjeantson, D. & Woolgar, C.M. (2006): Fish consumption in Medieval England. – In: Woolgar, C. et al.
506 (eds.): Food in Medieval England: Diet and nutrition. – Oxford University Press (Medieval History and
507 Archaeology Series), Oxford, pp. 102–130.
508 Siegel, S. & Castellan, N.J. (1988): Nonparametric statistics for the behavioral sciences (second edition).
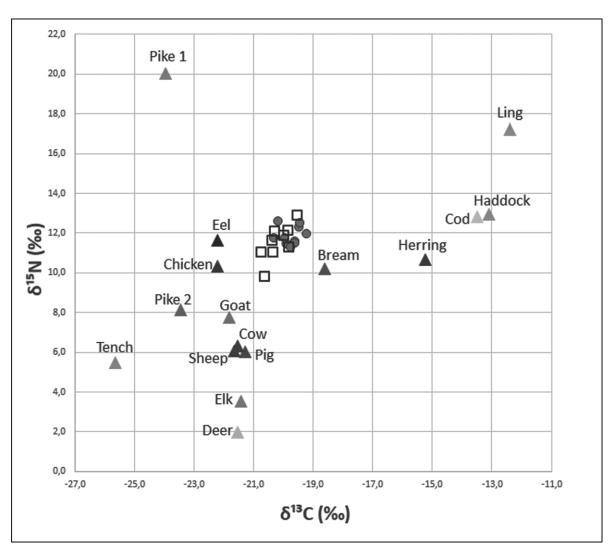509 – McGraw-Hill, New York.

510   Stone, D.J. (2006a): The consumption of field crops in medieval England. – In: Woolgar, C. et al. (eds.):
511   Food in Medieval England: Diet and nutrition. – Oxford University Press (Medieval History and
512   Archaeology Series), Oxford, pp. 11–26.
513   Stone, D.J. (2006b): The Consumption and Supply of Birds in Late Medieval England. – In: Woolgar, C. et
514   al. (eds.): Food in Medieval England: Diet and nutrition. – Oxford University Press (Medieval History and
515   Archaeology Series), Oxford, pp. 148–161.
516   Tauber, H. (1981) ^{13}C evidence for dietary habits of prehistoric man in Denmark. – Nature **292**:332–333.
517   Taylor, G.M. et al. (2013): Detection and Strain Typing of Ancient *Mycobacterium leprae* from a Medieval
518   Leprosy Hospital. – PLoS ONE **8**: e62406.
519   Touati, F.O. (2000): Contagion and leprosy. Myth, ideas and evolution in medieval minds and societies.
520   – In: Conrad, L. & Wujastyk, D. (eds.): Contagion. Perspectives From Pre-Modern Societies. – Ashgate
521   Publishing Limited, Tyne and Wear, pp. 163–177.
522   van der Sluis, L.G. et al (2016): A palaeodietary investigation of a multi-period churchyard in Stavanger,
523   Norway, using stable isotope analysis (C, N, H, S) on bone collagen. – J. Archaeol. Sci. Reports **9**:120–
524   133.
525   Yoder, C.J. (2006): The Late Medieval Agrarian Crisis and Black Death plague epidemic in medieval
526   Denmark: a paleopathological and paleodietary perspective. – PhD dissertation, submitted at the Texas
527   A&M University, Texas.
528   Yoder, C. (2010): Diet in medieval Denmark: a regional and temporal comparison. – J. Archaeol. Sci. **37**:
529   2224–2236.
530   Yoder, C. (2012): Let them eat cake? Status-based differences in diet in medieval Denmark. – J. Archaeol.
531   Sci. **39**: 1183–1193.
532
533
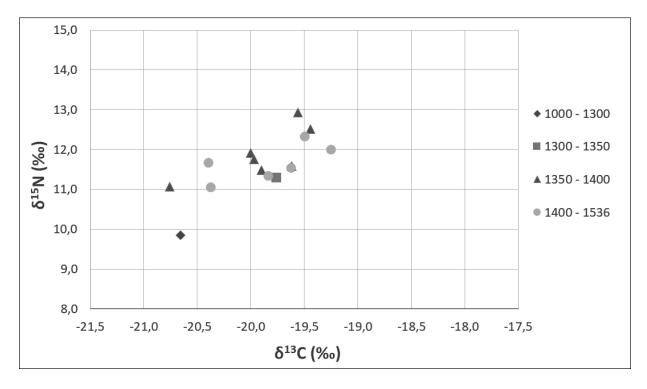
Figures

536   **Figure 1.** Map of Denmark, showing the location of Næstved. The inset illustrates the distance between
537   the medieval town of Næstved and its suburb, Aaderup. The location of the *leprosarium's* cemetery is
538   marked by a cross. (Background map adapted from "Denmark physical map" by NordNordWest, based
539   on a work by Urutseg *Public Domain Dedication license (CC0 1.0 Universal)*. Inset based on Madsen
540   (1985:14, table IV)).

541

542
543

544   **Figure 2.** δ^{13}C and δ^{15}N values for the individuals from the *leprosarium* at Næstved (9 females, square;
545   10 males, circle) as well as for the animals mentioned by Yoder (2010, Table 1).
546

547
548
549
550
551

552 **Figure 3** δ^{13}C and δ^{15}N of the leprosy patients from Næstved, grouped chronologically (information
553 about the position of the arms was only available for fifteen skeletons).
554

555
556

Tables

Table 1 Collagen δ^{13}C and δ^{15}N values of the twenty skeletons from the leprosy hospital at Næstved.

Sample	Sex	Age	Elem.	C/N	C%	N%	δ^{13}C	δ^{15}N
41	male	35-45	rib	3.4	43.0	14.7	-20.2	12.6
78	male	25-40	rib	3.3	42.4	14.8	-20.3	11.7
99	female	25-29	rib	3.3	42.6	15.2	-20.3	12.1
126	female	25-45	rib	3.2	42.7	15.6	-19.6	12.9
204	female	20-30	rib	3.2	42.4	15.2	-19.8	11.3
269	male	30-40	rib	3.3	42.6	15.3	-19.2	12.0
275	female	25-40	rib	3.3	42.9	15.3	-20.8	11.1
277	male	35-45	rib	3.3	43.1	15.2	-19.6	11.6
368	female	25-45	rib	3.4	42.0	14.5	-20.0	11.9
371	female	30-40	rib	3.7	45.1	14.2	-21.2	12.3
374	male	35-45	rib	3.2	42.0	15.3	-19.6	11.5
380	male	20-30	rib	3.2	42.8	15.6	-19.9	11.5
382	male	25-35	rib	3.2	41.9	15.1	-19.5	12.3
400	female	35-45	rib	3.3	42.8	15.1	-19.8	12.1
405	female	25-45	rib	3.4	44.0	15.3	-20.7	9.9
413	male	25-35	rib	3.3	42.0	14.9	-19.4	12.5
469	female	30-40	rib	3.4	43.5	14.8	-20.4	11.7
510	male	25-35	rib	3.2	42.6	15.5	-19.8	11.3
517	female	25-35	rib	3.3	42.9	15.3	-20.4	11.0
593	male	30-40	rib	3.4	43.8	15.1	-20.0	11.8

Table 2 Stable isotope values and summarised information of various populations from northern Europe.

Site	Location	Period	N	δ^{13}C Mean	δ^{13}C Min.	δ^{13}C Max.	δ^{15}N Mean	δ^{15}N Min.	δ^{15}N Max.	Interpretation of isotope values	Source
Stavanger, Norway	coastal	Viking Age	2	-20.7	–	–	10.8	–	–	terrestrial-based diet	van der Sluis et al (2016) Journal of Archaeological Science: Reports
Sigtuna, Sweden	coastal	Medieval	5	-20.2	-21.0	-19.3	13.3	12.7	14.3	terrestrial-based diet, contribution of freshwater protein	Linderholm and Kjellström (2011) Journal of Archaeological Science
Næstved *leprosarium,* **Denmark**	**coastal**	**Medieval**	**19**	**-20.0**	**-20.8**	**-19.2**	**11.7**	**9.9**	**12.9**	**terrestrial-based diet, some contribution of freshwater resources, limited contribution of marine resources**	**present paper**
Dalheim, Germany	inland	Medieval	24	-20.0	–	–	9.9	–	–	terrestrial-based diet, "[...] without evidence of marine resource input into the diet" p.1053	Olsen (2018) Archaeological and Anthropological Sciences
Bishopstone, England	coastal	Late Anglo-Saxon	8	-19.9	–	–	–	9.7	10.9	"[...] diet predominantly based upon temperate terrestrial C3 with a possible small marine component", p. 202	Marsall et al. 2010, in: The Later Anglo-Saxon Settlement at Bishopstone: a downland manor in the making. Council for British Archaeology Research Report 163
Stavanger, Norway	coastal	Post-reformation	7	-19.4	–	–	12.9	–	–	"[...] decreased amount of marine protein consumption [...]", p. 130	van der Sluis et al (2016) Journal of Archaeological Science: Reports

Northern England	coastal and inland	Medieval	77	-19.4	-20.6	-18.1	12.2	10.5	14.9	mixed terrestrial, freshwater and marine diet	Müldner and Richard (2005) Journal of Archaeological Science
Stavanger, Norway	coastal	Early Medieval	9	-18.7	–	–	13.7	–	–	"The highest stable isotopic values, suggesting considerable marine consumption,were observed in the early Medieval individuals, [...]", p. 132	van der Sluis et al (2016) Journal of Archaeological Science: Reports
Gotland, Sweden	coastal	Early Medieval	6	-17.2	—	—	11.6	—	—	mixed terrestrial and marine diet	Kosiba et al. (2007) Journal of Anthropological Archaeology
Træna, Norway	coastal	Early Medieval	11	-16.9	-19.0	-15.7	—	—	—	mixed terrestrial and marine diet	Johansen et al (1986) Radiocarbon
Flakstad, Norway	coastal	Stone Age	2	-13.4	-14.0	-12.8	—	—	—	"[...] a diet of more than 90% marine food, especially fish, seems likely", page 757	Johansen et al (1986) Radiocarbon

Table 3 Descriptive statistics of the isotope values of skeletons with leprosy bone lesions from the leprosy hospitals at Næstved and Winchester (Roffey et al. 2017) and from medieval Norwich (Bayliss et al. 2004) and Sigtuna (Linderholm and Kjellström, 2011).

Site	N	δ^{13}C Mean	δ^{13}C Min.	δ^{13}C Max.	δ^{15}N Mean	δ^{15}N Min.	δ^{15}N Max.
Næstved *leprosarium*	19	-20.0	-20.8	-19.2	11.7	9.9	12.9
Winchester *leprosarium*	43	-19.3	-20.5	-18.2	10.5	8.7	13.1
Norwich	8	-19.1	-19.9	-17.9	11.3	10.0	13.5
Sigtuna	5	-20.2	-21.0	-19.3	13.3	12.7	14.3

Table 4 Descriptive statistics of the isotope values of human data from the leprosy hospital at Næstved and the Danish medieval sites: Holbæk (Jørkov et al. 2009), Øm Kloster, Viborg and Ribe (Yoder, 2010).

Site	N	δ^{13}C Mean	δ^{13}C Std	δ^{13}C Min.	δ^{13}C Max.	δ^{15}N Mean	δ^{15}N Std	δ^{15}N Min.	δ^{15}N Max.
Næstved *leprosarium*	19	-20.0	0.4	-20.8	-19.2	11.7	0.7	9.9	12.9
Holbæk	58	-19.4	0.6	-20.3	-18.0	11.8	0.8	9.9	13.8
Øm Kloster	98	-19.7	0.5	-20.6	-18.5	12.0	0.9	9.8	14.6
Viborg	45	-19.2	0.4	-20.1	-17.9	12.4	0.7	10.8	13.5
Ribe	54	-19.2	0.5	-20.5	-17.9	12.8	0.9	10.9	14.3

Table 5 Mean values of the leprosy patients from Næstved and of the three social groups from Øm Kloster (Yoder, 2010).

Site	Social group	δ^{13}C Mean	δ^{15}N Mean
Øm Kloster	Elites	-19.9	12.5
Øm Kloster	Monks	-19.8	12.3
Øm Kloster	Peasants	-19.9	11.6
Næstved	Leprosy patients	-20.0	11.7