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RESEARCH

Forest history from a single tree species perspective: natural occurrence, near extinction and reintroduction of European yew (*Taxus baccata* L.) on the Darss-Zingst peninsula, southern Baltic Sea coast

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Abstract
The forests along the southern Baltic Sea coast harbour some stands of the rare and endangered European yew (*Taxus baccata* L.), which are hypothesised to be autochthonous. Using the example of an occurrence on the Darss-Zingst peninsula, the population dynamics of the yew since the late Holocene are interdisciplinarily investigated and linked to the forest history of this area. Pollen analysis shows that yew has been present in the study area for at least 2600 years and thus indeed represents an autochthonous tree species in the area. The yew was probably originally part of a second tree storey and of forest margins within a mixed forest mainly consisting of several deciduous tree species and Scots pine. Historical evidence reveals that yew was still occurring in the forest in the middle of the eighteenth century, but then had nearly disappeared by the end of the nineteenth century. This was caused by several factors including forest grazing by livestock, high game populations and clear-cutting. First replanting of yew took place in the 1930s/1940s and 1950s/1960s, followed by planting campaigns in the 1990s and 2000s. Planting material from local and regional autochthonous relict populations was used, at least in part. The current yew population mainly comprises young individuals with a total number of ca. 1300 trees. It has thus been possible here to re-establish an autochthonous yew occurrence that was nearly extinct in historical times. This local example of targeted re-enrichment of native tree diversity may also encourage further measures to give this species a new chance again elsewhere in the wider region.

Keywords Yew · Population history · Late Holocene · Reintroduction · North-east Germany · Historical ecology

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In memory of Konrad Billwitz (1938–2021).

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Introduction

From the perspective of forest, the history of the north-eastern Central European plain in the last millennium can be summarised as a ″drama of losses”. The price for the massive expansion of human occupation and the associated clearing of this originally largely forested landscape mainly since the twelfth–thirteenth centuries was the millionfold death of venerable tree individuals, the extinction of large forest mammals, the reduction of the carbon and nutrient stocks cycling in the forest ecosystems, large-scale soil erosion as well as extremisation of the local and regional climate and water balance (e.g. Bork et al. 1998; Brown and Pluskowski 2011; Hoffmann 2014; Roberts et al. 2018; Kaiser et al. 2020; Lamentowicz et al. 2020; Czerwiński et al. 2022). Extensive remains of primaeval forests, which had survived the previous prehistoric settlement phases, and widespread near-natural secondary forests were then converted into widespread farmland and other land use, a history comparable to the destruction of tropical rain forests today. Similar dramatic deforestation has of course taken place in other parts of Europe as well, such as in western and southern Europe, but often already earlier (Kaplan et al. 2009; Hughes 2011; Shrubsole 2022).

Initially, the mediaeval to early modern use of the remaining forests was probably associated with an increase in micro-site habitats (mainly due to thinning as a result of tree felling and wood pasture) and thus also in woody taxa and total biodiversity (Sukopp and Trepl 1987). However, at least since the mid-nineteenth century the intensification of land use and the reforestation of this region with mostly pine monocultures were primarily associated with a wide decrease in tree diversity and stand vitality. In general, the natural tree species potential in that area is currently far from being (re-)developed und used (Guyot et al. 2016).

The European yew (*Taxus baccata* L.; Thomas and Polwart 2003; Benham et al. 2016) was a particularly prominent botanical victim of this process. As evidenced by its palaeobotanically proven broader distribution before the Middle Ages (Averdieck 1971; Brande 1994; Krupiński et al. 2004; Deforce and Bastiaens 2007), the formerly coherent distribution area of the yew disintegrated into isolated occurrences in western, central and north-eastern Europe (Fig. 1A). And even within these occurrences, the local populations of this species are often very poor in individuals and young in age, which means specimens of a few decades old (Fukarek 1967; Svenning and Magård 1999; Navys 2000). First, in the thirteenth–sixteenth centuries the wood of older yew trees from Central Europe was exported in large quantities to England for the production of longbows. This process is very well documented by historical sources and had a lasting impact on the reproduction of yew stands in Central Europe (Hilf 1925; Hageneder 2007). Subsequently, the modern intensification of forest use first by widespread forest grazing of livestock (due to forest management and livelihood) and later by the clear-cutting of monocultures (due to forestry) led to unfavourable conditions for the reproduction of yew. Last but not least, a purposeful liquidation of yew stands is to be expected: as an extraordinarily poisonous plant particular for horses, cattle and domestic pigs (also for humans, but not for roe deer and deer), the yew was not tolerated (Thomas and Polwart 2003). However, in parallel with their widespread disappearance from the forests, the occurrence of planted yew trees in towns and villages increased enormously. Today, there is no town, no park or cemetery and hardly a village in the lowlands of Central Europe without yews used as an ornamental and symbolic tree (Roloff et al. 2010, 2013).

For about three decades now, the remaining wild occurrences of the yew have been the focus of forestry and nature conservation activities in Europe and beyond. This tree species has been shown to have significant forestry, pharmaceutical and biodiversity potential, but is locally still and maybe even increasingly endangered (e.g. Onrubia et al. 2010; Schirone et al. 2010; Linares 2013; Thomas and Garcia-Martí 2015; Jensen and Svenning 2021; Casier et al. 2024). The ongoing conversion of the prevailing lowland pine monoculture forests towards ecologically and climatically stable, i.e. mixed deciduous stands is also locally based on the reintroduction of the yew, as corresponding programmes and projects in Poland and Germany, for example, underline (Falencka-Jabłońska 2004; Litkowiec et al. 2018; Steffen and Harriehausen 2018; Rau et al. 2021).

The current scientific literature on this tree species in Europe is dominated by works on population ecology, genetics and pharmaceutical properties. Historical studies that focus on the earlier distribution, local survival, disappearance or reintroduction of the yew are rare (e.g. Willerding 1968; Sarmaja-Koijonen et al. 1991; Delahunty 2007; Uzquiano et al. 2015; Iszkuło et al. 2016; Noryśkiewicz 2017; Bebchuk et al. 2024). Only both perspectives, however, the historical and the current, allow for a really multifaceted picture of the widespread disappearance, the local survival and the probable re-spreading of the yew to be drawn, including its ecological, genetic and usage characteristics.

The coasts of the Baltic Sea and the North Sea are part of the natural distribution area of yew (Fig. 1A). However, as in the continental area to the south, the occurrences are isolated and older individuals are rare (Fig. 2). While the southern North Sea coast, Denmark and north-west Germany (lowland part) have almost no natural yew occurrences (e.g. Jensen and Svenning 2021), there are still some yew stands along the southern Baltic Sea coast, i.e. in Mecklenburg-Vorpommern (north-east Germany; Winkelmann 1906; Fukarek 1967; Jeschke 2015) and Pomerania (north-west Poland; Conwentz 1892; Król 1986; Cedro 2023). For the yew occurrence on the Darss-Zingst peninsula, which is the focus here, a widespread disappearance towards the end of the nineteenth century was reported and a reintroduction took place in the twentieth and twenty-first centuries (see chapters “Historical yew stands and their disappearance from the forest” and “Reintroduction of yew”). Accordingly, we use the term “near extinction” in the title, which generally refers to a very critical reduction in the number of individuals of a species (e.g. Ferrer and Negro 2004). Here it refers specifically to the widespread disappearance of *Taxus* in the forests of Darss and Zingst.

The history as well as the “restarting future” of the yew population on the Darss-Zingst peninsula is exemplary for the fate of this tree species in north-eastern Germany and beyond. The findings on its local historical development,

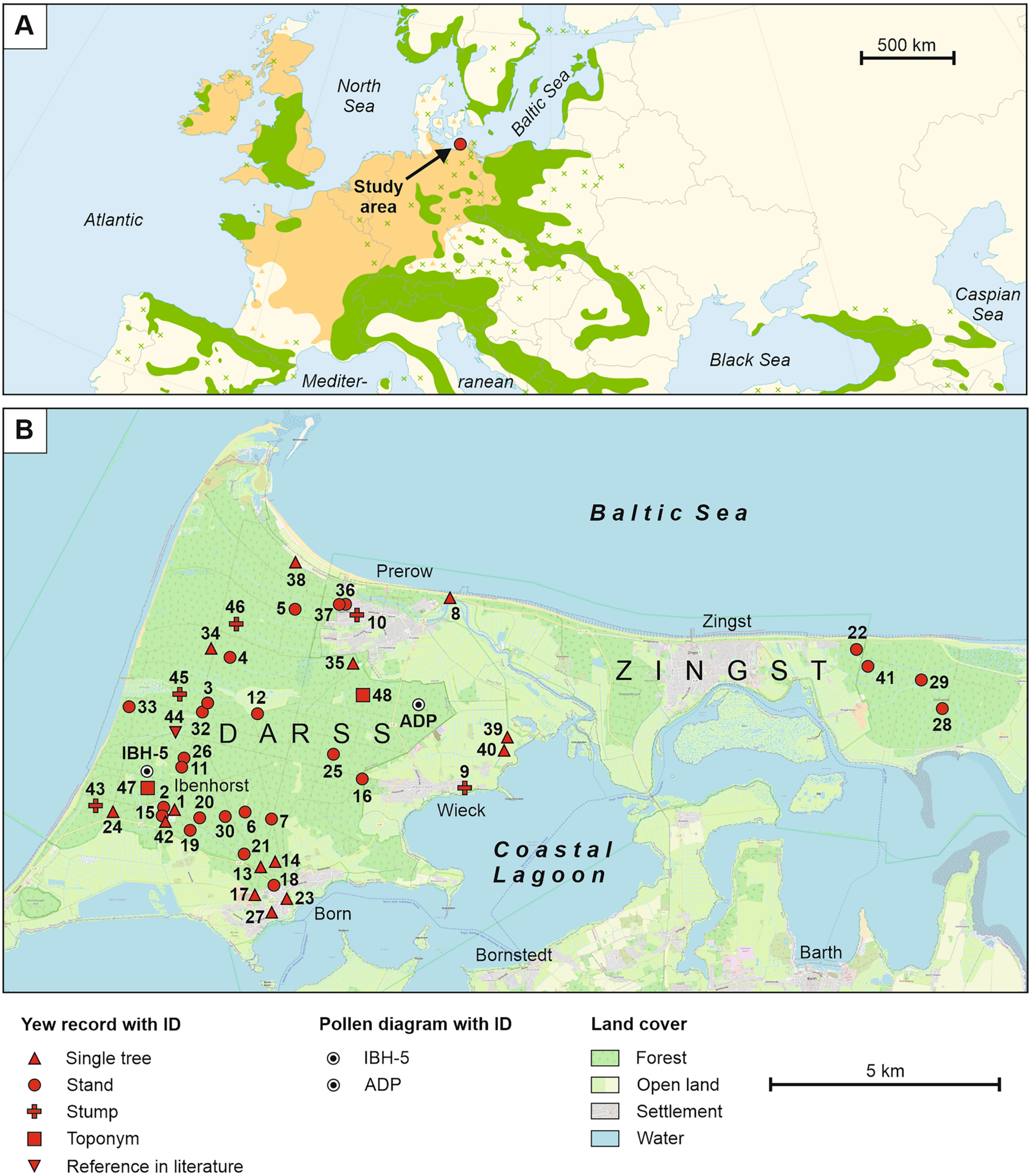


Fig. 1 European and local distribution of *Taxus baccata*. **A**: Chorological map for *Taxus baccata* for large parts of Europe (data from www.euforgen.org, CC-BY 4.0; Caudullo et al. 2017). Green areas and "x" symbols = native range and isolated population, respectively; orange areas and triangle symbols = introduced and naturalised (synanthropic) area and isolated population, respectively. **B**: Records of *Taxus baccata* on Darss and Zingst and other characteristics (map background: www.openstreetmap.de)

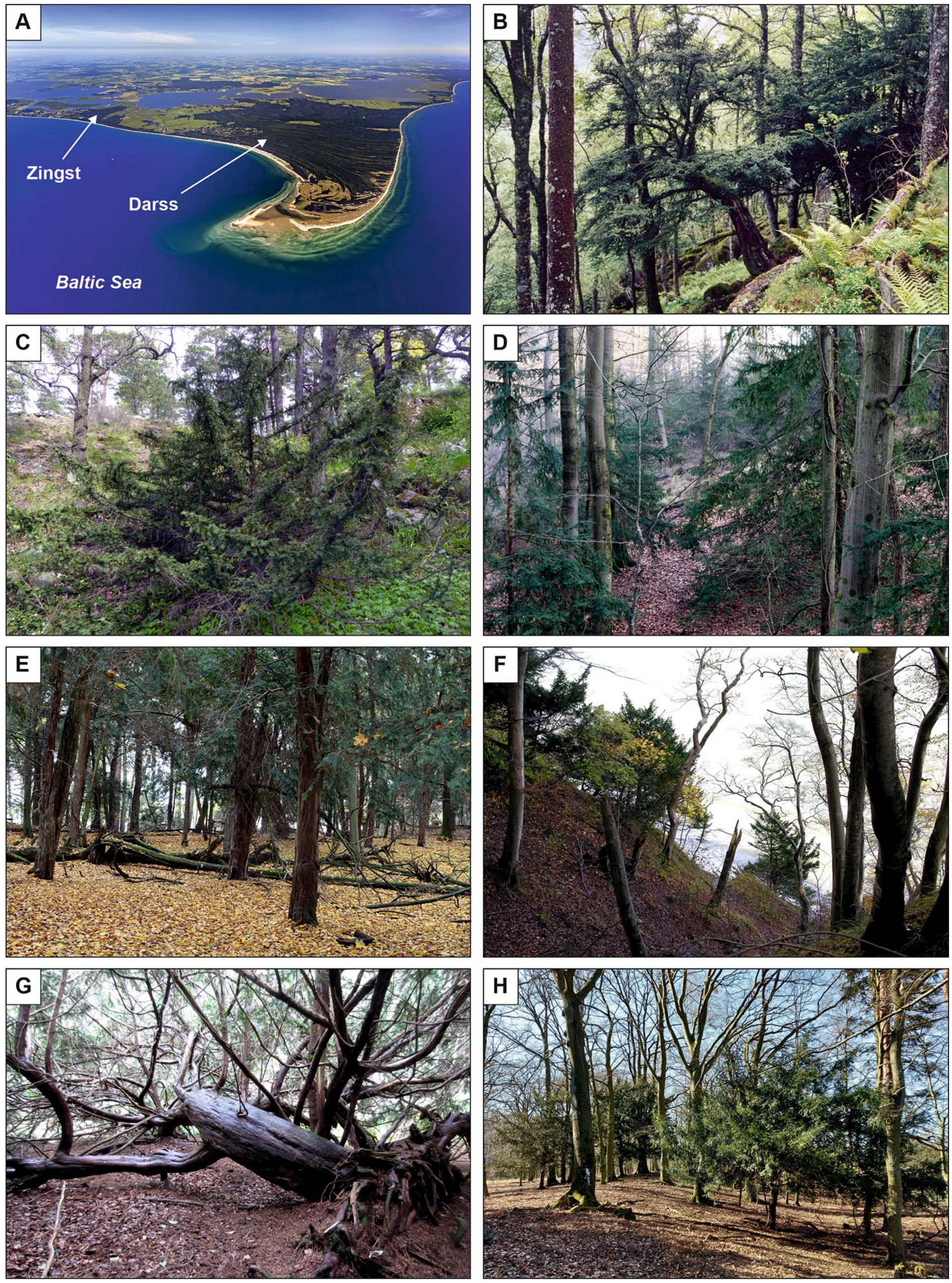


Fig. 2 Photographs of the study area and of selected current occurrences of *Taxus baccata* on the coasts and the inland of the Baltic Sea and North Sea. **A**: Oblique aerial view of the Darss-Zingst peninsula study area, looking south from the Baltic Sea (photograph: Voigt & Kranz UG Prerow). **B**: Varaldsøy Island in the Hardanger Fjord, western Norway (photograph: Tor Myking). **C**: South of Stockholm, eastern Sweden (photograph: Jouko Lehmuskallio). **D**: Munkebjerg at the Vejle Fjord, southern Denmark (photograph: www.commons.wikimedia.org). **E**: Nature reserve Cisy Staropolskie at Mukrz Lake in the Bory Tucholskie forest, north-western Poland (photograph: www.commons.wikimedia.org). **F**: Jasmund cliff at Rügen Island, north-eastern Germany (photograph: Lebrecht Jeschke). **G**: Meyershausstelle site in the Rostocker Heide forest, north-eastern Germany (photograph: Knut Kaiser). **H**: Eibenkamp Luckow site in the Ueckermünder Heide forest, north-eastern Germany (photograph: Knut Kaiser)

especially in the context of the general forest history of the last centuries, can certainly be generalised to a certain extent. The efforts to save, de facto to re-establish a local occurrence may also encourage measures to give this endangered and hitherto underestimated tree species a new chance again elsewhere.

In this paper, we address the following specific research questions grouped into palaeobotanical, historical and forestal perspectives: (1) Can the hypothesis of a local autochthonous yew occurrence be confirmed, i.e. since when in the Holocene can this tree species be detected in the area? (2) What was the past forest structure with the share of the yew? (3) How did the local yew populations develop in the last few centuries, i.e. since the eighteenth century? (4) What ultimately led to their disappearance from the forest? (5) How did the reintroduction of the yew take place in the area? (6) What are the structural characteristics in terms of current stand size, age and population dynamics?

Study area

Until about 17.000 cal. BP, the Weichselian inland ice covered this area (Kaiser and Lampe 2009; Fig. 1B). Glaciolacustrine sediments, especially fine sands up to ca. 20 m thick, originate from the subsequent Pleniglacial deglaciation and together with Lateglacial and Holocene aeolian sands form the partial landscape of Altdarss (Kaiser 2001). From the Lateglacial to the mid-Holocene, the entire area was part of the land, into which the Baltic Sea transgressed around 7500 cal. BP. Higher-lying areas as the Altdarss developed into islands. Through coastal morphodynamics, i.e. erosion and sedimentation, the (Fischland-)Darss-Zingst peninsula was subsequently formed with a different age of its partial landscapes Vordarss, Neudarss and Zingst from ca. 2600 cal. BP onwards (Lampe and Lampe 2018). For the potential immigration of woody plants including yew in the Holocene, this basic palaeogeographical constellation must therefore be considered.

The highest point in the Darss-Zingst area is 14 m a.s.l. on a dune east of Prerow. However, substantially lower areas between 0 and 5 m a.s.l. dominate. The soils consist of sand and peat. Depending on the age of the soil surface and the local water balance, Arenosols/Regosols and large areas of Podzols as well as Gleysols and Histosols are developed (Billwitz 2009). These soils show a wide pedochemical range from extremely acidic to neutral and from nutrient-poor to nutrient-rich. Thick layers of raw humus are characteristic, which can reach a thickness of ca. 10 cm to over 40 cm.

The present climate of the study area at Born is characterised by a mean annual temperature of 8.3 °C and a mean annual precipitation of 563 mm with dominating summer rainfalls for the reference period 1982–2012 (Seliger et al. 2021). The strong thermal contrasts between land and surrounding water areas result in higher dew and fog precipitation, so that the ecoclimatic water balance on the land areas is more humid than the relatively low precipitation value suggest. This rather luxurious water supply, together with the high groundwater table over a large area, has striking consequences for the local soil and vegetation characteristics (e.g. thick raw humus cover, high vitality of beech even on very poor sandy sites; Billwitz 2009).

The regional hydrology is determined by the Baltic Sea and its lagoons. The distance to the groundwater on land is mostly small due to the low surface elevation of the landscape. In many cases, local freshwater is underlain by saltwater. Larger near-surface groundwater bodies are formed in the area of Altdarss, Zingst and in dune massifs. Since the nineteenth century, and more intensively in the second half of the twentieth century, there have been major manipulations in the water balance for agriculture, forestry, coastal protection and water management by dyking, drainage and water pumping. On the Altdarss, a cone of groundwater depression up to 5 m deep and 1.2 km wide resulted from drinking water extraction (Bauerhorst et al. 2009; Bauer and Scheytt 2019). Accordingly, the soil hydrological conditions for the current vegetation and the conservation status of local geoarchives, i.e. mires and palaeosols, have changed radically (Kaiser et al. 2006).

The potential natural vegetation (Chiarucci et al. 2010) of the forests in all partial landscapes of the peninsula is dominated by deciduous tree species supplemented by a certain proportion of Scots pine/*Pinus sylvestris* (Altdarss: European beech/*Fagus sylvatica*, Neudarss: beech and alder/*Alnus glutinosa* according to the regular beach ridge pattern of dry and wet sites there, Vordarss: pedunculate oak/*Quercus robur* and hornbeam/*Carpinus betulus*, Zingst: downy birch/*Betula pubescens* and oak; Jeschke and Slobodda 2009). However, due to centuries of human impact, pine dominates the current forest vegetation. Intensive forest use until the twentieth century in the form of timber extraction, forest grazing and litter raking as well as resin, tar and charcoal extraction, tended to lead to oligotrophication through nutrient export and generally to site disturbance. A potential development to a climax forest vegetation could thus take place very locally only. In the present, there is therefore a very heterogeneous pattern of near-natural (especially in the coastal western area of the Neudarss) and strongly anthropogenically influenced forest vegetation (especially planted pine stands on the Altdarss and drained peatland forests on the Zingst). The yew is, as will be shown in detail below, an admixed tree species in the area since the late Holocene, which nearly disappeared from the forest in the nineteenth century and was reintroduced in the twentieth/twenty-first century. Few subrecent and recent records of yew on the Darss occurred in forest stands rich in beech and oak with admixed pine (Fukarek 1961; Jeschke et al. 1978; Landesamt für Forstplanung Mecklenburg-Vorpommern 1996). The yew is listed as a rare tree species on the Darss in connection with the Natura 2000 habitat "Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (Quercion robori-petraeae or Ilici-Fagenion)" (habitat type code 9120; Landesamt für Forsten und Großschutzgebiete Mecklenburg-Vorpommern 2002).

The first archaeological traces of settlement on the Darss can be dated to the Neolithic and the Bronze Age (Schlungbaum and Voigt 2001; Terberger 2009). While a Germanic Iron Age settlement can only be assumed, finds and some toponyms (e.g. Darss, Born, Prerow, Zingst, Kirr) prove a subsequent Slavic Iron Age settlement period. The pollen diagram "Prerower Torfmoor (ADP)" on the Altdarss (Kaffke and Kaiser 2002; Fig. 1B) shows from about 5750 cal. BP (ca. 3750 BC) onwards, which archaeologically corresponds to the Neolithic period, a phased land-use pattern through agriculture, grazing and forest use of mostly weak intensity. The larger settlements of the Darss-Zingst peninsula are first mentioned in documents in the thirteenth–sixteenth centuries (Berg 1999; Schleinert 2009). Since then agriculture, forestry and fishing, as well as shipbuilding in the eighteenth and nineteenth centuries, formed the basis of the local economy. For centuries, the Darss forest was used as hunting ground by regional and supra-regional rulers. At the end of the nineteenth century, tourism developed, which became the most important local economy at the end of the twentieth century. The development of industrial agriculture and forestry in the second half of the twentieth century was reversed in the meantime by large-scale nature protection measures.

The first modern nature conservation efforts in the region date back to the 1920s/1930s (Jeschke 2009). In the 1950s/1960s, larger areas on the Vordarss, Neudarss and Zingst as well as islands in the coastal lagoons (so-called Bodden) were then designated as nature reserves. The National Park "Vorpommersche Boddenlandschaft" with an area of 80,500 ha was established in 1990. The largest area (85%) contains water areas in the Baltic Sea and in the lagoons. For some years now, the forests on Darss and Zingst (together ca. 6000 ha; Landesamt für Forsten und Großschutzgebiete Mecklenburg-Vorpommern 2002) have no longer been managed, i.e. their rewilding has been initiated.

A note on the use of the toponym "Darß/Darss": In the text of this paper we normally use "Darss" because it corresponds to the English spelling. In the historical source context, however, we will use the original German spelling used here (e.g. "Darß", "Dars").

Data and methods

Pollen analysis and radiocarbon dating

Based on nine test drillings around Ibenhorst, sediment core IBH-5 was selected for pollen analysis as the site (an alder carr) with longest local sequence of organic sediments (Fig. 1B). For pollen analysis, we retrieved a 1-m-long sediment core with a chamber corer (1 m long, 7.5 cm diameter). Along that core, a total of 10 samples (1 cm^3 sample volume) were taken for pollen analysis. Samples were prepared following the standard procedure described by Fægri and Iversen (1989) and includes treatment with 25% HCl, 10% KOH, sieving at 120 µm mesh size and 7 min acetolysis at 100 °C. To estimate pollen concentrations (Stockmarr 1971), two tablets with Lycopodium spike (*Lycopodium clavatum* spores, Batch No. 050220211) were added to each sample. Samples were finally washed with 2-propanol (isopropyl) and transferred to silicon oil. Pollen samples were analysed at 400 × magnification with a Zeiss-Axiolab microscope. Pollen percentages were calculated based on a pollen sum that includes pollen of trees, shrubs and herb taxa preferentially growing on terrestrial sites. With one exception, the pollen sum is at around 300 pollen grains.

To date the pollen record, three samples of plant macrofossils and charcoal have been radiometrically analysed. The obtained radiocarbon ages were calibrated with Calib 8.10 and the Intcal20 calibration curve.

Historical data

The historical investigations can be methodically assigned to forest history (e.g. Agnoletti and Anderson 2000; Hasel and Schwartz 2006; Muigg and Tegel 2021; Çolak et al. 2023), which can also be understood as part of a broader historical ecology (Szabó 2015; Armstrong et al. 2017). Documents from archives, museum exhibits (e.g. tree remains), regional floras, scientific papers, historical maps, historical photographs and oral traditions as well as further sources (popular scientific essays, journalistic and literary literature; see chapter “Historical yew stands and their disappearance from the forest”) served as sources for information on the historical occurrence of yew trees on the Darss-Zingst peninsula. In addition, archived local forest planning documents since the 1990s were used. Original German citations from written and cartographic sources of the nineteenth and twentieth centuries have been translated into English.

Current yew stand data

This study focuses on the yew stands in the forests of Darss and Zingst. But additionally, some single tree occurrences in the settlements (Ibenhorst, Born, Wieck, Prerow) were recorded as being important for yew replantation (i.e. origin of planting material) or for other reasons. Due to their mostly very small area (< 0.2 ha), the local yew stands are only partially recorded in the forest management register. Consequently, further sources of information were used (file notes, protocols, observations). In spring 2021, an assessment of the yew stands present in the forests was carried out by the respective district foresters. All known and suspected yew occurrences at that time were visited. Most of the known and assumed occurrences could be confirmed, while some proved to be non-existent. The counted or estimated number of tree individuals per site (forest unit), the ranges of heights and breast height diameters, the estimated age and other characteristics (number of female and male specimens, existence of natural regeneration, vitality, signs of game browsing) were recorded.

Dendrochronology

Tree-ring data from old *Taxus* trees were collected from 11 locations across the Darss-Zingst peninsula in autumn 2022 (Fig. 1B). Per location, between one and three vital and representative trees were selected. An increment borer was then used to extract two increment cores per tree at breast height (1.3 m) from the selected trees. In total, 38 increment cores from 19 trees were collected. After air-drying the cores, they were glued on wooden holders and surface-prepared using an orbit sander to highlight annual rings. The prepared tree-ring samples were subsequently digitalised with an ATRICS system (Levanič 2007). The software CooRecorder/CDendro (version 9.6.3., Cybis Elektronik & Data AB, Sweden) was used to measure tree-ring width on the resulting images, as well as to visually and statistically cross-date the measurements. As the pith of the tree was mostly not hit while coring, we estimated the number of missing rings based on the tree-ring curvature and previous ring widths using the DTP function in CooRecorder whenever possible. To estimate tree age, we furthermore added five annual rings to acknowledge for the time that the sampled trees needed to reach breast height. The year of yew introduction at a specific location was finally defined as the earliest year found in that way.

Remarks on data sources

In this interdisciplinary study, it is important to note the different methodological approaches of the disciplines involved, which belong to the humanities, the natural sciences and the engineering sciences. The studies on yew in historical times are based on a large number of written, oral and object sources, which must already be referenced in the results chapter. The natural science and forestry studies, however, primarily use their own analysed data or observations. Consequently, citations of data sources at the results level play no role here.

Results

Late Holocene yew occurrence

The pollen diagram IBH-5 can be divided into the zone A–C (Fig. 3). The radiometric age at the base of the profile at a depth of 69–71 cm shows 2463–2724 cal. BP, while the middle part of the profile at 59–61 cm and at 49–51 cm dates 2489–2728 and 2331–2491 cal. BP, respectively (Table 1). Thus, the data are very close together and a rapid rate of sedimentation is evident in this section of the profile.

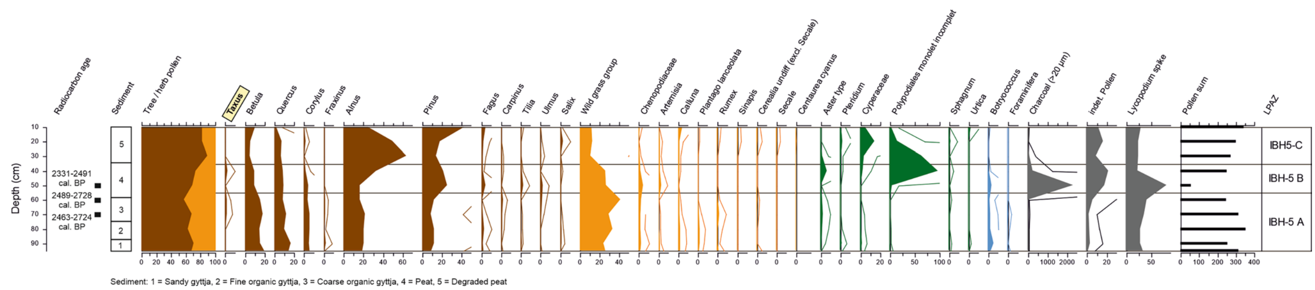


Fig. 3 Pollen diagram IBH-5 from the Vordarss area (for location see Fig. 1B)

Table 1 Radiocarbon data from pollen diagram IBH-5 in the Vordarss area and from one sample from the Hütelmoor mire in the Rostocker Heide forest

Sample ID	Sample depth (cm)	Lab. No	Dated material	Radiocarbon age (BP)	Calibrated age, 2-sigma range (cal BP)	Reference
IBH-5 49–51	49–51	Poz-146215	Charcoal	2360 ± 35	2331–2491 (0.99)	This study
IBH-5 59–61	59–61	Poz-146602	Bud scale and needle of *Pinus sylvestris*, charcoal	2505 ± 30	2489–2605 (0.55), 2608–2662 (0.21), 2663–2728 (0.23)	This study
IBH-5 69–71	69–71	Poz-146603	Needles and bark of *Pinus sylvestris*, charcoal	2490 ± 30	2463–2724 (0.99)	This study
Prahmgraben (Hütelmoor)	ca. 200	UtC-7692	Wood of *Taxus baccata*	3671 ± 38	4094–3890 (0.92), 4144–4123 (0.03)	Kokesch (1999)

The lowermost zone A (95–55 cm) is characterised by high proportions of wild grass group pollen (25–40%), as well the presence of further herb pollen, such as Chenopodiaceae and Amaranthaceae, *Artemisia*, *Calluna*, *Plantago lanceolata* and *Rumex*. Also, several cereal pollen grains were found. Among the tree pollen, *Alnus* (~15%), *Betula* (~15%), *Quercus* (~10%), *Pinus* (~10%) and *Corylus* (~5%) are most abundant. The pollen types *Fagus*, *Fraxinus*, *Carpinus*, *Tilia*, *Ulmus* and *Salix* are present but rare. Pollen of *Taxus* was found at 60 cm and 70 cm depth in low numbers (1.2%). Overall, the results suggest that the vegetation in the vicinity of the coring site was at least partly open. Forests were dominated by deciduous tree taxa, pine likely played a minor role only. Yew was present during that period. Moreover, the presence of the green algae *Botryococcus* indicates that an open shallow water body existed at the coring site. The presence of foraminifera even indicates some at least periodic brackish influence.

The second zone B (55–35 cm) is characterised by a massive peak in micro-charcoal at 50 cm followed by a peak in fern spores at 40 cm. These findings suggest local fire(s), followed by expansion of ferns at or near the coring site. The proportion of wild grass group pollen is somewhat lower, whereas *Alnus* is somewhat more abundant then before, suggesting less open vegetation than during zone A. Moreover, the shift from gyttja to peat reflects that the shallow water body terrestrialised. Some pollen grains of *Taxus* (1.9%) were found at 40 cm depth.

In the uppermost zone C (35–10 cm), the proportion of wild grass group pollen is much reduced (~10%), whereas *Alnus* (up to 60%) and *Pinus* (up to 40%) are more abundant. Higher proportions of *Alnus* may reflect the local presence of an alder carr at the coring site, as existing today. The higher proportion of *Pinus* pollen instead likely reflects a higher abundance of pine in the Vordarss area. Besides, the presence of several anthropogenic indicators (e.g. Cerealia, *Secale*, *Centaurea cyanus*, *Plantago lanceolata*, *Rumex*) again points at agricultural activities in the surroundings. Pollen of *Taxus* has not been found in this zone, which may be related to the poor pollen preservation of all samples from this zone. Pollen of *Taxus* is more fragile than other pollen types and may hence be undetectable under poor pollen preservation conditions.

Historical yew stands and their disappearance from the forest

The earliest mention of yews on the Darss was in the last third of the eighteenth century in the "Flora Pomerano-Rugica" (Weigel 1769). According to this, the occurrence of yews is described as "abundant" (p. 183): "*Taxus baccata*… On the Dars abundant… "

Already a century later, however, according to the "Flora von Neu-Vorpommern und den Inseln Rügen und Usedom", the yews on the Darss seem to have almost disappeared from the forest (Marsson 1869). It is speculated whether single individuals might still exist (p. 609): "*T. baccata* L. … formerly, as it seems, very common, as still indicated by the names 'Ibenhorst, Ibenbruch', but eradicated by forest cultivation. On the Dars, where the plant seems to have been common, 'stumps' are still found as the remains of thick stems, some of which may still be alive".

The "Preußisches Urmesstischblatt" (Engl.: Prussian Ordnance Survey Map) records the toponyms "Ibenhorst" (ID 47 west of Born; Table 2, Figs. 1B, 4A; Landesvermessungsamt Mecklenburg-Vorpommern 1998a) and "Prerow Ibenhorst" (ID 48 south of Prerow; Table 2, Figs. 1B, 4B; Landesvermessungsamt Mecklenburg-Vorpommern 1998b) for the year 1835 at two locations on the Darss. The term "Ibe" comes from Middle High German and means "Eibe" (Engl.: yew; Hageneder 2007). The term "Horst" can refer to a small stand (group) of trees as well as to a small tree-covered elevation. Thus, a presence of yew stands can be assumed at both sites at least around/before 1835. The toponym "Ibenhorst" to the west of Born was transferred to a forester's lodge nearby around 1885 and refers today to a youth hostel at the same location (Fig. 1B).

In the "Schwedische Matrikelkarte" (Engl.: Swedish Register Map; Curschmann 1944; Jansen et al. 2009) available for the region as early as the 1690s, however, no local references to the yew are available. Despite high cartographic accuracy, a favourable map scale and detailed descriptions of the village areas on Darss and Zingst, the record of forest structures, including tree species composition, is in principle quite brief.

At the beginning of the twentieth century, a systematic search for yews on the Darss by Winkelmann (1905, 1906) reveals, on the one hand, that only two probably older trees still existed on a dune on the border of Altdarss and Neudarss (ID 44 in Fig. 1B). On the other hand, the remains of yew trees, i.e. stumps, from historical times were found at two sites on Neudarss (IDs 45 and 46; Table 2, Figs. 1B, 4C) and hints were given as to the cause of the local disappearance of the yew (Winkelmann 1905, p. 3–4): "An extinct yew mound…, only existing in old stumps which are completely overgrown with moss and herbs. In the garden of the head forester's office in Born, there are some excavated stumps on which the root branches, which have become overgrown many times, are conspicuous. The wood is excellently preserved. In earlier years, when the farmers' grazing rights extended to the forests, the cows were driven into the forest, which must have been rich in old yew trees. The cows that ate from the yew died, which is why the farmers partly cut down the trunks and partly burnt them down. The stumps are mostly hollow on the

Table 2 Records of *Taxus baccata* on the Darss-Zingst peninsula

ID	Yew record	Partial landscape	Forest unit	Tree number (n)	Tree height (m)	DBH (cm)	Planting year
1	Single old tree in front of the former forester's lodge at Ibenhorst	Altdarss	45a8	1	8.8	42	1957
2	Tree stand at Ibenhorst N of "C-Gestell"	Altdarss	55a1	80	2–3	6–10	1993
3	Tree stand NE of Raesfeld memorial stone	Neudarss	120a6	4	1.5–10.3	10–37	1945
4	Tree stand N of "Mausefallenweg"	Neudarss	143b5	300	1.8–10.8	2–28	1938, 2003
5	Tree stand N of "Mittelweg"	Neudarss	185a1/2	50	8–10.2	4–19	1952
6	Tree stand W of "Großmutter"	Altdarss	62a3	50	1–3	2–7	1993, 1998
7	Tree stand at Forestry Association memorial W of "Großmutter"	Altdarss	62a1	2	3–4	5–7	ca. 2000
8	Single old yew in the parish garden in Prerow	Zingst	–	1	13.8	86	Eighteenth/nineteenth century
9	Stump of an old tree in front of house Wieck-Südkaten 10, felled around 2017	Altdarss	–	1	–	–	ca. 1885
10	Stump of an old tree in front of the museum in Prerow	Neudarss	–	1	–	–	–
11	Tree stand W of "Große Damwildwiese"	Altdarss	84b1	25	3–4	8–10	1993
12	Tree stand at the hunting lodge S of "Buchhorster Maase"	Altdarss	110a3	25	3–5	4–12	1993
13	Single tree	Altdarss	29b	1	3.5	10	1993
14	Single tree	Altdarss	33	1	3	5	-
15	Tree stand at Ibenhorst S of "C-Gestell"	Altdarss	45a7	250	1.5–2	2–6	1993
16	Tree stand at the forester's lodge at Wieck	Altdarss	87y1	8–10	2–3	4–8	1993
17	Single tree at the new forester's lodge at Born	Altdarss	1023Lh	1	9	18	ca. 1940
18	Tree stand	Altdarss	2028Aa1	75	3–4	6–10	1993
19	Tree stand	Altdarss	44a2	70	3–5	8–12	1993
20	Tree stand	Altdarss	44b2	23	0.3–1.5	1–3	1993
21	Tree stand	Altdarss	34a6	50	0.2–1.5	2–4	1993
22	Tree stand	Zingst	8a2BHE3 + 4	88	0.5–15	1–26	1969, 1993, 2003
23	Single tree at the new forester's lodge at Born ("Alte Oberförsterei")	Altdarss	1023nx	1	9	21	ca. 1900
24	Single tree at "Drei Eichen" parking site	Vordarss	46b1	1	4	11	ca. 1940
25	Tree stand	Altdarss	108a1	4	0.5–2.5	2–6	2003
26	Tree stand	Altdarss	84a4	5	1.5–2.5	2–4	2003
27	Single old tree Born-Chausseestraße ("Sparkasse")	Altdarss	-	1	10	32	-
28	Tree stand	Zingst	354a2	6	3–4.5	4–8	2003
29	Tree stand	Zingst	370a2	38	0.5–5	2–8	2003
30	Tree stand	Altdarss	53b6	18	0.2–0.4	1–3	2003
31	Tree stand ("Kleine Maase")	Neudarss	132a6	8	1.5–8	2–3	2003
32	Tree stand at Raesfeld memorial stone	Neudarss	120a4	5	1.5	2	ca. 2000
33	Tree stand S of "Müllerweg"	Neudarss	123a1	3	8.1–12.6	19–27	1939
34	Single young tree W of "k-Gestell"	Neudarss	144a3	1	3	4	–
35	Single tree S of "Schießplatz Prerow"	Neudarss	161a4	1	2,5	10	1980
36	Tree stand W of "Prerow-Waldstraße"	Neudarss	184Nb	40	7–10.1	10–21	1953
37	Tree stand N of "Prerow-Bernsteinweg"	Neudarss	184Nb	3	1.6–12	4–23	1951
38	Single young tree "Prerow-Zeltplatzstraße"	Neudarss	199	1	0.8	-	–
39	Single tree E of Wieck ("Schwinkels Moor")	Neudarss	–	1	4	15	–
40	Single young tree E of Wieck ("Schwinkels Moor")	Neudarss	–	1	1.6	5	–
41	Tree stand	Zingst	3a8	38	0.5–14.7	1–24	1967
42	Single old tree W of Ibenhorst	Altdarss	45La6II	1	12.5	42	ca. 1940

Table 2 (continued)

ID	Yew record	Partial landscape	Forest unit	Tree number (n)	Tree height (m)	DBH (cm)	Planting year
43	Stump of an old tree in the museum in Born, excavated around 1977/1978 in forest unit 47	Vordarss	47c	1	–	ca. 70	–
44	ehemaliges Alteibenexemplar (aus Literaturquelle)	Neudarß	93	1	–	–	–
45	Tree stump according to literature reference Winkelmann (1905, p. 3)	Neudarss	121	1	–	–	–
46	Tree stump according to literature reference Winkelmann (1905, p. 3)	Neudarss	154	1	–	–	–
47	Toponym "Ibenhorst" according to "Preußisches Urmeßtischblatt" (1835)	Vordarss	66	–	–	–	–
48	Toponym "Prerow Ibenhorst" according to "Preußisches Urmeßtischblatt" (1835)	Neudarss	149/150	–	–	–	–

inside, but the outer part is well preserved. Since a large part of the forest was newly cultivated in 1901, the stumps in it had to be excavated. They have a circumference of 1.75 to over 2 m, with the root branches cut off 2 to 3 m in diameter".

One of the trees mentioned above under ID 44 was apparently still present in the 1950s (Günther 1957), only to disappear in the 1970s/1980s (Gudrun Jasmand, Born, pers. comm.). It is almost certain that the yews under ID 44 are the last (known) naturally grown, i.e. not planted, specimens of *Taxus* in the Darss forest, dying here in the course of the twentieth century.

In the early 1930s, the head forester on the Darss, Franz Mueller (-Darß), reported that only three small yew bushes existed as remnants of once larger yew stands (Mueller 1933, p. 56): "…so the old yews (*Taxus baccata*), which used to grow in huge specimens in the Darss forest and which today are only remembered by the name of the forester's lodge Ibenhorst. The sad remains are three small yew bushes…"

In addition to the yew stumps from the Darss documented by Winkelmann (1905, 1906; Fig. 4C), there are two more "subfossil" stumps, so to speak, which are in the Forestry and Hunting Museum in Born (ID 43; Table 2, Figs. 1B, 4E) and in the Darss Museum in Prerow (ID 10; Table 2, Figs. 1B, 4F). The yew stump ID 43 with a maximum diameter of 70 cm was excavated around 1977/1978 in forest unit 47 on the Vordarss. It stood for decades in front of the house of its former owner (Klaus Gadow, Born). Due to the strong weathering of the surface, it has not yet been possible to determine the number of annual rings and thus the relative age of this tree. The yew stump ID 10 with a maximum diameter of the root plate of 110 cm was excavated at an unknown location in the Darss forest in the early 1950s (Anders 1956) and had been lying in the open in front of the museum since then. This stump is even more weathered than the Born specimen. The tree trunk rising from the roots is hollow.

For both stumps, wood anatomical analyses carried out within the framework of this study showed that they represent indeed *Taxus* wood. These stumps are the only remaining tangible physical evidence of the former yew stands in the Darss forest. In addition, in the settlements on Darss and Zingst, for example in Born, Prerow and Zingst, there are some living yew trees that are at least around a hundred years old, and in some cases even older (Figs. 1B, 4D). It is highly probable that these trees have arrived in the settlements as young plants from the nearby forest. An origin from tree nurseries outside the Darss-Zingst area can probably be excluded for this period. Due to their genetic characteristics, these old trees in the settlements later play a significant role as local provenance for the reintroduction of yew on Darss and Zingst (see chapter "Reintroduction of yew").

It is noticeable that in the times of the intensive geobotanical research of the Darss in the 1940s to 1960s, potentially existing occurrences of the yew were either not mentioned at all (Libbert 1940; Kreisel 1957; Fukarek 1961) or were reported as very rare (Günther 1957). Apparently, there were almost no more older yew trees in the forest on Darss at that time. Another source mentions *Taxus* here in the last third of the twentieth century (Jeschke et al. 1980), without making it clear whether the species still exists in the forest. In fact, however, younger planted yew stands existed, although mostly very hidden in the forest (see chapter"Reintroduction of yew").

A special narrative in popular scientific, journalistic and literary literature about this area is the alleged clearing of old yew trees on the Darss during the short Danish occupation phase in the years 1715–1720 (Berg 1999). Together with other types of wood, the yew trees were felled by the Danish military and transported to the nearby mainland by ship for the construction of the Danish castles Rosenborg and Amalienborg as well as for the reconstruction of the capital Copenhagen. This motif of "yew robbery" appears for the first time in the 1920s (Mueller 1926) subsequently

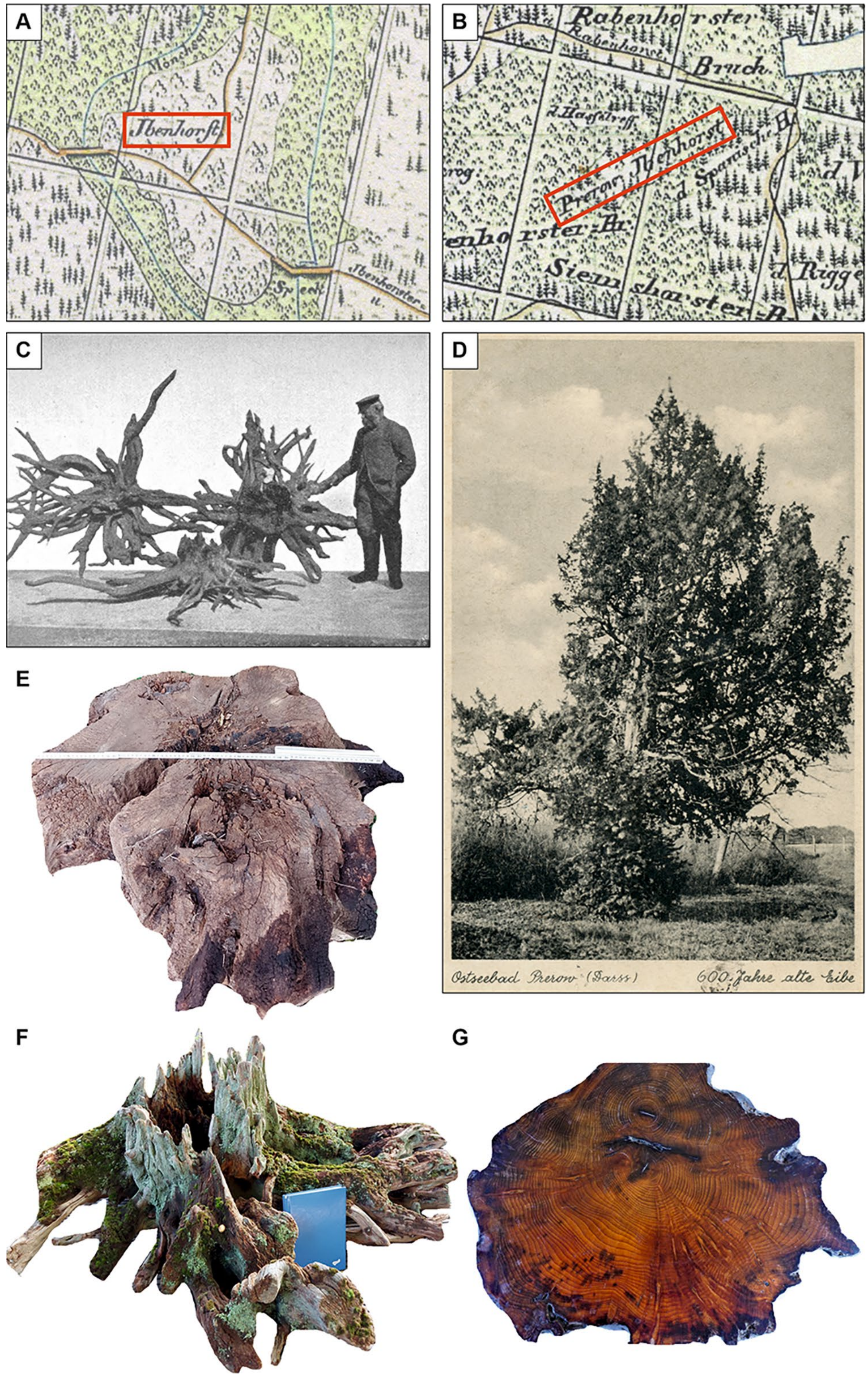


Fig. 4 Historical records of *Taxus baccata* on the Darss-Zingst Peninsula and beyond. **A**: Evidence of the toponym "Ibenhorst" (ID 47; marked with a red rectangle) in 1835 on the Vordarss west of Born on the so-called Prussian Ordnance Survey Map, Sheet 1540 Ibenhorst (Landesvermessungsamt Mecklenburg-Vorpommern 1998a). **B**: Evidence of the toponym "Prerow Ibenhorst" (ID 48; marked with a red rectangle) in 1835 on the Neudarss south of Prerow on the so-called Prussian Ordnance Survey Map, Sheet 1541 Prerow/Darss (Landesvermessungsamt Mecklenburg-Vorpommern 1998b). **C**: Yew stumps from the Darss forest, taken out of the ground in 1901 during the planting of pine trees and exhibited in the head forester's office in Born (ID 43; photograph from Winkelmann 1905). **D**: Old yew in the parish garden in Prerow (ID 8; photograph: postcard, probably 1930s). According to the caption, it is said to be 600 years old. This yew tree still exists and may actually be several hundred years old (200–300 a?). E: Yew stump in the Forestry and Hunting Museum at Born (ID 43; photograph: Knut Kaiser). F: Yew stump with root plate in the Darss Museum at Prerow (ID 10; photograph: Knut Kaiser). G: Stem cross section of yew from the Hütelmoor in the Rostocker Heide forest. It has a radiocarbon age of 3671 ± 38 BP (4144–3890 cal. BP; Kokesch 1999; photograph: Franz Kokesch)

taken up, but normally not questioned, by numerous other popular scientific and literary authors up to the recent (e.g. Anders 1956; Meyer-Scharffenberg 1971; von Soden 2019). Only a few authors, however, doubted this historical episode (Berg 1999; Schulz 2002), not least due to the apparent lack of regular historical sources that prove the concerted felling of yew trees at the beginning of the eighteenth century.

In the context of this study, an enquiry at the Royal Danish Collection revealed that yew wood is not known to have been used in Rosenborg and Amalienborg Castles as well as in the city of Copenhagen, neither for constructive purposes (e.g. building foundations or roof trusses) nor for interior design purposes (Peter Kristiansen, Copenhagen, pers. comm.). This is confirmed by an identical inquiry and answer from Copenhagen, which Franz Fukarek apparently initiated at the same institution already in the 1950s/1960s (Fukarek in Schulz 2002). Thus, the above-mentioned "yew robbery" on Darss at the beginning of the eighteenth century can probably be ruled out.

This leads to the question, what caused the apparent local disappearance of yew in the forest in the nineteenth century? If the information on the yew on Darss in the "Flora Pomerano-Rugica" (Weigel 1769) is really correct, then there is only a century between its still frequent occurrence in the last third of the eighteenth century and its almost complete disappearance in the last third of the nineteenth century (Marsson 1869). Winkelmann (1905, 1906) confirms this finding of an almost total loss of the yews by record only two living trees left in the Darss forest despite a systematic search. Possible causes of the disappearance are already mentioned by the authors above: forest cultivation and cutting or burning down the yews to protect grazing cattle and perhaps also horses from poisoning.

Systematic modern forestry has taken place on Darss and Zingst since the 1830s, after Swedish rule, which had lasted since the middle of the seventeenth century, ended in 1815 and the area became part of the Kingdom of Prussia (Purps 1996). Prior to this, unsystematic timber exploitation took place. This was mainly because the area had been the hunting ground of various rulers since the Middle Ages (Billwitz and Porada 2009). On the basis of forest planning and supported by forest aisle construction and drainage, afforestation then took place from the middle of the nineteenth century, mainly of pines as monocultures of same age. The extent to which the yew trees, which were certainly still present at certain locations, had a "disturbing" effect during this intensification of forestry use and, thus, were actively destroyed by the foresters cannot be clarified. There are no contemporary statements on this.

The reproduction conditions for yews on the Darss have probably gradually deteriorated. First of all, in heavily thinned forest stands or even in larger clearings (as often reported for the Darss forest from the late eighteenth to the early twentieth century; von Raesfeld 1926; Mueller 1933; Purps 1996) the lack of protection by sheltering trees can lead to an overload of seedling resistance especially to low temperatures. For the year 1891, the local head forester, Ferdinand von Raesfeld, reported that out of a total size of the Darss forest of about 5000 ha, about 2000 ha consisted of more or less open areas, i.e. land poor in trees and covered by heath, grassland and bushes (von Raesfeld 1926). Although *Taxus* has a high shade tolerance, the subsequent afforestation with pine, forming very dense stands in the first decades of their life, is likely to result in high seedling mortality as well (Iszkuło 2011).

Finally, the high local game populations due to hunting promotion are another reason for potentially high losses of young yew trees. For the year 1891, a red deer population of about 1100–1200 individuals is reported from the Darss forest (von Raesfeld 1926). This corresponds to a red deer density of 4.2–4.5 individuals per ha. Measured against the estimated current red deer density in this area of 0.1 individual per ha (Deutsche Wildtier Stiftung 2010), this is an extremely high value with corresponding strong effects on the reproduction of browsing-sensitive tree species such as yew. However, the red deer numbers reported by von Raesfeld (1926) for 1891 are considered exaggeratedly high by Berg (1999, p. 182), who, in contrast, reported a red deer number for 1868 of 250 individuals.

However, the intensive use of the forest for pasture and pannage, respectively, by cattle, domestic pigs, sheep and perhaps goats as well as horses, and the probable active destruction of the yew trees associated with this, is likely to have had the greatest impact. As a contemporary area description for the beginning of the nineteenth century informs, a very large herd of cattle was grazing in the Darss forest at that time (von Wehrs 1819, p. 105): "Several thousand heads of cattle must live from the Darß forest".

And still at the end of the nineteenth century, paintings show cattle grazing in the forest here, thinning it out very strongly (Fig. 5). This intensive browsing impact generally promoted robust conifers, such as pine and juniper, on the one hand, and suppressed the regeneration of deciduous trees, including oak and beech, on the other. In view of the large number of grazing livestock and their high material value for local people, a targeted eradication of the remaining, perhaps very conspicuous and certainly extremely poisonous yew trees is well conceivable. The replacement of the old forest utilisation rights, especially for forest grazing and pannage, of the villages on the Darss and Zingst took a very long time compared to other regions in Prussia, namely from 1821–1870 without ever being fully completed by 1945 (Berg 1999).

Reintroduction of yew

According to the dendrochronological data on living yews, which are presented in detail in chapter "Dendrochronological data" below, the oldest yew individuals planted as groups in the Darss forest (IDs 3, 4, 33; Table 2, Fig. 1B) have an age of 70–78 years in 2022, which corresponds to the introduction years 1938–1945. Their actual planting is indicated by stand characteristics (same age of trees, occurrence in rows) and partial entry in the forest logbook. This dating points to a first phase of the reintroduction of yew already before 1945, which year, due to the fundamental societal

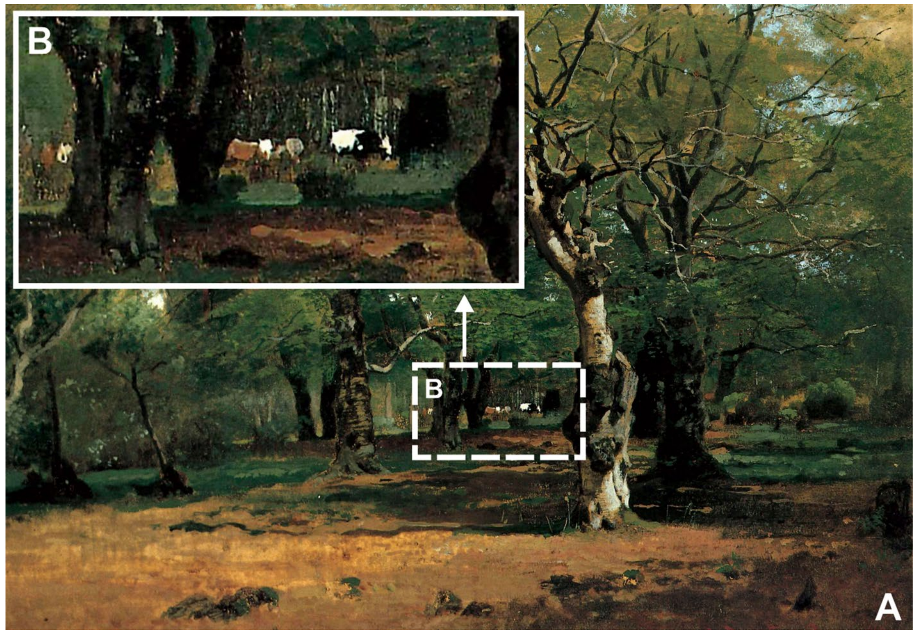


Fig. 5 Oil painting documenting the grazing of the Darss forest by cattle still at the end of the nineteenth century. Louis Douzette, "Midday sun in the Prerow beech forest", 1882 (Courtesy of the Pomeranian State Museum Greifswald). **A**: General view of the painting showing an older beech stand that has been heavily thinned out by grazing. Indicative of this are the lack of a higher herb layer and the absence of shrubs and tree regeneration. **B**: Detail showing the cattle

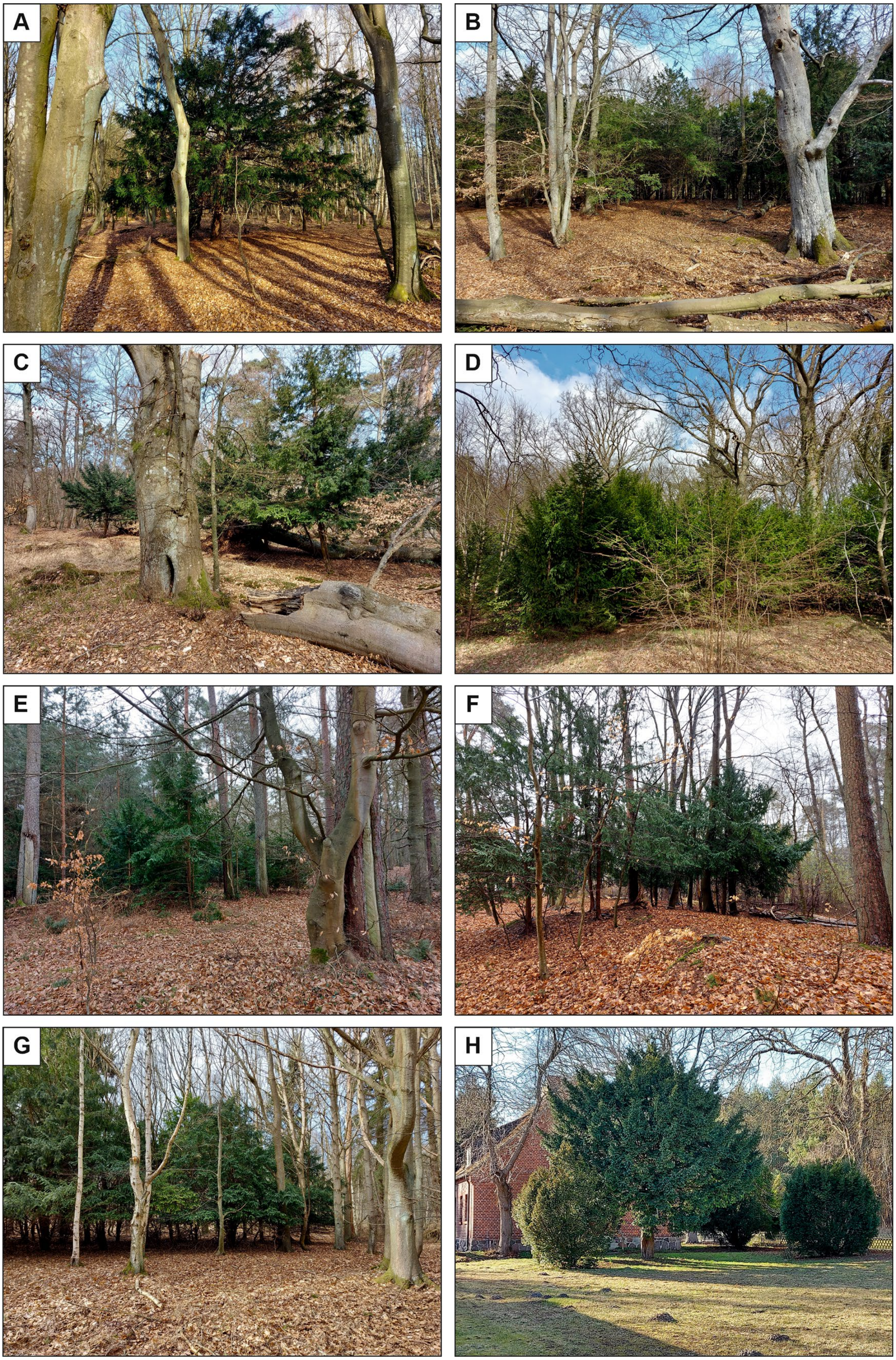
conditions that were changing, must also be understood as a social–political but also economic and forestry caesura (Billwitz and Porada 2009; Kasparick 2019). A potential natural return of the yew from the refugial locations of the settlements to the surrounding forest is conceivable. The spread of yew seeds via birds, which has often been observed elsewhere (e.g. Seidling 1999; Giertych 2000; Pietzarka 2005), plays a special role here. However, the lack of individual or grouped specimens without planting characteristics in the forest speaks locally against the significance of such a process.

If one dates the widespread disappearance of the yew in the Darss forest to the second half of the nineteenth century, despite the last natural yew ID 44 apparently living until the 1970s/1980s, then there is almost a century between this time and its reintroduction. The planting at the sites ID 3, 4 and 33 thus took place at a time when Franz Mueller-Darß (1890–1976) was head forester on the Darss (1923–1945). Neither the motivation for the yew planting nor the origin of the planting material is known. However, since Mueller-Darß also intensively pursued nature conservation efforts at times, including the intended establishment of a so-called Urwildpark (Engl.: wildlife park) on the Darss and realised measures for tree protection (Schulz 1995; Frank 1997), a nature conservation background for the yew plantations as well as the use of local planting material is very probable. It should be noted that this commitment to nature conservation was only one of the many facets of Mueller-Darß, who, as head forester and at the same time high SS officer, was not least responsible for the systematic training of concentration camp guard dogs and the use of concentration camp prisoners as labour forces on Darss and Zingst in the 1940s (Kasparick 2022).

Incidentally, for ID 4, an inspection of this yew stand and subsequent maintenance measures, including the clearing of surrounding shady trees, are reported for 2 September 1959 by a subsequent head forester (Martens 1995).

Further both small-scale and more extensive plantings (range of 3–90 surviving trees) then took place in the 1950s/1960s on the Neudarss (IDs 5, 36, 37) and in the 1960s in the "Osterwald" on the Zingst (IDs 22, 41; Table 2, Fig. 1B). Here, too, the use of local provenances for the planted yews can only be assumed.

As early as the 1980s, efforts were made to record rare tree species in the forests of the wider region (Lutz-Rüdiger Bockisch, Neustrelitz-Fürstensee, pers. comm.). Since the early 1990s, the regional forestry authority has then systematically worked on a programme to record, preserve and replant native and forestry-important tree species as a forestry genetic resource (Landesforst Mecklenburg-Vorpommern 2004; Voth 2006). This project concerned, among others, the yew. In this context, genetic investigations of samples from older yew stands on the Darss (Hertel 1996; Hertel and Kohlstock 1996) and tree physiological investigations on cuttings from there (Schneck 1996) were carried out. The genetic data showed that the coastal yew populations differ significantly from those in the north-eastern German inland as well as from those in central and southern Germany. The existence of such a "coastal population" of yew with a distinct genetic distance to the inland occurrences was later proven again for the Jasmund area on the neighbouring Island of Rügen (Forstbüro Ostbayern 2013).



◂**Fig. 6** Photographs of current *Taxus baccata* stands on the Darss-Zingst peninsula (all photographs: Knut Kaiser). For details on these yew occurrences see Table 2. **A**: ID 3 (Neudarss). **B**: ID 4 (Neudarss). **C**: ID 5 (Neudarss). **D**: ID 18 (Altdarss, west of Born). **E**: ID 19 (Altdarss, east of Ibenhorst). **F**: ID 36 (Neudarss, west of Prerow). **G**: ID 41 (Zingst, Osterwald). **H**: ID 1 (Altdarss, Ibenhorst settlement)

In 1993, about 9600 yew seedlings were planted in 12 forest units on the Darss ($n=9$) and Zingst ($n=3$) (Table 2). As there is no clear information on the origin, however, it can only be assumed that native planting material, i.e. obtained on the Darss-Zingst peninsula or from the wider region, was used at the time. In future studies, comparative genetic analyses should clarify whether the yew plantations have been carried out with local plant material since the 1930s/1940s. Genetic reference data from Darss and Zingst as well as from the wider region are already available (Hertel 1996; Hertel and Kohlstock 1996). In 1994, seeds and cuttings were obtained from old yew trees from settlements on the Darss and Zingst (Ibenhorst, Wieck, Prerow-Friedhof) and grown into young plants in the state forest nursery at Gädebehn (Voth 2006). Of these, 45 seedlings were planted in 1998 in a forest unit on the Darss (ID 6). For the last time in 2003, 320 seedlings were planted in 11 forest units on Darss and Zingst. The planting material for this was previously obtained in the Jasmund area on the Island of Rügen. The plantings in 2003 were mostly made at the sites of the 1993 plantings. In summary, a total of 10,150 yew plants were planted from 1993 to 2003, of which about 1300 plants still existed after an evaluation in 2021, including the stands already planted in the 1930s/1940s and in the 1950s/1960s (see chapter"Distribution and tree properties").

Current yew stands characteristics

Distribution and tree properties

In the forest on Darss and Zingst, 34 yew sites were found, distributed over 26 yew stands ($n \geq 2$ individuals) and 8 single tree records (Table 2, Figs. 1C, 6). Most records are available for the Altdarss and Neudarss, with further records for Vordarss and Zingst. The largest stands contain about 300 (ID 4; Fig. 6B) and 250 individuals (ID 15), respectively, and occupy a maximum area of 0.2 ha (ID 4). Eight yew stands are older than about 1970 (see chapter "Dendrochronological data"). Most stands, however, are from the 1990s and 2000s. The current yew occurrences on Darss and Zingst thus mainly comprise young individuals with a total number of ca. 1300 trees. According to this age structure, the tree heights in the yew stands vary from 0.2 to 15 m and the diameter of the breast height from 1 to 40 cm. The largest breast height diameters are reached by old trees in the settlements of Prerow (ID 8 = 86 cm; Fig. 5D) and Ibenhorst (ID 1 = 42 cm; Fig. 6H).

There is generally a balanced mix of female and male individuals, which is an important aspect in view of a potential spread of the trees due to the dioecy of yew (Iszkuło 2011). The vitality of the stands can be assessed as largely good, although some younger stands are evaluated as darkened and heavily browsed and swept by red deer and roe deer. For example, the yew stand ID 19 (Fig. 6E), which was fenced out a few years ago, shows severe deer damage on its marginal trees, while the trees inside are largely undamaged. The impact of game also has an influence on the expansion of the yews into their immediate surroundings. While very good natural regeneration has developed at a few sites (e.g. ID 4), this is currently not the case at most other sites. Browsing of other tree species, their lack of natural regeneration despite the sites' suitability in principle and a well-developed "browse line" are clear indications of the strong influence of game here.

Dendrochronological data

Tree-ring chronologies developed for 11 older yew trees from different locations (IDs 1, 3–5, 8, 22, 33, 36, 37, 41, 42) indicate a strong common growth signal of *Taxus* across the Darss-Zingst peninsula (Fig. 7). The "mean Gleichläufigkeit", which is a similarity measure quantifying common signs of year-to-year growth changes, amounts to 68%. The number of tree rings varies between and 45 and 89. For nine locations, it was possible to estimate the reintroduction year of *Taxus* (Table 3). Planting dates back to 1938 and 1939 at IDs 4 and 33, respectively, whereas years ranging from 1945 to 1969 were found for the other locations. The age of the two obviously oldest trees (ID 8 = old yew in the parish garden in Prerow, ID 42 = single tree SW of the Ibenhorst youth hostel; Fig. 1) could not be determined. The reason is that the pith of the sampled trees was not hit and the curvature of the inner rings did not allow for an estimation of the number of missing rings to the pith.

Discussion

Holocene yew records in the region

The pollen diagram IBH-5 proves, although in only small percentages, the local existence of *Taxus* around ca. 2600–2400 cal. BP on the Darss (Fig. 8). Thus, the assumption already made by Fukarek (1967), which *Taxus* on the Darss represents an autochthonous yew occurrence, can be confirmed. However, an examination of the other about 45 pollen diagrams available so far from the area of Darss and Zingst as well as the immediately adjacent land and

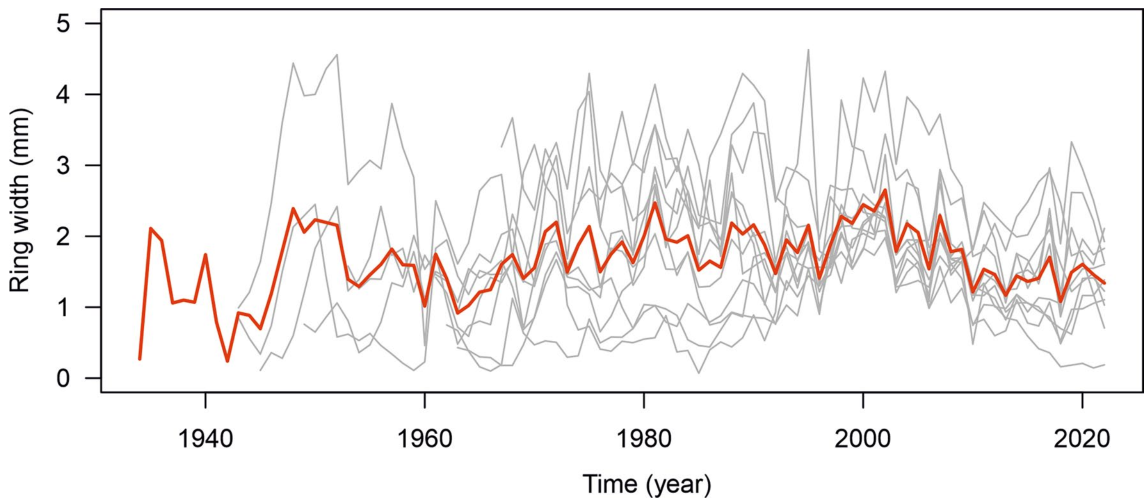


Fig. 7 Tree-ring chronologies for 11 analysed trees of *Taxus baccata* on the Darss-Zingst peninsula (grey lines). The mean chronology across locations is plotted in red. Chronologies for the individual locations were calculated as bi-weight robust means of the average ring-width series per tree

Table 3 Properties of *Taxus baccata* for dendrochronologically studied locations on the Darss-Zingst peninsula. For nine out of 11 locations, introduction years could be estimated

ID	DBH[1] (cm)	Tree height[1] (m)	Tree rings (number)	Tree introduction (year)
1	42.2 (1)	8.8 (1)	56	1957
3	33.2–37.0 (2)	10.0–10.3 (2)	70	1945
4	19.8–27.8 (3)	8.6–10.8 (3)	74	1938
5	16.5–19.0 (3)	5.6–10.2 (3)	61	1952
8	85.5 (1)	13.8 (1)	89	–
22	26.5 (1)	14.9 (1)	45	1969
33	18.9–27.0 (3)	8.1–12.6 (3)	78	1939
36	21.1 (1)	10.1 (1)	62	1953
37	16.7–23.4 (2)	7.8–9.3 (2)	60	1951
41	23.5 (1)	14.7 (1)	49	1967
42	35.3 (1)	12.5 (1)	76	–

[1]The number in parentheses refers to the measured tree individuals

sea area (see overview in Kaffke and Kaiser 2002) did not show evidence of *Taxus* in any further case. This can be attributed to the fact that *Taxus* pollen is generally difficult to identify (e.g. Averdieck 1971; Noryśkiewicz 2017) and that the "Greifswald school of palynology" (see exemplarily its first prominent representative and work: Fukarek 1961), which was mostly active in the Darss-Zingst area in the past, usually did not detect or report this pollen type. But the absence of *Taxus* pollen in all these pollen diagrams hence does not proof past absence of *Taxus* in the Darss-Zingst forests. Given the limited evidence from the palaeo-record currently available, it is not possible to reconstruct the distribution pattern of *Taxus* in the Darss-Zingst forest, nor to deduce with certainty in which local forest communities *Taxus* were present and with which frequency.

Although the relatively new pollen diagram ADP, located about 7 km north-east of diagram IBH-5, has been taxonomically and stratigraphically well resolved and radiometrically dated (Kaffke and Kaiser 2002; Fig. 1B), it shows a hiatus in the time interval ca. 4000–2000 cal. BP. Therefore, it cannot provide any information on the local forest vegetation in this particular time period, which is synchronous to the *Taxus*

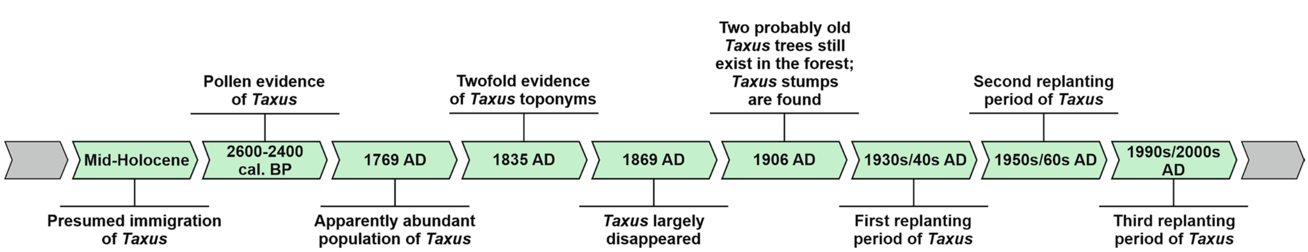


Fig. 8 Timeline of events and records on the history of *Taxus baccata* on the Darss-Zingst peninsula. With the exception of the presumed immigration in the Mid-Holocene, shown in the first place, all subsequent events and records are supported by evidence

pollen record in diagram IBH-5. However, other older pollen diagrams from the Darss and its surroundings (e.g. Fukarek 1961) as well as ecological considerations (e.g. Jeschke and Slobboda 2009) suggest that *Taxus* could mix with beech, oak, pine and others in a second tree storey and at forest margins in the last about two millennia. In addition, the European holly (*Ilex aquifolium*) is a typical shrub to small tree in this tree species community, as it is still widespread here today.

Also from the immediate vicinity of other recent yew occurrences on the north-eastern German and north-western Polish Baltic Sea coasts, such as in the Rostocker Heide forest (Fig. 2G), on Rügen Island and surroundings (Fig. 2F), and in the Oder/Odra River estuary region (Ueckermünder Heide and Puszcza Goleniowska forests; Fig. 2H), there is pollen and wood evidence for the existence of *Taxus* in the mid- to late Holocene (Fig. 9, Supplements 1, 2).

The nearest subfossil occurrence of *Taxus* is located about 30 km to the south-east in the Hütelmoor mire, situated on the edge of the Rostocker Heide forest to the Baltic Sea (Fig. 9). This area is generally very comparable to the Altdarss in terms of geological evolution and current site conditions (Kaiser 2001; Buczko et al. 2023). As early as 1979/1980, tree remains of *Taxus* were recovered from a depth of about 2 m in this mire during drainage works (Kokesch 1999). Based on the cross sections of four tree trunks (Fig. 4G), relative tree ages of partly more than 100 years could be determined with an average year ring width of 1.3 mm. Radiocarbon dating of one wood sample yielded an absolute age of ca. 4000 cal. BP (Table 1, Supplement 2).

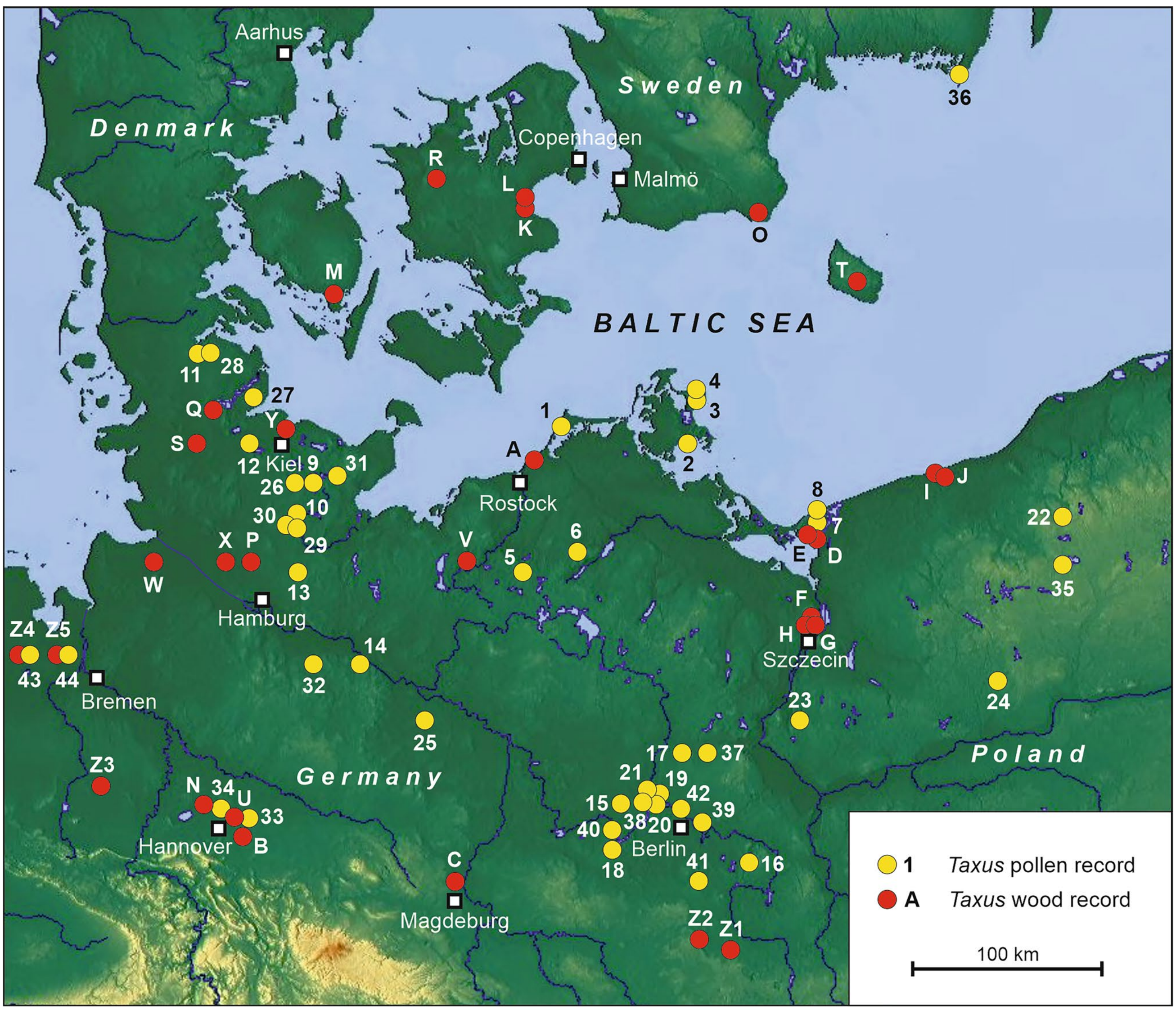


Fig. 9 Map on Holocene records of *Taxus baccata* in the lowland of northern central Europe using pollen and wood evidence (for details see Supplements 1, 2; map background: www.wikipedia.com)

The closest further pollenanalytical *Taxus* records at the Baltic Sea are available in north-east and east direction from the islands of Rügen (Herthamoor and Stubnitz mires, ca. 80 km distance; Lange et al. 1986) and Großer Vilm (ca. 70 km distance; Mrotzek 2015), respectively (Fig. 9, Supplement 1). *Taxus* pollen was occasionally detected in the two mires on Rügen within the last about 800 years, and this with a maximum proportion of only 1%. The finding on Großer Vilm island is particularly remarkable in two respects. First, there is a continuous record between about 8000 and 1500 cal. BP. This means that since at least the mid-Atlantic biozone *Taxus* can be detected in the wider region. Thus, such a high age of the Holocene *Taxus* occurrence can therefore potentially be assumed for older land surfaces in the Darss and Zingst area too, which are now largely covered by marine sediments or by water. On the other hand, the proportion of *Taxus* pollen in the period ca. 6200–5200 cal. BP (late Atlantic to early Subboreal) amounts to 15%, which is a very high value compared to the usual proportion of *Taxus* in pollen diagrams in northern Central Europe. Here, percentages of around or below 1% dominate with a few exceptions such as in the Totes Moor record with 20% (Achterberg et al. 2011) and in the Poolsee record with 11% (Averdieck 1983), both dating to the Subboreal (Fig. 9, Supplement 1). To our knowledge, the highest percentage of *Taxus* in a pollen record ever reached in Europe is at 50% around 3800 cal. BP in the Ipweger Moor site, north-west of Bremen (Hayen 1960). Furthermore, in the Reenadinna Wood pollen record, which is located within a ca. 25 ha large *Taxus* dominated present-day forest in south-west Ireland, *Taxus* amounted to 40% around 2800 cal. BP (Mitchell 1990).

The nearest palaeoecological evidence adjacent to the recent *Taxus* occurrences in the Oder/Odra estuary is found on the Baltic Sea island of Wolin and in the city of Szczecin, located about 150 km and 170 km south-east of the Darss-Zingst area, respectively (Fig. 9, Supplements 1, 2). Pollen analytical records at Kołczewo and Lake Racze on Wolin island support an occurrence of *Taxus* in the late Atlantic and the early Subatlantic (Latałowa 1992). Artefacts made from *Taxus* wood, including a four-headed figurine (ca. 850–900 AD) depicting the Slavic god "Światowit" (Svantevit), were found during archaeological excavations of early to late mediaeval settlements in the eponymous town of Wolin and in the old town of Szczecin (Cywa 2018; Szczepanik 2020).

The findings above thus prove that *Taxus* occurred in the mid- and late Holocene along today's southern Baltic Sea coast. At least locally apparently quite high proportions are probable. Sites of very different soil quality (e.g. sandy–wet, loamy–dry, stony) were covered by this tree species. Due to the methodologically conditioned only selective pollenanalytical record, a potential detection is to be expected in many more cases than the present ones.

An overall view of the currently available Holocene evidence of *Taxus* in northern Central Europe shows first of all, in addition to findings loosely distributed over the entire area, certain density centres (e.g. in and around Berlin, in the eastern part of the German federal state of Schleswig–Holstein; Fig. 9, Supplements 1, 2). On the other hand, large areas in the inland of northern Germany and northern Poland but also in the south of Denmark and Sweden are without *Taxus* evidence. In general, there are hundreds of pollen diagrams in the total area, which have been analysed there since the early twentieth century. The comparatively few *Taxus* records are probably due to the rather difficult detectability of its pollen already described above, indicating a research bias. Thus, a very clear dependence on certain "schools of palynology" is recognisable in the density centres so far, for example in the areas in and around Berlin and around Kiel.

The temporal distribution of *Taxus* pollen records shows the first occurrence in the late Boreal (pollen zone V according to Firbas 1949, ca. 10,600–9200 cal. BP) with one record in north-east Germany (Figs. 9A, 10A, Supplement 1) and a second one very next to the mapped area in southern Sweden (Berglund 1966). The earliest occurrence at all in central Europe dates around 10,900 cal. BP from a site in NE Poland and thus into the late Preboreal (pollen zone IV, ca. 11,500–10,600 cal. BP; Karpińska-Kołaczek et al. 2014). In the early Atlantic follow a few records (pollen zone V, ca. 10,600–9200 cal. BP), in the late Atlantic (pollen zone VI, ca. 9200–7500 cal. BP) several records (Fig. 10a). The occurrence peak is in the Subboreal (pollen zone VIII, ca. 5700–2400 cal. BP), followed by a marked decline towards the Subatlantic (pollen zones IX and X, ca. 2400–1200 and 1200–0 cal. BP, respectively; Fig. 10a).

Such an occurrence peak in the Subboreal and a decrease thereafter was already suspected, for example, by Averdieck (1971), Brande (1994) and Deforce and Bastiaens (2007) with, however, a much smaller data base and is also confirmed here. This Subboreal optimum of the yew applies to very different forest types. The spectrum ranges from the spruce–fir–beech forests of the northern marginal Alps to the oak forests in the oceanic north-west and the pine–oak forests in the continental north-east of Central Europe (Brande 2004). This points to a remarkable adaptability of yew to changing environmental conditions in the past. As causes for the later decline of *Taxus*, the above-mentioned sources have hypothesised increasing competition primarily from *Fagus*, climatic changes at the expense of *Taxus* reproduction and vitality, as well as human impact in the form of altered reproductive conditions, active utilisation of wood and also targeted local extinction of *Taxus* occurrences.

Most *Taxus* wood finds origin from archaeological contexts and date dominantly in the early Middle Ages to early Modern period (Figs. 9B, 10B, Supplement 2). Even before that, i.e. between about 4500 and 3300 cal. BP, a small data

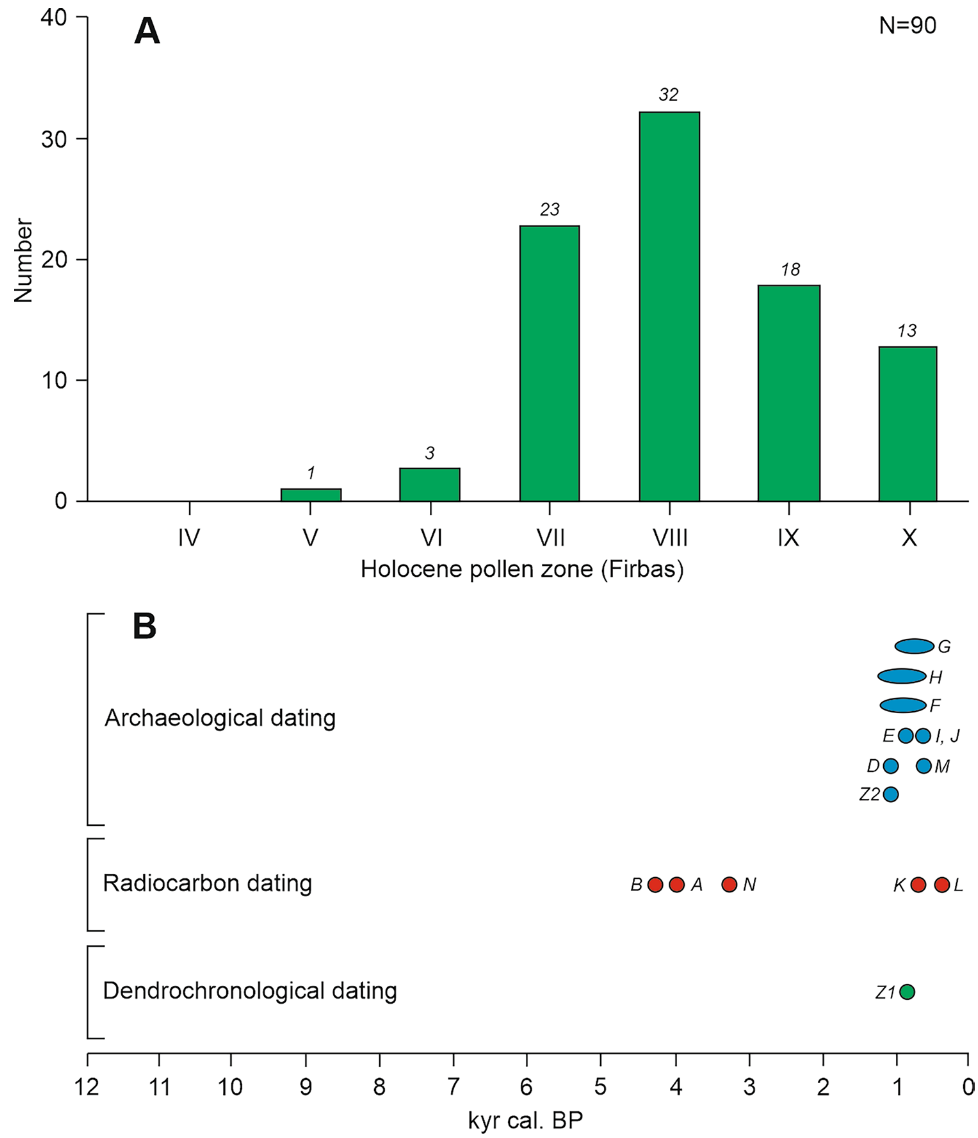


Fig. 10 Dating of Holocene records of *Taxus baccata* in the lowland of northern central Europe. **A**: Histogram showing coverage of Holocene pollen zones by Firbas (1949) with evidence of *Taxus* in pollen diagrams. The number of pollen diagrams is 44, while the number of pollen zone coverings is 90. Several pollen zones can therefore be potentially covered in one pollen diagram. **B**: Distribution of dated *Taxus* wood along the Holocene time axis. Compared to the relatively large number of general wood records ($n = 30$), the number of precisely dated wood records (i.e. dated by radiocarbon analysis or dendrochronology) is much smaller ($n = 6$)

set of subfossil *Taxus* wood and artefacts dates, with a yew arrow from Wietingsmoor near Bremen (Pfaffenberg 1957) and a yew bow from Koldingen near Hannover (Beckhoff 1977) providing the regionally oldest dates so far at about 4500 cal. BP and 4300 cal. BP, respectively. These yew artefacts are about a millennium younger than another record in Central Europe from the Polish Carpathians (Margielewski et al. 2010). Even older dating of subfossil yew woods in Central Europe to the mid-Holocene is suspected (Supplement 2), but radiometric confirmation is lacking so far.

Historical and present-day yew occurrences in the region

In order to place the yew occurrence on Darss and Zingst in a regional context, it is necessary to briefly characterise the other autochthonous occurrences on the north-east German and north-west Polish Baltic Sea coast. The occurrences in the Rostocker Heide forest, on Rügen and in the Oder/Odra estuary region were the focus of botanical and historical investigations in the nineteenth/twentieth century. Regional floras and further publications generally characterise the yew as a rarely occurring tree in forests (e.g. Boll 1860; Marsson 1869; Winkelmann 1906; Fukarek 1967; Fig. 8).

Particularly intensive attention was paid to the so-called thousand-year-old yew in Mönchhagen east of Rostock and a yew group in the nearby Rostocker Heide forest next to Meyershausstelle site (e.g. Becker 1791; Krause 1885; Beißner 1906). The single tree in Mönchhagen has a breast height diameter of about 100 cm. According to Kokesch (1980), the estimated age given in the research literature since 1884 varies between 330 and 2000 years, while the actual age according to a dendrochronological model approach is probably between 450 and 500 years. In any case, it is the oldest living yew tree in north-eastern Germany. This impressive veteran tree is probably not the remnant of an original forest population. Rather, it goes back to a plantation or spontaneous growth in the middle of this settlement, as the village of Mönchhagen is mentioned in a document as early as 1252. The yew group in the Rostocker Heide forest with a maximal breast height diameter of 50 cm is undated (Fig. 2G). However, its existence is attested already at the end of the eighteenth century (Becker 1791; Beißner 1906).

A further yew occurrence, already mentioned in the eighteenth century, exists on the Island of Rügen (Weigel 1769). Older and younger trees also currently occur on the dynamic chalk cliffs of the Stubnitz area exposed to the north-east. They are a relatively rare natural element of beech slope forests and scrub communities here (Jeschke 1964, 2015; Jeschke and Knapp 2019; Fig. 2F).

In the Oder/Odra estuary region, there are several occurrences of old yew trees in the forests to the north-west (Ueckermünder Heide) and north-east of Szczecin (Puszcza Goleniowska; Winkelmann 1906; Król 1986; Cedro 2023). Here, the sites near Luckow (west of Lake Neuwarper See) and Rokita (east of Stettiner Haff/Zalew Szczeciński) are particularly noteworthy. Near Luckow, the breast height diameter of older trees reaches up to 60 cm, and the age of some trees exceeds one hundred years (Fig. 2H). For Rokita, old trees with breast height diameters between 60 and 85 cm and an age between 150 and 170 years are mentioned (Król 1986). A more recent dendrochronological study showed an exemplary tree age of about 100 years (Cedro 2023). There are also several yew stands on the nearby Baltic Sea island of Usedom, which have been created by populations running wild in settlements and by deliberate planting in nearby forests (Daute 2023).

One method to reconstruct further earlier occurrences of yew in the region is the systematic mapping of corresponding toponyms. In north-eastern Central Europe, the yew is indicated by the name components "Ibe" (German) and "Cis" (Slavic/Polish). This usually allows a reliable localisation of earlier occurrences. However, depending on the local settlement history, their dating is limited to a vague minimum age from the Middle Ages to the Early Modern Period (Conwentz 1892; Fukarek 1967; Związek et al. 2021).

In general, the yew occurrences along the southern Baltic Sea coast presented above can be regarded as autochthonous sites, as is evidenced by geobotanical (Fukarek 1967) and palaeobotanical findings (see chapter “Holocene yew records in the region”). However, this also includes the planting of yew trees to re-establish local occurrences, such as on the Darss or in Rokita (Dobrowolska et al. 2012). Remarkably, the question of the autochthonous occurrence of yews on the southern Baltic coast and inland, as opposed to their anthropogenic introduction, was systematically raised as early as the mid-nineteenth century (Brande 2002). It was also recognised early on that yews had declined sharply in recent centuries, mainly due to human impact eradicating the tree to support forest grazing of domestic animals (Boll 1860; Seehaus 1862; Marsson 1869).

In terms of their natural habitats, the historic and present-day yew occurrences along the southern Baltic Sea coast are dominated by sandy sites close to the groundwater. Loamy soils and peat are also covered. The steep and very dynamic chalk cliff sites on Rügen Island represent an extreme. Thus, the site inventory of the yew in the region shows a very wide range: from dry to moist, oligotrophic to eutrophic and shady to sunny. Different landforms are covered, such as plateaus, slopes, dunes and depressions. All this underlines the role of *Taxus* as a, figuratively speaking, generalist and opportunist. This undoubtedly offers opportunities for the future of this tree species in the coastal region and beyond.

Importance of yew for nature conservation in the North German lowlands

After its excessive use as bow timber in the Middle Ages, the yew largely disappeared from the focus of economic forest use in Central Europe. As a marginally used wood, however, the yew was, as in prehistory, of local interest for prestige articles and objects with special significance such as valuable furniture and wooden sculptures (Hageneder 2007). As it was now a tree species without economic significance, the text records that had previously sometimes concerned the yew also virtually came to an end. This contrasted with the increasing importance of yew as an ornamental plant in parks and gardens since the Renaissance, with ubiquitous use first in the Baroque French formal garden and later in the Classic English landscape garden (Turner 2005). While most of the yew's forest sites in Central Europe fell victim to the intensification of modern use, parks, gardens and cemeteries became refuges for this tree species.

Close parallels to the history of yew on Darss and Zingst (Fig. 8) can be found with regard to site conditions, the decline in the nineteenth century and its potential causes in a study that is already more than 130 years old from former West Prussia, south-west of Danzig/Gdańsk (Conwentz 1892). Natural yew stands were only found there in small numbers in remote forests, partly only as subfossil stumps. Causes for an almost complete decline of the species were mainly identified as intensified forest use (drainage, change of tree species, clear-cutting) and direct damage by both animals (game, cattle) and humans. Conwentz (1892) therefore concluded in an overall view of the situation in Central Europe that the yew represents a “dying forest tree”. In his opinion, at the time its general extinction in the forests can probably be delayed locally, but on the whole, it can probably no longer be prevented.

Remarkably, there is a very close relationship between the specific research of Hugo Conwentz (1855–1922) on the southern Baltic yew occurrences and the general development of nature conservation in Central Europe. According to Scheeder and Brande (1997), Conwentz was particularly inspired by the fate of the yew tree in his native West Prussia when developing a system for the protection of natural monuments including old and rare trees (Conwentz 1904). This ultimately gave rise to the first state institution in Central Europe to systematically deal with nature conservation as a public matter, which was established in 1906 by Prussia at Danzig/Gdańsk.

At present, the forest occurrences of the yew in Germany are protected under the category "particularly protected species", as the tree is rare here and its population is endangered. The German Red List only lists the species in the category "near threatened" with a "moderate decline" as the long-term population trend (The German Red List Centre 2023). In the regional Red List for Mecklenburg-Vorpommern, however, and thus representing the territory along most of the German Baltic Sea coast and the immediately adjacent inland, the yew is classified as "extremely rare" (Voigtländer et al. 2005).

Nominated as the German "Tree of the Year" in 1994, the yew subsequently attracted growing scientific as well as conservation and forestry interest (e.g. Kölbel and Schmidt 1996; Pietzarka 2005; Hattemer and Ziehe 2018). An inventory of yew in German forests resulted in an estimated number of about 60,000 trees distributed in about 340 local occurrences (Forstbüro Ostbayern 2013). Regional focal points are mountainous and hilly areas, especially in central Germany (in particular Thuringia with about 33,000, southern Niedersachsen with 1500 and Hesse with 1800 individuals) and southern Germany (in particular Bavaria with about 15,000 and Baden-Württemberg with 2600 individuals), representing together about 90% of the German yew population. The population of the federal state of Mecklenburg-Vorpommern adjacent to the Baltic Sea is estimated at about 3000 individuals (of which currently about the half on Darss and Zingst). In the north-eastern German inland, i.e. largely in the federal state of Brandenburg, about 1200 registered yews occur.

In addition to the protection and re-establishment of autochthonous occurrences on the Baltic Sea coast, such as on the Darss-Zingst peninsula (Fig. 8) but also in neighbouring southern Denmark (Jensen and Svenning 2021) and north-western Poland (Dobrowolska et al. 2012), new yew stands have also been planted in recent decades, such as in Schleswig–Holstein (Steffen and Harriehausen 2018). In both Schleswig–Holstein and Brandenburg, yew as a forest tree became extinct in historical times (Brande 1994). However, larger yew stands developed here in the nineteenth/twentieth century, for example around Berlin and in the Uckermark near Chorin, as spontaneous rejuvenation from original anthropogenic tree plantings in gardens, parks and cemeteries (Seidling 2001; Forstbotanischer Garten der Hochschule für nachhaltige Entwicklung Eberswalde 2020).

Conclusions

Preserving and restoring a natural tree species composition is a reasonable approach to cope with climatic and biological changes in the longer term. The European yew represents a natural tree species that occurs in very small quantities in the forests of the southern Baltic Sea coast and its hinterland. It completes the naturally predominant tree composition, which consist of various deciduous tree species, especially beech and oak, and pine as a conifer. Due to its historical population dynamics in the direction of a regionally almost realised extinction, the yew is to a certain extent a living memorial for the consequences of a particularly intensive forest use for varying purposes.

We draw the following conclusions from our interdisciplinary research on the population history of the yew on the Darss-Zingst peninsula:

(1) Pollen analysis shows that yew has been present for at least 2600 years and thus represents an autochthonous tree species in the area.
(2) In the natural forest since that time, the yew has probably been part of a second tree storey and a component of forest margins adjacent to, for example, mires, waters and active coastal dunes.
(3) Historical findings show that the yew was still quite common in the Darss forest in the middle of the eighteenth century, but by the end of the nineteenth century it was almost extinct here.
(4) The causes of near extinction lie in a combination of forest use by livestock grazing and pannage including targeted eradicating of the tree, high game populations for the promotion of hunting and intensive forestry (age class forests primarily of pine with clear-cutting). As a result, natural reproduction of the yew was no longer possible and older tree individuals disappeared gradually from the forest. However, some older specimens survive in local gardens and cemeteries, which originally came from the neighbouring forest as young plants.
(5) The reintroduction of yew initially took place on a small scale by local forestry in the 1930s/1940s and 1950s/1960s. Within the framework of nature conservation measures, extensive re-establishment of yew stands took place in three campaigns in the 1990s and 2000s. Planting material from seeds and cuttings from

old yew trees in the settlements on Darss and Zingst was used, at least in part.

(6) Currently, there are 26 yew stands with a total population of ca. 1300 trees in the forest on the Darss-Zingst peninsula. A few older stands with trees up to 78 years old are contrasted by predominantly young yew stands with an age of ca. 25–35 years. The stands have developed well, with varying degrees of damage caused by game. Some stands have developed intensive natural regeneration, so that the yew is already expanding into the surrounding forest here.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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