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Fishing with Stationary Wooden Structures in Stone Age Denmark: New Evidence from Syltholm Fjord, Southern Lolland

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*An abundance and diverse range of prehistoric fishing practices was revealed during excavations between 2012 and 2022 at the construction site of the Femern Belt Tunnel, linking the islands of Lolland (Denmark) and Femern (Germany). The waterlogged parts of the prehistoric Syltholm Fjord yielded well preserved organic materials, including the remains of wooden fish traps and weirs, and numerous vertical stakes and posts driven into the former seabed – evidence of long term fishing practices using stationary wooden structures from the Mesolithic to the Bronze Age (*c*. 4700–900 cal BC). Here, we present the results of a detailed study on these stationary wooden fishing structures, making this the most comprehensive and detailed description of prehistoric passive fishing practices in Syltholm Fjord to date. The exceptional scale of the excavated area (57 ha) and abundance of organic materials encountered during excavations provides us with a rare opportunity to identify individual weir systems and information on their construction, maintenance, and use. To contextualise further, we provide an up-to-date compilation of comparable finds in the Danish archaeological record, including a dataset of directly dated specimens, based on both published and unpublished sources. Our results show that stationary wooden fishing structures are an invaluable archaeological resource, and their study, combining landscape reconstruction, ethnographic analogy, and fishing technology, together with artefactual evidence and radiocarbon dating, allows us to reconstruct prehistoric fishing strategies in depth. Due to the long chronology and diversity of the study materials, our results complement previous research on the many nuances and regional specificities of the persistence of fishing practices in the western Baltic Sea over time, despite introductions of new cultures, populations, and livelihoods. Finally, we emphasise that the Neolithisation process in Northern Europe was not as straightforward and uniform in terms of subsistence as commonly assumed.*

Keywords: Mesolithic, Neolithic, fishing techniques, stationary wooden structures, Denmark, radiocarbon dating, marine resources, subsistence practices

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INTRODUCTION

Fish is a protein-rich and highly nutritious food that can be caught with relatively little effort. Technologically, the easiest way to exploit fish is by using bare hands in shallow water or with tools such as containers and mallets. Other active techniques include hook and line, spear, bow and arrow, and leister fishing. In contrast, people also developed passive fishing methods, which do not require a physical presence during the practice of fishing if the equipment is correctly placed and maintained in prime locations. In Northern Europe, archaeological evidence demonstrates that nets were manufactured and used for fishing from the Early Mesolithic, *c.* 8400 cal BC onwards (eg, Pälsi 1920; Kernchen & Gramsch 1989; Miettinen *et al.* 2008), while stationary wooden traps and weirs were employed from *c.* 7000 cal BC (eg, Petersson & Olausson 1952; McQuade & O'Donnell 2007; Klooß 2015a; 2015b; Hansson 2018; Nilsson *et al.* 2018).

Throughout Northern Europe, stationary fishing implements include fish traps, eg, the woven basket (Pedersen 1995; 1997), either with or without an inner funnel (Brinkhuizen 1983; Mertens 2000), or a barrier weir type of structure made of wood or stone (or a combination of both). Both were often strategically placed near an estuary, stream, river, or fish passage (Pedersen 1997), taking advantage of natural barriers and other local topographical features. Their construction and maintenance are thought to have been labour and resource intensive, requiring communal effort, but providing a convenient means of catching large quantities of fish with relatively little effort throughout the year (eg, Koivisto & Nurminen 2015). Whilst the basic principles of fishing with stationary structures are fairly similar regardless of time and place (eg, Sirelius 1908; Clark 1948), some variations exist according to specific environmental conditions, the use and availability of suitable raw materials, and the species of targeted fish.

Studies on Stone Age fishing practices in Northern Europe, especially in the Baltic Sea region, have gradually increased over recent decades (eg, Schmölcke *et al.* 2006; Pickard & Bonsall 2007; Bērziņš 2008; Klooß 2015b; Koivisto & Nurminen 2015; Piličiauskas *et al.* 2019; 2020a; 2020b; 2023). Equally, prehistoric fisheries research has advanced our understanding concerning aspects of fishing and the exploitation of marine resources (eg, Enghoff 1994; Fischer 2007; Hartz *et al.* 2014; Butler *et al.* 2019), manufacturing and woodworking techniques (eg, McQuade & O'Donnell 2007; Klooß 2015b), forest management (eg, Christensen 1997; Out *et al.* 2020), climate and water level changes (eg, Hansson *et al.* 2016), coastal erosion (eg, Erlandson 2006), human adaptation (eg, Groß *et al.* 2018), and cultural resource management (eg, Koivisto 2017; Bailey *et al.* 2020). This research has also confirmed the prolonged use of remarkably similar devices (eg, Pedersen 2013), sometimes at the very same fishing locations over extended periods of time. Fishing with stationary wooden structures has been documented in archaeological contexts throughout Northern Europe (eg, Clark 1948; Brinkhuizen 1983; Pedersen 1995; 1997; Mertens 2000; Fischer 2007; Pedersen 2013), and the techniques appear to have been a common means of obtaining food throughout the Mesolithic, Neolithic, and later periods, continuing well into modern times.

Prior to this study, approximately 50 Stone Age sites with fishing structures were known in Denmark, yielding basket fish traps, the remains of woven wattle panels from weir fences, vertical wooden stakes and posts (eg, Pedersen 1995; Smart 2003; Fischer 2007; Pedersen 2013; Klooß 2015b), and horizontal scattered finds of tapered stakes and other wooden debris in marine sediments, which may represent either dismantled and/or fallen remains of such structures (eg, Andersen 2013). Several early chance discoveries from peat digging and wetland drainage (Becker 1941; 1943; Clark 1948; Mathiassen 1948) and later archaeological fieldwork in wetland and underwater contexts has demonstrated that fishing with stationary wooden structures in southern Scandinavia has its roots in the Middle Mesolithic (eg, Pedersen 1995; 1997). The oldest known weir is from the site of Kalø Vig I in eastern Jutland, which has been directly dated to *c.* 6420 cal BC, corresponding to the transition between the Early Mesolithic Maglemose and Middle Mesolithic Kongemose periods (Fischer & Hansen 2005). Fishing structures are, however, fairly common finds from submerged and waterlogged archaeological sites dating to the subsequent Late Mesolithic Ertebølle period (*c.* 5400–3900 cal BC) (Pedersen 1995; 1997; Mertens 2000; Smart 2003; Fischer 2007; Pedersen 2013). In Denmark, the oldest securely dated basket fish trap is from the Villingebæk Øst A site in north-east Zealand, dating from *c.* 5900 cal BC (Tauber 1973).

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The relatively small number of fishery sites with stationary structures – given the expansive coastal areas, islands, and paludified inland waterways in Denmark – has been explained by unfavourable conditions for the preservation of organic materials and lower frequencies of fieldwork at potential locations (Fischer 2007). Moreover, a relatively small number of wooden remains have been directly dated by radiocarbon (eg, Smart 2003), meaning that the majority have only been dated contextually. In addition, some sites and regions have been extensively studied, accounting for the majority of the published data, such as the wooden fishing structures discovered at the construction site of the Great Belt Bridge (Fischer 1995a; 1997; Pedersen *et al.* 1997; Pedersen 2013).

Here, we present a detailed study, including Bayesian modelling of radiocarbon dates, of a large assemblage of wooden structures associated with prehistoric passive fishing practices which were found during developer-led archaeological fieldwork on the south coast of Lolland, south-east Denmark, as part of the Femern project (2012–2022; see Måge *et al.* 2023 for an overview). Our findings are considered in terms of human adaptation, the development of fishing strategies, and the importance of marine resources to the local populations occupying the coastal fjord landscape in prehistory. To contextualise further, we present a comprehensive and updated list of all evidence for stationary wooden fishing structures in the Danish archaeological record, based on both published and unpublished sources, and direct radiocarbon dates (Appendix S4). This data are then examined in the wider context of similar archaeological evidence from Northern Europe, and reflected upon the many nuances and regional specificities of the persistence of fishing practices in the western Baltic Sea over time, despite the introduction of new cultures, populations, and livelihoods.

STUDY SITE

Archaeological fieldwork (2012–2022)

The construction of the Femern Belt Tunnel affects more than 368 ha of southern Lolland, of which approximately 187 ha is an area of reclaimed former seabed. Prior to construction, an archaeological assessment was required in the area of the prehistoric Syltholm Fjord under the *Danish Museum Act*. As it would have been neither practical nor cost-effective to fully excavate the entire area, preliminary investigations, incorporating systematic coring and trial excavations, were carried out to identify potential areas for further examination (Sørensen 2016; Måge *et al.* 2023). In total, approximately 57 ha were subjected to archaeological excavation (on both dryland and in wetland) (Måge *et al.* 2023). This area was divided into more than 60 fieldwork projects, with several sites further sub-divided into individual sub-units (Fig. 1).

Evidence for prehistoric fishing was particularly abundant at waterlogged sites adjacent to the coastal settlements due to favourable conditions for organic preservation. Active fishing was evidenced by finds such as composite leisters, bone points, and wooden spears, which have been reviewed elsewhere (eg, Sørensen 2016; Chaudesaigues-Clausen 2023; Jensen & Sørensen 2023; Koch *et al.* 2024). Several fragments of dugout canoes and wooden paddles were also found preserved in the marine sediments, attesting to the importance of this coastal landscape and its resources to prehistoric populations (eg, Sørensen 2023). Abundant and diverse evidence for passive fishing methods using stationary wooden structures was also evident which, to date, has only seen preliminary publication (Stafseth & Groß 2023).

Environmental background

The environmental development of the study area was thoroughly investigated before and during the archaeological excavations (Mortensen *et al.* 2015; Bennike & Jessen 2023; Bennike *et al.* 2023). A systematic coring programme of nearly 1000 auger samples characterised the deposits and depths of the geology of the former fjord basin. This, together with direct radiocarbon dating, has enabled a detailed reconstruction of the prehistoric seabed relief and distribution of the different sediment types (Mortensen *et al.* 2015).

The results indicate that the area has remained relatively stable since the last deglaciation, from *c.* 9700 cal BC, although certain changes have affected the dynamics of the coastal landscape, particularly during the Mid-Holocene (*c.* 6200–2200 cal BC). Marine transgression began in the area *c.* 5000 cal BC and resulted in the formation of a small fjord basin in a reed bed zone along the coastline of what is today southern Lolland (Bennike & Jessen 2023). As sea level continued rising, the area evolved into a shallow water lagoonal landscape behind protective sandy

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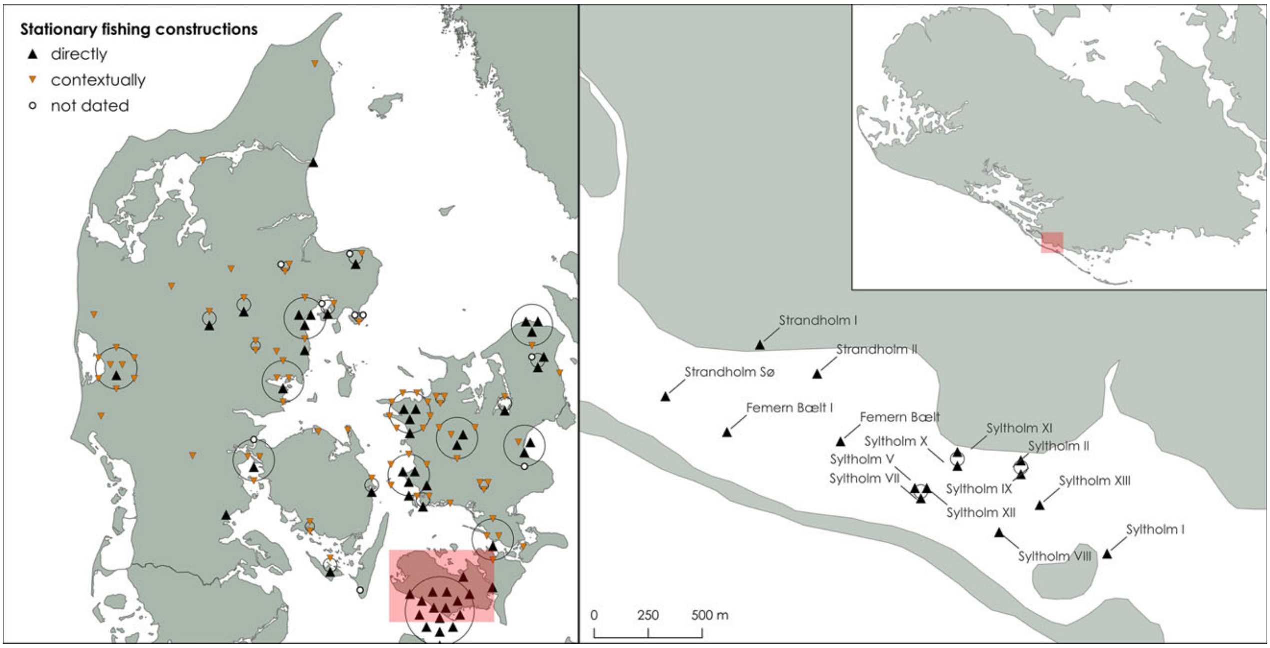

Fig. 1.
Left: Directly and contextually dated stationary fishing structures in Denmark (background map: © EuroGeographics for the administrative boundaries); right: locations of archaeological sites in the Syltholm Fjord mentioned in the text. The inset and close-up maps show the historic coastline of AD 1777, which is somewhat comparable with the Neolithic coastline

coastal spits – so-called barrier islands – transforming the deeper areas into shallow basins with fine-grained organic and inorganic gyttja, with the reed beds gradually moving further inland. Sandy layers identified within the gyttja horizons suggest that the coastal spits were either breached or overflowed with masses of water during storm events, which increased in frequency as the transgression progressed from *c*. 3000 cal BC (Mortensen *et al*. 2015; Bennike & Jessen 2023; Bennike *et al*. 2023). Alongside rising sea level, the coastal spits gradually migrated inland and thick sandy deposits eventually covered the earlier gyttja deposits. During the Late Holocene (*c*. 2200 cal BC to the present), transgression promoted more frequent breaches and overflows of the barrier islands, but still, the local environment remained relatively stable with shallow, brackish, lagoonal waters until the area was reclaimed and diked for storm protection in the late 19th century (Mortensen *et al*. 2015; Bennike & Jessen 2023). Fortuitously, groundwater levels in the area have remained relatively high after reclamation, enabling good conditions for the preservation of prehistoric organic archaeological remains.

MATERIALS AND METHODS

Stationary wooden fishing structures in Syltholm Fjord

Excavations revealed the remains of several preserved wooden fish weirs, fish traps, isolated horizontal wattle panel sections, and several thousand vertical, oblique, and horizontal wooden stakes, posts, and rods embedded in the prehistoric marine sediments. The exceptional scale of the excavated area and abundance of prehistoric organic materials provides us with a rare opportunity to identify individual weir systems and information on their construction, maintenance, and use. The recent review by Stafseth and Groß (2023) provided a preliminary overview of the main types of wooden structures and their radiocarbon dates. Here, we analyse, evaluate, and contextualise the findings in more detail within a local, regional, and wider Northern European context. Detailed descriptions of the recorded finds and structures, their locations, and other relevant observations at individual sites (interpreted as evidence for fishing structures) were identified, compiled, and analysed from the excavation archive (located at Museum Lolland-Falster, Nykøbing F., Denmark). Their synthesis, including details of, for example, environmental context, stratigraphy, excavation, and sampling strategy, is included in the supplementary Appendix S1, making this the most comprehensive and detailed description to date of the Femern project's field observations relating to prehistoric passive fishing practices.

As stationary fishing structures were in use in our study area for a considerable length of time, their temporal and spatial distribution is widespread. Since not all the wooden remains have been dated, we opted for a GIS-based approach to identify potentially related structural weir elements. To identify the remains of partially preserved structures we compiled all available dates derived from vertical and oblique wooden posts, stakes, and rods and clustered them according to their location. This was undertaken using the QGIS (v3.34.6) DBSCAN clustering plugin, with a minimum cluster size of three points and a maximum distance of 2 m between points. The 2 m distance was chosen arbitrarily to mitigate cluster splitting, based on the observation that upright stakes have a distance of up to *c.* 75 cm when a central stake was missing, for example.

Comparative materials

To further evaluate and contextualise the results we compared them with similar sites and materials in the Danish archaeological record. We identified and analysed published data from archaeological literature and archival sources. New data was sought using the online Sites and Monuments database (Fund og Fortidsminder 2024) together with archived materials from regional museums using relevant keywords (eg, *fiskegård*, *fiskeplads*, *enkeltfund*, *hegn/gærde*).

Sites included in the dataset ($n = 151$) are provided with an official (*Fund og Fortidsminder*) site ID, together with information on, for example, the structural remains recorded, the environmental setting, and associated finds and features, where available. In addition, information on the dating and quality of the age determination (directly/contextually) is provided. The radiocarbon dates of the directly dated samples ($n = 518$, including 399 radiocarbon dates from the Femern project alone) are reported based on the available published information, while details, such as context (waterlogged/submerged), sample type, and species information (where available), and type and component of the structure in question (eg, post from weir, rod from wattle structure, withy from fish trap, etc) was added. This data was compiled and analysed and is included as Appendix S3).

Radiocarbon dates

Radiocarbon ages were calibrated in OxCal v4.4.4 (Bronk Ramsey 2009) using the IntCal20 calibration curve (Reimer *et al.* 2020). All calibrated radiocarbon dates in this paper are reported at 2 σ range (95.4% probability).

The spatial clustering of wooden remains was used to generate age models for the different stationary wooden fishing structures. The isolated clusters were combined using SUM calibrations (Bronk Ramsey 2017), while the segments that provided more contextual information were modelled according to their stratigraphic and spatial relationship using phase and sequence models (Bronk Ramsey 2009; see details in Appendix S2).

To identify potential fishing structures that were poorly preserved (ie, fragmentary, where only a portion of the upright stakes had survived), we applied a spatial clustering approach based on the location and evaluated the radiocarbon dates, if available. We classified them to three levels of reliability:

1. dating and location: the features are spatially clustered, and the radiocarbon dates suggest contemporaneity of the construction elements;
2. dating only: the features are spatially related and are contemporaneous, but are not spatially clustered, eg, because the distance between them is >2 m; and
3. location only: the construction elements are spatially related but lack a sufficient number of radiocarbon dates for a qualified evaluation.

RESULTS

Altogether 15 individual excavation projects (covering 24 sub-sites) yielded evidence of stationary wooden fishing structures (Fig. 1): four with remains of preserved wattled weir sections, five with remains of fish traps (or fragments thereof), and all 15 with varying numbers of tapered vertical, oblique, and horizontal wooden stakes, posts, and rods. The types

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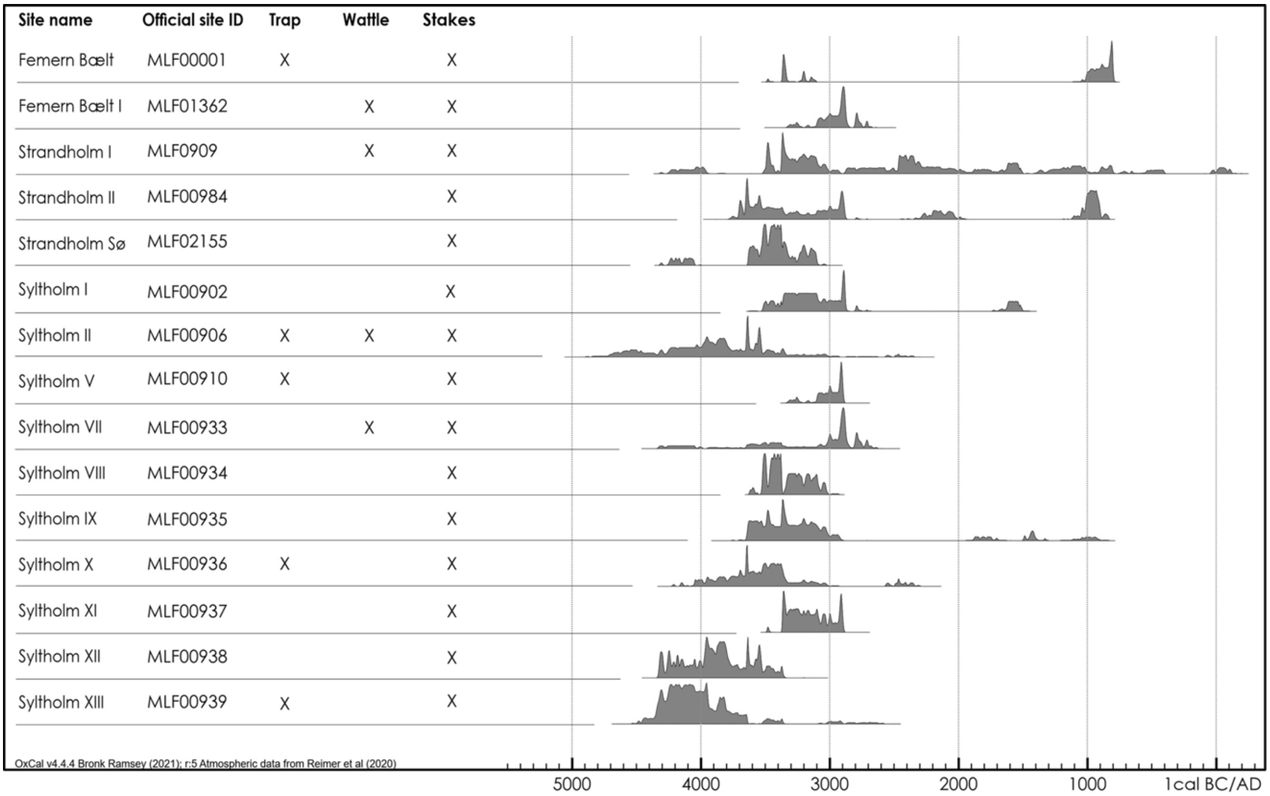

Fig. 2.
Sites of the Femern project with evidence for stationary wooden fishing structures and the ranges of their calibrated radiocarbon dates

and locations of the fishing related structures and their radiocarbon dating are illustrated in Figures 2 & 3, and more detailed descriptions of the individual excavation projects are provided in the Appendix S1).

Remains of fish traps

Remains of fish traps were present at five sites (Figs 2 & 4; Appendix S1). The best-preserved fragment of a wickerwork trap came from Syltholm X (MLF00936; see Fig. 4A), which dates to the earliest Neolithic, 3975–3799 cal BC. The small size of the preserved fragment did not permit a detailed reconstruction of the actual trap type, its size and shape, but it was woven using the so-called twining technique from split withies of red dogwood (*Cornus sanguinea*). This wood is not typical among comparable materials in Denmark but is known in Sweden (Larsson 1983; Mertens 2000), the Netherlands (Out 2008), and northern Germany (Klooß 2015a; 2015b). For example, woven fish traps at Late Mesolithic Ertebølle sites in northern Germany are woven exclusively from red dogwood or guelder rose (*Viburnum opulus*), while alder strips (*Alnus glutinosa*) and/or pine roots (*Pinus sylvestris*) were used as binding materials (Klooß 2015b). Interestingly, Late Mesolithic and Neolithic fish traps in the northern Netherlands are made from *Salix* species and/or hazel (*Corylus avellana*), whereas red dogwood was favoured for their manufacture in the south. This is probably due to functional selection and availability of suitable raw materials rather than cultural preferences or chronological variation, as also supported by archaeological and palaeoecological data (Out 2008).

Several other types of potential trap fragments were recovered from Syltholm II (MLF00906), including two examples of wooden trap mouth frames (Fig. 4C), a few wooden sticks woven with tree bast fibres (Fig. 4D), and three concentrations of withies, probably representing the remains of dismantled traps

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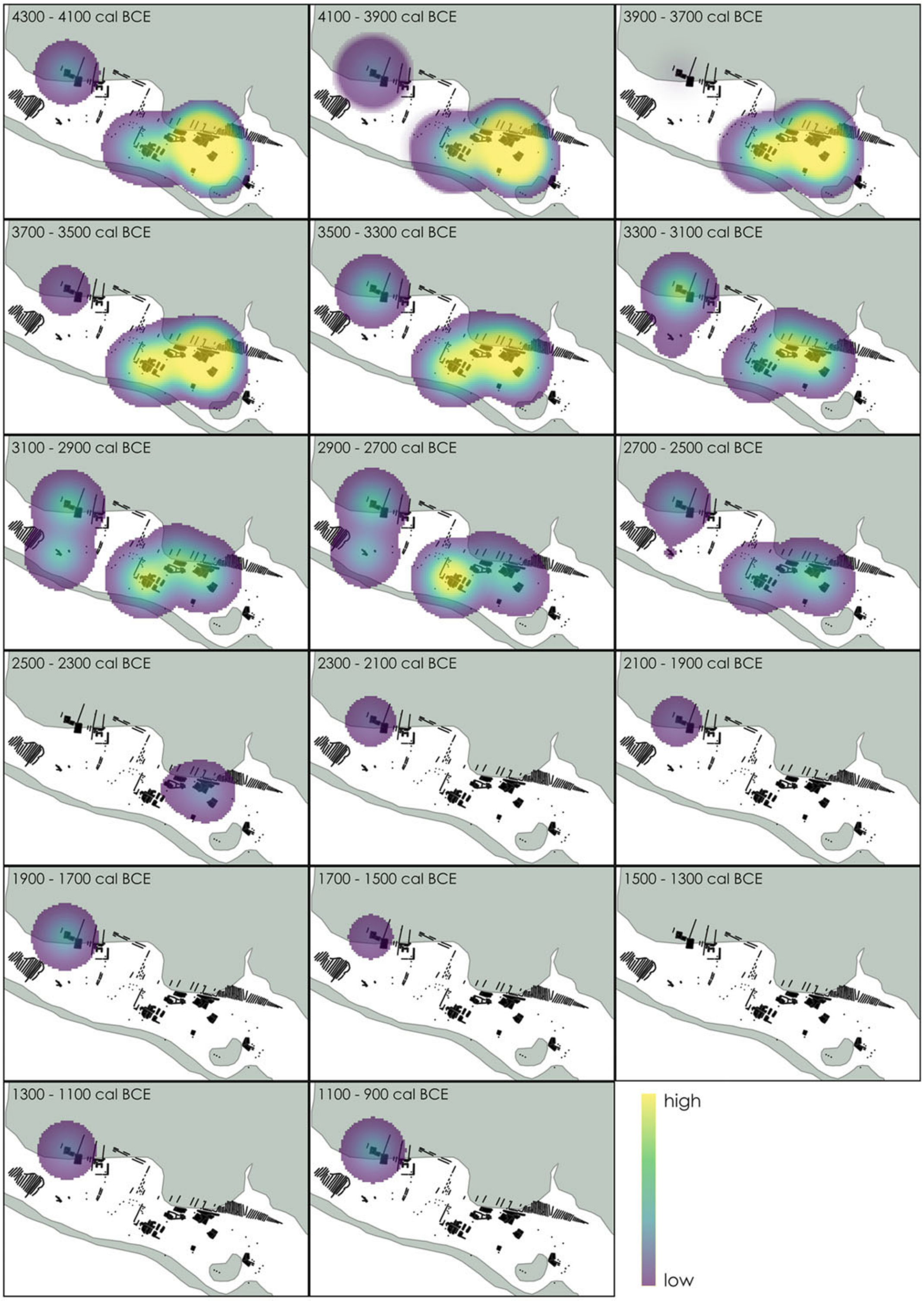

Fig. 3.
Density of radiocarbon dated stationary wooden fishing structures: black: areas excavated in the Femern project with documented remains of such structures

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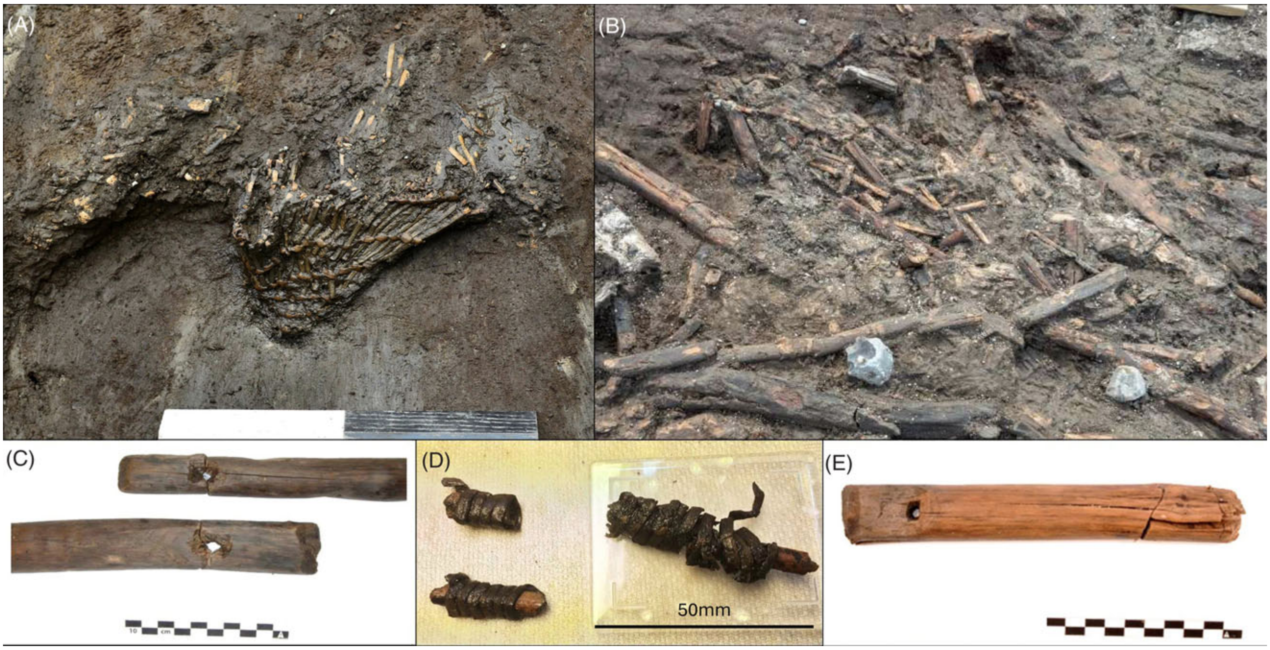

Fig. 4.
Fish traps from the Femern project excavations: A. Fragment of woven fish trap (X4186) *in situ* at Syltholm X (MLF00936); B. collection of thin branches and associated woven withies (X16700) *in situ* at Syltholm II (MLF00906-III); C. half of a suggested fish trap mouth frame (X8197) from Syltholm II (MLF00906-II); D. wooden stick with bast binding (X9878) probably from the tail of a basket trap from Syltholm II (MLF00906-II); E. fragment of trap mouth frame (X1805A) from Syltholm X (MLF00936) (photos © Museum Lolland-Falster)

(Fig. 4B). The wooden sticks (MLF00906-I: X9878) were bound with simple cords of tree bast. Similar finds are known from a number of Stone Age sites in Denmark and northern Germany (eg, Mertens 2000; Andersen 2013) where they have been interpreted as bindings of the tail end of the basket trap. A further cluster of uniformly sized branches of red dogwood (MLF00906-III: X16700, X22403, & X22404) with associated woven withies probably represent the remains of another dismantled woven trap.

Altogether six wooden rods with perforations at their ends, interpreted as mouth frames of semicircular or conical fish traps (eg, Andersen 2013), were recovered (see Figs 4C & 4E). The lengths of the intact artefacts ranged from 71.0 to 55.5 cm, with an average diameter of 3.2 cm; all identified specimens were made from *Corylus avellana*. Similar artefacts are known from a few Stone Age sites in Denmark, eg, Tybrind Vig (Andersen 2013), Ronæs Skov (Andersen 2009), and Jesholm I (unpublished). Originally interpreted as parts of dugout canoes or skin boats (Mathiassen 1943), they were subsequently identified as deriving from fish traps (Andersen 2013) with semicircular, square, or rectangular 'mouth' openings (see Brinkhuizen 1983). They are also known from prehistoric contexts in, for instance, the eastern Baltic (Rimantienė 2005). Based on ethnographic accounts, these types of fish traps were still in use in north-east Europe until the early 20th century (Sirelius 1908).

A total of ten radiocarbon dates has been obtained on fish trap fragments from Syltholm Fjord, ranging from *c.* 4670 to 2890 cal BC, and corresponding to the Late Mesolithic–late Middle Neolithic. Several additional fragments of wooden withies, branches, and sticks are also in the assemblage, which may originate from dismantled or destroyed fish traps.

CONSTRUCTION & CONTEXTUALISATION

Fish traps consist of long withies, binding materials, and re-inforcing structures. Their elements include the tail, mouth, chamber, and inner funnel or 'throat' (eg, Brinkhuizen 1983; Out 2008). The trap types in Syltholm Fjord are simple funnel shaped traps and

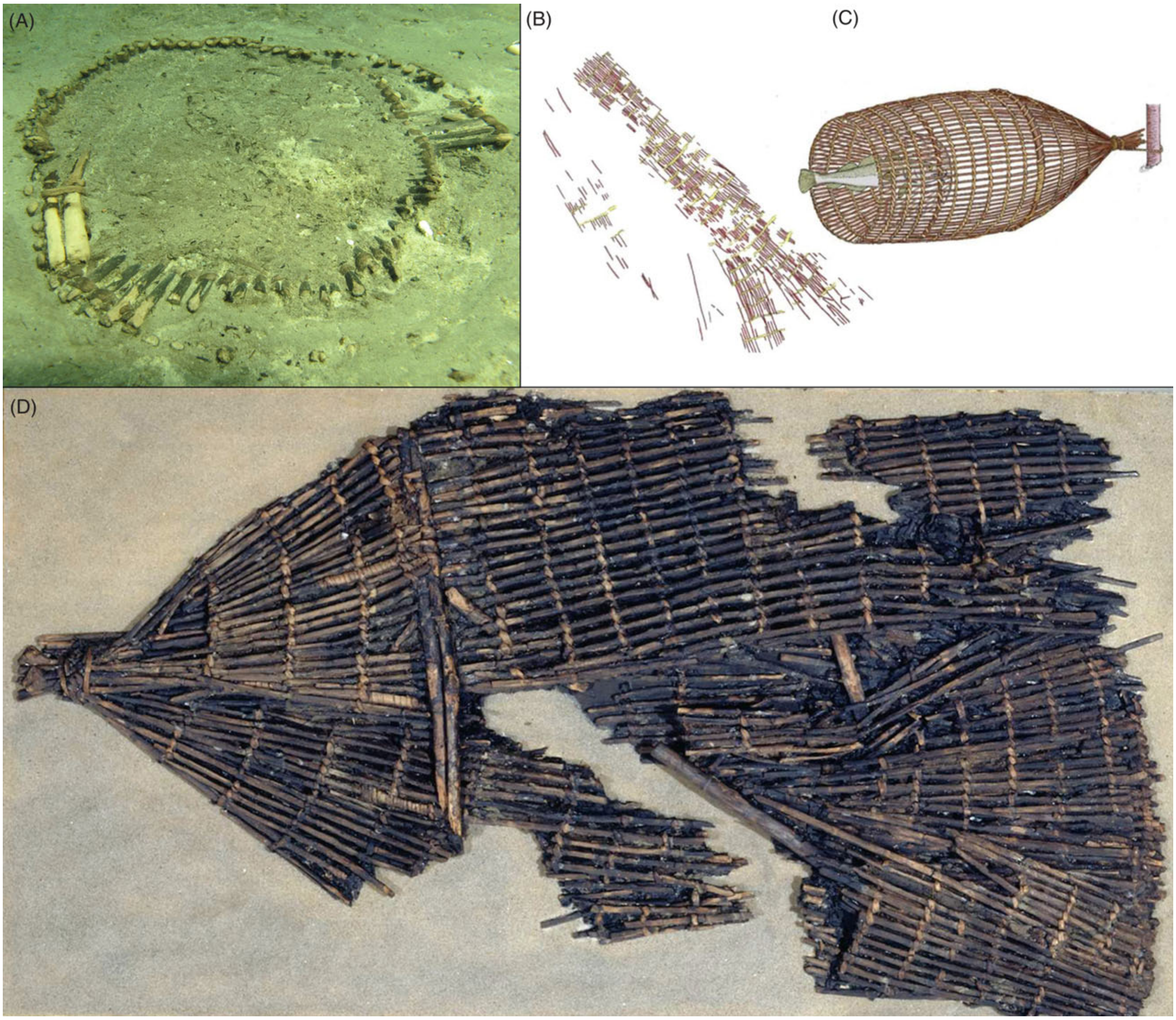

Fig. 5.
Examples of basket fish traps from Danish archaeological contexts: A. *in situ* trap at the underwater site of Tudsehage in 2021; B. plan of the excavated trap at Åtoftegård in 2020 with C. its reconstruction; D. trap found at Lille Knabstrup (photos & illustrations: A. Peter Moe Astrup © Viking Ship Museum; B, C. Tim Grønnegaard (reconstruction inspired by F. Bau) © Museum North Zealand; D. Kit Weiss © National Museum of Denmark)

those with semicircular or rectangular openings, as demonstrated by the presence of perforated mouth frame rods. The traps could have been used individually by fastening them to a post on the seabed (see Fig. 5C) or affixed to a larger weir installation by attaching them to the apex – a tapering end – of a wattle and stake weir. In slow and stagnant waters the simple funnel trap may not have been efficient due to low water pressure, meaning the fish could have easily swum in and out of the trap. To prevent this, inner-funnelled traps were developed (Brinkhuizen 1983). Given the small and fragmentary remains from Syltholm Fjord, it remains unknown whether there are any inner-funnelled examples in the assemblage.

It has previously been suggested (Stafseth & Groß 2023) that no fish traps were found connected to

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weirs. However, the wickerwork trap fragment (X4186) from Syltholm X was found in association with a curved, 4.6 m long, row of wooden stakes. The radiocarbon dates of the trap and stakes align (*c.* 3900–3600 cal BC), suggesting that the two elements were used in tandem. Interestingly, two of the stakes (made of *Corylus avellana*) had a perforation at the tapered end suggesting re-use of the fish trap mouth frame rods in the weir structure.

Fish traps or their remains have been found at 23 archaeological sites in Denmark (Fig. 5; Appendix S3), four of which (excluding the ten dates from the Syltholm Fjord examples) are directly radiocarbon dated to between 6216 cal BC (Villingebæk Øst A, K-1486) and 5223 cal BC (Åtoftegård, Poz-129015; Figs 5B & 5C), placing them in the Middle and Late Mesolithic. The well preserved specimens have remarkable similarities in detail and construction with ethnographically documented basket traps from north-east Europe (eg, Sirelius 1908), and the 'eel pots' from historic Denmark (Pedersen 2013). Trap remains have been recovered at, for example, Nidløse (Becker 1941; Brinkhuizen 1983; Mertens 2000) and Villingebæk (Kapel 1969; Tauber 1973), and there are almost intact specimens from eg, Åtoftegård (unpublished) and Lille Knabstrup (Fig. 5D) (Becker 1946; Andersen 1995). Based on their raw materials and manufacturing techniques (Mertens 2000), the withies were typically 0.3–0.6 cm in diameter which were placed at 0.5 cm intervals, whilst woven bindings were placed spirally or individually at intervals of a few centimetres to keep the structure firm and durable. The withies ended smoothly at the top 'tail' of the trap where they had been tied together with root or tree bast bindings. Withies of birch (*Betula*), willow (*Salix*), hazel (*Corylus avellana*), and lime (*Tilia*) were most commonly used for woven Mesolithic traps in Denmark, and the bindings were typically made from pine (*Pinus* sp.) roots, plant fibres, or tree bast, using the so-called twine weaving technique (Brinkhuizen 1983; Mertens 2000). Traps made of birch withies usually had the bark on, while those made of hazel and willow had been peeled, the purpose for which remains unresolved (Mertens 2000). However, the colour of the trap may have played a role by camouflaging it amongst the aquatic vegetation, preventing fish from avoiding it (cf. Sirelius 1908).

Wattle and stake weir structures

Evidence of wooden weirs with wattled structures was identified at four of the Syltholm Fjord sites (Fig. 2; Appendix S1). The best-preserved examples consist of wattle-and-stake 'leaders' forming wooden fence-like barriers set in various geometric arrangements, shapes, and lengths (Fig. 6). At two sites (MLF01362 & MLF00933), the wattle sections were found almost intact – deposited in their original configuration in a vertical or slightly inclined position, with some stakes still standing upright in the former fjord sediments. Isolated wattle sections of varying length and width, lying horizontally on the seabed, were identified at three sites and/or sub-units.

At Femern Bælt I (MLF01362), two 'leaders' were recorded, approximately 33 m and 63 m long, made of upright stakes and woven wattle panels. Together they formed a V-shaped weir at an angle of 45° (Fig. 6C) and their preservation varied, with the lowest layers being the best preserved. Three successive constructional phases were recorded, which have been dated to 3084–2705 cal BC (K1; $n = 2$ dates), 3328–2907 cal BC (K2; $n = 2$ dates), and 3011–2675 cal BC (K3; $n = 2$ dates). At one end of a wattle, the joint structure to the supporting stake was also preserved, consisting of the two lowest horizontal rods extending around a vertical stake and back around the adjacent rod. Four rods were identified as hazel, while two uprights could not be determined. Two additional, isolated, horizontal wattle panel sections were also found at the same site but these were not directly dated, so their association with the V-shaped weir remains uncertain. One, measuring *c.* 6.6 × 1.0 m, was discovered *c.* 80 m north-east of the V-shaped weir. It was made of a series of upright tapered stakes and woven long rods of varying lengths and thicknesses. The thicker root ends of the rods were oriented towards the ends of the wattle, while the thinner tops joined in the middle. Another very fragmentary isolated section of horizontal wattle, *c.* 3 m long, was found only 2 m from the V-shaped weir but it appeared to be woven from slightly finer and thinner rods than the larger structure.

Excavations at Strandholm I (MLF0909) revealed two sections of horizontal wattle panels (K1 & K2), probably from the same construction, together with vertical and diagonal stakes and posts – two of the thicker ones firmly anchored in the former seabed. K1 was a 20 m long and *c.* 80 cm wide, partially

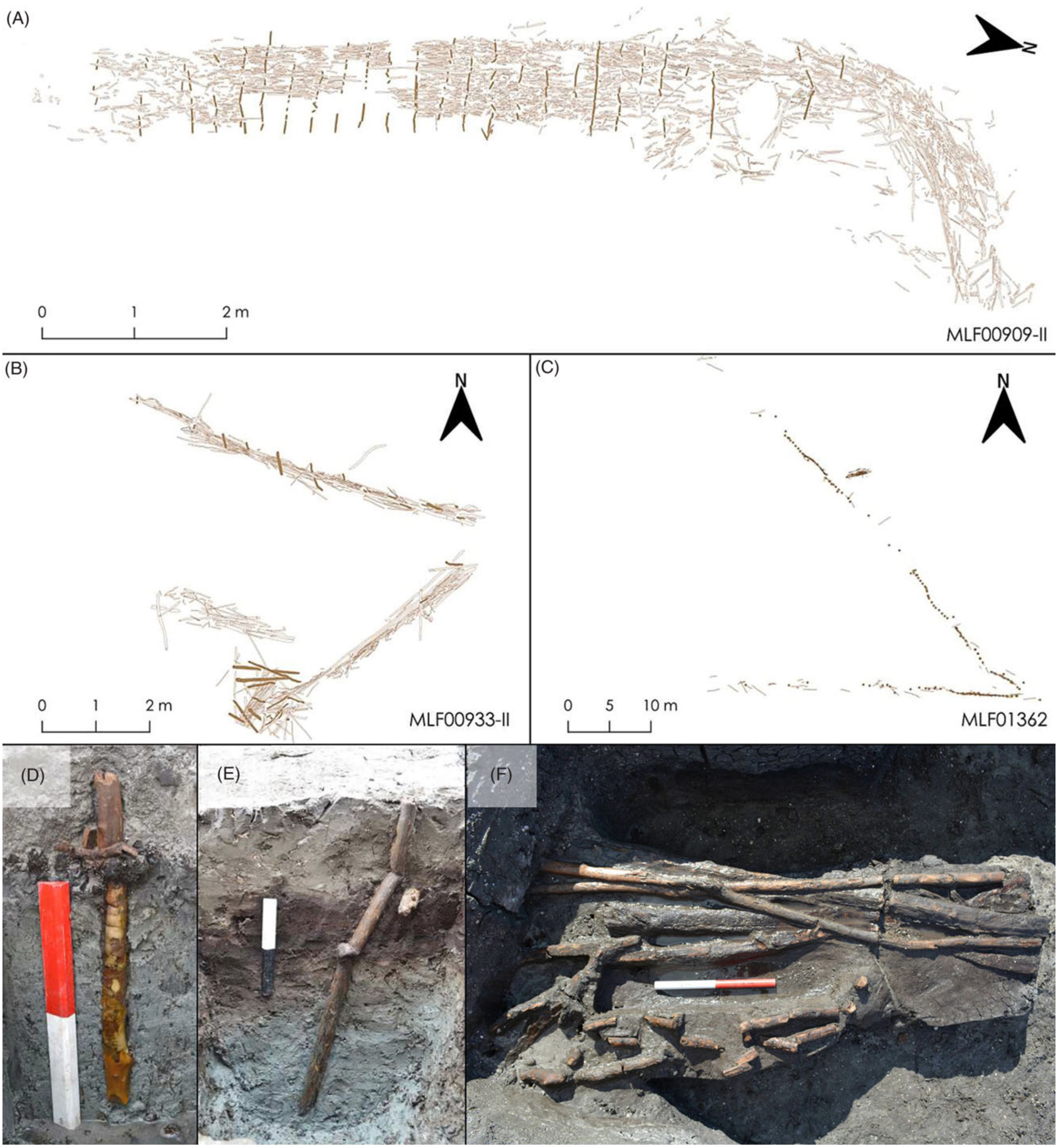

Fig. 6.
Plans of weirs (A–C) and fragmentary evidence for stationary wooden fishing structures (D–F) from the Femern project excavations: A. plan of the horizontally lying presumed U-shaped wattle weir (K1) at Strandholm I; B. plan of the V-shaped weir (K1) at Syltholm VII; C. plan of the V-shaped weir (K1) at Femern Bælt I; D. remains of wattle preserved on a single vertical stake (X13) at Syltholm IX (MLF00935-II); E. a single stake (X1710) driven through gyttja, peat, silt, and into clay associated with a fishing structure at Syltholm X (MLF00936-I); F. a cluster of horizontal stakes (K3) at Syltholm XII (MLF00938) (photos & illustration: © Museum Lolland-Falster)

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preserved, wattle panel section lying horizontally in a sand layer near the former shoreline. It had the shape of an arch or letter U (Fig. 6A), with the opening roughly facing the fjord. It was made of long, slender, uniform rods (0.6–1.8 cm in diameter) woven tightly between 56 closely spaced uprights (1.0–1.9 cm in diameter). The entire wattle structure appeared to have been woven in one long course rather than in several sections, which distinguishes it from the other wattle panel specimens in the study area. K2 was a similar but poorly preserved woven panel (almost 16 m long) embedded horizontally in a layer of sand and shell, *c.* 25 m north of K1. However, structural similarities suggest that the two may have been of the same construction, which is further supported by the radiocarbon dates (K1: 2472–2205 cal BC ($n = 3$ dates) and K2: 2454–2036 cal BC ($n = 2$ dates)). This wattle also consisted of relatively slender rods, woven tightly around almost equal slender uprights, spaced 21–30 cm apart. Both structures were made of hazel. In addition, several vertical stakes and rods with radiocarbon dates ranging from 4227 cal BC to cal AD 121 ($n = 13$ dates) were found at the site.

At Syltholm II (MLF00906-I), a partially preserved, isolated section of wattle was found lying horizontally on the seabed. It was younger (2574–2302 cal BC) than the fragments of fish traps (see above) found at the same site, indicating that they were not used together. The wattle section was woven with slightly finer rods than those from Syltholm VII (MLF00933-II) and Femern Bælt I (MLF001362). It consisted of 19 uprights (*c.* 2.0 cm in diameter) and interwoven thinner rods (*c.* 1.0 cm in diameter), and the wattle itself was very dense and carefully woven, with no twists, side shoots, or other irregularities as observed on the other wattle panels mentioned above.

Several of the weir sites in the circum-Baltic region also contained stone structures (eg, Price *et al.* 2001; Skaarup & Grøn 2004; Andersen 2009; 2013; Hartz *et al.* 2014; Klooß 2015b), interpreted as stepping stones or platforms to help people access the weirs eg, for maintenance and emptying the basket traps, especially in soft gyttja sediments. In Syltholm Fjord, stone rows and/or packings were recorded at MLF00909-I, MLF00935-II, and MLF00939-I, often associated with clusters of wooden stakes (especially MLF00939-I), most of which were found in soft gyttja horizons and interpreted as being artificially deposited. Natural stone belts were also found on the seabed, with a few larger flat stones possibly added subsequently for the same purpose. In addition, at MLF00933-II and -III, numerous human footprints were found in the soft gyttja deposits associated with the wooden weir structures (see Bennike *et al.* 2023).

RESEARCH SPOTLIGHT: SYLTHOLM VII

At Syltholm VII (MLF00933-II & III) three weir sections were discovered almost on top of one another (Figs 6B, 7, & 8). Based on the stratigraphy, spatial relationships, and radiocarbon dates ($n = 11$), the structures can be identified as consisting of four construction phases of weir elements (K0, K1, K2, & K3) in the same location. All phases had a clear relationship to each other, but probably represent different episodic repairs of the same weir which, according to our revised Bayesian chronological model, was in use for at least 43 years (see Appendix S2).

Construction

The oldest phase, K0, consisted of a single, dense brushwood fence (A7) that was stratigraphically located below the following phases (see Fig. 8C). The subsequent construction phase, K1, consisted of a V-shaped weir, which was the best preserved. The uncovered part formed two 'leaders' positioned at an angle of *c.* 45°. It consisted of supporting stakes and three wattle panels, forming a *c.* 15 m long barrier structure, and a further four wattle panels forming another *c.* 12 m long 'leader'. The longer of the two was still standing upright, while the majority of the wattle panels of the shorter structure were lying horizontally on the seabed. There were relatively few supporting stakes and posts and they did not appear to have been arranged in a clear pattern or systematically spaced. However, one of them was found driven almost 0.8 m into the seabed, which would have provided sufficient support for a more extensive structure. A total of seven wattle panels was recorded at K1, overlapping at the edges by approximately 1 m. The lengths of the individual panels ranged between 4.5 m and 6.0 m and the uprights (*c.* 2.0–5.5 cm in diameter) were set at a spacing of 45–55 cm. Hazel (*Corylus avellana*) was the predominant species used for the rods and uprights, while ash (*Fraxinus* sp.) and lime (*Tilia* sp.) were also used for the supporting stakes and posts. Individual rods were regularly woven consecutively in front of and behind the single uprights, but occasionally one rod crossed two

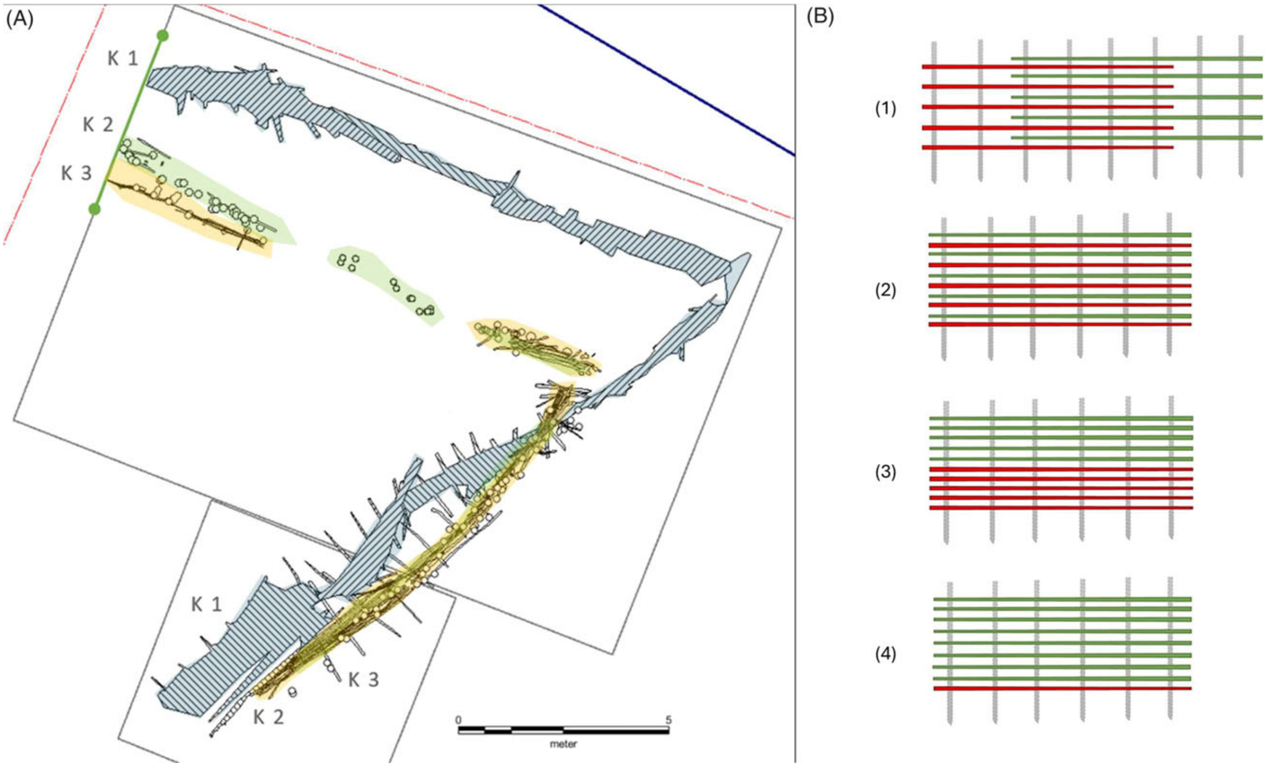

Fig. 7.
A. Plan of the V-shaped weir showing the three constructional phases (K1 in blue, K2 in yellow, K3 in green) at Syltholm VII (MLF00933-II); B. types of wattling in the preserved panel sections with the thick root end facing left (red) or right (green): 1. Type 1 – rods set with thick ends facing outwards and thin ends overlapping in the centre (section A40); 2. Type 2 – rods set similarly as in Type 1, ie, thick ends outwards, but with rods running through the whole panel (section A7); 3. Type 3 – woven through rods, set in opposite directions in the upper and lower halves of the panel (section A9); 4. Type 4 – woven through rods, all set with thick end to one side of the panel (section A8) (map & illustrations: © Museum Lolland-Falster)

uprights on the same side. At Syltholm VII four wattling techniques were identified (see Fig. 7B).

Potential traces of maintenance and repair of the wattle structures was also evident. A few panels (in K1) appeared to have a few extra branches/sticks (40–60 cm long, 2.0–2.5 cm in diameter) placed at a transverse angle across the horizontal rods. These elements may have been added during maintenance to provide additional strength and/or to re-inforce the woven structures.

The second phase of construction (K2) was not as well preserved and appeared difficult to interpret, especially in relation to the other constructional phases. It probably constituted an intermediate phase – a repair before replacement with K3 (see Stafseth & Groß 2023) – consisting of two rows of stakes and almost horizontally lying, fragmentary wattle sections woven from rods and branches of varying shapes and diameters. In contrast to K1, the full extent of K2 was unclear due to limited preservation. One of the 'leaders' seemed to have been moved a couple of metres to the south where a new apex was placed on top of the previous K1 'leader'. Together, they formed a V-shaped structure: one 'leader' orientated north-west (*c.* 12 m long) and another south-west (*c.* 25 m). There were three other woven panels associated with this phase, and a cluster of solid posts and plank-shaped pieces of wood had been placed at the apex. The best preserved wattle panel measured 7.5 m in length and consisted of eight uprights (3.1–6.1 cm in diameter) placed at 60–65 cm intervals and 15 horizontal rods (0.8–4.0 cm in diameter and 120–238 cm in length), wattled in the Type 3 variant (see Fig. 7B).

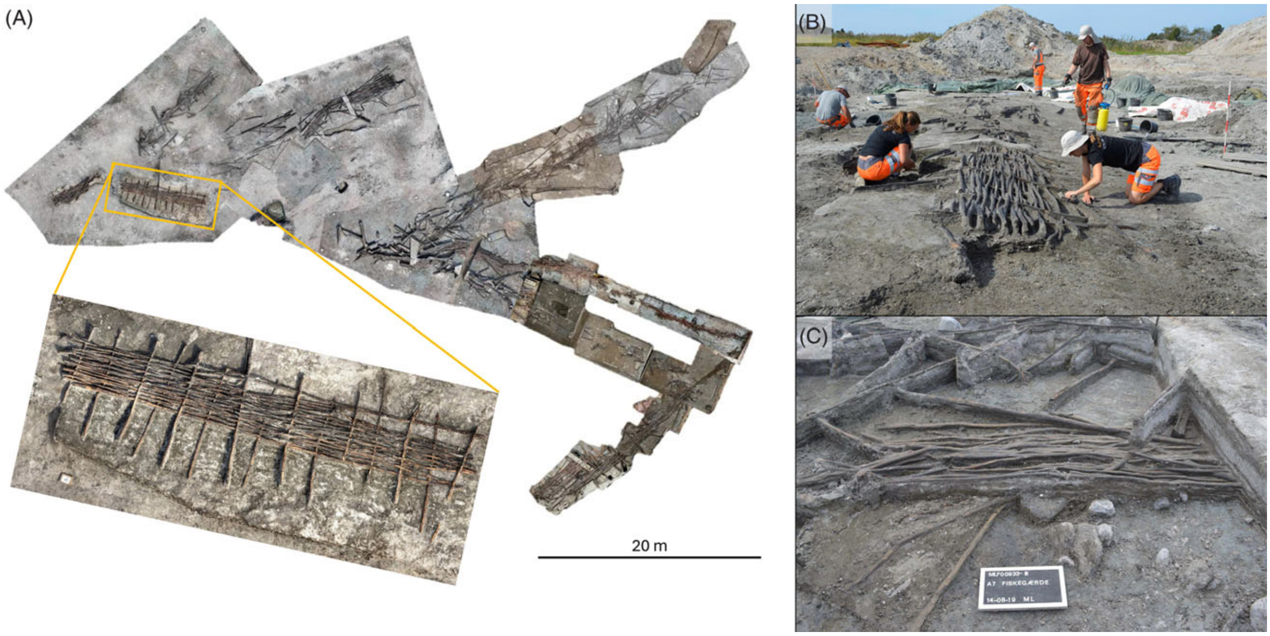

Fig. 8.
Weir structures from Syltholm VII: A. orthophoto of the excavated structures at sub-sites MLF00933-II and MLF00933-III, including a zoomed-in photograph of a wattle panel section, A10; B. excavation of the wattle panel section, A8; C. weir structure, A7, and the overlying younger segment, A5, in the foreground, probably part of the larger weir in the background. Note the stratigraphy on the right: A7 is embedded in a lower, humic layer and separated from the overlying structures by two distinctly intersecting sand layers (photos: © Museum Lolland-Falster)

The excavated part of the latest phase, K3, was of a different type (see Fig. 9C), but its elements still formed a V-shaped weir. It consisted of two rows of vertical wood (121 stakes, branches, and twigs of various shapes and diameters) densely arranged in a screen-like structure, forming two 'leaders': one facing north-west (60 uprights) and the other south-west (61 uprights). These two rows met at the apex, which again contained a few plank-shaped pieces of wood and vertical posts. The wood of the uprights was hazel (*Corylus avellana*), while one of the sturdier posts in the apex was oak (*Quercus* sp.).

Another leader, also standing vertically in the seabed, was found at sub-site MLF00933-III, *c.* 25 m west of K0–3, and orientated south-west to north-east. They together probably formed a Z-shaped weir rather than two isolated V-shaped constructions (Fig. 8A). A further four fragmentary sections of wattle panels were found in the western part of the site (Figs 8A & B), probably originating from other locations and representing a dismantled and drifted weir, as they had similar structural characteristics and were found facing in the same direction. The northernmost wattle (A14) may have formed another V-shaped weir, some 8–10 m from the larger structures.

Dating

The spatial and stratigraphic relationship of the wattle and stake structures at Syltholm VII allowed us to produce a detailed radiocarbon model (see Appendix S2 for the chronological model and OxCal CQL Code). In the Z-shaped segment of the construction, wattle structure A7 (at sub-site MLF00933-III) represents the stratigraphically oldest construction (3034–2902 cal BC). It is clearly overlaid by structure A5 (see Fig. 8C) and the potentially contemporaneous construction phases K1 (2898–2876 cal BC), K2 (2890–2873 cal BC), and K3 (2887–2873 cal BC). Another wattle and stake structure A7 (at sub-site MLF00933-II), at the south-west end of K0–K3, is of a similar age and may be contemporaneous (2943–2891 cal BC).

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As the horizontally lying wattle sections in the western part of the excavation were not clearly related to the Z-shaped structure, they were treated independently. However, they all date from between 2900 and 2860 cal BC and are hence contemporaneous and possibly part of the same structure.

COMPARATIVE MATERIALS

Evidence of similar wattle structures used in fish weirs is known from a further 21 sites in Denmark (see Appendix S3). While the majority are located in coastal contexts, including estuaries and sheltered lagoons, a few have been identified in riverine and lacustrine environments. A total of 33 radiocarbon dated wood samples are available from eight sites (excluding those obtained by the Femern project), while the remainder are only dated contextually. The oldest specimen derives from Køge Havn, eastern Zealand, which is dated to the Middle Mesolithic (earliest Kongemose period), 6599–6237 cal BC (Fiedler *et al.* 2023). Similarly, the oldest example of wattled weirs in the wider vicinity derives from Haväng, south-east Sweden, which is dated to 6646–6457 cal BC (Hansson 2018). The youngest Danish example is from Sondrup Strand II, eastern Jutland, which is dated to the historical period, cal AD 1648–1798.

One of the most extensively studied Danish examples is the Neolithic wattle panel section from Oleslyst, western Zealand (eg, Pedersen 1995; 1997; Christensen 1997), the two construction phases of which have been dated to *c.* 3500–2600 cal BC. Here, a belt of vertical stakes was observed over a stretch of *c.* 40 × 2 m on the seabed, and a wattle panel section *c.* 5.5 m long and 1.7 m wide was found almost intact and selected for excavation (Pedersen 1995; 1997; 2013). In the panel, both the uprights (2.0–3.0 cm in diameter) and the rods (*c.* 2.0 cm in diameter) were made of hazel and a few rods ran almost the full length of the panel, with both ends beginning with the thicker root ends of the rods, while the thinner upper ends met and overlapped in the middle (Christensen 1997); this was also observed in the wattles from Syltholm Fjord (see Type 1 in Fig. 7B). In this way the length of the panel could almost be doubled with the used rods. Evidence of forest management to obtain sufficient quantities of suitable raw material for the weirs was suggested for Oleslyst (Pedersen 1995; 1997; 2013; Christensen 1997), and a few other Danish weir sites, for example the Mesolithic weir at Halsskov, western Zealand (Christensen 1997) and the Neolithic specimen at Nekselø (also known as Fletværket in the literature), north-western Zealand (eg, Pedersen *et al.* 2018). In the latter example, a 200 m long and 15–20 m wide weir system with several phases of rebuilding is thought to have extended from the south-west end of Nekselø to a water depth of 2.5 m in Sejerø Bay (eg, Pedersen & Fischer 1991; Fischer 1998).

Closer examination of the weir materials in Syltholm Fjord revealed a different type of structure, contrasting with the more common wattle and stake type used in Denmark and north-west Europe. K3 at Syltholm VII (MLF00933-II) represents a wooden screen structure, which was made of densely arranged vertical (roundwood) rods of hazel (see Fig. 9C). Interestingly, we found comparable structures at a few sites throughout Denmark: Halskov Overdrev (Willemoes *et al.* 1989; Pedersen 1995; Fund og Fortidsminder 2024), Oreby Rende (Dencker 1991; Fund og Fortidsminder 2024), Svinninge Vejle (Becker 1941; 1943), and Nykøbing Falster (unpublished), with their dates ranging from the Late Mesolithic (contextual date from Svinninge Vejle) to the Late Neolithic (direct dates from Nykøbing Falster, 2857–2492 cal BC) (Fig. 9B). Similar structures have also been identified, for example, in underwater contexts at Lake Arendsee, Germany. Here, thin parallel hazel rods which had been erected vertically in the ancient lakebed were found (Fig. 9A), with radiocarbon dates falling in the Late Neolithic (3rd millennium cal BC; Leineweber *et al.* 2011). The 'rod screens' at Lake Arendsee were bound with maple bast fibres, while at Syltholm VII no binding materials were preserved. In principle, the structure type is similar in design and manufacture to the split pine lath fishing screens known in north-east Europe, which date primarily to the Neolithic, eg, in the eastern Baltic (Bērziņš 2008; Piličiauskas *et al.* 2019), Finland (Koivisto 2012; 2017), Sweden (Hallgren 2023), and north-west Russia (Gusentsova & Sorokin 2017; Piezonka *et al.* 2020). These examples, however, were manufactured out of different species of wood – presumably what was locally available and best suited to the waterlogged settings. This type of fishing structure may in fact be much more widespread than currently known, and its examples therefore require further study.

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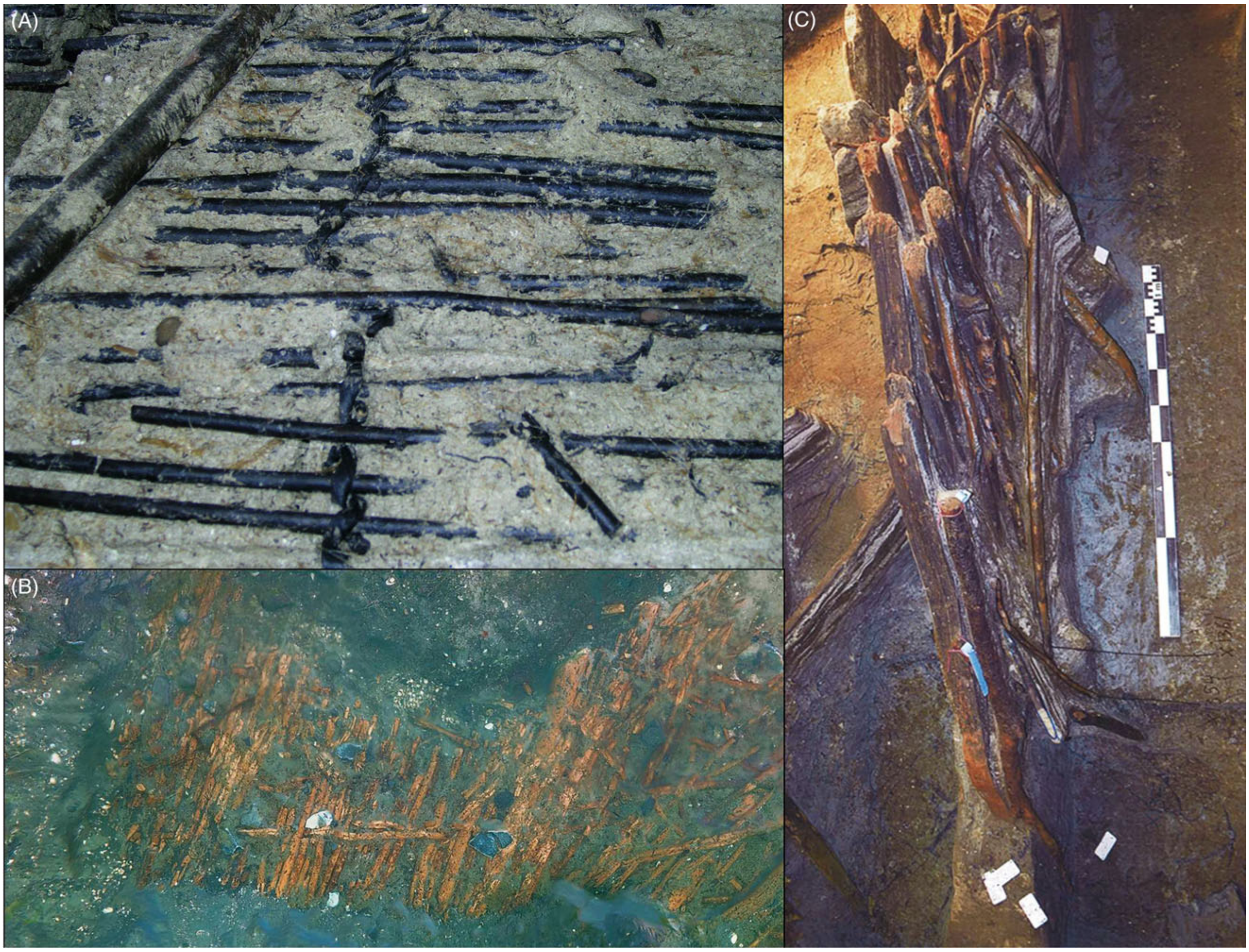

Fig. 9.
Examples of weirs made of screens of vertical rods from: A. Lake Arendsee, Germany; B. Nykøbing Falster; C. Syltholm VII (K3 at MLF00933-II) (photos: A. Rosemarie Leineweber © LDA Sachsen-Anhalt; B. Morten Lundbye © Viking Ship Museum; C. © Museum Lolland-Falster)

Stakes and posts

In total, over 2000 wooden stakes were recorded during the excavations in Syltholm Fjord (see Figs 2 & 6) which, until now, had not been directly associated with the stationary fishing structures. For example, at Syltholm II (MLF00906-III), a total of 328 stakes were found, set obliquely ($n = 196$) or vertically ($n = 132$) into the ancient seabed, and radiocarbon dated to between 4720 and 3040 cal BC ($n = 16$ dates). A further 225 stakes were recorded at the adjacent subsite (MLF00906-II), 127 of which were also set obliquely or vertically into the former seabed and dated to between 4340 and 2930 cal BC ($n = 27$ dates). The function of the stakes at Syltholm II – and at other Femern project sites with similarly numerous wooden remains – has not yet been resolved.

Interestingly, at several of the sites where stakes were recorded (eg, MLF00909-II, MLF00936-I, MLF00939-I and II) they appeared to follow the contours of the underwater topography, framing depressions in the seabed, similar to excavated sites with preserved wattled structures. At MLF00939-I, rows of stakes framed two stone settings. During the preliminary phase of the investigations (from MLF00935-II & MLF00939-I), a number of wooden stakes were encountered during coring, while subsequent trenching yielded remnants of woven rods (see Fig. 6D), probably from wattles that had been

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TABLE 1. EXAMPLES OF ARCHAEOLOGICAL SITES WITH STATIONARY WOODEN FISHING STRUCTURES THROUGHOUT THE CIRCUM-BALTIC REGION

Site Name	*Reference*
Sweden	
Rönneholms mosse	Sjöström 2018
Dagsmosse	Hallgren 2023
Ekebymossen	Hallgren 2023
Ageröd V	Larsson 1983
Tågerup	Karsten & Knarrström 2001
Germany	
Travenbrück LA5	Hartz 1997
Kayhude LA8	Hartz 1997
Rüde 2	Schwabedissen 1958
Heidmoor	Schwabedissen 1958
Satrup bog	Feulner 2012
Timmendorf-Nordmole I	Klooß *et al.* 2009
The Netherlands	
Hoge Vaart	Peeters *et al.* 2002
Hardinxveld-Giessendam De Bruin	Out 2017
Latvia	
Sārnate	Bērziņš 2008
Lithuania	
Šventoji	Rimantienė 2005
Finland	
Purkajasuo	Koivisto & Nurminen 2015
Lamminoja	Koivisto *et al.* 2018

attached to them. We therefore propose that there is sufficient evidence to suggest that the majority of stakes and posts in the study area derive initially from fishing structures (see below).

Traditionally, tapered wooden stakes, posts, and rods in Danish Stone Age contexts have been interpreted as the remains of fishing structures (eg, Pedersen 1997; Fischer 2007) or wooden debris deposited in refuse zones in front of dryland settlements (eg, Andersen 2013; Skriver *et al.* 2018). In our dataset (Appendix S3), the vast majority (77%) of the proposed fish weir sites consist solely of wooden stakes and/or posts – either as vertical, oblique, or horizontal isolated remains, or forming clusters, rows, or other geometric features, with no preserved remains of wattled structures. Such evidence is relatively frequent at coastal Ertebølle sites in the western Baltic as well as in Mesolithic and Neolithic contexts throughout the circum-Baltic region (see examples in Table 1).

DISCUSSION

Development of fishing practices at Syltholm Fjord in prehistory

The coastal area of southern Lolland has been an attractive landscape for settlement and subsistence for several millennia. Previous studies on prehistoric fishing activities in Syltholm Fjord have emphasised a marked transition from active to passive methods and suggested, based on the radiocarbon dates of the wattled remains, that stationary wooden weirs were not used in the area before 3300 cal BC (Måge *et al.* 2023; Stafseth & Groß 2023). By collating all the wooden evidence deposited in the waterlogged areas, including their direct dates, spatial distribution, wood species, and sample types, our re-analyses of individual sites and their characteristics refutes the earlier view.

For example, in some earlier publications on Syltholm II and its findings (Sørensen 2020; 2023), the hypothesis that the hundreds of wooden stakes, posts, and rods recorded in the ancient seabed represent the remains of fish weirs was disregarded, largely based on the observation that they did not occur in systematic clusters or linear arrangements and their radiocarbon dates covered a broad range. Instead, it was suggested that they represented a form of ritual space in the shallow waters in front of the dryland settlements, where specific materials, such as animal mandibles and wooden artefacts (eg, spears, axes, and paddles – some of them having partly charred surfaces), were deliberately deposited during the Late Mesolithic and Early Neolithic (Sørensen 2020; 2023). Interestingly, similar vertically deposited wooden artefacts, such as paddles, spears, and shafts have been found at several Late Mesolithic submerged contexts in Denmark and northern Germany (Andersen 2009; 2013; Klooß 2015a; 2015b) which, in contrast, were interpreted as having been re-used in stationary wooden fishing structures or as firewood.

In the prehistoric Syltholm Fjord, the evidence for using such large numbers of wooden structures specifically for ritual activities is not adequately supported, especially as the area had been used for fishing for several millennia. Furthermore, similar species were used to construct the wooden stakes and posts and preserved weir structures, including those with preserved wattle fragments, and most were found located in areas suitable for weir fishing based on the underwater topography. Thus, we interpret the

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wooden stakes, posts, and rods as the remains of fishing structures; either as support elements of partially dismantled wattle weirs, left at prime fishing locations to mark them and ready for use, and/or representing fragmented and only partially preserved weir elements. Moreover, geological data indicate that clay gyttja deposits in the area had been overlain by layers of sand separated by an erosive boundary in between (Bennike & Jessen 2023), suggesting that previously existing clay gyttja deposits – along with possible weirs – may have eroded, with only a portion of their wooden structures remaining preserved in the ancient seabed.

Taken together, this evidence suggests that Syltholm Fjord had been used for passive fishing for much longer than previously thought and that both active methods using composite leisters with wooden lateral prongs and bone points (Chaudesaigues-Clausen 2023; Koch *et al.* 2024), and passive methods were used, likely together. Wooden weir elements were built and fixed to the seabed, taking advantage of the local underwater topography and changes in shoreline and water depth, where they were also vulnerable to varying weather conditions, water level changes, and coastal erosion. Based on ethnographic accounts (eg, Møller 1953; Pedersen 2013), the wattle modules and basket traps survived several years if removed from the water for winter, while the support stakes and posts could be left at sites for future seasons. As a result, a significant number of wooden structures and their debris have accumulated in good fishing areas, especially if they had been in use for extended periods. This likely explains the abundance of prehistoric wooden finds and structures in Syltholm Fjord. Similar observations – though to a lesser degree – have also been made at several submerged and waterlogged sites with comparable materials in the western and north-east Baltic Sea (eg, Fischer 2007; Andersen 2009; Koivisto 2012).

We acknowledge that several other types of wooden remains and structures have been found in submerged and waterlogged contexts in Denmark and Northern Europe, for instance, platforms (Becker 1947; Ellis *et al.* 2002), trackways (Godwin 1960; Jørgensen 1977; Achterberg *et al.* 2015; Casparie 1989; Olsen *et al.* 2024), and piers (Andersen 2009), which may well have existed in our study area. However, the vast majority of wooden structures in Syltholm Fjord were made of similar species and dimensions to the preserved fish weirs, while the stakes and posts in other types of structures are typically made of more robust elements and a wider range of taxa (eg, Andersen 2009).

The portability and organic raw material of wooden weirs and basket traps were important in terms of adaptability to changes in local habitat and seabed characteristics, such as changes in water level, water flow, sedimentation, and erosion – and hence fish routes. Moveable traps and their fragmentary remains, dated in Syltholm Fjord to *c.* 4670–3110 cal BC, were most likely used in conjunction with larger weir structures, attached at their apexes and removed, repaired, and re-used between fishing seasons. Their use would not have been dependent on changing water levels if used independently and mounted on posts (see reconstruction in Fig. 5C), or 'actively' as hand-held baskets in shallow water (Malm 1995; Smart 2003), and therefore they formed a very adaptive catching facility. Composite leisters were used for spearing fish in near-shore areas for a considerable time, from the Middle Mesolithic Kongemose period to the Early Bronze Age, *c.* 6010–1780 cal BC, either from a dugout, by wading into the water, or by standing on a large stone, as was the interpretation at Syltholm X (see Appendix S1). Interestingly, there is currently no evidence of hook and line and/or net fishing in our study area. Either the evidence was lacking from excavated areas, or the local landscape favoured the other types of fishing methods.

Seasonal and longer term environmental changes have potentially led to the modification and relocation of weir structures, or parts of them. Based on ethnographic accounts (eg, Møller 1953), the historic eel weirs in Danish coastal waters were placed to take advantage of the shallow water zones and sand barriers in coastal flats, estuaries, and fjords, facing a break or channel in a sandbank, so that a current through the opening would flush fish along the weir and into the trap (Pedersen 2013). Interestingly, the sites with preserved wattle structures in Syltholm Fjord had been clearly positioned in relation to the barrier islands, suggesting paths for currents and overflows into the sheltered lagoon, which is further supported by the geological data (Bennike *et al.* 2023). The weirs were thus placed in optimal locations for maximum success in guiding fish into the traps, which could be described as an adaptive fishing strategy using portable and flexible wattled modules and basket traps.

The use of the coastal landscape and its fish resources can be further assessed by drawing upon the fish bone assemblages analysed so far. For example, excavations at Syltholm II (MLF0906-II) yielded hundreds of unburnt fish remains (73% of which were identified to the species level), presumably representing the natural fish fauna residing in the area and not necessarily directly associated with prehistoric fishing activities. As all skeletal elements are represented with no clear tendencies within or between species, it is also unlikely that the assemblages reflect waste disposal into the water from the processing of fish catches on shore. Nonetheless, they provide insights into the local fish fauna and the likely species targeted using the stationary wooden structures. Most of the identified specimens belong to European plaice (*Pleuronectes platessa*), European eel (*Anguilla anguilla*), and shorthorn sculpin (*Myoxocephalus scorpius*), followed by righteye flounders (Pleuronectidae), turbot (*Scophthalmus maximus*), and eelpout (*Zoarces viviparus*). Similar taxa have been identified at other sites in the study area, suggesting that this composition was typical of this coastal landscape (eg, Schmölcke & Ritchie 2010). Preliminary analyses of fish remains from various sites in Syltholm Fjord show that the preferred prey were bottom feeders, mainly different species of Pleuronectidae and shorthorn sculpin. This applies to the entirety of the study period. In addition, Atlantic cod (*Gadus morhua*) and European eel were occasionally of economic importance. Small specimens or by-catches of species with little economic relevance are regularly recorded, such as the three-spined stickleback (*Gasterosteus aculeatus*). Basket traps have earlier been described as a relatively unselective means of catching fish (Enghoff *et al.* 2007), which is in agreement with the potential species caught using stationary structures in Syltholm Fjord.

Active fishing with leisters began in the area around 5900 cal BC (earliest directly dated wooden leister prong from MLF00906-I), while the earliest vertical stakes date to *c.* 4600 cal BC (MLF00906-III), suggesting passive fishing in the eastern lagoon in shallow water (*c.* 1–1.5 m) during the Late Mesolithic. Fish traps appear in the material soon after, *c.* 4530 cal BC, also in the eastern lagoon (MLF 00906-III), and continue to be used into the Neolithic, at least to *c.* 3350 cal BC (latest trap mouth frame from MLF00001-VII). The best preserved wattle weirs date from the Middle to the Late Neolithic, 3330–2040 cal BC, coinciding with observable changes in the environmental proxy data (Jessen *et al.* 2018): the rising sea level gradually led to higher salinity and a slight increase in water depth in the brackish water environment, which may have had an effect on the abundance and diversity of fish communities residing in the area. At around 3500 cal BC, a sandy ridge separating the two lagoons was inundated, connecting the two basins with shallow waters in between. This narrow shoal zone is where the earliest of the preserved V-shaped wattle weirs were built (Femern Bælt I MLF01362), followed by the construction of another V-shaped structure on the eastern side of the shallow (Syltholm VII MLF00933-II). From *c.* 3000 cal BC onwards, sandy layers accumulated on top of the gyttja horizons, suggesting increasing energy due to general sea level rise and resulting in more regular inflows through the barrier islands (Bennike & Jessen 2023). This was also observed in the sediment layers surrounding the best preserved wattle structures, evidenced as a layer of sandy deposits a few centimetres thick, suggesting erosive impulses at fairly regular intervals. In fact, this may be the reason why the fish weirs from this particular period were the best preserved in the study area, as they were covered rather rapidly with protective sandy deposits and hence were not as vulnerable to erosion as the more exposed structures from other periods.

Cultural and societal aspects of weir fishing

Fish was an important food source for the Late Mesolithic populations (*c.* 5400–4000 cal BC) of southern Scandinavia, as demonstrated by abundant evidence from shell middens (eg, Rowley-Conwy 1983; Astrup *et al.* 2021), fish remains (Enghoff 1994; 2011; Ritchie 2010), stable isotopic compositions of human remains (eg, Allentoft *et al.* 2024), aquatic biomarkers in pottery (Lucquin *et al.* 2023), and fishing gear (eg, Fischer 1995a; 2007; Andersen 1995; Smart 2003). Passively operating fishing structures have been associated with people's reduced mobility (Nilsson *et al.* 2018; Boethius *et al.* 2020), as their use required pro-active maintenance, repair, and attendance – especially during high fishing seasons.

The use of stationary wooden fishing structures in Mesolithic and Neolithic contexts in the circum-Baltic region has repeatedly been linked to mass fishing and delayed-return economies (eg, Koivisto & Nurminen 2015; Boethius *et al.* 2020), which may also have involved storage adaptations and trade (Butler *et al.* 2019). In addition, territorial aspects have been considered, for example within the Late Mesolithic Ertebølle fisheries in coastal Denmark (eg, Pedersen 1997; Smart 2003; Ritchie 2010), also incorporating aspects of fishing rights, deep knowledge of local habitats and resources, and people's attachment to a particular place. The prime fishing locations – occupied and marked with wooden structures – may have been crucial for the Late Mesolithic hunter-gatherer-fishers to re-inforce territoriality.

Recent archaeogenetic evidence has indicated that a population turnover took place in Denmark at the onset of the Neolithic, which was completed by around 3800 cal BC (Allentoft *et al.* 2024), coinciding with the marked dietary change from marine to terrestrial foodstuffs evidenced through isotopic compositions of human remains (Fischer *et al.* 2007; Allentoft *et al.* 2024). Despite this, there is limited evidence demonstrating the co-existence of hunter-gatherer-fishers and incoming Funnel Beaker Culture (FBC) farmers during the first centuries of the Early Neolithic (Jensen *et al.* 2019; Allentoft *et al.* 2024). The Neolithisation process appears to have included elements of cultural diffusion, as evidenced by new forms of material culture appearing in the archaeological record. Recent organic residue analyses undertaken on Ertebølle and Funnel Beaker pottery from Danish contexts has suggested that hunting, gathering, and fishing were an integrated – and in some cases even dominant – subsistence strategy of the incoming Neolithic FBC people (Lucquin *et al.* 2023). The continued use of Mesolithic sites in prime fishing locations into and throughout the Neolithic, such as Syltholm Fjord, is in line with these interpretations.

However, the Mesolithic–Neolithic transition and related archaeogenetic narratives need to be critically evaluated and reflected upon against the archaeological evidence, due to limitations (both geographical and chronological) of the sampled materials and breadth of interpretations (see, for example, Cummings *et al.* 2022). To test, we examined the radiocarbon dates obtained on Danish fishing structures (see Appendix S3) and found that 167 specimens (32%) fall within the Mesolithic (*c.* 6600 cal BC (Køge Havn, AAR-24742) to *c.* 3800 cal BC (Syltholm II MLF00906-I, AAR-21966)), pre-dating the proposed population turnover at *c.* 3800 cal BC (Allentoft *et al.* 2024). Altogether 332 samples (64%) post-date 3800 cal BC and are referred to as Neolithic (*c.* 3800 cal BC (Syltholm II MLF00906-II, AAR-25097) to *c.* 1730 cal BC (Strandholm I MLF00909-II, AAR-25369)). The remaining 19 samples (4%) date to the Bronze Age, and later periods (*c.* 1680 cal BC (Syltholm I MLF00902-II, AAR-23531) to *c.* 1700 cal AD (too recent date, probably out of range, Sondrup Strand II, AAR-29902)). To our surprise, the majority of directly dated fishing structures in Denmark are in fact Neolithic, suggesting that very similar gear – as well as some of the earlier fishing locations – continued to be used by incoming farming groups after 3800 cal BC. Syltholm Fjord is thus an excellent case study for examining the role of aquatic resource exploitation over time, and our data indicate that more sites with stationary fishing structures are known here in the centuries around 4000 cal BC than from anywhere else in Denmark (Fig. 10).

Regardless of period, the weir sites in our Danish dataset (Appendix S3) have largely been found in coastal environments (98%), with a small proportion (2%) in inland lakes, indicating a lack of change in their typical contextual settings across the Mesolithic–Neolithic transition. Among the wood species present, hazel dominates (67%) in the Mesolithic specimens, followed by *Quercus* (4%), *Fraxinus* (4%), and *Cornus sanguinea* (2%), although 20% of the samples remain undetermined. The Neolithic examples show more variation, albeit slight, with hazel (55%) still dominating, although to a lesser degree than in the preceding Mesolithic, followed by a slight increase in the other species used: *Fraxinus* (10%), *Alnus* (5%), *Tilia* (4%), *Quercus* (4%), and *Acer* (2%), with 18% of the samples remaining undetermined.

The types of fishing structures also exhibit slight temporal changes. Wattled hazel weirs were used in coastal fishing from the Middle Mesolithic (specimens from Køge Havn and Halsskovholmen), albeit a small proportion of the overall dataset (2%, $n = 4/167$), while fish traps account for 5% ($n = 9/167$). Indeed, the vast majority (89%) of securely dated Mesolithic remains are tapered wooden stakes and posts found in marine contexts, with 4% of an uncertain function, likely representing stationary fishing structures. In the Neolithic, wattled weirs are more common, accounting for 18% ($n = 59/332$), fish traps being less typical with 2% ($n = 5/332$), and again the majority (78%) of wooden remains falling into the category of tapered stakes and posts or other wooden elements, interpreted as fishing structures. This indicates that wattled weirs became more common during the Neolithic, but

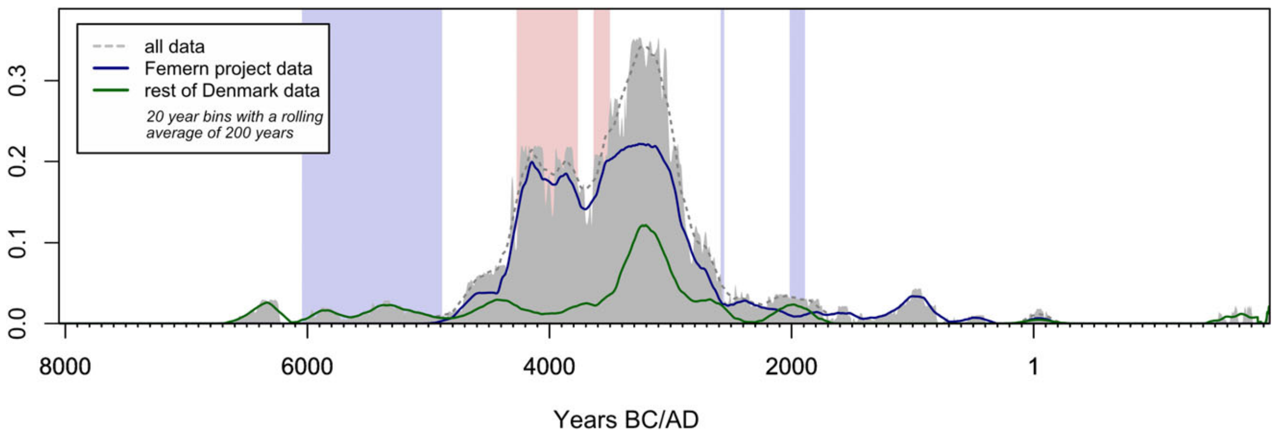

Fig. 10.
The summed probability curve of directly radiocarbon dated stationary wooden fishing structures from the Syltholm Fjord (blue line) compared to all other structures from Denmark (green line) against the background of all data from Denmark (grey shading). The blue areas mark negative deviations from the mean, while the red areas are positive deviations of the Syltholm Fjord dataset

certain representational biases must be considered when evaluating the overall evidence. In addition to differential preservation issues, there is obviously an over-representation in specimens from extensively studied areas (such as Syltholm Fjord), or periods (eg, Late Mesolithic Ertebølle) or indeed types of archaeological sites; for instance, underwater fieldwork in Denmark has concentrated on certain water depths (max. 5 m bsl) (eg, Astrup 2018), whereas industrial dredging has recently revealed well preserved specimens from even greater depths and from earlier periods (Fiedler *et al.* 2023). However, the observed general trend of an increase in the frequency of wattled weir structures throughout the Neolithic is interesting and requires further study.

Fishing during the earliest Neolithic has also been central to debates concerning the Mesolithic–Neolithic transition in north-west Europe (Gron & Sørensen 2018; Jensen *et al.* 2019; Cummings *et al.* 2022; Allentoft *et al.* 2024). It has been suggested that coastal Mesolithic groups in the western Baltic may have survived in a partially acculturated form in geographical 'refugia' pockets, where they continued their Mesolithic lifeways. Towards the Middle Neolithic, the archaeological evidence suggests the hunter-gatherer-fisher or combined farmer-fisher modes of subsistence became more evident, for example among the Pitted Ware Culture groups (PWC) of Fennoscandia from about 3300 cal BC onwards (Vanhanen *et al.* 2019; Philippsen *et al.* 2020; Iversen *et al.* 2021; Cummings *et al.* 2022). Interestingly, our results contribute and make some relevant additions to these discussions. The use of similar fishing structures in Danish contexts in the Mesolithic and Neolithic (and even later) may be explained by three possible scenarios:

1. the good procurement areas were used by local hunter-gatherer-fisher groups for much longer than current archaeogenetic studies suggest (cf. Cummings *et al.* 2022);
2. there was a much longer and deeper interaction and co-existence between local hunter-gatherer-fishers and neighbouring farming groups (cf. Gron & Sørensen 2018; Lucquin *et al.* 2023); and
3. the evidence may point to the gradual adoption of fisheries and the learning of viable fishing technologies by incoming groups from local hunter-gatherer-fishers over the course of the Neolithic, and an increased role of marine foods; which is supported by the aquatic biomarkers frequently found in Neolithic pottery in Denmark and northern Germany (Lucquin *et al.* 2023).

Whatever the specific processes were, our results argue for a more fluid transition between the Mesolithic and Neolithic. To understand further, notwithstanding procreation, cultural adaptation, or

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modes of subsistence for example, it is becoming increasingly apparent that we need to bring together data from several disciplines and analytical approaches and not base our narratives solely on single method approaches.

In addition, our data suggest an increase in the use of wooden weirs in Denmark during the Middle Neolithic, *c.* 3500–3000 cal BC (see Fig. 10), with similar structures as in the preceding periods and with a higher percentage of preserved wattled structures. Contemporary pollen records suggest that farming involved cycles of deforestation and regrowth, which created landscapes with open areas and secondary forests of birch and hazel, as primary forests of lime and elm declined (Andersen 2012; Allentoft *et al.* 2024 and references). Raw materials were thus abundant for the production of wattled structures – both for fishing and for other wooden elements at settlements and activity areas. During this time, the FBC groups remained relatively stable, with little evidence of large scale migration or cultural change until the late 4th/early 3rd millennium BC (Allentoft *et al.* 2024), when four distinct cultures co-incided, further shaping southern Scandinavia for several hundred years: the Early to late Middle Funnel Beaker Culture (FBC; 3300–2600 BC), the coastal hunter-fisher-gatherer-inspired Middle Neolithic Pitted Ware Culture (PWC; 3100–2450 BC), the Middle Neolithic Single Grave Culture (SGC; 2850–2250 BC), and the Middle Neolithic Battle Axe Culture (BAC; 2800–2200 BC) (eg, Iversen 2016). Of these, the latter two belong to the broader Steppe-related Corded Ware Culture (CWC) complex that spread across Northern Europe from *c.* 2850 cal BC onwards (eg, Iversen *et al.* 2019; Haak *et al.* 2023; Allentoft *et al.* 2024). Although the FBC is considered to have ceased by 2800 BC, there is evidence for its prolonged presence, particularly in eastern Denmark. Here, it combined with elements of the PWC, SGC, and BAC traditions to form a distinct cultural expression (see Iversen 2016). Contemporaneous changes can also be traced in the settlement pattern and subsistence economy; for example, settlement features (eg, pits, cultural layers, and house constructions) decrease on the eastern Danish islands from *c.* 2600 cal BC, suggesting a new settlement organisation. Moreover, there is a change in the subsistence strategies, and occasionally the revival of earlier hunting and fishing strategies, especially among groups influenced by PWC hunter-fisher-gatherers (Iversen 2016). In the case of fishing structures (see Fig. 10), it appears that the cultural developments of the early 3rd millennium did not incorporate weir fishing on a larger scale, as the most pronounced decline in our modelling occurs between *c.* 3000 and 2550 cal BC, after which the use of wooden weirs seems to have generally declined in Denmark. In coastal areas and on islands, however, weir fishing continued to play a certain role in prehistoric subsistence at least until the Late Bronze Age (*c.* 1100–530/520 BC).

However, the marked decline in stationary fishing structures from the Late Neolithic onwards is clear in our data. In addition to cultural factors, this might also be explained by changes in environmental conditions, such as more frequent and severe storm events, unpredictability of fish catches, changes in topography reducing the effectiveness of weirs, and erosion and sedimentation, as also suggested in Syltholm Fjord, which may have altered and reduced the significance of fishing. These factors may have made fishing with stationary wooden structures unprofitable in a wider sense (eg, Hurcombe 2014). Mid- and Late-Holocene climatic shifts, particularly the 2250 cal BC (4.2 ka BP) cooling trend and subsequent abrupt cooling periods (*c.* 1850–1450 cal BC) (Bunbury *et al.* 2023), may have played a role in this process. Taken together, notwithstanding cultural changes and other fundamental transformations that took place over the course of the Neolithic, subsistence strategies and other human activities appear to have shifted to terrestrial landscapes where their wild resources, and domesticated plants and animals, were increasingly exploited. Despite this, fishing and the utilisation of aquatic resources continued to thrive in the background throughout subsequent periods, the archaeological evidence for which needs to be uncovered and integrated into wider narratives of Northern European prehistory.

CONCLUSIONS

Extensive developer-led archaeological fieldwork from 2012–2022 at the Femern Tunnel construction site in south-east Denmark has revealed a wealth of evidence concerning the use of the coastal landscape and construction and use of passive fishing technologies in Syltholm Fjord throughout the Stone Age to the Early Bronze Age. The study area on the southern coast of the island of Lolland is one of the best preserved and most extensively studied examples of prehistoric

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landscapes in Northern Europe, allowing detailed analysis of the archaeological and palaeo-environmental remains and their interpretation. In particular, the abundant evidence for the use of passively operating wooden fishing structures during prehistory is exceptional on a European scale, permitting a detailed study of the structure types and their use in the coastal landscape. Typically, similar materials have not survived intact in dynamic waterlogged and submerged contexts, and it has been difficult or impossible to determine with certainty their original design and which – if any – of the wooden elements were part of the same structure. An unusually large corpus of securely dated wood samples has allowed us to construct a detailed chronology and improve our knowledge of the precise periods of use of individual sites and associated structures.

Syltholm Fjord was used for passive fishing for much longer than previously thought, and active and passive methods were used in combination. It was a valuable fishing ground for Late Mesolithic and Neolithic populations, and its use continued until at least the Early Bronze Age. Based on radiocarbon dates and structural evidence, the sites with wooden remains can still be considered as palimpsests of human activity, where large quantities of wooden remains, artefacts, and features were deposited over time. Wooden posts, stakes, and wattle structures in weirs were constantly replaced and repaired, and their fragile elements such as basket traps and wattled panels were removed after prime fishing seasons. Therefore, the radiocarbon dates of various elements do not necessarily indicate when actual fishing activity first began in the area or at a particular site.

Fishing activities at Syltholm Fjord coincide with the gradual formation of a sheltered lagoonal landscape, protected behind sandy barrier islands, optimal for fishing practices using stationary structures, as also supported by ethnographic evidence. Structural remains from specific periods stand out in the overall material – particularly in the form of the best preserved wattle weirs from the Middle–Late Neolithic (*c.* 3330–2040 cal BC) – while structures from other periods have only partially survived in the ancient seabed. While the thousands of wooden stakes, posts, and rods had not previously been directly associated with prehistoric passive fishing practices, our results suggest that they are likely the remains of partially preserved fishing structures. The wood taxa present are similar to those of the well preserved weirs, while the radiocarbon dates demonstrate their extensive deposition and accumulation in shallow water areas over two millennia during the Mesolithic and Neolithic (*c.* 4720–2470 cal BC). Similar remains in Danish Stone Age contexts have traditionally been interpreted as the remains of fishing structures and, in our compilation of sites, the vast majority (77%) of the proposed weir sites consist solely of wooden stakes and/or posts, with no preserved remains of wattle structures.

With regards to the use of different wood based raw materials in the construction of stationary wooden fishing structures, it can be concluded that the majority of the weirs in Syltholm Fjord, as well as in the comparable materials in Denmark and north-west Europe, were built with hazel stakes, supported in places by sturdier posts of ash and oak, and that the wattle panels were mainly woven with long and homogeneous hazel rods, using a simple under–over weave around one or more hazel uprights. The portability and organic raw material of wooden weirs and traps were important in terms of adaptability to changes in the local habitat. Evidence for the use of similar wattle structures in fish weirs as in Syltholm Fjord was found at 21 sites in Denmark, most of them in coastal marine contexts, including estuarine fjords and sheltered lagoons, with eight sites directly radiocarbon dated from the Middle Mesolithic to the historic period.

The continued use of Mesolithic sites in prime fishing locations into the Neolithic, such as Syltholm Fjord, is an intriguing question and highly relevant to debates concerning the Neolithisation process in the western Baltic Sea, containing important insights into interactions, changes in diet and subsistence, and the relevance of the area's location at the south-east edge of Denmark and as a link to continental Europe. The continued and intense use of aquatic resources during the Neolithic as well as the technological continuity underline a more diversified development of human interaction in the 5th and 4th millennium BC. In our compilation of securely dated Danish fishing structures, 38% are Mesolithic, 58% Neolithic and 4% younger. The marked decline in our data from the Late Neolithic onwards is obvious and probably indicates changes in environmental and climatic conditions and cultural transformations that changed the earlier ways of life towards inland areas, their resources, and domesticates.

Our results also highlight the enormous scientific value of wetlands in archaeology, which can preserve a wealth of material culture that is often found accidentally, eg, through ditching, dredging, building, or erosion. However, our study sites and their rare organic evidence were discovered through a phased approach dictated by archaeological legislation and systematic, extensive fieldwork, which is still a rare practice in Northern European wetlands, especially in developer-led investigations.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/ppr.2024.15

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RÉSUMÉ

Pêcher avec des structures en bois stationnaires au Danemark à l'âge de Pierre: de nouvelles preuves de Syltholm Fjord, au sud de Lolland, par Satu Koivisto, Harry K. Robson, Bente Philippsen, Terje Stafseth, Marie Brinch, Ulrich Schmölcke, Peter Moe Astrup, Claudio Casati, Mogens Bo Henriksen, Otto Uldum, Morten Lundbye, Rikke Maring, Marie Kanstrup, Bjørnar Tved Måge, et Daniel Groß

Des indices abondants et divers de pratiques de pêche préhistorique ont été mis au jour entre 2012 et 2022 lors des fouilles menées sur le site de construction du tunnel de Femern Belt, qui relie les iles de Lolland (Danemark) et de Femern (Allemagne). Les parties gorgées d'eau du fjord préhistorique de Syltholm ont livré des vestiges organiques bien préservés, notamment des vestiges de pièges à poisson et de barrages en bois, et de nombreux piquets et poteaux verticaux plantés dans l'ancien fond marin – autant de témoignages de pratiques de pêche sur le temps long, utilisant des structures en bois stationnaires, datant du Mésolithique à l'âge du Bronze (*c.* 4700–900 cal BC). Dans cet article, nous présentons les résultats d'une étude détaillée des structures de pêche en bois stationnaires dans le fjord préhistorique de Syltholm. Pour le contextualiser davantage, nous présentons une compilation à jour des découvertes archéologiques comparables faites au Danemark, notamment un jeu de données de spécimens datés directement, établie à partir de sources publiées et précédemment inédites. Nos résultats montrent que les structures de pêche en bois stationnaires constituent une ressources archéologique inestimable, et leur étude, associant reconstruction du paysage, parallèles ethnographiques et technologie de la pêche, ainsi que le mobilier archéologique et les déterminations radiocarbones directes, nous permet de reconstituer en profondeur les stratégies de pêche préhistorique. De plus, nous démontrons l'importance significative de la pêche passive avec des structures stationnaires pour les populations préhistoriques de l'ouest de la Baltique sur le temps long. En raison de cette longue chronologie et de la diversité du matériel étudié, nos résultats complètent les recherches précédentes sur les nombreuses nuances et les spécificités régionales de la persistance des pratiques de pêche au cours du temps, malgré l'introduction de nouvelles cultures, populations et modes de vie. Enfin, nous soulignons que le processus de néolithisation dans le nord de l'Europe n'a pas été aussi simple et uniforme en termes de subsistance qu'on ne le pense généralement.

ZUSAMMENFASSUNG

Fischen mit fest installierten Holzstrukturen im steinzeitlichen Dänemark: Neue Erkenntnisse aus dem Syltholm-Fjord, Süd-Lolland, von Satu Koivisto, Harry K. Robson, Bente Philippsen, Terje Stafseth, Marie Brinch, Ulrich Schmölcke, Peter Moe Astrup, Claudio Casati, Mogens Bo Henriksen, Otto Uldum, Morten Lundbye, Rikke Maring, Marie Kanstrup, Bjørnar Tved Måge, und Daniel Groß

Bei Ausgrabungen zwischen 2012 und 2022 an der Baustelle des Fehmarnbeltunnels, der die Inseln Lolland (Dänemark) und Fehmarn (Deutschland) verbindet, wurden zahlreiche und vielfältige Zeugnisse prähistorischer Fischereipraktiken gefunden. In den unter Wasser befindlichen Bereichen des prähistorischen Syltholm Fjords wurden gut erhaltene organische Überreste gefunden, darunter die Reste von hölzernen Fischreusen und Wehre sowie zahlreiche senkrechte Pfähle und Pfosten, die in den ehemaligen Meeresboden getrieben wurden – Belege für langfristige Fischereipraktiken unter Verwendung stationärer Holzkonstruktionen vom Mesolithikum bis zur Bronzezeit (*c.* 4700–900 cal BC). In diesem Beitrag stellen wir die Ergebnisse einer detaillierten Untersuchung der fest installierten hölzernen Fischereistrukturen im prähistorischen Syltholm Fjord vor. Zur weiteren Kontextualisierung stellen wir eine aktuelle Zusammenstellung vergleichbarer Funde aus dänischen Kontexten zur Verfügung, einschließlich eines Datensatzes direkt datierter Exemplare, die sowohl auf veröffentlichten als auch auf bisher unveröffentlichten Quellen beruht. Unsere Ergebnisse zeigen, dass stationäre hölzerne Fischereistrukturen eine unschätzbare archäologische Quelle darstellen, deren Untersuchung durch die Kombination von Landschaftsrekonstruktion, ethnographischer Analogie und Fischereitechnologie zusammen mit Funden und direkter C^{14}-Datierung eine eingehende Rekonstruktion prähistorischer Fischereistrategien ermöglicht. Darüber hinaus zeigen wir die langzeitliche große Bedeutung der passiven Fischerei mit fest installierten Strukturen für prähistorische Populationen in der westlichen Ostsee. Aufgrund der langen Chronologie und Diversität des Fundmaterials können unsere Ergebnisse die bisherige Forschung ergänzen über

die vielen Nuancen und regionalen Besonderheiten des Fortbestehens von Fischereipraktiken im Laufe der Zeit, trotz der Einführung neuer Kulturen, Bevölkerungsgruppen und Lebensweisen. Schließlich betonen wir, dass der Neolithisierungsprozess in Nordeuropa in Bezug auf die Subsistenz nicht so geradlinig und einheitlich verlief, wie gemeinhin angenommen.

RESUMEN

Pesca con estructuras fijas de madera en la Edad de Piedra en Dinamarca: Nuevas pruebas del fiordo de Syltholm, en el sur de Lolland, por Satu Koivisto, Harry K. Robson, Bente Philippsen, Terje Stafseth, Marie Brinch, Ulrich Schmölcke, Peter Moe Astrup, Claudio Casati, Mogens Bo Henriksen, Otto Uldum, Morten Lundbye, Rikke Maring, Marie Kanstrup, Bjørnar Tved Måge, y Daniel Groß

Durante las excavaciones entre 2012 y 2022 en la construcción del túnel Femerm Belt, que une las islas de Lolland (Dinamarca) y Femern (Alemania), se reveló una abundante y diversa evidencia de prácticas pesqueras prehistóricas. Las partes sumergidas del fiordo prehistórico de Syltholm permitieron documentar restos orgánicos excepcionalmente preservados, incluyendo restos de trampas y presas de pesca en madera, y numerosos postes y estacas verticales clavados en el antiguo lecho marino - estos hallazgos constituyen una evidencia de prácticas pesqueras a largo plazo con la utilización de estructuras fijas de madera datadas desde el Mesolítico a la Edad del Bronce (*c*. 4700–900 cal BC). En este artículo presentamos los resultados de un estudio detallado de estas estructuras pesqueras fijas en madera en el fiordo prehistórico de Syltholm. Para contextualizar este hallazgo, aportamos una revisión actualizada de restos similares en el registro arqueológico danés, incluyendo una base de datos de especímenes directamente datados, basándonos tanto en fuentes publicadas como inéditas. Nuestros resultados reflejan que las estructuras de pesca fijas en madera son un recurso arqueológico invaluable, y su estudio combinando la reconstrucción del paisaje, la analogía etnográfica y la tecnología pesquera, junto con la evidencia artefactual y las determinaciones radiocarbónicas directas, nos permiten reconstruir las estrategias de pesca prehistóricas en profundidad. Además, demostramos la gran importancia de la pesca pasiva en estas estructuras fijas para las poblaciones prehistóricas en el oeste del Báltico a largo plazo. Debido a la larga cronología y diversidad de los materiales estudiados, nuestros resultados complementan investigaciones previas estableciendo numerosos matices y especificidades regionales en la persistencia de las prácticas de pesca a lo largo del tiempo, a pesar de la introducción de nuevas culturas, poblaciones y formas de sustento. Por último, subrayamos que el proceso de neolitización en el norte de Europa no fue en términos de subsistencia tan directo y uniforme como comúnmente se asume.