Reports

Mesolithic and Neolithic Subsistence in Denmark: New Stable Isotope Data

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The change in subsistence at the Mesolithic/Neolithic transition in Denmark is often characterized as rapid, with a dramatic shift from a marine diet in the Mesolithic to a terrestrial-based diet in the Neolithic. This view has been largely based on the work of Tauber (1981), who observed this dietary shift in stable carbon isotope values for human bone from various coastal sites. Crucial to Tauber's argument are the radiocarbon dates he obtained for each of the isotope samples, for the ages are used to categorize samples as Mesolithic or Neolithic. In this reassessment of his pioneering work, we report on new carbon and nitrogen stable isotope values and radiocarbon dates for Danish Mesolithic and Neolithic humans, including some obtained by remeasuring a number of Tauber's samples. We first briefly describe the Late Mesolithic and Early Neolithic in Denmark and the major characteristics of the transition. We next consider the work by Tauber that has been seminal in studies of the transition. In subsequent sections we present new radiocarbon dates and stable isotope measurements from human skeletal material from the Mesolithic and Neolithic. The concluding discussion summarizes our results and emphasizes the need for more analyses of radio- and stable isotopes from this important transition period.

THE MESOLITHIC-NEOLITHIC TRANSITION IN DENMARK

The Mesolithic and Neolithic archaeological record in Denmark is exceptional in Western Europe. It has rich artifactual evidence from both periods and provides us with some of the best material data for exploring the process of change that occurred at the Mesolithic/Neolithic transition.

The Late Mesolithic Ertebølle culture is found in northern Germany, Denmark, and extreme southwestern Sweden between approximately 5400 and 3900 cal B.C. (Larsson 1990, Price 1991). The Ertebølle is characterized by both flaked and ground stone assemblages. An elaborate blade technology, projectile points, and flake and core axes are typical, and ground stone artifacts include axes, celts, and other tools. A wide range of fishing gear, including nets, weirs, leisters, hooks, and harpoons, is known from this period. Ceramic containers came into use after 4700 cal B.C. in several forms. This pottery and other distinctive artifact types such as T-shaped antler axes, bone rings, and Danubian shaft-hole adzes document the exchange of both ideas and materials between Scandinavian hunter-gatherers and the farmers of Central Europe 100 km or so to the south (Fischer 1981, Zvelebil and Rowley-Conwy 1984).

The primary focus of settlement in the Ertebølle was along the coast, where hunter-gatherers used boats and paddles, erected large fishing weirs, and successfully exploited the rich resources of both the sea and the land. Fish, fowl, mollusks, crustaceans, and sea mammals were all prey for them, and a wide range of fish from both marine and freshwater habitats was taken with a variety of equipment (see, e.g., Enghoff 1994). Large shell middens along some coasts document the incorporation of shellfish into Mesolithic diets. Terrestrial resources were also varied and abundant. Red deer, wild pig, and roe deer were the primary terrestrial animals of economic importance. Other animals were also hunted and trapped, including a variety of small fur-bearing species: marten, otter, wolf, wildcat, and squirrel. Plant foods also contributed substantially to the diet. Enormous quantities of hazelnut shells are found at many Mesolithic sites, along with the remains of acorns, water chestnuts, and nettles, and fruits such as wild strawberry, apple, and sloe, hawthorn, rowan berries, and raspberries (Price 1989, Regnell 1995, Zvelebil 1995). A recent study of the plant remains from Tybrind Vig, dating to 5600–4000 cal B.C., indicates the variety of plants, including aquatic species, used by Mesolithic peoples (Kubiak-Martens 1999).

Evidence is often present at coastal sites for summer, autumn, and winter residence, making year-round occupation likely. The picture is one of large settlements extending 200–300 m along the coast (Andersen 1991, Price et al. 2001). House structures are rare (cf. Sørensen 1995), but cemeteries are an important hallmark of later Mesolithic settlements (e.g., Albrethsen and Pedersen 1977; Larsson 1984, 1989). Numerous examples of trauma and violent death among Mesolithic burials suggest conflict, perhaps a result of intergroup raiding.

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The Early Neolithic in Denmark, known as the Funnel Beaker culture (TRB), is conventionally dated between 3900 and 3300 cal B.C. Funnel Beaker pottery and polished flint axes are its hallmarks. Cereal cultivation and animal husbandry were practiced, with domesticated plants including emmer and einkorn wheat and naked and hulled barley (Koch 1998) and domesticated cattle, pig, sheep, and dog. The oldest reliable published radiocarbon date for a domestic animal other than the dog comes from a cow bone at the site of Øgårde in the Store Åmose, Zealand, ca. 3850 cal B.C. (Koch 1998, Persson 1999).

Evidence for the Danish Early Neolithic comes from settlements, long barrows with timber burial chambers, bog site offerings, and flint mines. The number of initial Neolithic settlement sites is limited; both residential sites and hunting stations are known, often on top of coastal Ertebølle sites. In general, however, Early Neolithic sites are situated in the interior, on lakes or streams where fresh water was easy obtainable and conditions for cattle grazing were favorable (Madsen and Jensen 1982). Residential sites are small and have thin cultural layers compared with Late Mesolithic settlements, suggesting that coresident groups in the Neolithic were smaller or perhaps more mobile (e.g., Andersen 1993). This change may represent reduced numbers of people or perhaps changes in settlement associated with cattle pastoralism.

Evidence for substantial forest clearance or extensive cultivation is lacking before 3300 B.C. (Andersen and Rasmussen 1993). The basic pattern of subsistence involved terrestrial hunting and gathering, seal hunting, fishing, cereal cultivation, cattle breeding, and pig herding. Cattle were the most common livestock and increased in number in the course of the Funnel Beaker period, representing more than 80% of the domestic animals at some younger sites.

The transition from the Mesolithic to the Neolithic is a fascinating process. There is evidence for both change and continuity and for both rapid and slow transformation. The evidence for change takes the form of new artifacts (TRB pottery, polished flint axes), new types of graves (earthen long barrows), more inland settlements, exotic domestic plants and animals, and an emphasis on terrestrial foodstuffs. At the same time, continuity can be observed in the basic lithic industry, utilitarian pottery, and occupation of the same coastal localities. The overwhelming impression is one of the addition of new features to an existing cultural system. Because of the evidence for continuity, the transition is generally thought to represent the indigenous adoption of agriculture rather than colonization by foreigners (Koch 1998, Nielsen 1987, Price 2000*b*).

The rate of the transition can be understood as either slow or rapid. On the one hand, there were probably Neolithic groups at the mouth of the Oder, no more than 100 km distant, by 4500 B.C.; Mesolithic societies along the coast of the Baltic and the North Sea resisted the spread of the Neolithic for almost 1,500 years. Although there was some exchange of raw materials and finished products, the boundary between Mesolithic and Neolithic prevented the spread of domesticates and certain Neolithic features. On the other hand, once the barrier was raised, the Neolithic moved across northern Germany and southern Scandinavia like wildfire. Funnel Beaker ceramics are first found on the coast of Mecklenburg after 4100 B.C. and by 3900 B.C. in the Stockholm area of east-central Sweden, more than 700 km away (Hallgren et al. 1998, Lübke 2001, Price 2000*b*). Such rapid rates for the transition are generally thought to reflect demic diffusion associated with the Neolithic Cardial or Linearbandkeramik expansion in Europe (Price 2000*a*).

The shift from coastal to terrestrial resources documented by Tauber is an important component of most explanations of the transition. Some argue for resource stress, particularly declines in marine productivity associated with the climate changes of this period (Rowley-Conwy 1984, Larsson 1990). Others emphasize the shift to inland settlement as reflecting resource stress or incoming populations (Madsen 1985, Nielsen 1987). Fischer (1981), Jennbert (1985), and Price (1996) consider competition and prestige models responsible for the transition, and still others, such as Whittle (1996), see the adoption as somehow motivated by spiritual or religious changes in society. It is difficult to overestimate the importance of the coastal-terrestrial shift in diet described by Tauber in discussions of the transition from hunting to farming in the Stone Age of Scandinavia. The emphasis on a rapid change in diet and a concomitant shift from coastal to inland settlement has been particularly pronounced since Tauber's 1981 publication.

TAUBER'S ISOTOPE DATA

Tauber's study, the first application of stable isotope analysis of prehistoric human skeletal material in Europe, was remarkably sophisticated for its time. Tauber measured the stable carbon isotope ($\delta^{13}C$) values of radiocarbon-dated humans from the Mesolithic, Neolithic, and younger contexts in Denmark and found that the Mesolithic humans from coastal sites had strongly marine $\delta^{13}C$ values (approaching $-12‰$) that contrasted with the terrestrial $\delta^{13}C$ values (ca. $-20‰$) of humans in the subsequent Neolithic period and indeed all of the later time periods he examined. When he expanded this initial study to include more Mesolithic and Neolithic samples (Tauber 1983, 1986), he found the same pattern. He concluded that there was a dramatic change in diet with the introduction of the Neolithic into Denmark. We have replotted the data from Tauber (1983) in figure 1.

The apparent rapid change in diet at the Mesolithic/Neolithic transition may be misleading, as the data have not been corrected for the marine-reservoir effect. The differences in radiocarbon ages between organisms that derive their carbon from the ocean and those that derive it from the atmosphere are well known (Stuiver and Braziunus 1993). There is, on average, a difference of 400 radiocarbon years between similar-aged samples that de-

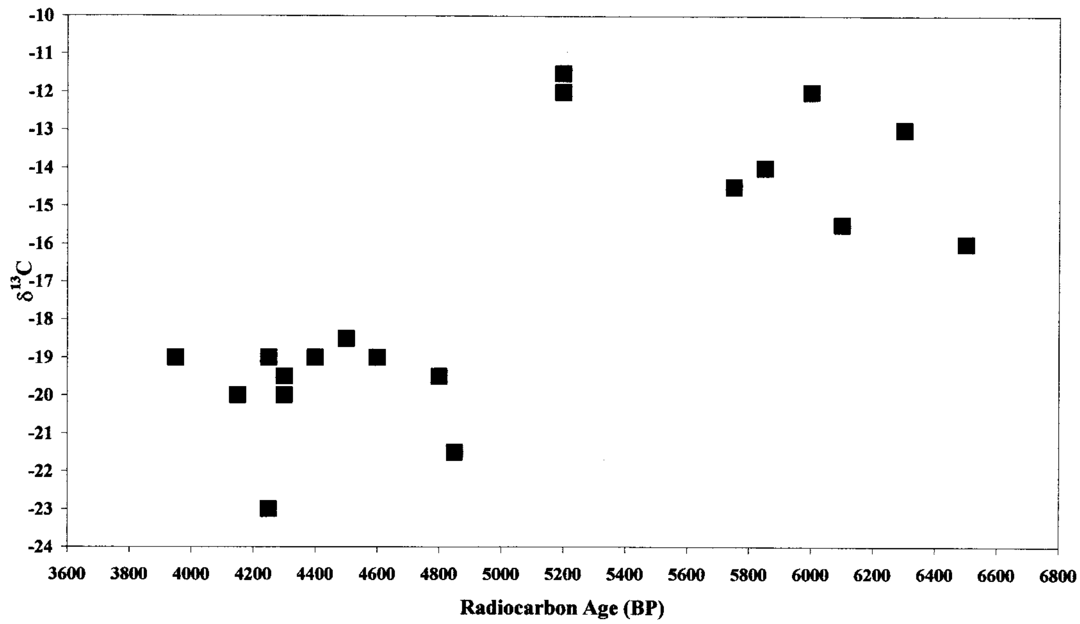

FIG. 1. *Radiocarbon ages and associated $\delta^{13}C$ values of humans from Mesolithic and Neolithic contexts in Denmark, taken from Tauber (1983). The radiocarbon ages have been converted from calibrated ages* B.C. *(originally calibrated by Tauber using the Clark [1975] calibration curve) to uncalibrated radiocarbon years* B.P.

rive their carbon from these two different reservoirs. Therefore, if the marine $\delta^{13}C$ values of the Ertebølle humans are reflecting a marine diet and the carbon in that collagen comes mostly from the marine reservoir, the radiocarbon ages for late Ertebølle humans may be too old by 200–400 years. Applying this correction to the latest Ertebølle humans makes them contemporary with the earliest Neolithic humans. Assuming the validity of this correction here, the latest Ertebølle and the earliest TRB actually *overlapped*.

However, correcting Tauber's radiocarbon dates for the marine-reservoir effect is not necessarily valid, because those dates are not conventional radiocarbon dates. By convention the $\delta^{13}C$ of all radiocarbon samples has to be measured to account for ^{14}C fractionation and corrected to a standardized average of −25‰ (Stuiver and Polach 1977). A $\delta^{13}C$ difference of 1‰ between the sample and the average subtracts about 16 radiocarbon years from the date. Marine shells have a $\delta^{13}C$ of 0‰ and therefore have to be corrected by $25 \times 16 = 400$ years. Therefore, 400 radiocarbon years have to be subtracted from the raw radiocarbon age to make it a conventional radiocarbon age. But Tauber (1983) argues that the marine-reservoir effect in northern Europe is 400 years and that there is no need to subtract 400 radiocarbon years from the age of the shell sample when it has to be added on again to account for the marine-reservoir effect. Therefore, Tauber does *not* correct marine samples for fractionation to −25‰ before reporting them. We interpret this as meaning that he did the same with his bone dates when they had $\delta^{13}C$ values of −12‰ (indicating a marine diet) and did not adjust them to the internationally accepted value of −25‰. Therefore, it is impossible to apply a marine calibration to the dates because they are not conventional radiocarbon ages and are probably close to the value they should be if they had been corrected for the marine effect.

To further illustrate this point, we focus now on two of the most interesting samples, the latest Mesolithic and earliest Neolithic dates from the site of Dragsholm. These burials are only two metres apart, and one is a male and the other two females. Two of the burials have been dated (Brinch Peterson 1974). The earlier, female burial has a $\delta^{13}C$ value indicating a marine diet and is buried with Mesolithic artifacts, and the later, male burial has a $\delta^{13}C$ value indicating a terrestrial-protein diet and is buried with Neolithic artifacts. If the female date is marine-corrected (Stuiver and Braziunus 1993) and the male calibrated using the atmosphere curve (Stuiver et al. 1998), the calibrated ages overlap, but this would be remarkable in that the two individuals have very different subsistence practices and material culture. If, however, we correct the date of the female burial to make it a conventional radiocarbon age and then apply the marine correction, it is unlikely that the burials overlap, and the female burial is older than the male (table 1).

Unfortunately, the original raw radiocarbon and isotope data for the Mesolithic and Neolithic humans (Tauber 1981, 1983, 1986) have never been published. We have suggested some possibilities for correcting and reinterpreting the dates, but without access to the original data it is impossible to do this accurately and confi-

TABLE 1
Dragsholm Radiocarbon Dates and $\delta^{13}C$ Values

Sample	Age/Sex	$\delta^{13}C$	^{14}C Age B.P.	Calibrated B.C.	Corrected to −25‰ B.P.	Recalibrated B.C.
K-2224	Adult female	−11.5	5,160 ± 100	3960–3460 (marine curve)[a]	5,375 ± 100	3910–3690
K-2291	Adult male	−21.5	4,840 ± 100	3730–3510 (atmospheric curve)[b]	n.a.	n.a.

[a]Stuiver and Braziunus (1993).
[b]Stuiver et al. (91998).

dently. Therefore, for the remainder of this paper we will focus on dates that we know conform to the current conventions for reporting radiocarbon dates.

NEW ^{14}C DATA

Since Tauber's time a significant number of new radiocarbon dates for Mesolithic and Neolithic humans in Denmark has become available, and as part of the radiocarbon dating process $\delta^{13}C$ values for bone collagen have also been measured. We have plotted these new data in figure 2. With these data the change in subsistence at the Mesolithic/Neolithic transition that Tauber reported is still apparent, but it is shifted farther back in time, coinciding better with the dates for the first appearance of TRB material culture in this region. Interestingly, these shifted values are almost identical to the dates for the earliest Neolithic of Britain and Ireland (Williams 1989). The data also indicate an interesting increase in the proportion of marine foods in Mesolithic diets over time.

$\delta^{13}C$ AND $\delta^{15}N$ VALUES

Since Tauber's pioneering work it has become easier to measure the stable nitrogen isotope ($\delta^{15}N$) value of bone collagen along with the $\delta^{13}C$ value. Both of these collagen isotopes tell us about the protein portion of lifetime (approximately ten years prior to death) diets (Ambrose and Norr 1993). Whereas the $\delta^{13}C$ value indicates whether the dietary protein was from marine or terrestrial sources (Chisholm, Nelson and Schwarcz 1982), the $\delta^{15}N$ value indicates the trophic level of the protein consumed, collagen $\delta^{15}N$ values in humans being 2–4‰ higher than the $\delta^{15}N$ value of dietary protein (Schoeninger and DeNiro 1984). We report the carbon and nitrogen isotope values for a number of Danish Mesolithic and Neolithic individuals in table 2 and fig. 3. The individual from Tybrind Vig and two samples from Vedbæk (graves 3 and 5) were measured by Tauber in the early 1980s.

Most of the samples were prepared following standard collagen preparation procedures (Richards and Hedges 1999). In short, whole bone samples were demineralized in 0.5M HCl at 5°C for 2–5 days. The samples were then gelatinized for 48 hours at 75°C in sealed tubes, and the resultant gelatin was filtered and then lyophilized before combustion. The Aldersro samples were also ultrafiltered (30 kd) before lyophilization (Brown, Nelson, and Southon 1988). Isotope measurements for most of the samples were undertaken at the University of Oxford; two of the Vedbæk (graves 5 and 8) samples were measured at Simon Fraser University.

MESOLITHIC STABLE ISOTOPE VALUES

Tauber (1983) reported a $\delta^{13}C$ value of −16‰ for Tybrind Vig, which dates to ca. 6,750 ± 80 B.P. (K-3558) (Andersen 1987). Our measurement of the $\delta^{13}C$ value was −17.6‰, indicating less marine protein in the diet. The associated $\delta^{15}N$ value is low, 8.5‰, supporting the idea that terrestrial foods were the dominant protein sources in this individual's diet. Tauber obtained three $\delta^{13}C$ values for Vedbæk, −13‰, −14.5‰, and −15.5‰, similar to the values we found. Our $\delta^{15}N$ values range from about 12‰ to 14‰. Comparing these $\delta^{15}N$ values with those of marine fauna suggests that shellfish or smaller fish were likely the staple protein source of individuals with $\delta^{15}N$ values of about 12‰, with the addition of some larger fish for the individuals with $\delta^{15}N$ values closer to 14‰ (Richards and Hedges 1999). The $\delta^{15}N$ values are too low to indicate that larger fish or marine mammals were the dominant protein sources. In contrast, similar-aged Mesolithic humans from Scotland and Brittany had $\delta^{15}N$ values of about 15–16‰ (Richards and Mellars 1998, Schulting and Richards 2001), probably indicating the consumption of fish rather than higher-trophic-level marine mammals or shellfish.

NEOLITHIC STABLE ISOTOPE VALUES

The Neolithic samples are from various bog bodies in the Store Åmose region of central Zealand (Koch 1998) and from the megalithic tomb of Aldersro (see Richards and Koch n.d. for discussion). The $\delta^{13}C$ values for all of the Neolithic individuals clearly indicate an absence of significant amounts of marine protein in their diets. The $\delta^{15}N$ values are fairly high, indicating a probable diet of mainly animal protein, either meat or milk. It is unlikely that freshwater fish were consumed in any significant quantities by these individuals, as significant consumption of freshwater fish leads to human $\delta^{15}N$ values of greater than 12‰ (Bonsall et al. 1997). Two of the samples were from juveniles, and because weaning and growth have physiological effects on juvenile $\delta^{15}N$ values (Herring, Saunders, and Katzenberg 1998) we do not attempt to interpret the results on them here.

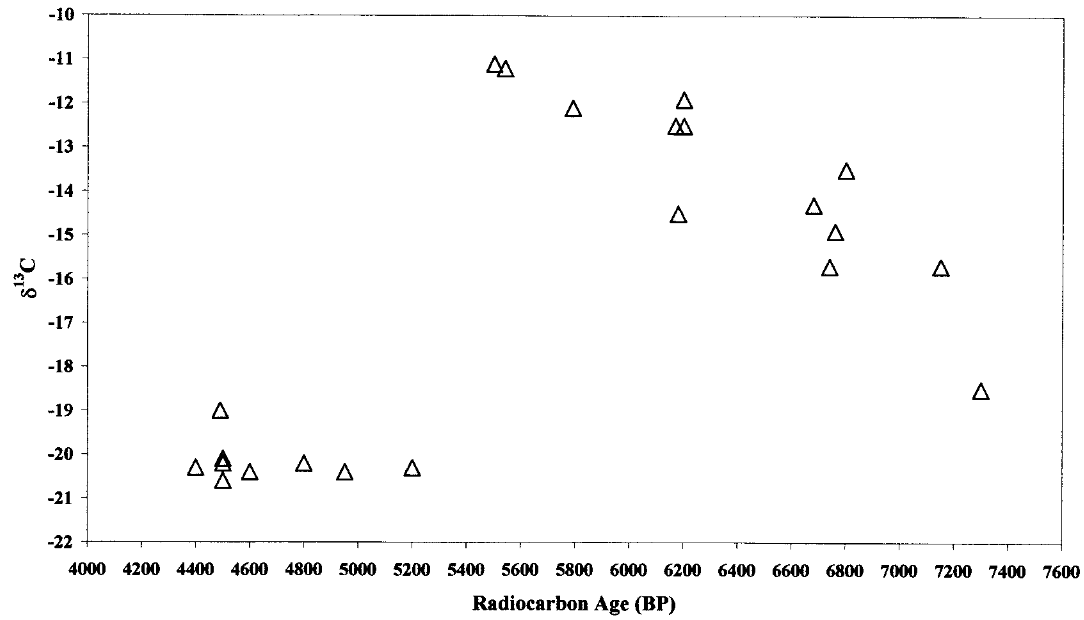

FIG. 2. *Radiocarbon ages and associated $\delta^{13}C$ values of humans from Mesolithic and Neolithic contexts in Denmark, taken mainly from Persson (1999) and excluding all of the data from Tauber (1981, 1983, 1986).*

DISCUSSION

The new radiocarbon and $\delta^{13}C$ values presented here confirm Tauber's findings indicating a dramatic change in diet associated with the introduction of Neolithic material culture into Denmark. However, measurements of both the $\delta^{13}C$ and $\delta^{15}N$ values for Mesolithic and Neolithic humans show that there is no distinct Mesolithic diet. The Mesolithic isotope data indicate a complex range of diets, with some individuals, despite being buried in middens, having partially terrestrial-protein-based diets. The later Neolithic diets, in contrast, are remarkably uniform, indicating the avoidance of marine in favor of terrestrial protein. We cannot tell, using isotopes, whether the terrestrial protein is from the domesticated plants and animals that appear in Denmark in this period, but we believe that this is a reasonable assumption.

The Danish stable isotope evidence presented by Tauber was a model study, and others have attempted to see if the same pattern of a relatively rapid change in diet occurred in other areas of Europe at the Mesolithic/Neolithic transition. Lubell et al. (1994) compared individuals from midden sites that were estuarine, not clearly marine, with Neolithic burials from caves in Portugal, and their data show generally that Mesolithic diets had a strong marine component and that by the middle Neolithic there was a significant shift to mainly terrestrial foods. Recent stable isotope work in Brittany has shown that Mesolithic diets were largely marine-based (Schulting and Richards 2001). In the United Kingdom the scarcity of Mesolithic human remains is a problem, but a few studies do show the importance of marine foods in the diets of Late Mesolithic coastal peoples from the site of Oronsay (Richards and Mellars 1998). There is now, however, a substantial amount of isotope data on Early and Middle Neolithic humans indicating a completely terrestrial diet (Richards and Hedges 1999). In south-eastern and eastern interior Europe there is stable isotope evidence of an aquatic-based diet (likely freshwater fish) along the Danube (Bonsall et al. 1997) and the Dneiper (Lillie and Richards 2000) that continued to be important in Neolithic times. Generally, Denmark has the best stable isotope data in northern Europe for the Mesolithic and Neolithic periods, and these data indicate a clear dietary transition which is echoed in the Breton and U.K. data. Earlier sites in southern and eastern Europe do not show such a transition. Stable isotope analysis in Europe is in its infancy, however, and new isotope data are being produced all the time that may lead to a clearer picture of dietary changes across the Mesolithic/Neolithic transition throughout Europe.

CONCLUSIONS

Denmark presents us with an excellent data set with which to explore the Mesolithic/Neolithic transition in Europe. Stable isotope measurements of human bone by Tauber in the 1980s indicated the Mesolithic diets were mainly marine-based and Neolithic diets terrestrial-based. He saw a rapid change in diets associated with the introduction of the Neolithic. His data have never been published comprehensively, and there are questions about how he arrived at the calibrated ages he reports. Specifically, it is largely unclear from his data that he has taken marine-reservoir effects into account. New $\delta^{13}C$ data associated with radiocarbon dates taken from

TABLE 2
Carbon and Nitrogen Isotope Values for Mesolithic and Early Neolithic Human Bone from Denmark

Sample	Site	Age/Sex	Age	^{14}C Age B.P.	^{14}C No.	^{14}C $\delta^{13}C$	$\delta^{13}C$	$\delta^{15}N$	CN	%C	%N	%Yield
CE7	Tybrind Vig	Adult F	E-Ert	6,750 ± 80	K-3558	−15.7	−17.6	8.5	3.7	27.7	8.8	1.7
Grave 3	Vedbæk	Adult F	L-Ert	6,050 ± 750	K-2781	−15.3	−13.6	11.3	3.0	36.1	13.9	5.2
Grave 4	Vedbæk	Adult M	L-Ert	—	—		−13.4	13.8	3.1	31.3	11.8	4.9
Grave 5	Vedbæk	Adult M	L-Ert	6,290 ± 75	K-2782	−13.4	−16.5	11.9	3.2	32.9	12.2	6.5
Grave 8	Vedbæk	Adult F	L-Ert	—	—		−14.7	10.6	3.0	35.2	13.4	—
Grave 9	Vedbæk	Adult M	L-Ert	—	—		−13.6	13.0	3.1	34.6	13.1	2.0
DK-2	Ostrup, Store Åmose	Adult F	TRB	4,510	K-5142		−19.6	9.9	3.2	43.5	16.0	6.8
DK-3	Ostrup, Store Åmose	Adult M	TRB	4,530 ± 90	K-5741	−20.7	−20.0	10.0	3.3	46.5	16.2	12.5
DK-4	Undlose, Store Åmose	Adult F	TRB	4,760 ± 95	K-6300	−20.2	−20.3	8.2	3.3	44.3	15.8	15.1
DK-5	Bodal, Store Åmose	Adult M	TRB	5,025 ± 40	AAR-5360	−20.8	−20.7	8.0	3.2	43.1	15.6	6.7
ARX-516	Aldersro	Adult F	TRB	4,010 ± 50	AAR-6544	−20.6	−20.7	7.5	3.2	43.4	15.8	6.7
ARX-528	Aldersro	Adult F	TRB	4,410 ± 55	AAR-6545	−19.5	−19.4	8.0	3.2	43.0	15.6	6.9
ARX-537	Aldersro	Adult M	TRB	4,190 ± 60	AAR-6546	−19.6	−19.8	8.0	3.3	42.0	15.1	3.2
ARX-553	Aldersro	Child (3–5)	TRB	—	—		−19.9	8.8	3.2	42.8	15.7	5.9
ARX-572	Aldersro	Child (5–7)	TRB	4,060 ± 45	AAR-6547	−20.2	−20.2	6.3	3.2	44.9	16.3	9.8
ARX-987	Aldersro	Adult	TRB	4,410 ± 55	AAR-6548	−19.6	−19.6	9.3	3.3	40.5	14.4	6.5
ARX-1115	Aldersro	Adult	TRB	4,420 ± 60	AAR-6549	−19.7	—	—	—	—	—	0.3
ARX-1191	Aldersro	Adult	TRB	4,100 ± 50	AAR-6551	−19.9	−20.0	8.7	3.2	45.1	16.7	9.4
ARX-1184	Aldersro	Adult	TRB	4,350 ± 50	AAR-6550	−19.2	−19.2	9.0	3.2	45.1	16.4	5.2

NOTE: Errors (1σ) are ± 0.3‰ for the $\delta^{13}C$ values and ± 0.4‰ for the $\delta^{15}N$ values. E-Ert, early Ertebølle; L-Ert, Late Ertebølle; M, Mesolithic; TRB, Funnel Beaker. The Tybrind Vig date and two Vedbæk dates (graves 3 and 5) are from Tauber (1983) and therefore may not be conventional radiocarbon ages. The Store Åmose dates are taken from Koch (1998) and the Aldersro dates from Richards and Koch (n.d.). The Vedbæk grave 5 isotope results are the average of two measurements made at Oxford ($\delta^{13}C = -16.35$, $\delta^{15}N = 12.09$) and at Simon Fraser University ($\delta^{13}C = -16.55$, $\delta^{15}N = 11.78$). The grave 8 isotope measurement was made at Simon Fraser University. The ^{14}C $\delta^{13}C$ values were determined by the radiocarbon labs when the dates were measured.

the literature support Tauber's findings but push back the age of the transition to about 5,200 B.P. (4000 cal B.C.), where Tauber's dates put it at closer to 5,000 B.P. (3800 cal B.C.). New $\delta^{13}C$ and $\delta^{15}N$ data for a number of the samples Tauber measured as well as new samples also show a difference between Mesolithic and Neolithic diets, although the numbers are small. However, the new data also show that Mesolithic diets were more complex than previously recognized, with some individuals in the Mesolithic having largely terrestrial diets.

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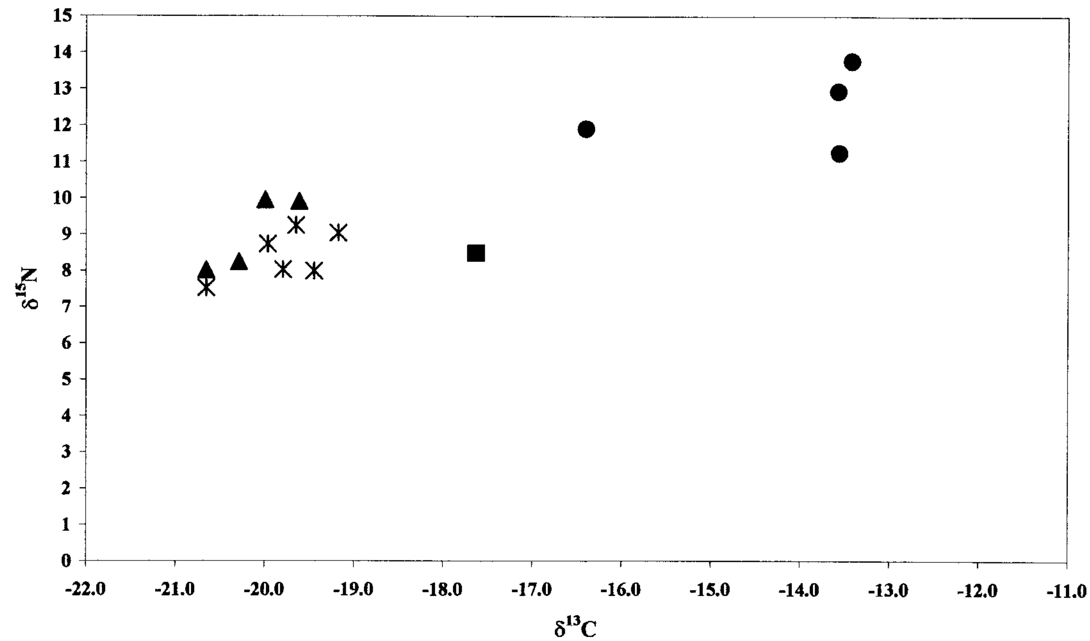

FIG. 3. *Bone collagen $\delta^{13}C$ and $\delta^{15}N$ values for various Mesolithic and Neolithic humans from Denmark. Errors are ± 0.3‰ on the $\delta^{13}C$ values and ± 0.4‰ on the $\delta^{15}N$ values.* filled circle, *Vedbæk Mesolithic;* filled square, *Tybrind Vig Mesolithic;* filled triangle, *Store Åmose Neolithic;* asterix, *Aldersro Neolithic.*

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