Title:

A Stable Isotope Method for Identifying Transatlantic Origin of Pig (*Sus scrofa*) Remains at French and English Fishing Stations in Newfoundland.

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Abstract

From the 16th century onward, various European nations shared fishing spaces off the coast of Newfoundland in an effort to provide salt-fish products to supplement increasing European demand. Faunal remains excavated at seasonal and permanent Newfoundland fishing stations indicate that pigs were the primary mammal species consumed by cod fishermen. It is not clear whether these pig remains derive from salt-pork and/or live pigs imported from Europe or, rather, from pigs bred and raised in Newfoundland. Based on the notion that Newfoundland-raised pigs would have had greater access to marine-derived foods from nearby fisheries compared to their European-raised counterparts, we analyzed stable carbon and nitrogen isotope values from 28 pigs and 117 other faunal specimens from Dos de Cheval (EfAx-09) and Ferryland (CgAf-02) in order to identify individuals with marine or terrestrial isotope dietary signatures. Results indicating two distinct groups of pigs with mean $\delta^{13}C$ and $\delta^{15}N$ values differing by ~6‰ and ~9‰, respectively, suggest differing pig-product origins at each site. This method for identifying the transatlantic origin of pig remains has potential to shed light on patterns in the provisioning of the early European transatlantic fishing industry and inter-community relations. It may also allow for the development of more sophisticated body part representation models for zooarchaeological reconstruction of barreled salt-pork use.

Key words:

Stable Carbon Isotope, Stable Nitrogen Isotope, Diet, Salt-Pork, Pigs, North Atlantic, Fishery.

1. Introduction

Domesticated pigs (*Sus scrofa*) and their derived pork products were an important and substantial component of the diets of French and British fishermen who seasonally visited and settled the shores of Newfoundland between the 16th and 20th centuries (de la Morandière, 1962: 77-79; Hodgetts, 2006; Noël, 2010a: 9). The forms in which pork was consumed (fresh meat, cured pork, lard, etc.) in maritime colonial settings are poorly understood due to methodological inadequacies of traditional zooarcheological methods such as body part representation analyses (e.g. Noël, 2010a; Tourigny, 2009: 166). Pork products could be obtained in several ways: pigs could be locally raised, brought over from Europe as livestock, and/or slaughtered, salted and barreled in Europe as provisions for fishing crews. Fishing stations were important commercial enterprises in early European activities in the New World, employing thousands of fishermen each year and producing codfish products for world markets (Fagan, 2006; Pope, 2004, 2008: 38). A better understanding of how these fishermen acquired and consumed pork products could help illuminate significant aspects of early colonial foodways as well as other details of inter- and intra-community dynamics.

Using archaeological case studies from historical English and French fishing stations, we present the results of a novel biomolecular approach for identifying the transatlantic origin of pig remains. Based on dietary information derived from stable carbon and nitrogen isotope analysis of bone collagen, we distinguish between the remains of pigs raised in New World colonial fishing stations and those shipped across the Atlantic either as livestock or barreled salted pork. Twenty-eight pigs from seasonal and permanent fishing station sites were analyzed to investigate this working hypothesis. Additionally, we analyzed specimens of other domestic and wild species to establish a baseline isotope ecology for each region and to enhance interpretations of pig stable isotope values.

2. Background information

2.1 Historical context and salt pork provisioning

Beginning in the early 16th century, Basque, French, English and Portuguese crews were fishing the waters off the coast of Newfoundland, returning to Europe with vast quantities of codfish (Pope, 2004: 39). As the demand for fish increased, so did the competition for access to the rich fishing grounds. European fishermen began to settle onto the shores of Newfoundland, seasonally or permanently, in order to dry and salt codfish fillets. The Basques occupied the west coast, the English and Portuguese occupied the Avalon Peninsula, and the Normans and Bretons fished on the coast of the Great Northern Peninsula (Pope, 2008: 2-6). In this context, we discuss the permanent English fishery site of Ferryland (CgAf-02) on Newfoundland's Avalon Peninsula and the seasonal French fishery site of Dos de Cheval (EfAx-09) on the Great Northern Peninsula (Figure 1).

The archaeological site of Ferryland is what remains of one of the earliest permanent English settlements on Newfoundland (Figure 1). Founded in 1621, it represents Sir George Calvert's first attempt at setting up a colony in the New World and was later home to Sir David Kirke, Governor of Newfoundland. The community served as the permanent settlement for a number of planters whose fishing vessels returned to Ferryland with fresh codfish ready to be processed and salted. The Ferryland fishery remained an important seat of power in the area until its destruction by the French in a 1696 attack (Gaulton and Tuck, 2003).

The site of Dos de Cheval, corresponding to the French fishing room of *Champs Paya*, is located in Cape Rouge harbour (Figure 1.). Breton crews are documented in this productive harbour as early as 1541, when Jacques Cartier pressed them for provisions (Pope, 2007), and dominated the region from the 17th to the 18th century. The earliest dateable artefacts recovered from the site can be placed around the 1650s. Most of the archaeological features excavated were built and used in the 18th and 19th centuries. After the 1713 treaty of Utrecht, which placed restrictions on the settlement rights of the French in Newfoundland, many French crews in the region hired Irish *guardiens* to protect their fishing rooms during winter months, although it appears that the fishing room of *Champs Paya* did not house an over-wintering Irish caretaker. Archaeological evidence, however, does indicate an Anglo-Newfoundlander fishermen presence at the site during the Napoleonic Wars (ca.1790-1815) (Noël, 2010a: 33).

INSERT FIGURE 1 HERE

Faunal analyses at Ferryland and Dos de Cheval indicate that pig, after cod, was the most widely consumed species (Hodgetts, 2006; Noël, 2010a: 9, 2010b: 6; Swinarton, 2007: 2; Tourigny, 2009). In zooarchaeology, body part representation studies have looked at the presence and abundance of pig elements thought to have been included or not included in barreled salt pork in order to identify pig remains deriving from cured as opposed to fresh pork products.

Historical documentation of the body portions included in salt pork barrels is fairly limited. The French *Traité d'Honoré Chéris* of 1762, which regulated the supply of the vessels, galleys and other ships of Louis XV, stipulated that salt meat should be provided without hocks, feet or heads (Anon, 1762: 29). However, these regulations were probably not systematically applied, and are not necessarily representative of the salt pork provisions brought on French fishing ships bound for Newfoundland. In 1781, the English sailor Samuel Kelly, who served on board a packet ship, observed that, "This ship being a contract one, our provisions were of infamous quality... the barrels of pork consisted of pigs' heads with the iron rings in the nose, pigs' feet and pigs' tails with much hair thereon" (Garston, 1925: 29). Early 19th century guidelines on butchering standards from Montreal, Canada, describe three qualities of salt pork: mess, prime and cargo. While the highest quality (mess) was supposed to include only ribs of fat hogs, the prime and cargo qualities could include all body parts, except the feet (Morris, 1820: 7).

The most convincing examples of salt pork body parts analyses come from casks excavated in ship wrecks. A salt pork cask excavated from the wreck of the *Mary Rose* (Henry VIII's flagship), which sank in 1545, contained no head bones or limb extremities, and the vertebrae and ribs were split open and chopped (Coy and Hamilton-Dyer, 2005: 574). On the contrary, in the French shipwreck *La Dauphine* which sank in 1704 near Saint-Malo in France, 61 percent of the pig bones were from skulls and exhibited extensive cut marks (Migaud, 2011: 288). Meanwhile, analyses of faunal remains from the wreck of the *William Salthouse*, a Canadian trading ship that sank in 1841 near Melbourne, Australia, indicate that skulls were common, as well as ribs, all vertebrae, and many hind and forequarters. No lower extremities were found (English, 1990: 65-67). Heads were also present in the casks excavated from the 19th century steamship *Oklahoma* at the bottom of the Red River in Oklahoma (Crisman and Lees, 2003).

On terrestrial sites, establishing the presence of salt pork has proved more challenging. At 19th century whaling stations in Tasmania, the absence of head and feet portions is seen as an indication that the pork was likely imported as salt pork, rather than raised locally (Lawrence and Tucker, 2002). At the Hoff Store site, an 1851 Gold Rush deposit in San Francisco, pig bones associated with a "prime pork" barrel lid were from all the body portions, except the lower extremities (Hattori and Kosta, 1990). English (1990: 67-68) indicates that distinguishing salt pork from retail or commercial cuts of pork at Australian terrestrial sites based on butchery patterns and body part representation is difficult, as both kinds of butchering produce similar patterns. Based on zooarchaeological and historical evidence from the early 19th century site of Fort George (Ontario, Canada), Betts (2000: 29-30) estimated that a certain amount of feet could be included in "prime" grade salt pork, in addition to the skulls and other body parts. At both sites discussed in the present paper, Ferryland and Dos de Cheval, pig bone elements from all parts of the body were found (Noël, 2010a; Tourigny, 2009).

The bulk of information on salt pork body part representation comes from 19th century sites in Australia and the United States. During this time period, production of salt meat for exportation was becoming more standardized, and regulations were set to control the quality of food products (e.g. Morris 1820). It is questionable whether the patterns observed in these case studies reflect earlier salt pork packing techniques in 17th and 18th century Newfoundland, France and England. Based on the grade of the salt meat, the cask could contain a range of cuts, from meaty ribs in high quality barrels, to all body parts in those of lower quality. Moreover, butchers in different parts of Europe likely had different butchering practices and packing techniques for salt meat and it is unlikely that standard national butchery methods were in place during this time period (Rixson, 2000: 195). For these reasons, we argue that distinguishing salt pork from fresh pork on terrestrial sites using body part representation alone can prove challenging and, in certain cases, may be impossible.

Differences in the nature of occupation at Newfoundland fishing stations can provide some basic information on possible differences in pork acquisitioning and pig husbandry at each site. At Dos de Cheval, seasonal fishermen had little time for long-term animal husbandry and would have been unable to maintain the permanent presence needed to see piglets birthed and raised. This is supported by pig age profile evidence suggesting that pig remains collected at that site derived from older individuals (Noël, 2010a: 133-136). If fishermen at Dos de Cheval had access to fresh pork they likely had to obtain it from Anglo-Irish settlers or carried live pigs along for the transatlantic journey. These two possibilities are not supported by any historical documentation. Provisioning contracts, however, show that most, if not all, of the meat products bought for fishing voyages were in the form of barreled salt pork (de la Morandière, 1962: 77-79). At Ferryland, on the other hand, the presence of fetal and neo-natal pig remains and historical documentation indicates that some pigs were raised onsite for consumption (Tourigny, 2009). The large numbers of cattle and swine being produced there in the second half of the 17th century (Poole, 1677) suggests that the community may have become a centre of livestock production, producing an excess of the local subsistence requirements (Hodgetts, n.d). Despite this evidence, the extent to which Ferryland residents relied on locally raised pigs vs. imported pork products is unclear.

2.2 Stable isotope theory

Based on the premise that 'you are what you eat,' and that different foods can have distinctive isotopic compositions, researchers analyze stable carbon and nitrogen isotope ratios preserved within different biological tissues to deduce broad trends in animal and human diet (see Katzenberg, 2008 and Sealy, 2001 for review). Ratios of ^{12}C to ^{13}C ($\delta^{13}C$) are often used to indicate relative proportions of plants with distinctive photosynthetic (C_3 or C_4) pathways contributing to dietary intake either through direct consumption of plant materials or indirectly though consumption of animal products (Schwarcz and Schoeninger, 1991). Due to differences in the carbon sources of plants in aquatic and terrestrial environments, $\delta^{13}C$ values are also good indicators of consumption of foods deriving from marine or freshwater ecosystems (Schwarcz and Schoeninger, 1991). In particular, plants and animals inhabiting marine ecosystems tend to have $\delta^{13}C$ values ~7‰ higher than those of terrestrial environments (Chisholm et al., 1982). Ratios of ^{14}N to ^{15}N ($\delta^{15}N$) show an increase of 3-5‰ with each trophic level step up a given food web and are thus generally capable of differentiating herbivorous, omnivorous and carnivorous diets (Ambrose and DeNiro, 1986; DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984; for review see Hedges and Reynard, 2007). Marine ecosystems often have extended food chains with several additional levels, and for this reason marine derived diets focusing on high trophic level species can also be differentiated from terrestrial focused diets based on $\delta^{15}N$ values (Schoeninger et al., 1983).

Basic information on bone growth and development is also necessary for interpreting stable isotope information from bone collagen. Stable isotope values of bone collagen primarily reflect the protein component of diet (Ambrose and Norr, 1993; Tieszen and Fagre, 1993). Bone collagen remodels slowly over a long period of time in a process called turnover. Rates of bone collagen turnover vary between bones, individuals, and species. For humans, it is generally thought that collagen stable isotope values from a piece of adult cortical bone will reflect up to or more than 20 years of dietary intake (Geyh, 2001; Hedges et al., 2007; Wild et al., 2000). As pigs grow much faster and have shorter life spans than humans, it follows that pig bone collagen stable isotope values will reflect a much shorter time period of dietary intake (for further information on the nature and stable isotope ecology of pig bone, see Tuross et al., 2008; Warinner and Tuross, 2009; Young, 2002: 61-86).

2.3 Working hypothesis: diet as pig origin

Pigs are voracious eaters, notorious for their ability to consume unconventional fare. For instance, in medieval and post-medieval Britain, pigs husbanded in urban centers were kept in backyards or allowed to roam the streets feeding on unwanted edible scraps and waste from human activities (Grant, 1998: 158; Rixson, 2000: 289; Wiseman, 2000: 8). This quality, in conjunction with a high demand for pork products to supply institutions such as the Royal Navy, made pigs ideal and lucrative domesticates for husbanding. Pig husbandry was a productive sideline in various early European industrial commercial contexts where pigs could be fed abundant byproduct refuse such as leftover fermented grain and fruit remaining from brewing and distilling activities in addition to locally available domestic waste (Rixson, 2000: 290; Wiseman, 2000: 12-13). In the context of isolated Newfoundland fishing stations, large amounts of edible fish offal could have provided pig feed.

Our working hypothesis is that pigs raised in New World colonial fishing stations such as Ferryland would have had greater access to isotopically distinctive foods, primarily fish offal, relative to their counterparts raised in Europe and that these isotopic signatures may help to differentiate pig remains originating from either side of the Atlantic. Newfoundland fishing stations produced salted cod fillets for export back to growing European markets which had previously partially depleted their fish stocks (Barrett et al., 2004a, 2004b). Excess cod parts, such as heads and entrails were not exported back to Europe and would have been amply available to feed pigs in Newfoundland, whereas such foods would be less readily available for the feeding of European pigs, particularly at inland locations (though historical documentation does not indentify exactly where in Europe Newfoundland fishermen sourced their salt pork provisions). It is therefore possible that pig remains showing strong marine stable isotope signatures derive from animals raised onsite at Newfoundland fishing stations and those with more terrestrial isotopic signatures derived from bone elements included in European barreled salt pork.

The feeding of leftover cod parts to pigs is anecdotally supported by historical documentation and the local folk stories of some Newfoundland fishermen. For instance, at Joe Batt's Arm, Fogo Island, Newfoundland, and other locations, pig pens have traditionally been situated adjacent to or on fishing stages (Dale Jarvis and Gerald Pocius, personal communication 2011), the locations where fish cutting and gutting occurred prior to salting. Presumably, intentional location of pig pens near fishing stages served two functions as it would allow for ease of pig feeding and efficient disposal of unwanted fish parts. A Newfoundland fisherman, who personally raised pigs in more recent times, attests to the superior quality of pork products deriving from fish-fed pigs (Derek Norman, personal communication 2010). Interestingly, however, he notes that unless pig diets are shifted away from fish two months before slaughter, the resulting pork products obtain a distinctly unpleasant 'fishy' flavor. This suggestion forms interesting connections to comments made in the diary of Joseph Banks, a naturalist who visited the town of St. John's in 1766 and found that pork from locally raised fish-offal-scavenging pigs had a displeasing "fishy" taste unlike that of European raised pork products (Lysaght, 1971: 147).

3. Methods

All faunal samples were taken from archaeological remains. Faunal elements analyzed from Ferryland were mainly those selected for use as indicators of minimum number of individual counts. These elements derive from middens associated with a high status manor house and date from the mid to late 17th century. Faunal elements selected from Dos de Cheval were chosen in the same way except for pigs which were initially selected to include specimens likely to be included or excluded in barreled salt pork. For this reason, it is possible that an individual pig could be represented by more than one sample. Based on archaeological provenience information and inter-specimen stable isotope variation we suspect that a minimum of 11 individual pigs are represented by the 15 pig specimens sampled at Dos de Cheval. Dos de Cheval faunal specimens derive from various deposits and temporal contexts spanning the site's seasonal occupation between the late 17th and late 19th centuries.

Bone collagen was extracted in accordance with procedures outlined by Richards and Hedges (1999) and modified as seen in research by Honch et al. (2006) and Müldner et al. (2011). Samples were demineralized in 0.5 M hydrochloric acid (HCl) at 4ºC. Resulting collagen pseudomorphs were gelatinized on a heating block at 70ºC adjusted to a pH of 3 with HCl for 48 hours. Gelatinized residues were then centrifuged and filtered using 5-8μm mesh Ezee® filters. Samples were then frozen and lyophilized in a freeze dryer for approximately 48 hours. Isotopic measurements were performed using a Carlo Erba NA 1500 Series II Elemental Analyzer® coupled via continuous flow to a Thermo Electron Delta V Plus® Gas Source Isotope Ratio Mass Spectrometer at the CREAIT Network's Stable Isotope Laboratory in the Department of Earth Sciences at Memorial University. Based on sulfanilamide standards (n=18), the instrumental error (1σ) for $\delta^{13}C$ and $\delta^{15}N$ measurements was ±0.18‰ and ±0.10‰, respectively. Collagen quality was assessed by means of percent collagen yield, percent carbon and nitrogen concentration as well as carbon to nitrogen ratio (C:N) criteria as discussed by Van Klinken (1999). Suitably well-preserved collagen must produce a collagen yield greater than 2%, carbon and nitrogen concentrations greater than 18% and 6% respectively and C:N values between 2.9 and 3.6 (DeNiro, 1985; Van Klinken, 1999) .

During sampling, it was discovered that some of the specimens selected from Ferryland were treated for curation with an aqueous solution of 20-30% Rhoplex AC-33, an acrylic polymer used as a consolidant to aid in post excavation preservation (Johnson, 1994). Rhoplex AC-33 does not contain nitrogenous ingredients and therefore should not influence $\delta^{15}N$ values (Tuross and Fogel, 1994; Tuross et al., 1994: 370). It does have carbon-bearing constituents and research has shown that Rhoplex AC-33 treatment can alter $\delta^{13}C$ values unpredictably (Tuross and Fogel, 1994; Tuross et al., 1994: 370-371). As Rhoplex AC-33 may not have completely penetrated denser areas of cortical bone, careful attention during bone sampling was exercised in order to avoid sampling contaminated regions of bone.

4. Results and discussion

Stable isotope data from Dos de Cheval and Ferryland are presented in Table 1 and Figures 2 and 3. Careful sampling appears to be successful in avoiding and/or removing Rhoplex AC-33 contamination as $\delta^{13}C$ values of treated specimens fall within or very close to the range of $\delta^{13}C$ values of untreated specimens. Furthermore, both C:N, as well as carbon and nitrogen concentration criteria for collagen quality, suggest no unusual contributions of exogenous carbon. Complications during the lyophilization process prevented quantification of collagen yields for some samples. However, qualitative observations suggest that affected samples produced collagen yields consistent with well-preserved collagen. Unless otherwise noted, all standard deviations for mean stable isotope values given below are indicated at the 1σ level of confidence.

INSERT TABLE 1, FIGURE 2 AND FIGURE 3 HERE

4.1 Local isotope ecology

Table 2 shows mean values for different groups of animals based on site, trophic level and cultural affiliation. With the exception of caribou and ptarmigans, herbivorous non-domesticate animals from both sites (n=5) have produced stable isotope values indicating environments dominated by C_3 plants ($\delta^{13}C$ = -22.5 ±0.8‰, n=5) with a low $\delta^{15}N$ baseline signature ($\delta^{15}N$ = 3.1 ±1.1‰,). While caribou and ptarmigans also have low $\delta^{15}N$ values, their $\delta^{13}C$ values are generally higher than other herbivorous non-domesticates by roughly 3‰. Considering the local environment, this may be due to dietary inputs from marine carbon, perhaps in the form of beached marine plants such as seaweed (Balasse et al., 2005). Future analysis of archaeological plant specimens collected at Ferryland may help assess this interpretation (see Bain and Prévost, 2010). Domesticate herbivores including cows and caprines from both sites have produced $\delta^{13}C$ values confirming the C_3 orientation of the region but have much higher $\delta^{15}N$ values reflecting aspects of human husbanding, possibly manure fertilizing of pasturing fields.

INSERT TABLE 2 HERE

4.2 Pigs at Ferryland

Stable isotope values from Ferryland pig specimens can be separated into two groups producing significantly different $\delta^{13}C$ and $\delta^{15}N$ values (One Way ANOVA, Post Hoc Bonferroni test, $P< 0.05$; Table 3; Figure 4) indicating separate animal husbanding practices. One group of six pigs has mean $\delta^{13}C$ and $\delta^{15}N$ values of -21.0 ±0.4‰ and 7.0 ±1.2‰, respectively, suggesting a mainly terrestrial diet. A second group of 11 pigs have a mean $\delta^{13}C$ value of -15.6 ±0.9‰ and $\delta^{15}N$ value of 16.3 ±1.8‰ which is consistent with a dietary regime dependent on consumption of high trophic level marine-derived foods. The dietary signatures of these 'marine-diet' pigs are best considered in relation to the isotope values of codfish. Cod (n=32) at both sites have produced a mean $\delta^{13}C$ value of -14.5 ±0.6‰ and $\delta^{15}N$ value of 15.2 ±0.6‰ indicating that a diet incorporating a substantial amount of this species from the region can produce bone collagen stable isotope values consistent with those observed in these 'marine-diet' pigs and suggests that these pigs were likely raised mainly on refuse from the fishery at Ferryland. Allowing pigs free-range to scavenge around a fishery site would be disruptive to cod salting and drying operations and, for this reason, it is not expected that the diets of pigs raised at Ferryland would incorporate foraged foods. However, it is possible that the stable isotope values of these 'marine-diet' pigs could also partially reflect consumption of other human dietary refuse deriving from marine fish, shellfish, and mammal species with similarly high stable isotope signatures and perhaps, to a lesser degree, refuse deriving from terrestrial foods (particularly during the final months before slaughter; see Section 2.3). While the possibility remains that these 'marine-diet' pigs could have been raised in coastal European parent-colonial contexts, it seems improbable given the previous relative depletion of their regional fish stocks (see below, this section). It is also possible that the weaning effect (Schurr, 1998) has contributed to some of the high $\delta^{15}N$ values observed in these 'marine-diet' pigs. While this may be the case for MARC 303 and 310 which were infants at their time of death, age estimates for other pigs are older suggesting that, on the whole, the weaning effect has not significantly influenced isotope patterns between the two groups.

INSERT TABLE 3 AND FIGURE 4 HERE

If it was possible to raise pigs largely on fish offal, then it would probably be less efficient to keep pigs fed with terrestrial-based foods which are proportionally less readily available at Newfoundland fishing stations. For this reason it seems unlikely that pigs with mainly terrestrial diets were raised at the Ferryland site or at any fishing station site where fishery byproducts were abundantly available. A European origin for these 'terrestrial-diet' pigs seems more probable. European fish stocks had been relatively depleted by the 16th and 17th centuries (Barrett et al., 2004a, 2004b) and fish products exported to Europe from New World fishing stations included mainly high quality salted cod fillets intended for human consumption. It seems reasonable to assume that relatively little fish material would remain for possible pig consumption after cod fillets were consumed in European markets. It is therefore likely that pigs husbanded in-and-around France and Britain, the regions which presumably supplied salt pork provisions to outgoing transatlantic fishermen, would have had relatively little access to marine byproducts. Isotopic evidence from human and pig remains from the city of York support this notion. Whereas human $\delta^{13}C$ and $\delta^{15}N$ values become higher over time, reflecting the increasing importance of fish in the diet of medieval and post-medieval England, contemporaneous pig stable isotope values continue to indicate an omnivorous diet incorporating terrestrial animal and plant materials (Mülnder and Richards, 2005, 2007). Furthermore, these pigs produce $\delta^{13}C$ and

$\delta^{15}N$ values statistically indistinguishable from those observed in the Ferryland 'terrestrial-diet' pigs (Figure 5) (One Way ANOVA, Post Hoc Bonferroni test, P> 0.05; Table 3). Thus, while it is possible that certain pigs raised at Ferryland were specially fed a separate diet of terrestrial based foods, it seems more reasonable to suggest that the 'terrestrial-diet' pig remains represent imported pork products deriving from European barreled salt pork.

INSERT FIGURE 5 AND TABLE 4 HERE

The suggestion that pigs with terrestrial-based diets from Ferryland were imported from Europe might be further explored using provenience oriented isotope techniques such as strontium and oxygen isotope analyses. Efforts are currently underway to assess this possibility. While these lines of analyses work well for establishing origin in terrestrial contexts, they often encounter difficulties in distinguishing provenience in coastal contexts where mobility isotope information can be masked by marine isotope signatures reflecting consumption of marine-derived foods, sea spray from a nearby ocean or local marine-derived sedimentary deposits (e.g. Montgomery, 2010; Montgomery et al., 2007).

4.3 Pigs at Dos de Cheval

Stable isotope values of pigs from Dos de Cheval (mean $\delta^{13}C$= -21.8±0.3‰ and $\delta^{15}N$=7.6±1.1‰, n=15) are similar to those of 'terrestrial-diet' pigs at Ferryland, as well as available data on medieval English and French pigs (Mülnder and Richards, 2005, 2007) (One Way ANOVA, Post Hoc Bonferroni test, P> 0.05; Table 3), suggesting generally similar pig husbanding practices (Figures 4 and 5). In conjunction with historical documentation, which does not indicate the import of live pigs to Dos de Cheval (Noël, 2010a: 126; Querré. 1998: 71), this suggests that pork products consumed there were of European origin, probably transported in the form of barreled salt pork.

This interpretation is further supported by considering isotopic evidence from other Dos de Cheval livestock. Herbivorous livestock (cows and caprines) have a high mean $\delta^{15}N$ value of 6.9 ±0.9‰ (n=7) which appears to be out-of-place relative to local herbivores (hares and caribou, n=5) with a low mean $\delta^{15}N$ value of 2.7 ±0.9‰ suggesting diets augmented by human husbanding practices, perhaps through provisioning with small amounts of locally available fish offal or fodder that had been fertilized with marine refuse from the fishery. This is consistent with historical documentation which notes ships provisioned with live cows, sheep, goats, and chickens sailing for Newfoundland's Great Northern Peninsula (Querré, 1998: 71). It is expected that pigs, as omnivores, could feed at a slightly higher trophic level than herbivorous sheep and goats ($\delta^{15}N$= 7.3 ±0.4‰, n=5), yet both share generally similar mean $\delta^{15}N$ values. Meanwhile, domestic fowl (chickens and turkeys) have a mean $\delta^{15}N$ value of 8.9 ±0.5‰ (n=6) which is higher than pigs and could suggest that fowl imported to, and briefly raised at, the fishery had some marine dietary contributions (a relatively rapid bone collagen turnover rate in developing fowl could allow bone collagen to record marine dietary inputs over a short period of time before slaughter). However, it seems unlikely that given equal opportunities chickens and turkeys would proportionally consume more fish byproducts relative to pigs. These considerations suggest that pig stable isotope values reflect husbanding under different circumstances than those which characterize other livestock husbanded at Dos de Cheval and suggest that pork products consumed at the site were of European origin during all periods of occupation.

5. Conclusion

Differences in animal husbandry practices identified by means of stable isotope analyses clearly have potential to address questions of pig origin. This approach has several practical applications to the archaeology of Newfoundland fishing stations and potentially similar maritime colonial contexts in other regions of the world. One application would be a use of this technique in conjunction with body part representation analyses to determine which pig elements and corresponding cuts of pork were included in barreled salt pork. Our results from Ferryland and Dos de Cheval, for instance, already suggest that crania, vertebrae, astragali, tibiae, metatarsals and phalanges were included in barreled salt pork which supports previous zooarchaeological findings (see Section 2.1). In addition to identifying the origin of individual pig remains, this technique can also, with more extensive analyses of pig specimens from fishing stations, provide a means for diachronically estimating proportions of pork products which were imported as opposed to being acquired from locally raised pigs. This novel capacity becomes even more significant when considering the extent to which early fishing enterprises were provisioned with pork products as well as the profitability of inexpensive pig husbandry in the context of contemporaneous European pork markets.

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Table1

Table 1. Stable isotope values and associated collagen quality data for Ferryland (CaFg-2) and Dos de Cheval (EfAx-09) faunal remains.

Lab ID	Taxon	Common Name	Site	Context	Element	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C:N	Yield (%)
MARC 65	*Sus scrofa*	Pig	EfAx-09	1	Humerus	-21.77	6.25	43.84	15.42	3.32	13.99%
MARC 66	*Sus scrofa*	Pig	EfAx-09	1	Phalange	-21.37	6.42	43.16	15.28	3.30	14.63%
MARC 217	*Sus scrofa*	Pig	EfAx-09	2	Patella	-21.01	7.35	43.56	15.82	3.22	14.13%
MARC 218	*Sus scrofa*	Pig	EfAx-09	2	Vertebrae	-21.57	7.27	44.90	16.05	3.27	13.70%
MARC 219	*Sus scrofa*	Pig	EfAx-09	2	Maxilla	-21.55	9.63	43.08	15.60	3.23	18.22%
MARC 220	*Sus scrofa*	Pig	EfAx-09	2	Femur	-21.96	6.57	42.54	14.99	3.32	17.89%
MARC 221	*Sus scrofa*	Pig	EfAx-09	3	Femur	-21.34	8.25	45.45	15.62	3.40	5.08%
MARC 222	*Sus scrofa*	Pig	EfAx-09	3	Maxilla	-21.49	6.88	43.66	15.20	3.36	12.34%
MARC 223	*Sus scrofa*	Pig	EfAx-09	3	Femur	-21.79	7.43	44.05	15.59	3.30	10.48%
MARC 225	*Sus scrofa*	Pig	EfAx-09	1	Phalange	-22.02	6.62	43.01	14.84	3.39	10.27%
MARC 226	*Sus scrofa*	Pig	EfAx-09	1	Rib	-22.09	6.67	42.78	15.48	3.23	14.88%
MARC 227	*Sus scrofa*	Pig	EfAx-09	4	Phalange	-21.97	8.61	43.92	15.77	3.26	6.25%
MARC 228	*Sus scrofa*	Pig	EfAx-09	4	Rib	-22.13	8.05	43.67	15.69	3.25	11.21%
MARC 229	*Sus scrofa*	Pig	EfAx-09	4	Phalange	-22.17	9.61	43.63	15.52	3.29	11.11%
MARC 230	*Sus scrofa*	Pig	EfAx-09	4	Tibia	-21.96	7.73	44.40	15.15	3.43	8.80%
MARC 232	*Gadus* sp.	Cod	EfAx-09	3	Vertebrae	-16.86	13.66	33.21	10.37	3.74	4.08%
MARC 233	*Gadus* sp.	Cod	EfAx-09	1	Vertebrae	-15.63	14.61	41.00	14.61	3.28	6.95%
MARC 234	*Gadus* sp.	Cod	EfAx-09	4	Vertebrae	-	-	-	-	-	<2%
MARC 263	*Rangifer tarandus*	Caribou	EfAx-09	5	Carpal	-17.46	1.86	43.96	15.94	3.22	17.09%
MARC 264	*Rangifer tarandus*	Caribou	EfAx-09	3	Calcaneus	-20.72	3.34	44.51	15.62	3.33	16.46%
MARC 265	*Leporidae* sp.	Hare	EfAx-09	6	Tympanic Bulla	-23.04	1.93	43.87	15.43	3.32	10.77%
MARC 266	*Leporidae* sp.	Hare	EfAx-09	6	Tympanic Bulla	-22.92	2.45	43.57	15.03	3.39	7.94%
MARC 267	*Leporidae* sp.	Hare	EfAx-09	6	Tympanic Bulla	-22.42	4.03	43.59	14.66	3.47	6.91%
MARC 268	Caprinae	Sheep or goat	EfAx-09	3	Calcaneus	-21.78	7.11	43.92	15.76	3.26	20.70%
MARC 269	Caprinae	Sheep or goat	EfAx-09	7	Femur	-21.62	6.97	43.11	15.40	3.27	14.71%
MARC 270	Caprinae	Sheep or goat	EfAx-09	1	Atlas	-21.09	7.05	43.49	15.53	3.27	15.89%
MARC 271	Caprinae	Sheep or goat	EfAx-09	1	Atlas	-21.24	7.33	45.04	16.17	3.26	14.60%
MARC 272	*Bos tarus*	Cow	EfAx-09	8	Tarsal	-21.84	4.97	44.10	15.37	3.35	19.74%

MARC 273	*Bos tarus*	Cow	EfAx-09	1	Calcaneus	-21.01	7.04	44.76	16.01	3.27	16.06%
MARC 274	*Rissa tridactyla*	Black Legged Kittiwake	EfAx-09	6	Tarsometatarsal	-14.36	13.89	43.79	15.58	3.29	17.71%
MARC 275	*Rissa tridactyla*	Black Legged Kittiwake	EfAx-09	1	Carpometacarpal	-14.71	16.63	44.22	15.56	3.32	19.66%
MARC 276	*Rissa tridactyla*	Black Legged Kittiwake	EfAx-09	1	Carpometacarpal	-14.93	17.46	44.10	15.72	3.28	21.13%
MARC 277	*Galus galus*	Chicken	EfAx-09	6	Carpometacarpal	-20.88	9.61	44.36	15.72	3.30	20.24%
MARC 278	*Galus galus*	Chicken	EfAx-09	6	Carpometacarpal	-20.52	9.08	43.85	15.79	3.25	20.78%
MARC 279	*Galus galus*	Chicken	EfAx-09	8	Tibiotarsus	-20.85	8.84	42.39	15.01	3.30	12.37%
MARC 280	*Galus galus*	Chicken	EfAx-09	8	Tibiotarsus	-20.92	8.98	41.81	14.53	3.36	12.59%
MARC 281	*Meleagris gallopavo*	Turkey	EfAx-09	8	Radius	-20.31	7.93	45.04	16.03	3.28	17.64%
MARC 282	*Meleagris gallopavo*	Turkey	EfAx-09	7	Humerus	-19.90	8.89	44.22	15.53	3.33	14.53%
MARC 291	Caprinae	Sheep or goat	CaFg-2	9	Radius	-19.68	4.13	44.31	15.92	3.25	15.15%
MARC 292*	Caprinae	Sheep or goat	CaFg-2	9	Astragalus	-22.64	8.07	44.57	15.97	3.26	-
MARC 293	Caprinae	Sheep or goat	CaFg-2	9	Mandible	-21.62	6.17	41.91	14.83	3.30	6.88%
MARC 294	Caprinae	Sheep or goat	CaFg-2	9	Mandible	-21.30	5.92	41.97	15.06	3.26	9.89%
MARC 295	Caprinae	Sheep or goat	CaFg-2	9	Mandible	-20.05	5.98	42.01	14.82	3.31	9.67%
MARC 296	Caprinae	Sheep or goat	CaFg-2	9	Mandible	-18.84	7.13	40.92	14.48	3.30	10.57%
MARC 300	Caprinae	Sheep or goat	CaFg-2	9	Radius	-21.19	6.54	42.55	15.19	3.28	10.66%
MARC 290	*Sus scrofa*	Pig	CaFg-2	9	Radius	-14.82	17.89	42.83	15.27	3.28	14.19%
MARC 298	*Sus scrofa*	Pig	CaFg-2	9	Humerus	-16.08	17.28	41.18	14.60	3.30	7.44%
MARC 301	*Sus scrofa*	Pig	CaFg-2	9	Metatarsal	-20.80	8.00	42.75	15.27	3.27	10.84%
MARC 302	*Sus scrofa*	Pig	CaFg-2	9	Metatarsal	-15.24	18.32	43.77	15.64	3.27	12.86%
MARC 303	*Sus scrofa*	Pig	CaFg-2	9	Mandible	-15.51	15.95	43.49	15.51	3.28	13.06%
MARC 304*	*Sus scrofa*	Pig	CaFg-2	9	Fibula	-14.11	14.26	40.34	14.95	3.15	-
MARC 305*	*Sus scrofa*	Pig	CaFg-2	9	Astragalus	-16.03	17.26	44.63	16.16	3.23	-
MARC 306*	*Sus scrofa*	Pig	CaFg-2	9	Astragalus	-21.71	6.03	43.82	15.66	3.27	-
MARC 307	*Sus scrofa*	Pig	CaFg-2	9	Astragalus	-20.64	8.97	41.20	15.01	3.21	6.75%
MARC 308*	*Sus scrofa*	Pig	CaFg-2	9	Humerus	-21.22	6.29	44.33	16.40	3.16	-
MARC 309	*Sus scrofa*	Pig	CaFg-2	9	Tibia	-20.63	6.43	43.65	15.45	3.30	13.39%
MARC 310	*Sus scrofa*	Pig	CaFg-2	9	Mandible	-15.99	18.82	43.36	15.77	3.22	14.32%
MARC 311	*Sus scrofa*	Pig	CaFg-2	9	Mandible	-15.70	15.51	38.92	13.99	3.25	15.71%
MARC 312	*Sus scrofa*	Pig	CaFg-2	9	Mandible	-17.75	13.55	42.68	15.11	3.30	13.74%

MARC 313*	*Sus scrofa*	Pig	CaFg-2	9	Rib	-14.91	14.10	32.49	10.83	3.51	-
MARC 314	*Sus scrofa*	Pig	CaFg-2	9	Vertebrae	-21.12	6.15	38.76	13.58	3.34	12.66%
MARC 315	*Sus scrofa*	Pig	CaFg-2	9	Metatarsal	-15.60	16.42	43.04	15.53	3.24	12.38%
MARC 316	*Bos tarus*	Cow	CaFg-2	9	Femur	-21.66	7.62	42.49	15.08	3.29	16.31%
MARC 317*	*Bos tarus*	Cow	CaFg-2	9	Ulna	-21.39	5.08	44.63	16.21	3.22	-
MARC 318	*Bos tarus*	Cow	CaFg-2	9	Ulna	-21.76	7.10	42.49	14.97	3.32	10.62%
MARC 319	*Bos tarus*	Cow	CaFg-2	9	Femur	-21.68	5.68	42.94	15.38	3.26	9.29%
MARC 320	*Bos tarus*	Cow	CaFg-2	9	Femur	-21.39	4.18	42.93	15.59	3.22	11.67%
MARC 321	*Bos tarus*	Cow	CaFg-2	9	Astragalus	-21.82	6.47	42.45	15.46	3.21	11.59%
MARC 322	*Bos tarus*	Cow	CaFg-2	9	Tibia	-19.68	6.15	42.38	15.34	3.23	8.80%
MARC 323	*Bos tarus*	Cow	CaFg-2	9	Femur	-22.11	6.56	42.20	15.21	3.24	9.56%
MARC 324	*Bos tarus*	Cow	CaFg-2	9	Astragalus	-22.37	4.13	43.62	16.03	3.18	12.85%
MARC 325	*Ratus ratus*	Rat	CaFg-2	9	Femur	-19.19	7.55	43.92	15.65	3.28	16.41%
MARC 326	*Ratus ratus*	Rat	CaFg-2	9	Femur	-19.17	7.07	43.79	15.75	3.25	14.59%
MARC 327	*Ratus ratus*	Rat	CaFg-2	9	Femur	-18.63	6.44	44.30	15.78	3.28	16.60%
MARC 328	*Ratus ratus*	Rat	CaFg-2	9	Femur	-18.00	7.88	44.73	15.97	3.27	16.34%
MARC 329	*Canis familiaris*	Dog	CaFg-2	9	Femur	-14.18	17.13	42.79	15.43	3.24	9.90%
MARC 330*	*Canis familiaris*	Dog	CaFg-2	9	Phalange	-15.67	16.08	44.84	16.71	3.14	-
MARC 332*	*Canis familiaris*	Dog	CaFg-2	9	Phalange	-14.32	15.00	34.61	12.42	3.26	-
MARC 944	*Lagopus lagopus*	Ptarmigan	EfAx-09	6	Carpometacarpal	-19.47	-0.26	44.36	15.80	3.28	30.00%
MARC 945	*Lagopus lagopus*	Ptarmigan	EfAx-09	6	Carpometacarpal	-19.91	-0.59	44.16	15.63	3.30	32.37%
MARC 946	*Larus delawarensis*	Ring-Billed Gull	EfAx-09	6	Humerus	-18.76	7.76	44.64	15.73	3.32	23.90%
MARC 947	*Larus argentatus*	Herring Gull	EfAx-09	6	Ulna	-14.58	15.68	44.55	15.92	3.27	22.27%
MARC 948	*Corvus corax*	Common Raven	EfAx-09	6	Carpometacarpal	-16.88	14.28	43.12	14.79	3.41	16.23%
MARC 950	*Rangifer tarandus*	Caribou	CgAf-2	10	Femur	-18.71	2.90	44.10	15.04	3.43	5.60%
MARC 951	*Rangifer tarandus*	Caribou	CgAf-2	10	Calcaneus	-17.94	3.02	35.71	12.27	3.40	11.37%
MARC 952	*Rangifer tarandus*	Caribou	CgAf-2	10	Rib (1st or 2nd)	-17.76	2.94	39.25	13.94	3.29	10.42%
MARC 953	*Rangifer tarandus*	Caribou	CgAf-2	10	Femur	-17.57	2.43	39.43	14.07	3.28	12.90%
MARC 954	*Rangifer tarandus*	Caribou	CgAf-2	10	Lumbar Vert.	-17.97	2.19	41.68	15.17	3.21	25.13%
MARC 957	*Corvus corax*	Common Raven	CgAf-2	10	Coracoid	-12.70	17.54	45.33	16.48	3.21	23.00%
MARC 958	*Corvus corax*	Common Raven	CgAf-2	10	Carpometacarpal	-14.48	17.62	39.11	13.84	3.30	13.25%
MARC 959	*Fratercula arctica*	Puffin	CgAf-2	10	Ulna	-14.97	15.87	40.85	14.41	3.31	15.78%
MARC 960	*Larus argentatus*	Herring Gull	CgAf-2	10	Coracoid	-13.81	17.04	45.17	16.41	3.22	26.25%
MARC 961	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Coracoid	-18.87	-0.61	45.65	16.23	3.29	18.53%

MARC 962	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Coracoid	-19.02	0.09	43.00	15.24	3.30	15.75%
MARC 963	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Scapula	-18.94	-0.54	46.23	16.67	3.24	30.42%
MARC 964	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Femur	-18.87	-0.75	43.59	15.50	3.29	23.49%
MARC 965	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Carpometacarpal	-18.92	-0.94	40.81	14.11	3.38	11.72%
MARC 966	*Lagopus lagopus*	Ptarmigan	CgAf-2	10	Coracoid	-18.35	-1.65	45.16	16.19	3.26	15.89%
MARC 967	*Bubo virginianus*	Great Horned Owl	CgAf-2	10	Scapula	-18.89	7.88	45.00	16.30	3.23	23.14%
MARC 968	*Larus marinus*	Great Black-Backed Gull	CgAf-2	10	Ulna	-14.41	18.28	44.70	16.11	3.24	21.67%
MARC 969	*Larus marinus*	Great Black-Backed Gull	CgAf-2	10	Carpometacarpal	-14.53	17.22	41.15	14.75	3.26	16.96%
MARC 970	*Larus marinus*	Great Black-Backed Gull	CgAf-2	10	Ulna	-14.80	17.64	39.49	14.03	3.29	14.11%
MARC 971	*Larus marinus*	Great Black-Backed Gull	CgAf-2	10	Radius	-14.95	17.92	40.98	14.53	3.30	16.67%
MARC 972	*Felis catus*	Cat	CgAf-2	10	3rd Metatarsal	-15.40	15.44	42.03	15.09	3.26	14.83%
MARC 973	*Castor canadensis*	Beaver	CgAf-2	10	Rib	-21.17	4.48	44.72	16.33	3.20	19.87%
MARC 974	*Castor canadensis*	Beaver	CgAf-2	10	Maxilla	-22.68	2.69	41.79	14.77	3.31	16.93%
MARC 975*	*Gadus* sp.	Cod	CgAf-2	10	Angular	-14.27	15.48	43.78	16.05	3.19	11.48%
MARC 976	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-13.82	15.83	36.14	13.25	3.19	6.90%
MARC 977	*Gadus* sp.	Cod	CgAf-2	10	Cliethrum	-13.61	15.15	38.35	13.94	3.22	11.75%
MARC 978	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.73	15.26	36.58	13.20	3.24	10.93%
MARC 979	*Gadus* sp.	Cod	CgAf-2	10	Cliethrum	-14.40	14.17	42.38	15.84	3.13	12.40%
MARC 980	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.36	14.40	36.20	13.33	3.17	11.48%
MARC 981	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.41	14.93	37.31	13.62	3.20	5.28%
MARC 982	*Gadus* sp.	Cod	CgAf-2	10	Angular	-14.47	14.92	34.00	12.14	3.27	7.56%
MARC 983	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.43	14.41	38.95	14.11	3.23	12.07%
MARC 985	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.81	14.98	31.75	11.20	3.32	5.38%
MARC 986	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.12	14.53	41.88	15.40	3.18	9.67%
MARC 987	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-13.88	15.05	29.76	10.84	3.21	6.65%
MARC 988*	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-15.21	16.15	26.90	9.21	3.41	10.81%
MARC 989	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.11	15.83	39.86	14.17	3.29	8.48%
MARC 990	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-14.12	15.30	43.06	16.02	3.14	10.81%
MARC 991	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-15.02	15.19	38.06	13.40	3.32	5.83%
MARC 992	*Gadus* sp.	Cod	CgAf-2	10	Supracliethrum	-13.85	16.74	40.71	14.74	3.23	4.38%
MARC 993	*Gadus* sp.	Cod	CgAf-2	10	Angular	-15.44	15.38	40.63	14.60	3.25	7.80%
MARC 994	*Gadus* sp.	Cod	CgAf-2	10	Frontal	-14.69	16.01	34.06	12.56	3.17	10.09%
MARC 995	*Gadus* sp.	Cod	CgAf-2	10	Angular	-14.46	15.40	35.21	12.63	3.26	11.33%

MARC 996	*Gadus* sp.	Cod	CgAf-2	10	Cliethrum	-14.16	15.16	43.72	16.02	3.19	11.35%
MARC 997	*Gadus* sp.	Cod	CgAf-2	10	Frontal	-13.59	16.11	40.96	15.23	3.14	14.04%
MARC 998	*Gadus* sp.	Cod	CgAf-2	10	Lumbar Vert.	-	-	-	-	-	1.89%
MARC 999*	Caprinae	Sheep or goat	CgAf-2	10	Vertebrae	-	-	-	-	-	0.00%
MARC 1001	*Equus ferus*	Horse	CgAf-2	10	Scapula	-21.87	6.48	24.06	8.55	3.29	12.08%
MARC 1002*	*Equus ferus*	Horse	CgAf-2	10	Scapula	-21.15	7.01	40.91	14.58	3.28	10.19%
MARC 1003	Phocidae	Seal sp.	CgAf-2	10	1st Metacarpal	-13.45	16.88	41.63	15.06	3.23	17.73%
MARC 1004	*P. groenlandicus*	Harp Seal	CgAf-2	10	Humerus	-14.24	16.34	40.66	14.45	3.29	10.88%
MARC 1005	*P. groenlandicus*	Harp Seal	CgAf-2	10	Humerus	-14.38	14.15	31.85	11.28	3.30	5.96%
MARC 1006	*P. groenlandicus*	Harp Seal	CgAf-2	10	Mandible	-14.07	16.87	40.78	14.56	3.27	7.26%
MARC 1007	*P. groenlandicus*	Harp Seal	CgAf-2	10	Temporal	-14.71	17.37	42.59	14.77	3.37	8.30%
MARC 1008	*Phoca vitulina*	Harbour Seal	CgAf-2	10	Mandible	-13.78	18.35	42.79	15.73	3.18	20.11%
MARC 1009	*Phoca vitulina*	Harbour Seal	CgAf-2	10	Auditory bulla	-14.03	16.97	41.80	14.76	3.31	11.47%
MARC 1010	*Gadus* sp.	Cod	EfAx-09	6	Angular	-15.76	14.98	35.64	12.40	3.36	11.39%
MARC 1011	*Gadus* sp.	Cod	EfAx-09	6	Angular	-14.15	15.56	42.39	15.42	3.21	10.34%
MARC 1012	*Gadus* sp.	Cod	EfAx-09	6	Angular	-15.93	14.76	36.61	12.43	3.44	9.72%
MARC 1013	*Gadus* sp.	Cod	EfAx-09	6	Angular	-13.76	14.57	42.66	15.19	3.28	7.72%
MARC 1014	*Gadus* sp.	Cod	EfAx-09	6	Angular	-14.53	14.88	42.13	15.17	3.25	11.65%
MARC 1015	*Gadus* sp.	Cod	EfAx-09	6	Angular	-13.99	15.09	41.83	14.94	3.27	8.84%
MARC 1016	*Gadus* sp.	Cod	EfAx-09	6	Angular	-14.36	14.29	42.21	15.34	3.22	11.61%
MARC 1017	*Gadus* sp.	Cod	EfAx-09	6	Angular	-15.08	14.77	39.68	13.94	3.33	7.04%

Asterisks' mark samples treated with Rhoplex AC-33. Contexts are numbered as follows: (1) French working area (ca.1760-1790), (2) French working area (ca. 1815-1900), (3) Anglo-Newfoundlander working area (ca. 1790-1815), (4) French officer's cook room (ca. 1700-1750), (5) French late 17th to early 18th C., (6) mid 18th C. French officer's cook room, (7) mid 18th C. French domestic midden, (8) French (ca. 1650-1725), (9) mid to late 17th C. upper status English midden.

Table 2

Table 2. Mean values for different groups of animals based on site, trophic level and cultural affiliation.

Site	**Trophic Level**	**Cultural Affiliation**	**Sp. Included**	**Mean $\delta^{13}C$ ‰**	**Mean $\delta^{15}N$ ‰**
Ferryland	Herbivore	Wild	Beaver (n=2)	-21.9 ±1.1	3.59 ±1.3
Dos de Cheval	Herbivore	Wild	Hare (n=3)	-22.8 ±0.3	2.8 ±1.1
Ferryland	Herbivore	Domesticated	Cow (n=9), Caprines (n=7), Horse (n=2)	-21.2 ±1.0	6.13 ±1.12
Dos de Cheval	Herbivore	Domesticated	Cow (n=2), Caprine (n=5)	-21.6 ±0.6	6.9 ±0.9
Dos de Cheval	Omnivore	Domesticated	Chicken (n=4), Turkey (n=2)	-20.1 ±0.4	8.9 ±0.5
Ferryland	Terrestrial Carnivore	Wild	Great Horned Owl (n=1)	-18.9	7.9
Ferryland	Marine Carnivore	Wild	Cod (n=23), Seals (n=6), Seabirds (n=5)	-14.4 ±0.5	15.8 ±1.2
Dos de Cheval	Marine Carnivore	Wild	Cod (n=8), Seabirds (n=4)	-14.7 ±0.7	15.2 ±1.0

Table 3

Table 3. Stable carbon and nitrogen isotope ratios from different groups of pigs from Europe and Newfoundland (see Table 1 and 4 for background information) compared via One Way ANOVA and Post Hoc Bonferroni test. F.L.(mar) = Ferryland pigs with marine diets, F.L.(ter) = Ferryland pigs with terrestrial diets, F.L.(all) = all Ferryland pigs, D.d.C. = Dos de Cheval pigs, F.G.(all) = all Fisher Gate pigs, T.R.(all) = all Tanner Row pigs, S.G. = St. Giles, and W.P. = Wharram Percy.

	F.L. (mar)	**F.L. (ter)**	**F.L. (all)**	**D.d.C**	**F.G. (all)**	**T.R. (all)**	**S.G.**	**W.P.**
$\delta^{13}C$								
F.L. (mar)	X	p=0.000	p=0.021	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000
F.L. (ter)	p=.000	X	p=0.000	p=1.000	p=1.000	p=1.000	p=1.000	p=1.000
F.L. (all)	p=0.021	p=0.000	X	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000
D.d.C	p=0.000	p=1.000	p=0.000	X	p=1.000	p=1.000	p=1.000	p=1.000
F.G. (all)	p=0.000	p=1.000	p=0.000	p=1.000	X	p=1.000	p=1.000	p=1.000
T.R. (all)	p=0.000	p=1.000	p=0.000	p=1.000	p=1.000	X	p=1.000	p=1.000
S.G.	p=0.000	p=1.000	p=0.000	p=1.000	p=1.000	p=1.000	X	p=1.000
W.P.	p=0.000	p=1.000	p=0.000	p=1.000	p=1.000	p=1.000	p=1.000	X
$\delta^{15}N$								
F.L. (mar)	X	p=0.000	p=0.044	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000
F.L. (ter)	p=0.000	X	p=0.000	p=1.000	p=1.000	p=1.000	p=1.000	p=1.000
F.L. (all)	p=0.044	p=0.000	X	p=0.000	p=0.000	p=0.000	p=0.002	p=0.000
D.d.C	p=0.000	p=1.000	p=0.000	X	p=1.000	p=1.000	p=1.000	p=1.000
F.G. (all)	p=0.000	p=1.000	p=0.000	p=1.000	X	p=1.000	p=1.000	p=1.000
T.R. (all)	p=0.000	p=1.000	p=0.000	p=1.000	p=1.000	X	p=1.000	p=1.000
S.G.	p=0.000	p=1.000	p=0.002	p=1.000	p=1.000	p=1.000	X	p=1.000
W.P.	p=0.000	p=1.000	p=0.000	p=1.000	p=1.000	p=1.000	p=1.000	X

Table 4

Table 4. Information on source data for post A.D. 1000 British and French pigs in Figure 5 and Table 3. Data are taken from Müldner and Richards (2005): St. Giles and Wharram Percy; Müldner and Richards (2007): Fisher Gate and Tanner Row; Bocherens et al. (1991): Besançon; Tripp et al. (2006): Mary Rose.

Site	**Time Period**	**# of Pigs**
St. Giles (UK)	12^{th}-15^{th} C.	4
Wharram Percy (UK)	Later Medieval	6
Fisher Gate (UK)	10^{th}-12^{th} C. High Medieval	5
Fisher Gate (UK)	13^{th}-16^{th} C. Later Medieval	7
Fisher Gate (UK)	1538-late 16^{th} C. Post-medieval	1
Tanner Row (UK)	10^{th}-12^{th} C. High Medieval	4
Tanner Row (UK)	13^{th}-16^{th} C. Later Medieval	2
Besançon (France)	14^{th} C.	1
Mary Rose (UK)	1545	1

Figure caption list

Figure 1. Locations of Ferryland (CgAf-02) and Dos de Cheval (EfAx-09) in Newfoundland (Drawing based on original by Norman Einstein http://commons.wikimedia.org/wiki/File: Gander_Lake_map.png)

Figure 2. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values of faunal remains analyzed from Ferryland (CgAf-02). Error bars show one standard deviation.

Figure 3. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values of faunal remains analyzed from Dos de Cheval (EfAx-09). Error bars show one standard deviation.

Figure 4. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values of individual pigs from Dos de Cheval (D.d.C.) and Ferryland (F.L.). Mean stable isotope values (error bars show one standard deviation) are also provided for pigs from Dos de Cheval (light grey triangle), pigs with marine diets from Ferryland (dark grey square), and pigs with terrestrial diets from Ferryland (light grey square).

Figure 5. Mean stable isotope values (error bars show one standard deviation) of pig remains from various medieval and post-medieval sites in England, France and Newfoundland. F.L. = Ferryland ('terrestrial-diet' pigs only), D.d.C. = Dos de Cheval, F.G. = Fisher Gate, T.R. = Tanner Row, S.G. = St. Giles, W.P. = Wharram Percy, B. = Besançon, and M.R. = Mary Rose. See Table 4 for background information and sources.

Figure 1
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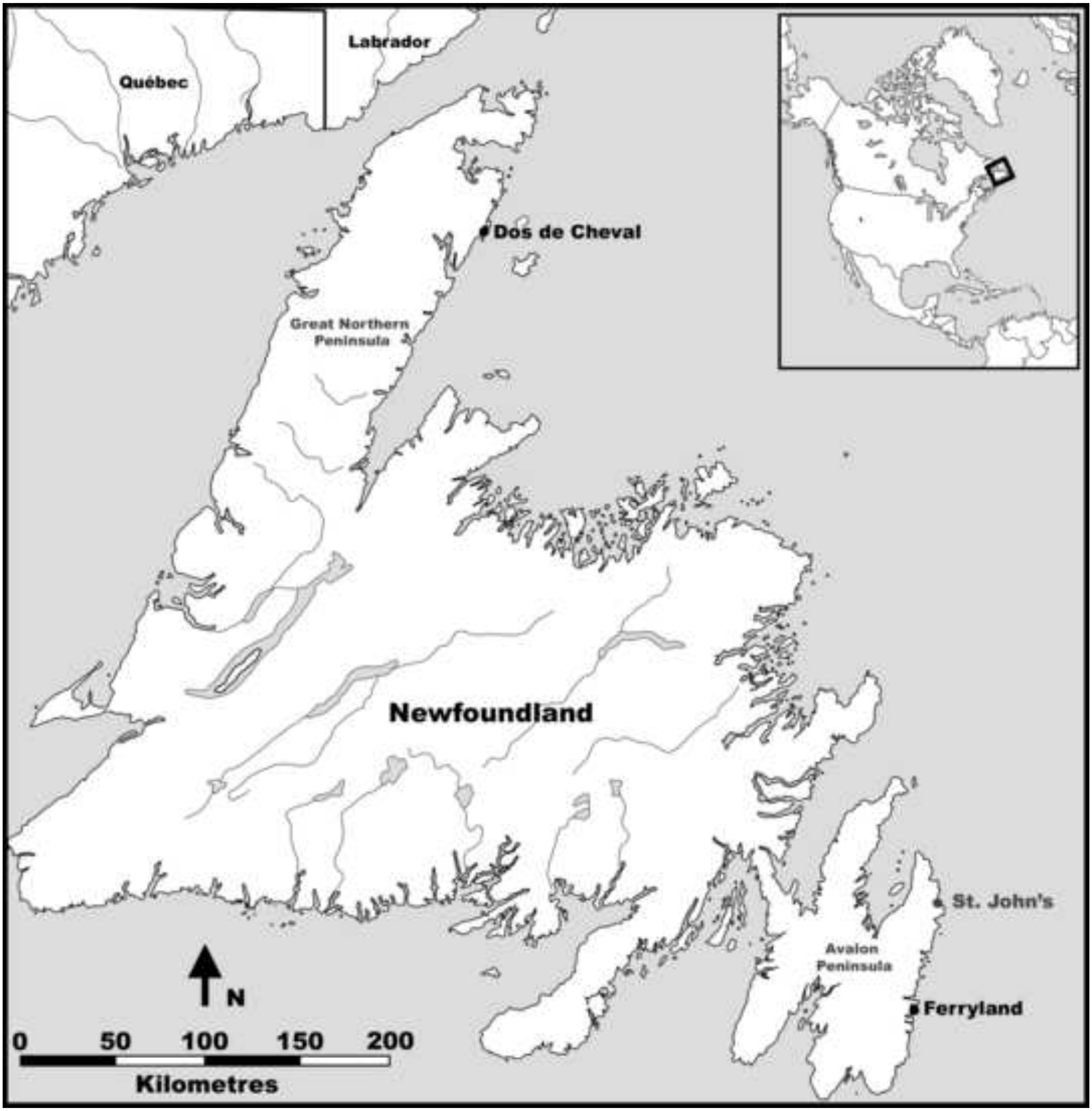

Figure 2

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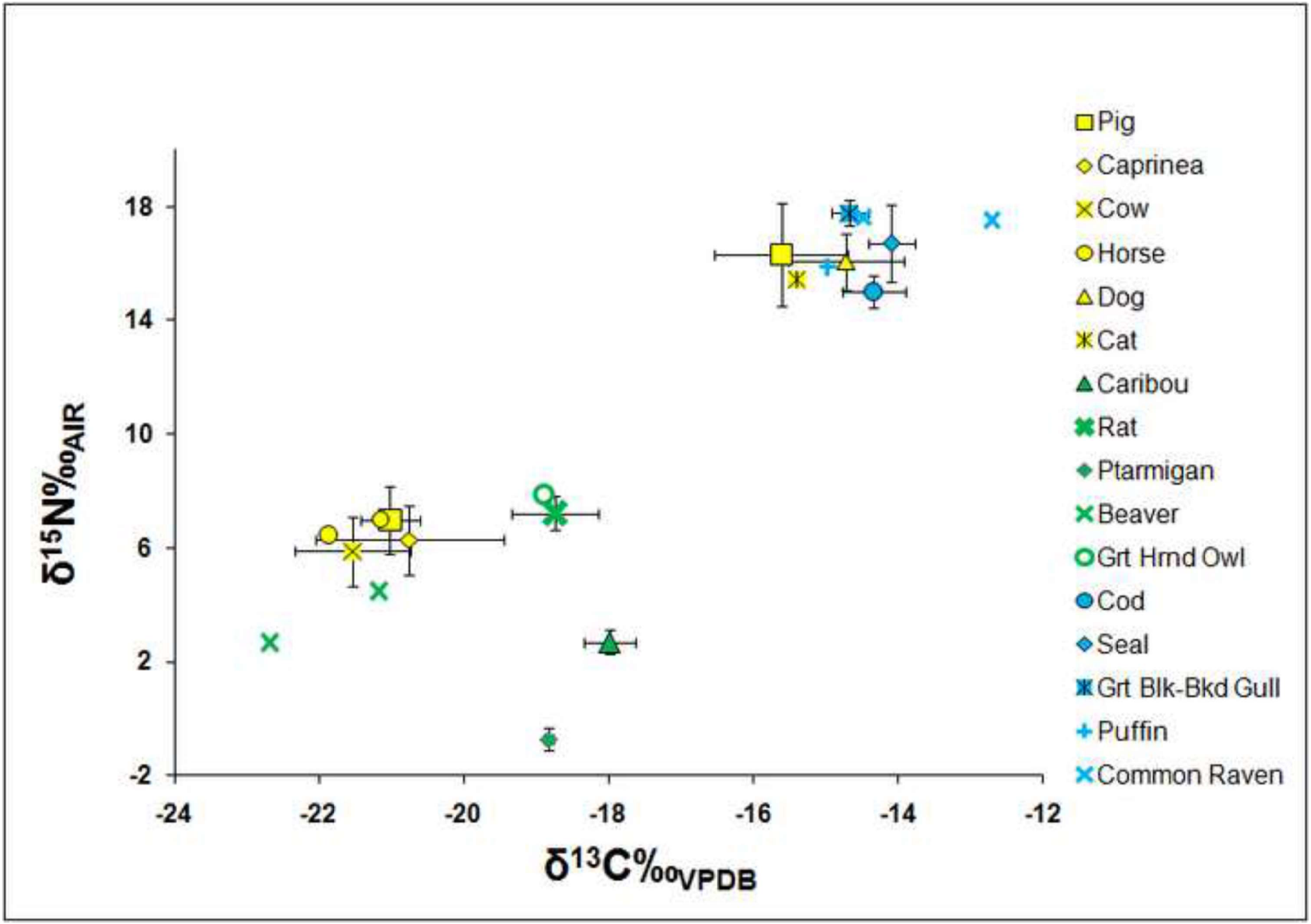
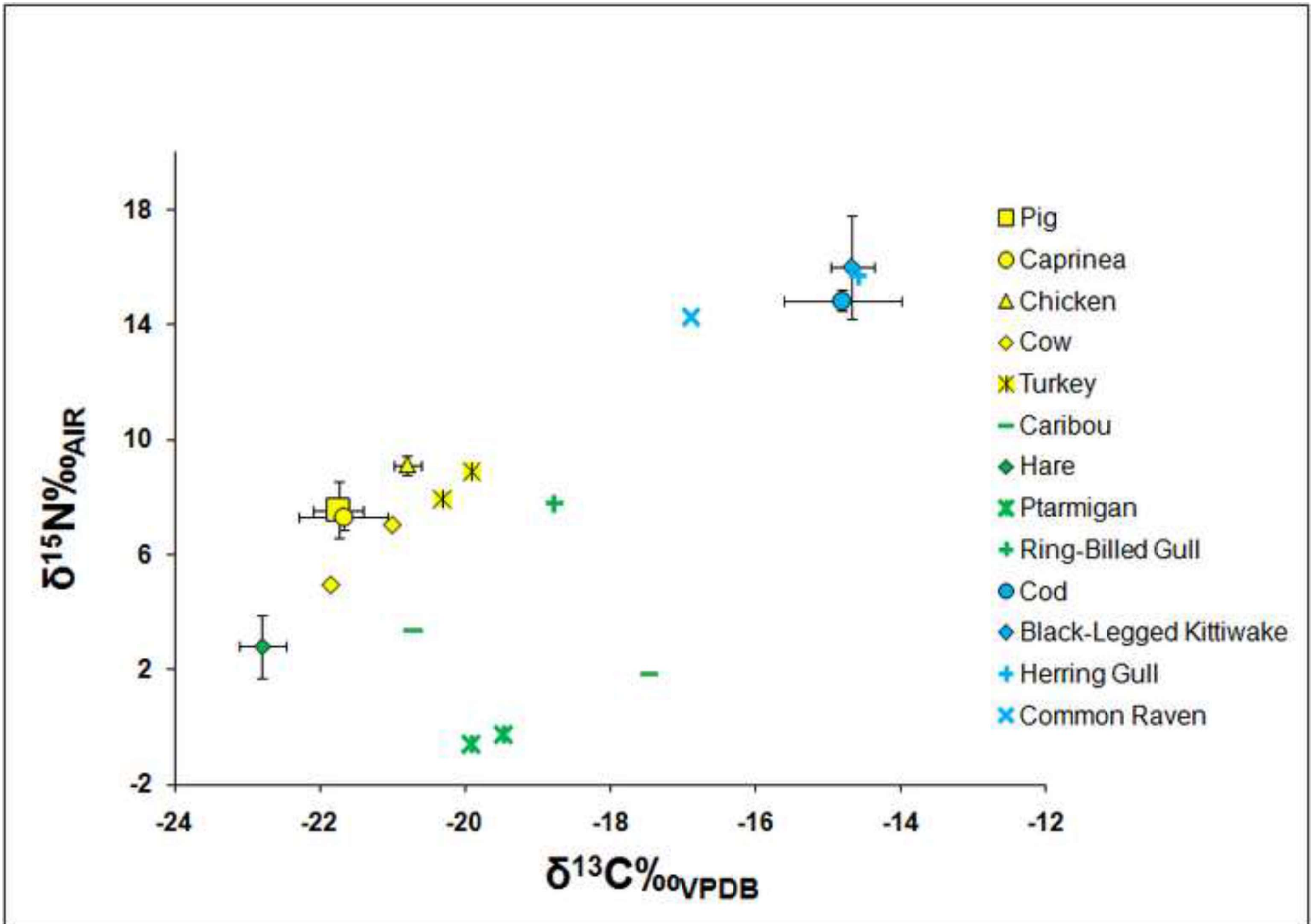


Figure 3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-16
-14
-12
δ15N‰AIR
δ13C‰VPDB
Pig
Caprinea
Chicken
Cow
Turkey
Caribou
Hare
Ptarmigan
Ring-Billed Gull
Cod
Black-Legged Kittiwake
Herring Gull
Common Raven

Figure 4

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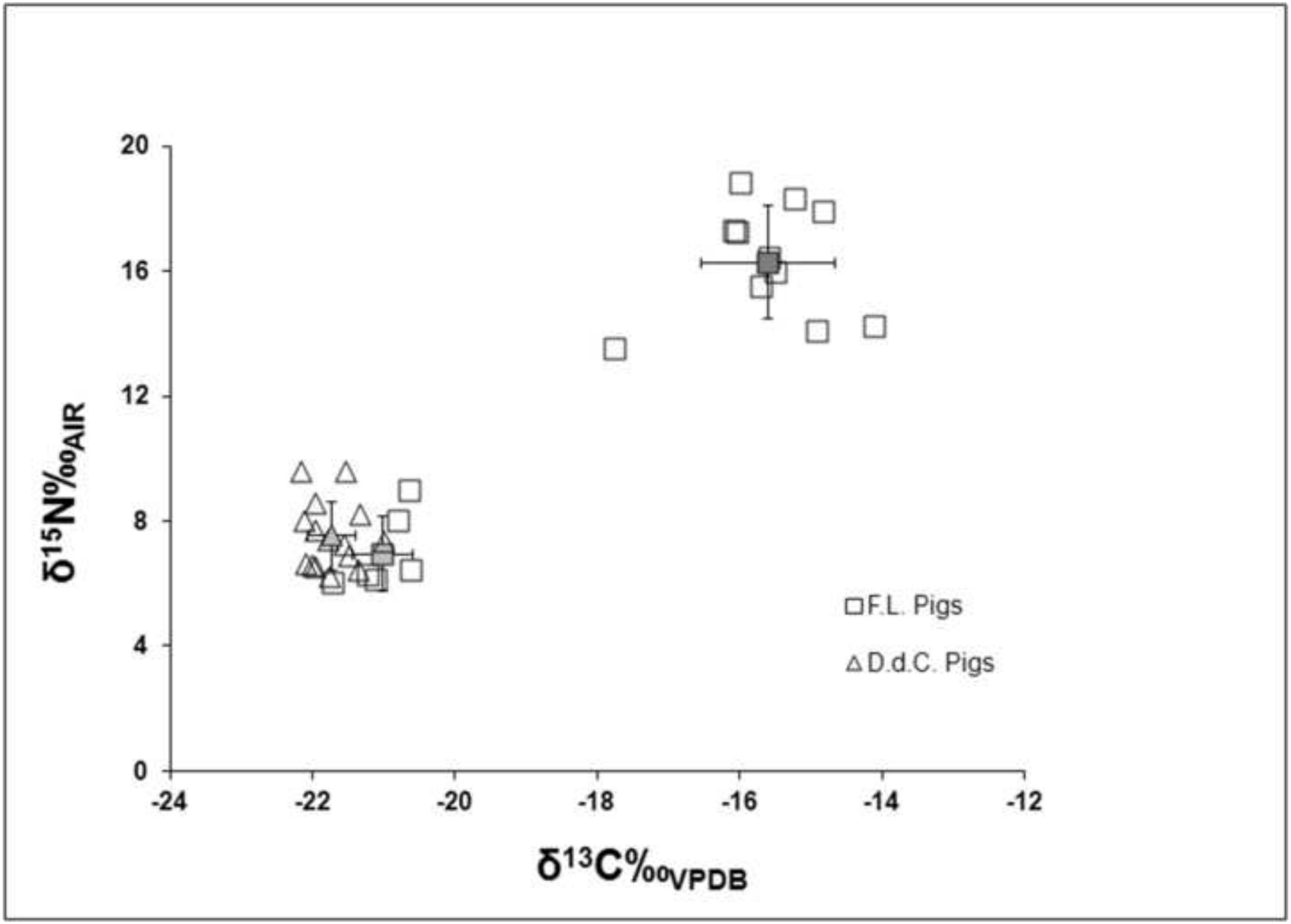

Figure 5
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