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# Old Wood in a New Light: An Online Dendrochronological Database

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**Abstract**

The *Old Wood in a New Light* database project focuses on the digitization and accessibility of the results of dendrochronological samples analyzed and archived at four Swedish university-based tree-ring laboratories at Lund University, Stockholm University, University of Gothenburg, and the Swedish University of Agricultural Sciences. Collaboration with the Environmental Archaeology Laboratory and Humlab at Umeå University enables long-term open access to data, raw data, and metadata. In this project, we (1) systematically undertake large-scale entry and open access publication of results from wood samples scientifically analyzed and archived by Swedish laboratories and the associated metadata, into the Strategic Environmental Archaeology Database (SEAD; www.sead.se) research data infrastructure, and (2) actively promote the database as a resource for new and ongoing interdisciplinary research initiatives. Including dendrochronological data in SEAD infrastructure allows interdisciplinary studies that combine major scientific and societal questions. Building on a pilot study of construction timber from southern Sweden and adaptation of SEAD digitization workflows, more than 70 000 samples archived at the four dendrochronological laboratories are now being handled in the project. The broad coverage of research

networks, stakeholder interaction, and strategic support from the cultural heritage community is guaranteed owing to the ongoing collaboration between laboratories and an established international and multidisciplinary reference group.

**Keywords**

archaeology – cultural heritage – dendrochronology – open data – Sweden – timber – tree rings

## 1 Introduction

Trees are natural archives of climate dynamics, environmental change, and human impacts on landscape management. Analysis of the ring-width patterns of the trees can yield a wealth of information. Dendrochronology is a well-established scientific discipline based on measurements of annual growth rings in trees and wooden objects, and the data and inferred results have been used in a wide range of research topics. The methodology for using the growth patterns of annual tree rings as a dating tool was established in the early 20th century (Douglass 1921, 1941), and since the beginning of the digitization of measurement and data management methods in the 1970s, there has been rapid development in the methodology for ring-width pattern analysis and its areas of use (Fritts 1976; Cook & Kairiukstis 1990; Pearl *et al.* 2020).

In Sweden, dendrochronological analysis has been an essential tool for cultural heritage research for several decades. Applications include studies of historical buildings (Almevik & Melin 2016; Edvardsson *et al.* 2021a), shipwrecks (Hansson *et al.* 2021), cultural history (Seim *et al.* 2015; Ljungquist *et al.* 2018), archaeological findings (Bartholin & Ödman 1987; Hansson 2001), and the fine arts (Edvardsson *et al.* 2021b). Dendrochronology is also extensively used in climatology (Gunnarson & Linderholm 2002; Linderholm *et al.* 2010), paleoclimatology (Gunnarson 2008; Edvardsson *et al.* 2016), paleoecology (Gunnarson *et al.* 2003; Edvardsson *et al.* 2014), plant physiology (Drobyshev *et al.* 2008), forest fire history (Drobyshev *et al.* 2022), biological conservation (Lindbladh *et al.* 2013), oceanography (Eggertsson 1994), and marine archaeology and geology (Hansson *et al.* 2018). Most of these tree-ring-based scientific disciplines are represented collectively at the four Swedish university-based dendrochronological laboratories, the Laboratory for Wood Anatomy and Dendrochronology (LWD) at Lund University, the Gothenburg University Laboratory for Dendrochronology

(GULD), the Stockholm Tree Ring Laboratory (STRL) at Stockholm University, and the Dendrochronological Laboratory (DELA) at the Swedish Agricultural University (SLU). Combined, these laboratories host data, raw data, and metadata from approximately 70 000 wooden samples. Collecting, compiling, and creating such extensive dendrochronological data available to the scientific community is a considerable challenge.

Digital methods for acquiring, storing, and visualizing data have been adopted early within archaeology, with the ongoing development of databases and database tools since the 1960s (Lock 2003). In recent years, there has been a push toward linking databases using standard ontologies such as the CIDOC conceptual reference model (Meghini *et al.* 2017), making data dispersed across many different systems and searchable through typical data portals. In the Old Wood in a New Light project, dendrochronological data from the four Swedish laboratories are now being integrated into and made available through the Strategic Environmental Archaeology Database (SEAD), an open-access, multiproxy, research data infrastructure with the capacity to store a range of data types of relevance for archaeological science (Buckland *et al.* 2018, 2022). SEAD is hosted by the Environmental Archaeology Laboratory and Humlab, the humanities computing laboratory at Umeå University, Sweden. Moreover, SEAD is a national research infrastructure for archaeology and environmental archaeology in Sweden (SND 2021); however, its design has an international scope with no geographical or chronological limits on the data it can manage. Although one of the aims of the project is to enable research into the cultural aspects of history and prehistory, it is recognized that records of natural environmental changes during the Quaternary are necessary to provide a background against which cultural data can be contextualized, including current calibration data, which provide a much-needed empirical basis for use in quantitative environmental reconstructions (Edwards *et al.* 2017).

SEAD can manage an array of proxy data sources, including biological such as insects, plant macrofossils, and pollen, geoarchaeological, i.e., soil chemistry and physical properties, and technical data, e.g., ceramics, stable isotopes, and lipids (Buckland *et al.* 2018). The project is fully open-access, and different open-source software and customized solutions are implemented to provide tools for the aggregation, analysis, and visualization of data via the SuperSEAD online interface (https://browser.sead.se/).

In this paper, we describe data, raw data, and metadata associated with the archived samples, present SEAD and explain the handling of open access dendrochronological data using this data infrastructure, guide end-users on taking advantage of the database, and provide examples of the potential use of published data. We also present a brief overview of comprehensive

wooden material existing as stored cores and cross-sections at the four Swedish university-based dendrochronological laboratories.

## 2 Materials and Methods

### 2.1 *Dendrochronological Laboratories and Data Contributors in Sweden*

The LWD has been active in the Department of Geology, Lund University, since 1973. The primary emphasis of the laboratory is on dendrochronological age determination of wood material from archaeological excavations, historical constructions, shipwrecks, and art. The LWD is a national research infrastructure, part of the consortium of Swedish Archaeological Science Facilities (ArchLab, http://archlab.se/), and connected to Heritage Science Sweden (https://heritagescience.se/). In addition to a considerable number of archaeological and cultural heritage analyses, research at LWD focuses on long-term climate and vegetation changes (Edvardsson 2013) and coastline dynamics (Hansson 2018).

The GULD is hosted by the Department of Earth Sciences, University of Gothenburg, and was founded in 2003. GULD is linked closely with the Regional Climate Group, where much of the research aims to combine climate information from observations and models with paleoclimatic data (Linderholm *et al.* 2018; Seftingen *et al.* 2020). GULD hosts ongoing collaborations with regional museums regarding archaeological wood and has an international profile, including being a partner in the Sino-Swedish Centre for Tree-Ring Research.

The STRL has been active since the 1980s in the Department of Physical Geography, Stockholm University. The laboratory focuses on paleoclimatology, and the wood samples mainly sourced from temperature-limited environments close to the treeline in the Scandes Mountains (Linderholm 2001; Gunnarson 2002; Grudd 2008). The laboratory also analyzes maximum latewood density data and energy dispersive X-ray fluorescence to identify elemental signals in tree-ring records (Rocha 2021). All collected wood material is digitized, archived, and partly published in the International Tree Ring Database (ITRDB) or locally in the Bolin Centre for Climate Research database.

The DELA at the SLU at Alnarp was founded in 1997 and is part of the Southern Swedish Forest Research Centre. The laboratory has for a long time actively researched factors controlling historic and modern forest fires (Niklasson & Granström 2000; Drobyshev *et al.* 2016), forest ecology (Drobyshev *et al.* 2010, 2014), and oak dendroclimatology (Drobyshev *et al.* 2008). The studies focus mainly on Nordic countries but include central-eastern Europe and North America.

### 2.2 *Types of Data*

Dendrochronological data and results consist of three parts: raw data, data, and metadata. Most raw data comprises measured tree-ring width sequences from individual samples (tree cores or cross sections from tree trunks). For each wood sample, one or several radii are measured depending on the shape and nature of the wood sample. An increment core from a tree or trunk with visible annual rings is usually measured only once. To allow for the measurement of as many annual rings as possible and to enable the first quality control of these measurements, two cores per tree or trunk are extracted for tree-ring analysis, enabling measurements of two or more radii for the cored samples. When cross-sections from living or dead trees, subfossil wood, and construction timber are available, two to four radii are often measured. Additional measurements can be performed for those samples with missing annual rings, are difficult to interpret, or are overly narrow (Edvardsson *et al.* 2021a). For trees that are measured several times, each radius can be compared statistically and visually by cross-dating (Wigley *et al.* 1987). If the measurement series exhibits satisfactory agreement, they can be combined into a mean record of the sample. In the mean record the influence of potential growth anomalies of each radii on the data series decreases, including several radii extending into the center and towards the tree-bark produces longer mean records than individual series. For a few samples, the ring widths of earlywood and latewood are measured individually. Additional analyses may include the measurements of maximum latewood density instead of or to complement ring width. Following rigorous quality control, tree-ring sequences, i.e., raw data, will be made accessible and connected to the data and metadata, allowing complete transparency in dendrochronological age determination. The process also includes the conversion of data from various formats, such as CATRAS (Aniol 1983), Heidelberg (Rinn 2003), or CDendro (Larsson 2014) used by different laboratories or periods, into formats that do not require access to license-restricted measurement programs. This data conversion is performed by individual laboratories using, for example, TSAP-Win (Rinn 2003) or Tellervo (Brewer 2014) software.

Data are obtained from sample analyses and information generated from associated raw data. Examples of data include tree species, number of measured rings, dating of the outermost ring, estimated felling year, and timber provenance (Table 1). These data items are commonly used when synthesizing or collating dendrochronological data for publications or interpretations of objects and sites. The metadata describe the context associated with the *raw* data and data (Table 2). Depending on the sampling context, metadata are classified into four categories: buildings, archaeology, shipwrecks, and living trees, but other types may be added during the construction process. Some

TABLE 1 Examples of data obtained from dendrochronological analyses

| General information | Type of information |
|---|---|
| Measurement information | Type of sample, number of radii, full ring or EW/LW measurement |
| Tree characteristics | Species, distance to pith, number of rings, number of sapwood rings, presence of waney edge/bark, estimated tree age |
| Dating information | Date of outermost ring, estimated felling year, estimated germination year |
| Other | Comments, samples from same tree |

TABLE 2 Examples of metadata obtained from dendrochronological

| General information | Type of information |
|---|---|
| Project information | Client, year, sampler, type of investigation, purpose |
| Geography | Coordinates, country, county, city, parish, national site ID |
| Timber | Shape, wood techniques, marks, timber re-use |
| Science | Short summary of the results |
| References | Lab report, client/Swedish heritage board project number, project documents |
| Publications | Lab reports, client reports, other sources of information |
| Building specific | |
| Building | Building type (church/house etc.), number of floors, roof shape/type, framework |
| Sample position | Floor/room, building part (roof, wall, floor etc.), exact sample position (e.g., second rafter from west, north side) |
| Archaeology specific | |
| Object | Type of feature, description according to the client |
| Sampling | Context, feature, layer, shaft, profile |
| Wreck specific | |
| Wreck | Type of wreck, description according to the client |
| Sampling | Sample placement |
| Living tree specific | |
| Stand information | Sample site morphology, forest type, |
| Sampling | Sample height and direction, tree characteristics (height, diameter etc.) |

metadata characteristics are uniform across categories, such as project information, geographical information, timber characteristics, and references/publications connected to the samples. Other metadata information differs between the four categories. For buildings, information on the building type and exact placement of the wood sample in the building is added. For archaeological wood samples, information on the type of archaeological object investigated and its context is added. Shipwreck-specific metadata includes information on ship type and sample placement, and metadata for living trees include various stand information, such as vegetation and soil types, as well as detailed sampling information, such as sampling height and tree diameter.

Other types of platforms such as TRiDAS (Brewer *et al.* 2011), have been considered, but as Umeå University has a platform that, with minor adjustments, can work for our purpose, SEAD was chosen. The advantages of using SEAD are that (i) archaeological data from multiple research disciplines are linked together and (ii) the long-term maintenance and operation of the database are secured. As a national research infrastructure, SEAD integrates and facilitates access to dendrochronological data and data from several disciplines employed in archaeological science. The long-term maintenance and operation of the database are secured via Umeå University, and its continued development is ensured via projects such as Old Wood in a New Light and the national infrastructure project SweDigArch (swedigarch.se).

### 2.3 *Data Compilation*

The structure of the SEAD has been prepared for the ingestion of dendrochronological results (Buckland *et al.* 2018). In a pilot study (Meissner *et al.* 2012), data on historical building timbers from the province of Småland, southern Sweden, were used to design a standardized multi-sheet Excel template for data entry (Fig. 1), which was reviewed in a related project in Norway (Meissner & Brekke 2017) and further implemented in the VISEAD project (Buckland *et al.* 2018). Similar routines have been created for geochemical and paleoecological data. Data homogenization, metadata enrichment, cleaning, and ingestion workflows have been developed for importing data through Excel templates, which are reviewed using an online peer-review system. The dendrochronological data and metadata are described by more than 70 fields, ranging from numerical measurements, e.g., number of rings, and age determinations, e.g., felling year, to the spatial location of samples such as coordinates, outer wall, or roof, other contextual information, e.g., axes and church property, and publications. In the pilot study by Meissner *et al.* (2012), data and metadata from 969 samples, including collated external metadata from third parties (e.g., museum and contract archaeology reports), were digitized (Fig. 1B). Protocols

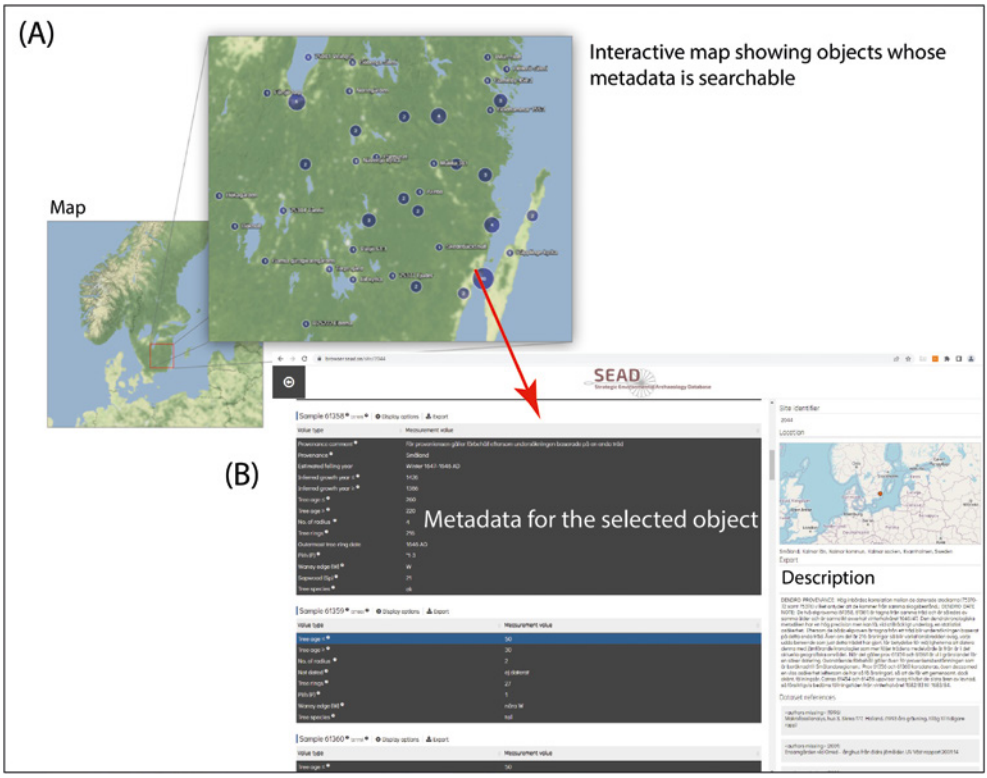


FIGURE 1 Example from the pilot study by Meissner *et al.* (2012), in which data on historical building timbers from the province of Småland, southern Sweden, were made accessible. (A) Each blue circle represents a site from which there is searchable metadata. (B) By selecting a site, it is possible to download metadata and a description of the study object.

for registering natural wood finds have been developed. Since there is no universal format for this type of data and metadata (Brewer & Murphy 2011) and many of the programs used in dendrochronological laboratories require licenses, all raw data are converted to standardized text and numerical data before they are presented in SEAD. However, before a dataset is published in the database, the data must be structured and controlled, which involves multiple steps.

### 2.4 *Data Accessibility*

The dendrochronological data will be successively accessible and explorable through the online browser SuperSEAD (https://browser.sead.se). The routine maintenance and development of the database will take place in sprints responding to user requests, which will be logged on GitHub (https://github

.com/humlab-sead) in an open development process. The Old Wood database and interface are being developed through an iterative process with close collaboration between developers and domain scientists (dendrochronologists). The process ensures that end users are well involved in the design of data access functions, and the developers' experience of previous projects and the capacity to experiment are taken onboard. Including the developers' perspective in SEAD aids the investigation of dendrochronological data and its implementation in other contexts. The process can be followed online using SuperSEAD to download all described data. However, often information on these chains of data entry are unrecorded, despite their importance in identifying error sources. SEAD can store such information, whereas other already established databases such as Arbodat (Kreuz & Schäfer 2002) often need to go through repeated phases of data entry mode while in use, which has contributed to more frequent use of the term "paradata" for describing information on data provenance (Kansa *et al.* 2020). However, the information on data provenance is still perceived by many as part of the metadata describing the analysis process.

### 2.5 *Database Structure*

As SEAD is primarily a tool for research, and not simply a data repository (Buckland et al. 2022), data storage does not involve storing single files with accompanying metadata descriptions. Emphasis is placed on usability rather than archive data formats, even though the database can be exported easily in text form, i.e., SQL, for sustainable access. SEAD is structured around a PostgreSQL relational database, meaning that data and metadata are stored in the form of data tables in the database and are defined according to their data type. These tables are related and based on shared information (fields), enabling the execution of several different data aggregations and visualization tasks via filters in the web interface. Before deciding on what data volume is necessary for a particular study, the user can explore, filter, and manipulate data through the browser and finally download and continue their research locally. In the future, computational access will be available through an application programming interface (API) and linked data for use in statistical and GIS software, as well as aggregation or federation with other database systems, such as the ITRDB (Fig. 2).

SEAD has a hierarchical structure wherein each "level" can be represented conceptually from higher to lower, between site, sample group, sample, and analysis result, or dates and measurements in dendrochronology (Buckland *et al.* 2018; Fig. 2). Each level features a core table with vital information, i.e., data, such as site name, sample number, or analysis result. Tables for storing

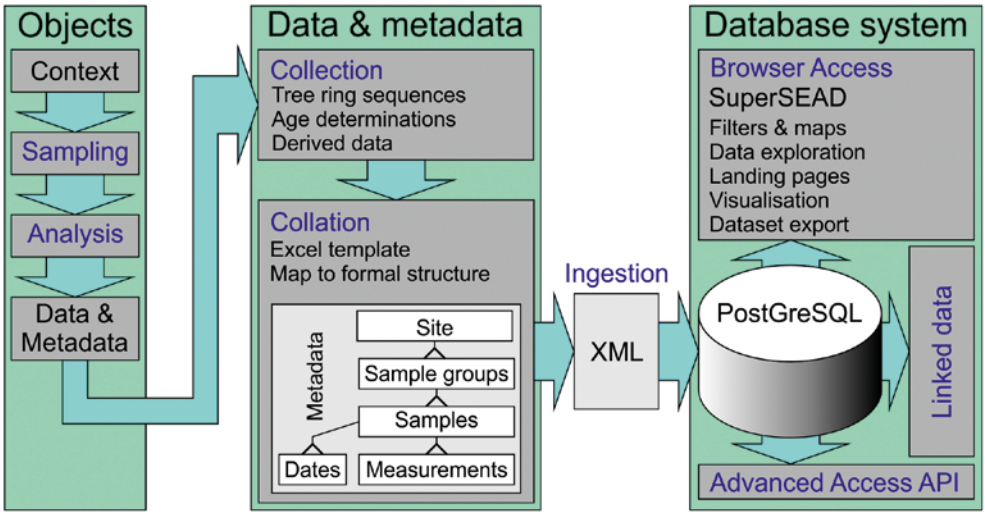


FIGURE 2 Simplified structure of the database, how data are entered and made available

additional metadata, e.g., sample alias and sampling context, are linked to each *data* table. This hierarchical relational structure of the database enables complex querying and data aggregation tasks, making it particularly user-friendly. Apart from these central data nodes, tables also are structured around managing the analysis methods, chronological methods, latest calibration data, location, and references.

To summarize the differences and advantages of SEAD compared with other dendrochronological databases, SEAD is not only aimed at dendrochronologists but also intended for an extended user circle that includes building historians, craft researchers, archaeologists, and those interested in forest history, climatology, and ecosystem changes. End-users can, therefore, search for more detailed metadata, information, and interpretation of analyzed wood samples in SEAD than in other databases, specifically regarding material from historical contexts. For example, if the end-user wants to study roof constructions made of oak in South Swedish churches, finding information about all existing study materials is possible. It will also be possible to link the studied objects with paleoecological data from other types of investigation. The possibility of contrasting dendrochronological studies with, for example, paleoentomology, pollen, or soil chemistry is one of the core strengths of the SEAD. The database is also a part of the SweDigArch infrastructure, which positions it as a central archaeological resource. Therefore, SEAD will provide the opportunity to process (aggregate) data at the interface. The results can subsequently be displayed via visualization tools and downloaded. Our intention is also to

make SEAD more user-friendly than, for example, ITRDB, making the addition of removal of search parameters easy without being forced to start the search process from scratch. Moreover, no registration similar to the Digital Collaboratory for Cultural Dendrochronology (Jansma *et al.* 2012) is required for the user. Finally, SEAD offers the most extensive presentation of dendrochronologically analyzed Swedish material.

## 3 Results

### 3.1 *Current Status of Database Entry*

Thus far, the digitizing process at LWD has focused on adding data and metadata from samples obtained from southern Sweden. The primary focus was on the two main sample subcategories of buildings and archaeology. By early 2022, written data and metadata from a total of nearly 18 500 samples, divided into 7800 buildings, 10 400 archaeological objects, 200 shipwrecks, and 60 living tree samples, have been converted into the respective Excel templates and are in the process of being transferred into the database. These data include samples from major urban archaeological excavations from Lund and Söderköping, churches from the counties of Skåne, Småland, Gotland, and Södermanland, and historical buildings in cities such as Stockholm, Malmö, and Linköping. Once completed, this ongoing process generates an estimated total of approximately 70 000 digitized samples.

### 3.2 *Database Structure and Adaptation for Dendrochronological Data*

Only minimal additions to the SEAD database structure were required for adaptation to the dendrochronological data. These included a generic pair of tables for handling qualitative classifications and metadata, as well as data (Tables 1 and 2), plus an additional link in metadata tables for sample groups, for example, samples from the same study object or site. Otherwise, mapping dendrochronological data and metadata to existing tables and fields was possible without modification, although these objects were not specifically for dendrochronological purposes, and documentation needs to be consulted to understand the mapping. As there are differences in the context and sampling of living trees, historical buildings, and archaeological material, contextual metadata needs to be managed in various ways. However, contextual differences in samples did not cause differences in storing the results. A dendrochronological site might be represented as a particular property containing several buildings, using building data as an example. Each building represents a sample

group because this type of data typically features a collection of samples collected within the same project. A sample, in turn, defines an analyzed tree core or cross-section from a trunk or beam. In the case of LWD, sample naming was based on the CATRAS system (Aniol 1983), which ensures data provenance and a link to the "grey literature." SEAD also can store several sample aliases, as samples often are given distinct names when excavated and analyzed by different labs. The tables were linked to an analysis entity ID to ensure that the results are connected to the sample information. In essence, the analysis entity in SEAD is what identifies a particular analysis result in the database.

Spatiotemporal patterns of samples can be analyzed by ingesting dendrochronological data and georeferencing them in SEAD. Further taxonomic and ecological reference data will considerably enhance the power of such studies (e.g., the use of different wood types over space and time). A core strength of research data infrastructures such as SEAD is their ability to spatially and temporally aggregate data. Analysis results, e.g., dates and tree species, and even descriptive/contextual data, e.g., building details and archaeological features, can be aggregated in specific periods or geographical areas. Depending on the research question, these aggregated results can include or exclude other proxies, e.g., plant macrofossils and fossil insects. It is possible to search the database for sites with certain tree species and combine sites with dendrochronological analyses with sites containing palaeoentomological, e.g., pests, or macrofossil evidence, e.g., seeds, by linking data to taxonomic references. The relational structure is essential for encouraging a multiproxy approach to scientific studies. Therefore, even if the initial interest is a proxy study of archaeological sites with plant macrofossils, the link to a particular tree species may identify areas with existing dendrochronological studies of relevant species, thereby broadening the research perspective.

## 4 Discussion

### 4.1 *Usage and Outcome of the Database*

Several case studies based on proxies other than tree rings have demonstrated the advantages of the SEAD (Pilotto *et al.* 2021, in press; Stilborg 2021). There are also examples of multidisciplinary studies that have been based on interregional syntheses of extensive collections of tree-ring data, such as the effects of climate change on human societal development and associated consequences, such as wars, starvation, and plagues (Pederson *et al.* 2014; Lagerås 2016; Ljungqvist *et al.* 2018). The tree-ring series may also contain records of environmental change, i.e., proxy data, preserved as changes in various elemental

and isotopic ratios in the wood, reflecting the past climate (McCarrol & Loader 2014; Edwards *et al.* 2017), pollution levels (Zuna *et al.* 2011) and aerosols emitted by volcanism (Pearson *et al.* 2020).

The digitized tree-ring data and metadata generated in this project as of September 2020 contributed to a European-wide study of building activity during the late medieval and early modern periods (Ljungqvist *et al.* 2022). The study, which explored felling dates of samples with the waney edge preserved, included roughly 54 000 felling years from across Europe and revealed building activity trends related to, for example, the late Medieval crisis and the Thirty Years' War. Moreover, a pilot study using metadata from more than 700 pine samples containing complete tree-ring sequences from the bark to the pith was conducted to generate sapwood statistics for pine trees in Sweden (Edvardsson *et al.* 2022). The sapwood statistics and statistical model developed can, for example, be used to improve estimates of the felling years of timber used in historical wooden constructions. Another pilot study using the database analyzed dendrochronological data and metadata within building history and possible methods to improve such interpretations (Edvardsson *et al.* 2021a). One more example is an ongoing research initiative in which tie beams from churches in the Diocese of Lund were studied (Melin *et al.* 2022). The soon-to-be-made public extended version of SEAD, containing more dendrochronological metadata, was used to identify the number and distribution of dendrochronologically investigated churches, the number of tie beams analyzed, distribution of tree species used for beam timber, the age distribution of beam timber, and provenance of beam timber. This information is valuable for craft researchers and historians who interpret the conduct of churches. It is possible to estimate the growth rate of wood used for tie beams, even if raw data are not currently available, using the knowledge of the age of trees at felling and the dimensions of the timber. These studies are pioneering examples of the exploration of digitized dendrochronological information to address specific research questions within various disciplines.

### 4.2 *Possible Improvements to the Database*

In the future, additional types of data and metadata, such as XRF and laser ablation results, will be uploaded, stored, and made accessible in the database. Publication of all data will follow a quality evaluation, transformation to an accessible data format, i.e., XML, further database development if needed, and systematic testing after ingestion and publication. Furthermore, wood anatomical analyses performed at LWD can be performed after the data and metadata templates are ingested into SEAD. Efforts to establish optimal keywords, a homogeneous vocabulary, descriptive texts with relevant information, and glossaries are ongoing to make the database more user-friendly. The

project reference group will be consulted continuously for advice and guidance on technical terms, search words, and filters that database users from different research disciplines are expected to demand.

### 4.3 *Usage Notes*

The SEAD system can be used by applying filters to reduce the number of sites that contain data that match the filter criteria. The filters can be stacked and differentiated from each other in descending order, which is a standard pattern on several websites, generally on e-commerce websites, providing the user with a familiar and intuitive interface to work with (Fig. 4). Each site can be studied in detail by inspecting the site report, containing a comprehensive presentation of all data associated with the site, including all measurements obtained from each sample taken at the site, with visualizations as possible and appropriate, together with general metadata describing the location and author references.

The SEAD system contains multiple data domains, one of which is dendrochronology. Other examples include paleoentomology, archaeobotany, plant macrofossils, geoarchaeology, isotope geochemistry, and ceramics. The system will adapt to each domain by selecting a domain in the domain menu or going directly to https://browser.sead.se/dendrochronology. Domain selection will, among other things, reduce the number of filters available to the ones most relevant for dendrochronological studies. The exact specification of filters to be implemented for the dendrochronology domain is yet to be established. However, the system will include filters sufficient to answer the most common research questions. For very marginal use cases, wherein the SEAD filter system may not be adequate, the user may be able to find the answer either by using the SEAD APIs or by exporting a part of the SEAD dataset for further local analysis.

Much care has been taken to provide best-effort visualizations based on a dataset with a great degree of uncertainty at varying levels, depending on the precise determination of a specific value. There must be clarity of source for a particular value, and despite visualizations being a valuable tool for understanding data, they may act as misrepresentations of reality if they are not sufficiently explicit in what they are presenting. For example, even if a sample has been dated, the felling year of the tree can be fixed or interpreted in different ways depending on whether sapwood, waney edge, or bark is present in the sample (Edvardsson et al. 2021a). Figure 3 shows the visualization of the measured and estimated annual rings in the samples. If an advanced user finds the graphical user interface inadequate for their purposes, SEAD offers several APIs. These can be queried programmatically by those with technical know-how and offer access to the raw data in a complete format.

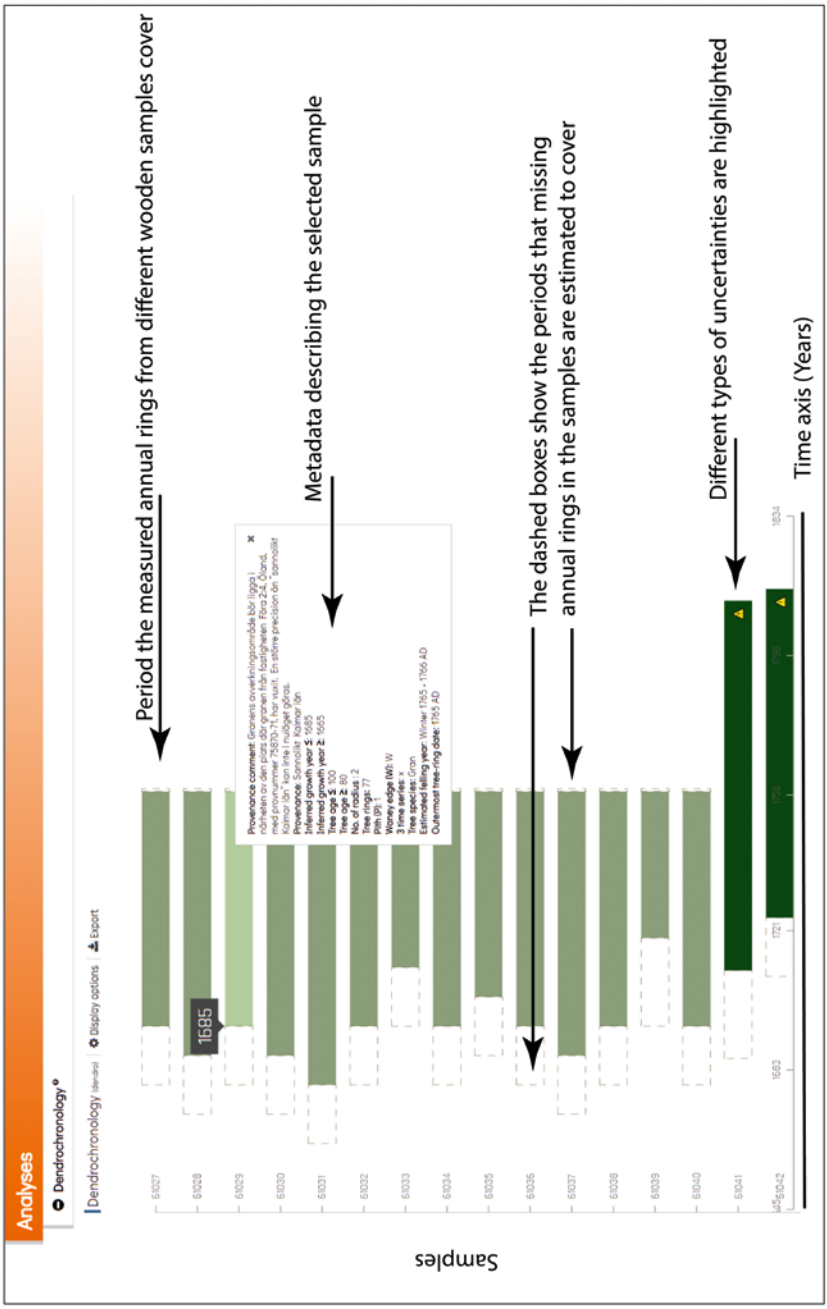


FIGURE 3 Example of visualization of a group of analyzed samples from a specific study site

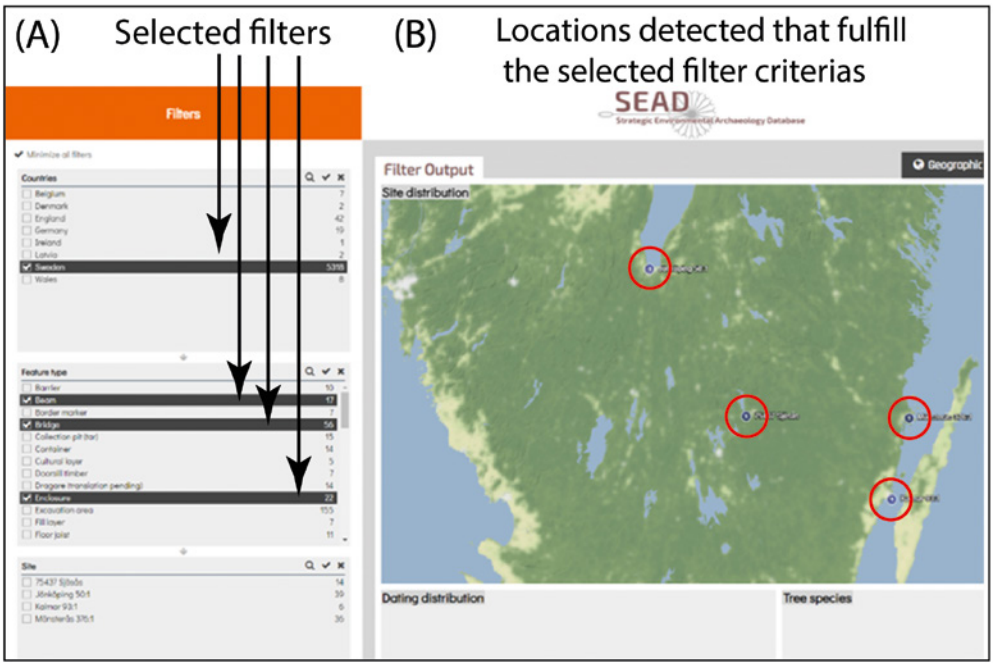


FIGURE 4 (A) The filter functionality allows, for example, selecting sites in Sweden which contain data regarding specific feature types, such as beams, bridges, enclosures, or certain tree species. (B) After the filtering, four sites containing the requested data are presented.

The API most relevant to the dendrochronological domain is the JSON site API, which can be queried in two main ways:

1. Fetching all data from individual sites with known site ID can be done via URLs, such as https://browser.sead.se/jsonapi/site/2000 for site ID 2000.
2. Attributes across all sites can be searched via a specific syntax that follows the pattern: https://browser.sead.se/jsonapi/search/site/[attribute[.subattribute]]/[value]. https://browser.sead.se/jsonapi/search/site/data_groups.physical_sample_id/36321

Please cite this publication using the SEAD-dendro-database (https://browser.sead.se/dendrochronology). Please also cite the relevant underlying data sources.

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