Excerpt from N. Milner, G. Bailey & O. Craig (eds.) Shell middens and coastal resources along the Atlantic facade. Oxford. Oxbow. 2007.

5

Coastal fishing in Stone Age Denmark – evidence from below and above the present sea level and from human bones

Anders Fischer

Introduction

Once upon a time there was a high school student who was keen on searching for Mesolithic settlements by walking the beaches close to his home (Fig. 5.1, area A). He had a big map of the area on the wall in his room and each time he found a new site he marked it on the map with a red drawing pin. One evening a dedicated hobby fisherman visited his parents. This fisherman was also rather dedicated to drinking beer. So after some time he had to leave the party to find the bathroom. Accidentally he happened to look into the student's room. That got him so upset that he forgot everything about the bathroom: he ran back to the party crying "who has told you the secrets of my best fishing sites?"! Nobody had: there was just a surprisingly high correlation between his fishing sites and the young man's Stone Age sites. This observation and subsequent similar observations lead to the development of what the author has termed "the fishing site model" (Fischer 1993b; cf. Johansson 1964; Fischer and Sørensen 1983) (Fig. 5.2).

This paper will outline how the fishing site model was developed and tested through extensive underwater surveying of the Danish waters. It will then detail evidence of preserved fish weirs, many of which date to the Neolithic period. Finally, it will comment on how this research impacts on the current dietary debates surrounding the Mesolithic Neolithic transition and the theory of "turning their backs on the sea" and will provide new interpretations which help integrate the stable isotope and archaeological datasets.

Testing the fishing site model by diving

The initial application of the fishing site model in combination with archaeological sea floor reconnaissance took place in the Småland Bight (Fig. 5.1, area C). The diving test profited significantly from the use of commonly available information on quaternary geology, coastal morphology and sea floor sedimentary conditions of the area under study. Through the use of this knowledge the survey could deliberately be focused on certain places which seemed relatively uninfluenced by erosion and sedimentation.

Astonishingly, it showed that in many locations worked flints of Late and Middle Mesolithic age were readily at hand on the surface of the sea floor, or only a few centimetres below. The success rate of predictions based on the model was in excess of 75% (as can be seen from the field report of which a large part is available in English, Fischer 1993b). During these underwater surveys a small number of relatively well preserved settlement structures were also recorded (Fischer 1993b, 71, 120, 127–129). Most spectacular was a Middle Mesolithic fireplace with charcoal and ash still in its original position (Fischer *et al.* 1987, 111; Fischer 2004, 27).

The high correlation between model-based prediction and finds of Mesolithic settlement remains in the Småland Bight supported the assumption that fishing with stationary structures was an important part of the subsistence economy, not only for the Late Mesolithic but also for the Middle Mesolithic in this part of the Danish archipelago.

Subsequent underwater surveys based on the fishing site model in the Storebælt, Øresund and Århus Bay areas (Fig. 5.1, areas D–F) resulted in the location of a series of settlement finds spanning not just the Late and Middle Mesolithic but also the Early Mesolithic (Fischer 1992, 1993c, 1997a, 1997b, 2001; Fischer and Malm 1997). In

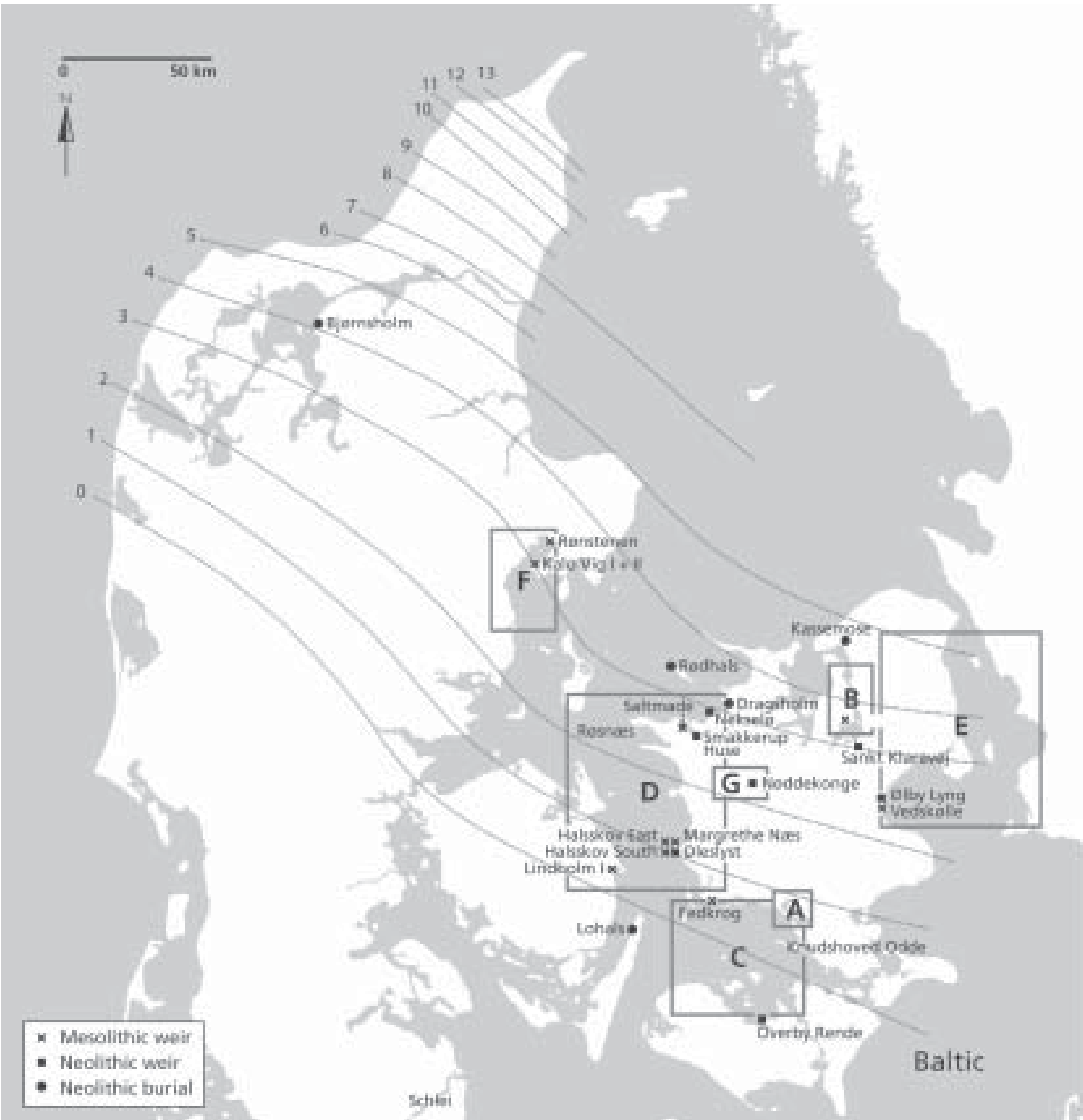

Fig. 5.1: Map of Denmark with sites and research areas mentioned in the paper. The dotted lines show the land rise, in metres, since the highest sea level around the shift from the Mesolithic to the Neolithic, according to Mertz (1924).

a number of cases the remains of stationary fishing fences (weirs) were found at a short distance down the slope from these sites. They showed up in the form of poles driven into the sea bed and remains of wicker-work material imbedded in marine deposits, apparently deposited during the habitation period of the adjacent sites.

During the underwater surveys in the Århus Bay area (Fig. 5.1, area F) there were several attempts to revisit sites previously reported to museums by amateur archaeologists and sports divers. The outcomes of these attempts were generally disappointing and in some cases totally unsuccessful. The main reason for this misfortune appeared to be imprecise recording of site locations in the museum files. In fact, it proved easier to find new sites, aided by the fishing site model, than to revisit the previously reported ones. Moreover, some of the newly found sites appeared more interesting than those found earlier on, either because they were significantly older and/or because they had sediments with cultural deposits of bone, antler and wood (Figs 5.3–5.5).

The first survey in the Århus Bay area was done with the aid of three sports divers possessing high standards of archaeological field experience and a small, rebuilt fishing boat. During this expedition a day at sea usually resulted in two, sometimes three new sites. Later the area was revisited twice with larger ships and larger teams (Fig. 5.6). Even though the latter teams generally comprised sports divers who were less trained archaeologically than the first group, the results of these expeditions were also highly rewarding (Fig. 5.7).

Following on from the survey expeditions, a professional team of underwater archaeologists have undertaken test excavations of one of the

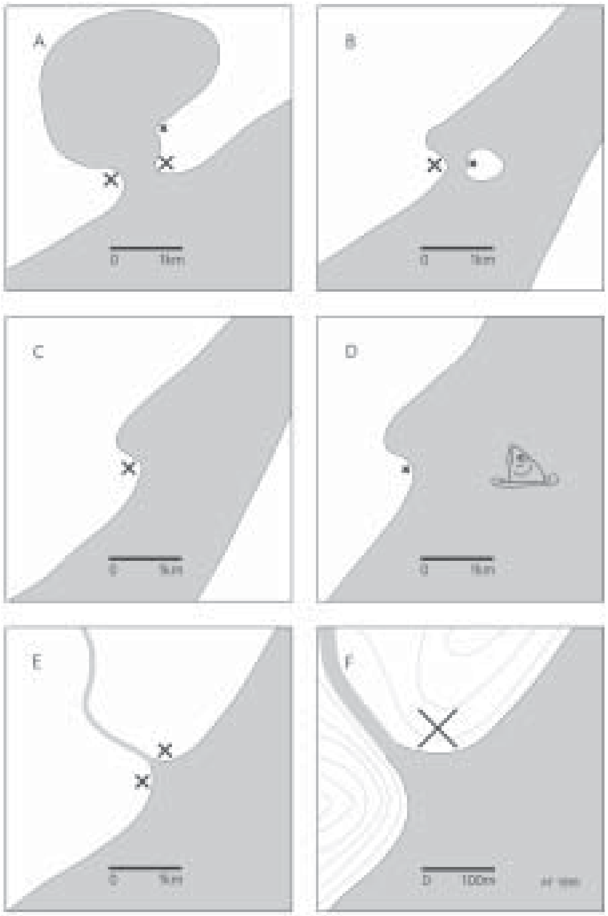

Fig. 5.2: The fishing site model, which is based on the assumption that coastal Mesolithic settlement clusters around places suited for fishing with permanent structures (Reproduced from Fischer 1997a).

most promising sites recorded in the Århus Bay: the Kalø Vig site. This consists of two horizontally and laterally displaced concentrations of worked flint. One is found at a present water depth of *c.* 5 m, while the other lies at a depth of *c.* 6.5 m (Fig. 5.8). The deeper one is from the very latest part of the Early Mesolithic, Maglemose culture. The higher one belongs to the subsequent, very early part of the Middle Mesolithic, Kongemose culture (Fischer 2001; Fischer and Hansen 2005). In a marine shallow water deposit off the former settlement, poles were found from a wooden fish weir (Fig. 5.9). One of these poles has been ^{14}C dated to *c.* 6400 cal BC. This is, at present, probably the oldest date for a permanent fishing construction known from Denmark.

Status

Over the years a variety of methods have been applied for the purpose of recording traces of Stone Age habitation on shallow stretches of the now submerged parts of the Danish sea floor. Visual inspection through diving is the easiest and cheapest approach and has, so far, been the most productive. Approaches using geological drilling equipment, industrial digging machines and sand pumping boats have also proved very helpful in the initial location of submerged culture layers, especially in areas covered by deep layers of post Mesolithic sediments.

At present, around 1500 Stone Age find spots on the Danish sea floor have been recorded in the national file of archaeological sites and monuments. Mesolithic coastal settlement is by far the most numerous category of Stone Age site (cf. Table 5.1). The experience from submerged systematic surveys as well as from contract archaeological work implies that there are many more sites of this category to be found.

In the majority of cases flint is the main type of find. The spectacular exceptions are sites with organic preservation which produce a huge variety of wooden implements and food remains. They are typically found in places where sea floor erosion has recently begun as a result of pollution, navigation or construction activities. Systematic underwater excavation of a small number of these sites has demonstrated a remarkable research potential for the study of *e.g.* prehistoric marine resource exploitation (*e.g.* Andersen 1985, 1995; Malm 1995; Skaarup and Grøn 2004).

Similar potential abroad?

In my opinion, similar approaches may also result in numerous finds of submerged Stone Age sites if applied in similar shallow water areas along the Baltic, Atlantic and Mediterranean façades of Europe, or even along other continents where there is relatively little wave exposure. However, there appears to be a significant discrepancy between the amount of fieldwork committed to the investigation of submerged Stone Age sites by archaeologists in Denmark as opposed to most other areas of the world. As an explanation for staying above the sea, colleagues from abroad have frequently expressed the opinion that submerged prehistoric sites will either have been so severely destroyed through erosion or will be so covered under deep layers of later sediments that it is not worth investing resources in the search for them.

However, an equally negative conclusion could be reached about the archaeological potential of the Danish sea floor if only geological maps were consulted. Approximately 80% of the Danish sea bed is classified as mud and sand, which to the inexperienced underwater researcher may sound like a non-rewarding place to start surveying. Nearly all the rest of the Danish sea floor may appear equally unpromising since it is generally described as eroded moraine surfaces and bedrock with possible thin layers of residual sediments (*e.g.* Kuijpers *et al.* 1992). It should be realised, however, that the geological maps represent highly generalised information. As the Danish underwater experience tells us, there are interesting sites to be found when working actively under the water.

Fig. 5.3: Erosion makes it possible to pick up Stone Age artefacts of organic material directly from the sea floor in many places in the Danish archipelago. Here the author has lifted a red deer antler from a submerged dump layer at the middle Mesolithic Rønstenen site (Photo T. Malm 1997).

Fig. 5.4: Hazel sticks from a Middle Mesolithic fish weir exposed by sea floor erosion right off the submerged Middle Mesolithic Rønstenen site. Subsequent excavation revealed that the thicker one had fine cut marks at its base from a flint axe (Fig. 5.5, upper) (Photo A. Fischer 1998).

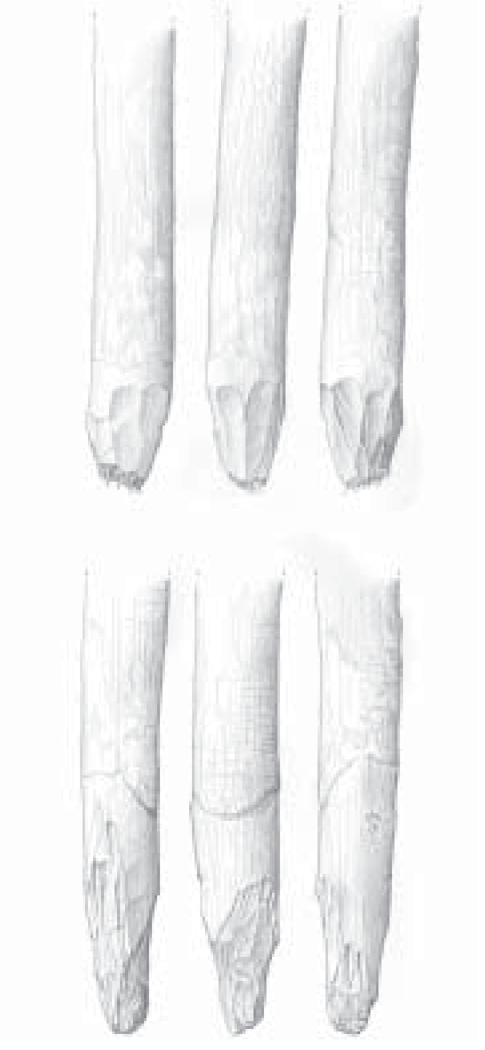

Fig. 5.5: Poles of hazel – parts of fish weirs exposed by sea floor erosion right off the Rønstenen site. Their ends have marks from shaping with axes. They have been ^{14}C dated to c. *5800 cal BC (upper one) and* c. *5450 cal BC (lower one) (Drawing L. Hilmar, Moesgård Museum).*

Table 5.1: Archaeological sites on the Danish sea floor, recorded in the national file of sites and monuments. Status provided by J. Christoffersen, the National Cultural Heritage Agency of Denmark, February 2006.

Period	Finds of "terrestrial" nature			Finds of maritime nature				Total by period
	Settlement	Single find (often of settlement character)	Diverse	Wreck or part of such	Defence construction	Other construction	Single find	
Stone Age	890	578	58	12			6	1544
Bronze Age	7	27	31				1	66
Iron Age	12	82	23	38	28	42	9	234
Prehistory unspecified	36	55	38	22		1		152
Medieval	1	22		48	8	117	8	204
Post reformation		10		58	6	19	12	105
Recent		35	8	3640	9	38	218	3948
Historic unspecified		24	3	110	4	313	29	483
Un-dated		19	20	195	7	20	6	267
Total by type	946	852	181	4123	62	550	289	7003

Fig. 5.6: The veteran ship Mjølner serving as field base for a group of c. *20 sports divers and professional archaeologists while working on the Rønstenen site in 1998 (Photo: T. Malm).*

Fig. 5.7: Enjoying flints and beer during a break in the field work on the submerged Rønstenen site (Photo A. Fischer 1998).

There must be great potential for finding and studying submerged Stone Age settlements along the coasts of numerous places around the world. Since the demographic, economic, innovative and social centres of the Ice Age and the early Holocene may very well have primarily been located along the coastlines a realistic impression of the early evolution of culture and society may only be gained through the work on sites that are now hidden under the sea (cf. Fischer 1993a, 1995, 2004; Bailey and Milner 2002; Bailey 2004). In many cases a simple way of getting started in searching for these sites could be through a locally adjusted approach, based on the methods described above, i.e.:

- predictive models of site topography
- depth contour maps of the sea floor (at a scale of 1:40,000, or more detailed)
- a small boat with standard echo sounding equipment
- divers with some degree of archaeological field experience.

Fish weirs: a primary means of food supply?

As outlined above, remains of permanent fishing structures built of wood are commonly found when digging in marine sediments in the near-shore areas of Mesolithic settlements in Denmark (*e.g.* Andersen 1995 and this vol.; Pedersen 1997; Fischer 2004; Price and Gebauer 2005). The huge volumes of fish bones that have been found in Mesolithic coastal cultural layers give an impression of what was caught in these devices. According to Inge Bødker Enghoff, who has classified almost 100,000 fish bones from coastal Mesolithic sites in Denmark, the catch can be characterised as a "non-selective sample of whatever fish was present in

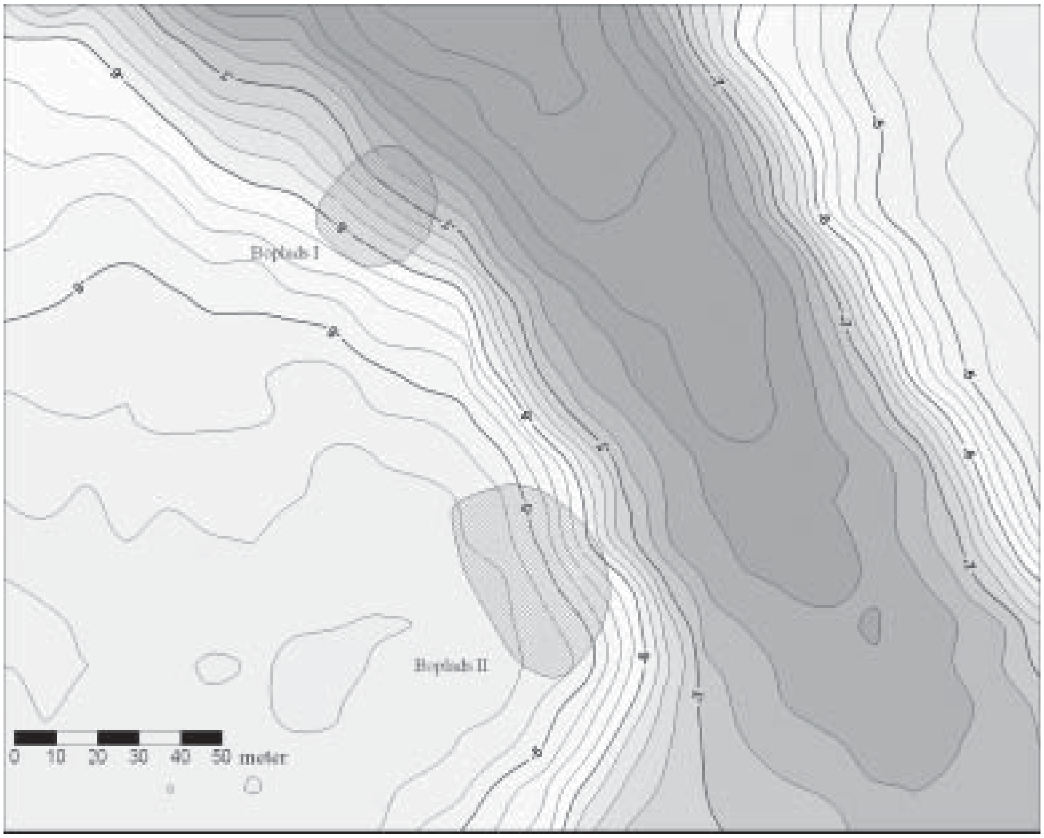

Fig. 5.8: A map of the sea floor around the Early and Middle Mesolithic settlements Kalø Vig I and II, produced through acoustic surveying. Depth contours in metres below average present sea level. The two sites were originally located at a narrow strait – a good site for fishing with stationary structures (Courtesy J. Schou Hansen, The Viking Ship Museum in Roskilde).

the local coastal waters during the summer half of the year" and the equipment used seems mainly to have been "stationary fish traps, which were left in place near the coast for at least one night" (Enghoff 1995, 72).

From this evidence, as well as from the topographic location of coastal sites, it appears that stationary fishing structures such as weirs built of wood must have been of fundamental importance for Mesolithic marine resource exploitation. Most settlements probably had several of these devices functioning simultaneously. Since they were relatively frail and were easily damaged by waves, currents and ice drifts it was probably part of the routine of coastal Mesolithic life to repair and build fish weirs.

Our knowledge of weirs of Mesolithic date derive from partly intact structures (Pedersen 1997; cf. Figs 5.4, 5.9 and 5.10), as well as from near-shore marine sediments with more or less densely packed drift material such as poles, wicker work stakes and remains of basketry traps (*e.g.* Andersen 1995; Pedersen 1997; Myrhøj and Willemoes 1997; Myrhøj 1997; Fischer 2004). Based on these observations it seems that the Mesolithic weirs basically consisted of wickerwork fences typically made of long slender hazel rods, 2–5 cm in diameter and basketry traps made of willow withies.

Fig. 5.9: A pointed stick, part of a weir, exposed by archaeological test excavation in marine gyttja off the Early Mesolithic settlement Kalø Vig I (Photo A. Fischer).

Neolithic wooden fish weirs are also well known from Denmark. Most of them have been recorded in coastal settings (*e.g.* Pedersen 1995, 1997), but there are also examples of small ones from wetlands in the interior (Troels-Smith 1960; Fischer 1985a). The most impressive are significantly longer and stronger in their construction than any of the Mesolithic ones found so far. Fig. 5.11 presents a reconstruction of what one of these large weirs of Neolithic date may have looked like.

Fig. 5.10: The Ventehuse site in 1956 appeared as nothing but a mess of vertical stakes standing densely in marine sediments formed in a narrow strait of a former Stone Age fjord. Subsequent studies of similar sites render it highly likely that the hundreds of wooden rods (some of them standing in line) were the remains of a multitude of Mesolithic fishing structures erected at almost the same spot during a considerable span of time. Observations made during the destruction of the site for the purpose of industrial extraction of marine shells show that the majority of the sticks were of hazel and had a diameter of 2–5 cm. Their lower ends were shaped into a point, apparently through the use of flint axes (courtesy of the Danish National Museum).

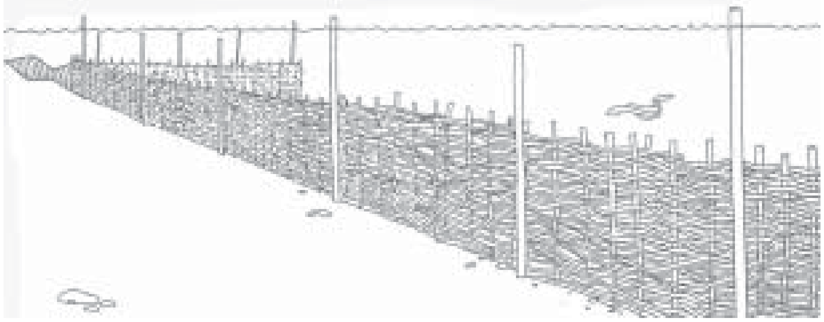

Fig. 5.11: Reconstruction of a Neolithic weir based partly on archaeological observations from the Oleslyst site and partly on local late nineteenth century historical data. The construction consisted of a tight fence made of panels of wattle work, supported by vertical poles and supplied with a basketry trap at the end furthest away from the shore. Such a construction effectively stopped the shoals of fish and directed them into the trap. In historical time such weirs were very common along the shores of the Danish Straits and were primarily used for catching migrating silver eel (Reproduced from Pedersen 1997).

The relatively stronger construction of some of these fishing fences may result in an over-representation of Neolithic weirs in the Stone Age record. Table 5.2 presents the presently available ^{14}C dates of wooden weirs from Denmark. It is remarkable that there are no examples postdating the Neolithic. This situation is highly surprising, since fish weirs very similar to the Stone Age ones are known to have been erected in large numbers every autumn along the coasts of the Danish archipelago during late historical times up until around AD 1900 (Fischer 1993b, 23 / 66; Pedersen 1995, 1997). Therefore, it is most likely that wooden weirs were also used frequently in Denmark during the intervening ages.

The present lack of finds of wooden weirs from the period spanning the Late Neolithic to historic times may partly be a result of a possible lack of concern among the researchers involved in the study of these periods. Most probably, however, the hiatus has mainly to do with differences in the degree of marine sediment accumulation over time. Based on observations from underwater archaeological surveys and contract archaeological excavations in marine environments it appears that huge quantities of clay and silt were eroded out of wave-exposed beaches and re-deposited in calmer coastal waters during the Mesolithic period and parts of the Neolithic.

The apparently much less significant deposition of fine grained marine sediments in many of the Danish coastal waters during the ages subsequent to the Stone Age rise in sea level (Christensen *et al.* 1997; Fischer and Hansen 2005) may, therefore, be a primary reason for the lack of such finds post-dating the Neolithic. However, this interpretation should not discourage the search for weirs of later ages. As shown by surveys during low tide in the estuary of the Shannon River, Ireland, places do exist along the Atlantic façade of Europe with significant sedimentation and well preserved weirs from the periods post-dating the Stone Age (O'Sullivan 2001).

The Nekselø weirs

In the coastal zone of the small island of Nekselø (Fig. 5.1, area D) an unusual concentration of remains of wooden fishing constructions has been recorded (Fischer 2006). The site probably has the longest Stone Age weirs found, so far, in Europe. The Neolithic stages of these constructions have stretched at least a quarter of a kilometre out from the contemporary shore line and would have originally reached a water depth of 4 to 5 metres. Most of this complex of poles and vertically deposited wattle work material has been found on the sea floor. Due to isostatic land rise, the near-shore part of the construction is now found in marine sediments above present sea

Table 5.2: ^{14}C dates of constructional wood from Danish fish weirs. The sites are listed in chronological order based on the earliest date from each site. The calibration of dates was carried out using OxCal version 3.10, http://www.rlaha.ox.ac.uk/oxcal/oxcal.htm (Bronk Ramsey 1995, 2001).

Site	**^{14}C years BP**	**cal BC ± 1 st.dv.**	**Lab. No.**	**Reference**
Kalø Vig I	7550±40	6450–6395	AAR-8415	Fischer & Hansen 2005
Rønstenen	6950 65	5900–5740	K-6967	Rasmussen 2000, 324
Rønstenen	6980 70	5980–5780	AAR-4622	Heinemeier & Rud 1999, 335
Rønstenen	6580 65	5610–5480	AAR-4621	Heinemeier & Rud 1999, 335
Vedskølle	6970±60	5970–5770	T-11331	Fischer 1997b: 68–69
Margrethes Næs	6030 100	5060–4790	K-5595	Fischer & Pedersen 1997, 322
Saltmade	6410±70	5470–5330	K-6382	Rahbek & Rasmussen 1996, 299
Saltmade	6180±80	5230–5010	K-6381	Rahbek & Rasmussen 1996, 299
Halsskov South	6320 100	5470–5210	K-5309	Fischer & Pedersen 1997, 321
Halsskov East	5850 100	4840–4580	K-5310	Fischer & Pedersen 1997, 321
Fedkrog	5580±65	4460–4350	K-6533	Fischer & Pedersen 1997, 320
Lindholm I	5520 70	4460–4320	K-6615	Fischer & Pedersen 1997, 320
Nøddekonge	5110 70	3980–3790	K-4630	Fischer 1985a
Nekselø	5560±80	4490–4330	K-6208	Rahbek 1995, 278
Nekselø	5440±70	4360–4170	K-6207	Rahbek 1995, 278
Nekselø	4770±85	3650–3380	K-6114	Rahbek 1995, 279
Nekselø	4750±95	3640–3370	K-6112	Rahbek 1995, 279
Nekselø	4700±80	3630–3370	K-6113	Rahbek 1995, 279
Nekselø	4660±65	3620–3360	K-5959	Rasmussen & Rahbek 1993, 279
Nekselø	4660± 65	3520–3360	K-5957	Rasmussen & Rahbek 1993, 279
Nekselø	4620±75	3620–3130	K-6473	Rahbek & Rasmussen 1996, 302
Nekselø	4600±70	3520–3120	K-5960	Rasmussen & Rahbek 1993, 279
Nekselø	4520±65	3360–3100	K-5955	Rasmussen & Rahbek 1993, 279
Nekselø	4520±70	3360–3100	K-5961	Rasmussen & Rahbek 1993, 280
Nekselø	4470±65	3340–3020	K-5958	Rasmussen & Rahbek 1993, 280
Nekselø	4440±90	3330–2930	K-6117	Rahbek 1995, 279
Nekselø	4420±65	3320–2920	K-5956	Rasmussen & Rahbek 1993, 280
Nekselø	4370±115	3330–2880	K-6116	Rahbek 1995, 279
Nekselø	4345±80	3090–2880	T-18053	Fischer unpublished data
Nekselø	4320±115	3350–2700	K-6115	Rahbek 1995, 279
Nekselø	4310±90	3100–2760	K-5643	Rasmussen 1992, 241
Oleslyst	4620 70	3520–3130	K-6436	Fischer & Pedersen 1997, 322
Oleslyst	4600 90	3520–3110	K-5594	Fischer & Pedersen 1997, 322
Oleslyst	4570 90	3500–3100	K-5593	Fischer & Pedersen 1997, 322
Oleslyst	4520 90	3370–3090	K-5592	Fischer & Pedersen 1997, 322
Oleslyst	4470 90	3340–3020	K-5590	Fischer & Pedersen 1997, 322
Oleslyst	4320 65	3030–2880	K-6437	Fischer & Pedersen 1997, 322
Oleslyst	4200 65	2900–2670	K-6438	Fischer & Pedersen 1997, 322
Oleslyst	4160 70	2880–2630	K-6439	Fischer & Pedersen 1997, 322
Oleslyst	4150 60	2880–2630	K-5591	Fischer & Pedersen 1997, 323
Oleslyst	4070 70	2850–2490	K-6440	Fischer & Pedersen 1997, 323
Oreby Rende	4440±90	3330–2930	K-5725	Rasmussen 1992, 241
Oreby Rende	4310±85	3100–2770	K-5724	Rasmussen 1992, 241
Smakkerup Huse	4630±90	3630–3130	K-6028	Rahbek & Rasmussen 1994, 281
Sankt Klaravej	4480±55	3340–3090	K-7043	Rasmussen 2000, 316
Ølby Lyng	4030±120	2900–2350	K-1010	Tauber 1967, 109

level (Fig. 5.12). At the nearest level spot along the Stone Age shore line a settlement and kitchen midden site contemporary with the weirs has previously been excavated (Becker 1953).

The presently available ^{14}C dates of constructional wood from the Nekselø complex of fish weirs are presented in Table 5.2. It includes dates of two slender poles from the later part of the Mesolithic, the Ertebølle. Most of the dates span the interval *c.* 3550 to 2950 cal BC, the late Early Neolithic and early Middle Neolithic Funnel Beaker Culture and the time of the erection of monu-

Fig. 5.12: The Nekselø site. Dots mark the positions of in situ *wooden poles from Stone Age fish weirs. Lines of poles have been found over a distance of* c. *250 m and air photographs show dark shadows in continuation of the presently recorded constructions indicating that they stretch much further out into the sea. The weirs have been re-built many times over a period spanning from the Late Mesolithic and into the Middle Neolithic. A settlement, representing the very same periods of use, has been excavated close to the landward end of the constructions (the Ørnekul site, marked with a filled in square) (Graphic by T. Eriksen, The National Cultural Heritage Agency of Denmark).*

Fig. 5.13: Nekselø. A wattle work panel made of long straight hazel sticks. It is part of a weir that has by accident been tipped into a horizontal position, where it soon became buried in marine sediments. These deposits are now disappearing, exposing the construction for a while, before it becomes destroyed by waves, currents, crabs and piddocks (Photo A. Fischer 1998).

Fig. 5.14: Nekselø. The basal part of a Neolithic weir, recently exposed by sea floor erosion, seen obliquely from above. The photo shows the remains of a wattle panel and a supporting pole still in their original vertical position. The weir provided a living place for oysters before it was buried in marine sediments (Photo A. Fischer 1998).

mental dolmens and passage graves in Denmark.

Observations on the sea floor testify to the existence of several chronologically separate building stages on nearly the same spot. This applies, for instance, to an approximately 40 m long line of wattle panels, tipped down in a horizontal position by waves or current and subsequently embedded in marine sediments (Fig. 5.13). Two separate lines of vertical poles from later construction stages are observed to have been driven down through this length of panels. At the time, the local accumulation of marine sediment must have been rather fast, since there are several observations of well preserved basal parts of wattle panels and supporting poles standing upright to heights of 10–30 cm above the sea floor (Fig. 5.14).

The stakes and poles of the Nekselø site are generally well preserved, including their bark cover. In one case it was observed that the inner-bark of a vertical pole still had its original bright green colour when it was dug out of the sea floor. However, its fresh look vanished quickly as soon as it came up into the oxygen-rich sea water. Wood-anatomical investigations by Thomas Bartholin (1996) indicate that most of the constructional materials are from coppiced hazel bushes. The quality of preservation of the wood has permitted observations on how the wood was cut down and shaped by the use of axes (Fig. 5.15). The width and the degree of concavity of the cut marks indicate that the cutting was done with polished flint axes of the thin-butted type, which is the most common type of flint axe from that period.

Preliminary calculations indicate that each building stage of the quarter kilometre long Nekselø weir took 6–7000 good quality, up to 4m long, straight hazel rods plus hundreds of larger poles, up to 6 m long. Modern experiments have demonstrated that the production of such quantities of wood would have been serious business in terms of work effort, as well as of the forest area exploited (Fischer unpublished data). Likewise, the erection of the construction implies a considerable technical and organisational capacity. Judging by the productivity information available from historical fish structures of this kind (*e.g.* Petersen 1899), it can be concluded that the quantity of fish that could be caught by means of the Nekselø weirs was large scale.

It should also be noted that there are stray observations of other Stone Age weirs in several places within visual distance from the hill tops of Nekselø. Most significant are a number of strongly built weirs, similar to the Nekselø ones and apparently contemporary with them (Table 5.2), found at Smakkerup Huse in the estuary of the Bregninge River only 10 km away as the crow flies (Nielsen 1992).

The design of the Neolithic Nekselø weirs may not have differed much from the reconstruction presented in Fig. 5.11. Several observations at the Nekselø site demonstrate that the wattle constructions were made so tight that it was not possible to find room for as much as an adult person's index finger in between the horizontal stakes of the panels (Fig. 5.16). This degree of tightness could only be reached through the use of long, perfectly straight stakes. Such stakes are hard to obtain in any quantity unless engaging in coppice forestry, which is time demanding. It may, therefore, be asked, what was the purpose in making the fence that tight? Catching mature eel (silver eel) in the autumn seems the most reasonable answer: eel are famous for being able to find their way even through very narrow openings.

In Denmark, eel are most easily caught in quantity in the autumn by the use of stationary devices positioned perpendicular to the coast along the migration routes on the way from the freshwaters and fjords around the Baltic to their spawning ground in the Atlantic. Until the end of the nineteenth century this kind of fishing was usually done by means of weirs built of tightly woven panels of straight hazel rods (*e.g.* Petersen 1899; Pedersen 1992) (Fig. 5.17).

Based on the preliminary investigations of the Nekselø weirs it seems safe to conclude that there must have been many Neolithic people in the neighbourhood of this site who, generation after generation, consumed significant quantities of fish, probably eel. This habit appears not to have been restricted to the Nekselø region: similar weirs have been used in many places along the coasts of Neolithic Denmark. Therefore the consumption of significant quantities of fish must have been a regular part of the Neolithic way of life in this part of the European coastal façade.

The special qualities of eel

The possible importance of eel to the Neolithic population of Denmark may be better understood when considering the characteristics of this fish (Pedersen 1997). Among the food resources available to Neolithic people silver eel was important for at least four reasons:

- On specific locations along the coasts of the Danish Straits (including the coast of Nekselø), silver eel could be caught seasonally in tremendous numbers
- Silver eel is extraordinarily rich in dietary fat, which must have been a commodity in the Neolithic
- Kept in cages underwater, eel can survive for several months without eating and could,

Fig. 5.15: An example of the lower end of a vertical pole from the Neolithic Nekselø weirs, showing clear marks from shaping with an axe (Photo K. Petersen).

Fig. 5.16: Nekselø. A close-up of a Neolithic wattle work panel. The consistent use of 4 m long, perfectly straight stakes made it possible to build the panel so tight that even a slim eel could not find a way through it (Photo A. Fischer 1998).

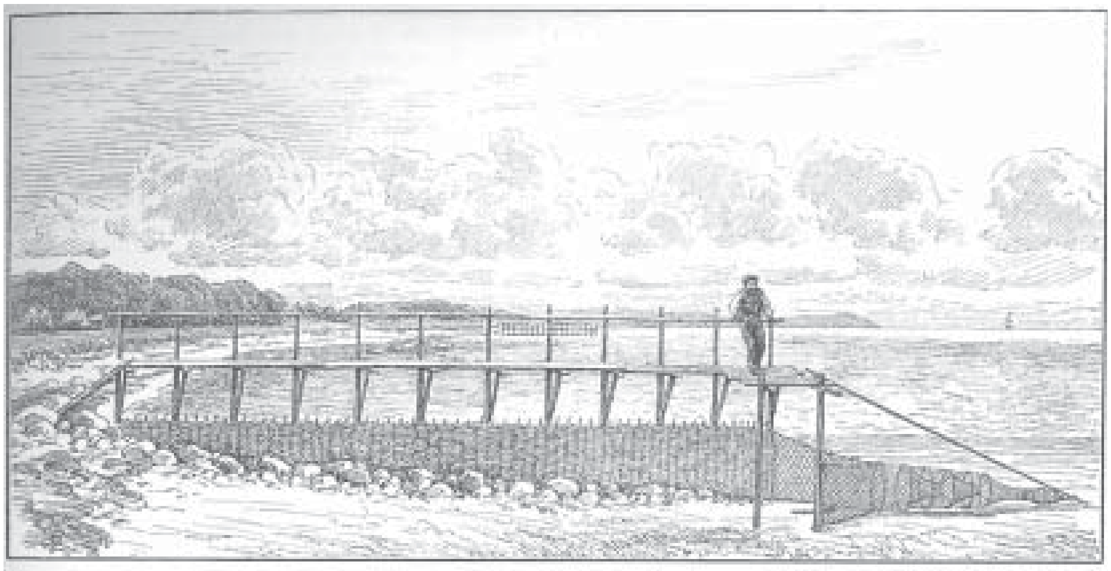

Fig. 5.17: Sketch of a traditional type of eel weir, frequently seen along the Danish Straits in the nineteenth century, for instance at the Røsnæs peninsula. The wattle work panel, which for the sake of ease of the artist is shown in an unusually short version, diverted the eel towards deeper water. Here funnel nets led the eel into a wickerwork trap. In this case the construction is supplied with a gangway that made it possible to empty the trap even in the case of large waves (Reproduced from Petersen 1899).

therefore, form a valuable food reserve in the critical months of winter and early spring

- Providing it is kept moist, eel survives for a long time and this species was, therefore, uniquely well suited for wide spread distribution among the Neolithic inhabitants of Denmark, including those who lived furthest away from the coastal regions.

The first of the above mentioned qualities of eel may also apply to herring (Muus *et al.* 1998), which has for instance traditionally been caught in wooden weirs in the West Baltic fjord of the Schlei (Lühning 1999). Even though there may be no historical evidence for fishing herring by means of weirs in the region of Nekselø, such a function of this site therefore, in principle, cannot be excluded. It should, however, be noted that herring does not share the other three qualities of eel mentioned above especially not the last two of them. In addition it should be stressed that massive Neolithic consumption of herring, which is a genuinely marine species, would have a much better chance of being detected through elevated δ^{13}C values in human bone collagen than would a comparably massive consumption of eel (see below).

Stable isotope evidence

Did Neolithic people turn their back to the sea?

This suggestion of a significant consumption of fish in Neolithic Denmark is in conflict with Henrik Tauber's (1981, 1986) ground-breaking isotope based study of diet in Stone Age Denmark. In Tauber's view, marine food was a dominant part of diet in the Late Mesolithic but was erased from the menu from the onset of the Neolithic. His interpretation has subsequently found widespread support from other researchers working with new data from Denmark and other countries along the coastal facades of Europe (*e.g.* Lubell *et al.* 1994; Lindqvist and Possnert 1999; Richards and Hedges 1999; Richards *et al.* 2003a, 2003b; see however Milner *et al.* 2004; Lidén *et al.* 2004; Hedges 2004).

The apparent conflict between δ^{13}C studies and traditional archaeological evidence from the Neolithic (such as food remains, site locations and fish weirs) has led to debate. The presently prevailing interpretations of stable isotope analysis of human bone collagen have been questioned (Milner *et al.* 2004). It has also been have suggested that Tauber's and subsequent scholars' isotopic studies are based on highly biased assemblages of human bones: supposedly coastal individuals from the Mesolithic and inland individuals, mainly high status persons buried in megaliths, from the Neolithic (*ibid.*).

The d^{13}C assemblage

Fig. 5.18 presents δ^{13}C values in radiocarbon dated human bone collagen from Denmark. The graph includes all data from Tauber's study, except his very early attempts of dating mixtures of bone apatite and collagen. It also includes radiocarbon dates produced after Tauber's most recent publication on the topic. All dates presented in the diagram have been corrected for natural isotopic fractionation and subsequently corrected for the marine reservoir effect. The correction for the marine reservoir effect is based on the assumptions that 100% marine diet will result in a reservoir effect of 400 years and that 100% marine diet and 100% terrestrial diet will result in δ^{13}C values of –10‰ and –20.6‰ respectively (Fischer 2002).

In Fig. 5.18 the significant drop in δ^{13}C levels,

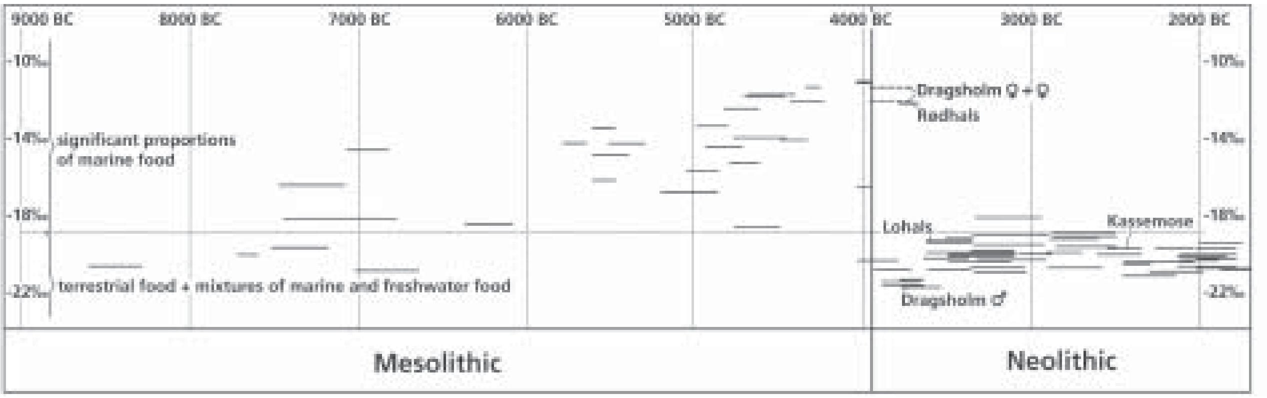

Fig. 5.18: δ^{13}C values versus ^{14}C dates of humans from the Danish Stone Age (from Fischer 2002 with minor corrections and adjustments). Each horizontal line represents a ^{14}C dated human bone/skeleton, and the length of the lines indicate the confidence interval (± 1 standard deviation) for each date. Recent research (Fischer et al. *in prep., Fischer unpublished data) indicate that individuals with δ^{13}C values larger than approximately –19‰ have consumed significant quantities of marine food regularly. The Early Neolithic man from the shell midden of Rødhals is a clear exception from the general pattern. He stuck to a Mesolithic-like food composition dominated by marine food (Fischer 2002; Fischer* et al. *2005; Fischer* et al. *in prep.). The two Dragsholm females, buried in a mutual grave, may represent additional exceptions. It is, however, uncertain if the radiocarbon dates of these two individuals can be relied upon. The one used in this diagram is Early Neolithic. The other one, which is declared unreliable by the radiocarbon laboratory due to possible contamination from preservative lacquer, is clearly Late Mesolithic.*

originally demonstrated by Tauber, is still clearly seen. The δ^{13}C values of Late Mesolithic individuals are varied, but generally high, as contrary to Neolithic individuals, who (with possibly three early exceptions) have much lower δ^{13}C values. Six of the Neolithic individuals with relatively low δ^{13}C values shown in Fig. 5.18 derive from indisputable coastal sites. They represent a chronological range spanning from the first half of the Early Neolithic to the last half of the Middle Neolithic. The coastal sites of Dragsholm, Lohals and Kassemose (Fig. 5.19) have each produced one individual (the latter two were buried in shell middens). The remaining three are from a burial mound less than 100 metres from the Late Mesolithic and Early Neolithic coastal shell midden of Bjørnsholm (cf. Andersen and Johansen 1992). It seems, therefore, that the general drop in δ^{13}C values around the transition from the Mesolithic to the Neolithic cannot be explained as a result of a geographical sampling bias, which should have excluded low social status individuals from coastal sites from the study.

Fig. 5.19: The Kassemose man, ^{14}C dated to c. *2430 cal BC, is an example of a Neolithic coastal individual, with a low δ^{13}C value. His burial was dug into a coastal shell midden. Since it contained no funeral gifts he was probably not a person of especially high social status (Photo the National Museum of Denmark).*

Fish in Neolithic diet?

In Tauber's study, δ^{13}C values in the order of –20‰ were taken as evidence of a diet based on terrestrial food (1981, 1986). Subsequent research has, however, revealed that δ^{13}C values of this magnitude can also be a result of mixed diets of marine and fresh-water resources (Fischer 2003).

Recent δ^{13}C measurements of Danish Stone Age fish bones (Fischer and Heinemeier 2003; Fischer *et al.* in prep.; Fischer unpublished data) make it possible to estimate roughly what proportion of marine to freshwater fish would be needed to produce human bone collagen with a δ^{13}C value of –20‰. Fish bones from four different fjords have δ^{13}C values within the range –8.8 to –14.7‰ (the more brackish, the more negative the δ^{13}C values). Neolithic fishbone from various freshwaters have produced δ^{13}C values within the range –20.9 to –26.7‰. Based on these data, assuming that bone collagen δ^{13}C values represent the isotope signature of the individuals' dietary protein, and taking into account the diet to consumer offset of approximately 1‰, the following tentative estimate of the marine to freshwater proportions can be offered: where the marine species were caught in typical brackish fjords the proportion would be approximately 1:2; if the marine species were caught in more open fjord environments it could be as high as 1:5.

In principle it should be possible to evaluate these estimates of the proportion of marine to freshwater fish on the basis of species of fish bones from Neolithic cultural layers. However, in practice it is hard to find any Neolithic fish bone assemblage from Denmark that can form a reliable basis for such a test. Danish scholars excavating Neolithic sites have usually done little to retain fish bone. In addition Neolithic sites generally provide relatively bad preservation for fish bone as compared to Mesolithic sites. Moreover, when fish bones are found in stratified shell middens their preservation appears to be better in the lower Mesolithic layers than the upper Neolithic ones. Finally, bones of fish species like eel and herring may have less chance of surviving due to their relatively high content of lipids, which during decomposition may in some situations dissolve their calcium components (Mézes and Bartosiewicz 1994). It is, however, worth remarking on the species composition of the Bjørnsholm kitchen midden, which has produced the largest Danish assemblage of Neolithic fish bones presently available in literature (n = 252). In this assemblage the genuinely marine and freshwater species are represented as 33% and 6% respectively. Herring is not represented among the Neolithic fish bones from Bjørnsholm, while eel constitutes no less than 61% of the assemblage (Enghoff 1993).

Eel thrives in marine and brackish coastal waters as well as in freshwater environments (Muus *et al.* 1998: 80). Many of the silver eels that are nowadays caught in the autumn along the Danish coasts (Fig. 5.20) have grown up in rivers, lakes and freshwater wetlands. In the Stone Age, before drainage of wetlands and pollution of rivers, the majority of silver eel that migrated out through the Danish archipelago, may very well have spent most of their life in freshwater (including the huge North and Northeast European river systems, which drain into the Baltic). This means that Neolithic humans may have consumed silver eel in quantity and nonetheless have ended up with $\delta^{13}C$ bone collagen values that look "terrestrial".

Fig. 5.20: Eel trap at Knudhoved Odde, Southern Zealand, October 2005. By the close of the nineteenth century eel weirs of hazel wood were displaced in Denmark by new constructions and new materials. Since then human made disturbances have reduced the number of eels dramatically in the Baltic drainage area of Northern and Northeastern Europe but still lots of mature eel migrate out through the Danish Straits. Each autumn, when the season begins, Danish fishermen put up pound nets for the purpose of providing the local market with silver eel, which by tradition is an important food for feasting.

Moreover, freshwater food did in fact constitute a significant part of the diet for at least a subset of the Neolithic population in Denmark. This can be said on the basis of well-preserved and carefully excavated Stone Age sites in the Åmose (Fig. 5.1, area G). Kitchen middens, *i.e.* dense accumulations of shells of freshwater molluscs, seem to characterise primarily or perhaps only the Neolithic stages of habitation in this mire (cf. Noe-Nygaard 1995; Koch 2003). In addition, these Early Neolithic kitchen middens are packed with bones and scales of freshwater fish such as pike and tench (Fischer 1985b; Enghoff 1995). These observations are reinforced by a recent study of food residue on pottery from the Åmose and other Neolithic sites from Denmark (Fischer and Heinemeier 2003; cf. Koch 1998; Fischer 2002). It shows that $\delta^{13}C$ values more negative than –26‰ in the pottery food residues, are testimony of the vessels' use in cooking freshwater food. The important thing to note here is that the more freshwater food there was in diet, the more it hampers a possible marine isotope signature in human bone collagen $\delta^{13}C$ values.

Three alternative explanations

In principle the significant drop in $\delta^{13}C$ values after the Mesolithic-Neolithic transition can be explained in the following ways:

1) neglect of marine resources
2) a dietary regime combining marine and freshwater food
3) a dietary regime combining marine, terrestrial and freshwater food.

If the Neolithic weirs were used for catching silver eel, many of which had grown up in freshwater, this adds credibility to explanations 2 and 3. In addition, studies of vegetation and settlement distribution indicate that from around 3500 cal BC (*c.* half a millennium after the introduction of cattle husbandry (Fischer and Gotfredsen 2006), farm products must have been an important if not dominant part of subsistence in Denmark (Madsen 1990; Rasmussen 2005). All in all, alternative 3, thus appears the most plausible. With the possible exception of the first centuries, the diet in Neolithic Denmark was most probably based on a combination of terrestrial and aquatic food. Future isotope studies of Neolithic human bones, including measurements of $\delta^{15}N$ and perhaps $\delta^{34}S$, may hopefully help clarify what were the actual proportions of marine, terrestrial and freshwater foods in the diet.

Conclusion

According to an old Danish saying "the sea erases all traces". However, this is certainly not true in regards to Stone Age sites and evidence of fishing along the now submerged shores of Denmark. In addition, it may also be misleading to apply this premise to many other regions around the world. The survey of the Danish sea floor, through the application of the fishing site model, has enabled a detailed picture to emerge regarding the use of the coast and its resources during the Stone Age. By combining different techniques of data analysis it becomes possible to put together a picture of the ways in which fish was caught and the degree to which it was consumed during the Mesolithic and Neolithic periods.

It has been known for a long time, from shell midden information and more recently stable isotope analysis, that marine fish was a very important part of the diet in Mesolithic Denmark. More recently it has become clear that in Denmark, fish must also have been a regular part of the diet during the Neolithic. This is indicated by the size, number and wide geographical distribution of fish weirs dated to that period. It is also interesting to note that Neolithic fishing structures are generally much larger and built much more solidly than their Mesolithic counterparts.

However, approximately from the onset of the Neolithic a general drop in $\delta^{13}C$ values in human bone collagen has been reported. This decline was previously explained as the outcome of a higher reliance on terrestrial (agricultural) food. The present paper adds an alternative explanation: it may also be the result of wide scale substitution of marine food for freshwater food.

In sum, looking at the full range of evidence presently available from above and below the present sea level, marine fish appear to have been the primary means of protein supply during the Middle and Late Mesolithic. In the Neolithic, terrestrial food probably took over as the dominant source of food: however, fishing was still an important part of subsistence. In comparison to the situation in the Mesolithic, fishing may have become more specialised, and probably more focused on freshwater species, not least eel. Although the latter species was most likely caught in the sea, much of the catch would have grown up in freshwater and could therefore have contributed to the surprisingly terrestrial $\delta^{13}C$ signatures seen in human bones from Neolithic Denmark.

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