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Dieter Eckstein's bibliography and legacy of connection to wood biology and tree-ring science

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A B S T R A C T

Prof. Dr. Dieter Eckstein (1939 - 2021) significantly influenced the global development of dendrochronology and the underlying science of wood biology. Eckstein's research areas included dendroclimatology, xylogenesis, ecophysiology, and quantitative wood anatomy. His personal and collaborative work continues to improve our understanding of both the natural environment and human cultural development. The techniques he developed and championed resolved long-standing difficulties in the application of tree-ring science to understand both natural processes and human effects on tree and forest development. As importantly, he nurtured and promoted both the careers and the lives of many fellow scholars and students around the world. Here we present a

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systematic bibliography of more than 280 publications that illustrates the development of tree-ring research in Europe and elsewhere throughout the almost 50 years of Eckstein's career. Throughout his scientific career, Eckstein pioneered, developed, and promoted research opportunities with his students and co-workers at the University of Hamburg and beyond. His greatest legacy for his students and colleagues, and which we are challenged to continue, is to continue to build the international spirit of a "dendrofamily".

1. A life dedicated to science and collaboration

On November 10, 2021, the dendrochronology community lost a dear colleague, mentor, and friend, Prof. Dr. Dieter Eckstein. Born on 15 March 1939 in Germany, he spent his professional career as researcher and professor of the University of Hamburg where he also had graduated and received his PhD. He was also a dean of the Wood Biology Department, director of the Institute for Wood Biology and Wood Protection (Federal Research Centre for Forestry and Forest Products) (1994–2004), and director general of the Forest Research Centre in Hamburg (2000–2003). To the world research community, Eckstein was an innovator who expanded the practical application of fundamental research on wood biology. He inspired his coworkers as a model for creative motivation. To generations of students, he was the teacher who demonstrated the value of interdisciplinary research and application in a supportive way.

Eckstein's laboratory and field work directly influenced the course of research in wood biology and dendrochronology, the art and science of interpretation of the tree-ring record. Perhaps more importantly, he nurtured scientists and scientist networks that influenced the course of the worldwide research community well beyond Eckstein's direct contributions.

He held many different roles: inspiring teacher, motivating supervisor, the critical scientist and binding leader who always strived for synergy while focused on advancing the science. In these roles he had a great impact on the development of wood biology, dendrochronology and the whole of tree-ring science, and the building of a worldwide scientific community (Čufar, 2021; Sander, 2022; Sass-Klaassen et al., 2005, 2022; Ważny et al., 2022).

In simple quantitative terms, Eckstein's scientific output could be expressed in terms of over 300 research papers accompanied by 54 MSc and 15 PhD theses (Anon, 2019) although his full bibliography has apparently not been made available. We take the challenge here to compile an essentially complete list of Eckstein's published works by combing the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) Bibliography of Dendrochronology (2023), Scopus, (2023), Web of Science (2023), and the library of Thünen Institute, Hamburg, Germany (2022). We use the compiled bibliography of over 280 items (Supplement S1) to tell the life story of a dedicated scientist and amiable colleague who influenced the development of dendrochronology, wood biology, and various sub-disciplines over the last five decades.

2. Early work: biodeterioration and Viking archaeology

As a student of wood science at the University of Hamburg, Eckstein was in the company of established experts as well as up-and-coming early-career scientists particularly interested in wood biology. In 1965, he presented his graduation thesis (Eckstein, 1965) on wood pathology titled "On the mutual influence of some mould rot fungi in mixed cultures" supervised by the renowned wood biologist Prof. Dr. Walter Liese (1926–2023) (Čufar, 2023). Being an outstanding student, Eckstein wanted to continue his studies as a PhD candidate in wood biology but "preferably on less rotten wood".

Certainly some decayed wood was involved in the doctoral project proposed by Dr. Kurt Schietzel of the Museum für Archäologie Schloss Gottorf and supervised by Prof. Liese (Fig. 1). The project was exciting and involved the Viking "heath-settlement" of Hedeby (Haithabu), active in the 8th-11th centuries and located in present-day Schleswig-Holstein, Germany. Eckstein accepted the challenge to date wooden Viking relics using tree-ring analysis. The work was complicated at the outset due to the lack of a reference chronology for oak in northern Germany (Bauch et al., 1967; Eckstein, 1969). His colleagues at the University of Hamburg successfully used chronologies from southern Germany to date timber from the mediaeval ship "Bremer Kogge" (end date of 1378) (Bauch, 1969; Liese and Bauch, 1965). It turned out that larger set of northern oak chronologies would be required to date wood more local to Hedeby. Especially during the first phase of his PhD, Eckstein was greatly supported by his colleague Prof. Dr. Josef Bauch, who joined the University of Hamburg in 1964 following his doctoral research at the Ludwig Maximilian University in Munich with Prof. Dr. Bruno Huber, a true pioneer of dendrochronology and tree physiology (Eckstein, 2001).

During his work at Hedeby, Eckstein excavated wooden structures, determined wood species, and measured tree-ring width from numerous samples. He crossdated hundreds of ring-width series and developed floating chronologies, which unfortunately remained undated when he completed his PhD (Eckstein, 1969). Nevertheless, his results showed that dendrochronology was a promising method that justified establishment of a dedicated laboratory in Hamburg. The laboratory would promote dendrochronological research and inform professionals and the general public that dendrochronology was a useful technique (albeit with limitations) for archaeological investigations (Eckstein, 1970b; Eckstein et al., 1972), and for many other purposes (Eckstein, 1970a; Liese and Eckstein, 1971). Systematic work, great motivation, and networking finally resulted in the absolute dating of the majority of the Hedeby samples. These findings enabled the reconstruction of how this spectacular Viking monument developed in the past and up to the present is an important "case to put dendrochronology into the picture" for many other projects (Eckstein, 1976, 1978).

Eckstein recognized that the common growth signal used to crossdate tree-ring series and construct chronologies could also be used to indicate a common geographic source or provenance of wood. The application of such inferences can be termed "dendroprovenancing." Dendroprovenancing of archaic timber and wood products illustrated

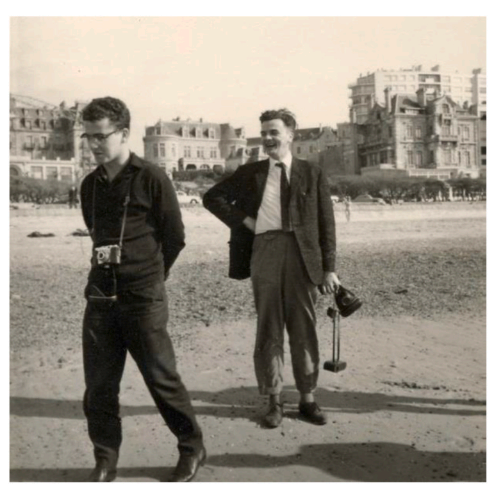

Fig. 1. Dieter Eckstein (left) with his supervisor Walter Liese in 1963 during an excursion in France.

ancient trade pathways as wood was moved across Europe and elsewhere (Eckstein et al., 1975). Combined with research from England (Baillie, 1984; Baillie et al., 1985; Fletcher, 1977) and the Netherlands, Eckstein helped to define the origin and major trade routes of oak in historical Europe (Eckstein et al., 1986). The pioneering work of Eckstein, Bauch, and Liese on objects of art and historical buildings was continued by a younger generation of scientists in Hamburg including Sigrid Wrobel and Peter Klein.

While Eckstein deepened his commitment to dendrochronology, he continued to contribute to practical aspects of wood biology and tree pathology. He described how urban stress from soil compaction, air pollution, traffic, building construction and especially de-icing salts affected the growth and wood anatomy of city trees (Eckstein et al., 1974, 1977, 1981a; Petersen and Eckstein, 1988). Drawing from the previous research partnership of Profs. Liese and Bauch with US forest pathologist and mycologist Dr. Alex Shigo, Eckstein worked on the anatomical basis of compartmentalization, the process that resists the spread of microbial infection following mechanical wounding. A strong compartmentalization response from a branch or stem wound yields a smaller volume of discolored, non-functional sapwood. Eckstein found that trees with a strong compartmentalization response had fewer and smaller vessels with fewer connections to other vessels (Eckstein et al., 1979). In theoretical terms, these findings were an example of the tradeoff between the safety provided by a strong wound response countered by decreased efficiency in xylem translocation. In practical terms, this research pointed to a potential means to select planting stock that minimized the loss of wood function following wounding.

3. Networks of chronologies and people

Once the Hamburg laboratory was successfully established, Eckstein strengthened the connections between around 25 dendrochronological laboratories that were active in Europe between 1972 and 1983 (Eckstein, 1972; Eckstein and Wrobel, 1983) as well as elsewhere around the world. From 1974–1994, Eckstein served as the elected president of the Tree-Ring Society (TRS), the international dendrochronological research community based in the USA. During the same period, Eckstein served as a member of the editorial board of the TRS journal "Tree Ring Bulletin" (now "Tree-Ring Research").

From the beginning, students were important scientific collaborators for Eckstein. Among them was Burghart Schmidt who completed his study of wood science in Hamburg with a graduation thesis on dendroclimatology (Schmidt, 1971). Although he moved to the laboratory of the Institute for Prehistory and Early History in Cologne in 1972, Schmidt continued to work on dendroclimatology of oak (Eckstein and Schmidt, 1974) and as Eckstein's first PhD student completed his dissertation in Hamburg (Schmidt, 1977). In Cologne, Schmidt developed a long oak chronology dating back to 2061 BC (Schmidt and Schwabedissen, 1982). In collaboration with Mike Baillie (Queen's University, Belfast, Northern Ireland), and Bernd Becker (University of Hohenheim, Germany), later an even longer oak chronology was developed for western Europe which dated back to 7237 BC (Becker and Schmidt, 1990).

When Eckstein's long-time collaborator Sigrid Wrobel joined the Hamburg laboratory, dendrochronology in northern Germany continued to flourish (Eckstein and Wrobel, 1982) as the old town of Lübeck provided opportunities for many investigations (Eckstein and Wrobel, 1986, 1991; Wrobel and Eckstein, 1984, 1986, 1993). The exciting success of dendrochronology to precisely date wood from northern Germany and the Netherlands infected Thomas Bartholin (Laboratory of Wood Anatomy, National Museum, Copenhagen, Denmark) with the "dendro-virus" (Fig. 2). Together with Eckstein, Bartholin discovered the similarity of the oak growth signal in chronologies from northern Germany to those of Denmark. The progress in Denmark then provoked interest in dendrochronology in Sweden and Bartholin took the opportunity to join the Institute for Quaternary Research in Lund to construct an oak chronology for southern Sweden. The northern German chronologies were of great help to date Swedish material, which led to the development of a set of new chronologies (Bartholin, 1975; Eckstein, 1978; Eckstein and Bauch, 1977; Gräslund, 1984). The wood collected and later dated with these chronologies contributed to the first dendroclimatic reconstruction of temperature in Fennoscandia (Briffa et al., 1990, 1992). In 1990 Thomas Bartholin together with Danish and Swedish colleagues organized an important international meeting "Tree Rings and Environment" in Lund, dedicated to Harold C. Fritts. The meeting proceedings published as the LUNDQUA Report is a valuable overview of European dendrochronology at the beginning of 1990 s (Bartholin et al., 1992).

Fig. 2. From left to right, Dieter Eckstein and Thomas Bartholin pioneered development of dendrochronology in northern Germany, the Netherlands, Denmark and Sweden; Risto Jalkanen researched dendrochronology in Finland; and Sigrid Wrobel advanced the work with historical objects in northern Germany.

4. Dendrochronology and authenticity in art and craft

Inspired by Bauch, Eckstein applied dendrochronology for dating of oak panels used by European painters in the medieval and renaissance periods (Bauch and Eckstein, 1970) (Fig. 3). Based on the pattern of tree rings in the panel, a *terminus post quem* or the "limit after which" date may be assigned, meaning that the tree had to have been felled after that date (Bauch et al., 1972, 1974; Eckstein and Bauch, 1974). This sometimes led to unpleasant surprises in artist authentication as for the case of oak panel paintings attributed to Rembrandt (1606–1669). A *terminus post quem* for more than 100 felling dates was determined from the panels, including some from trees felled after the death of Rembrandt, indicating that an artist other than Rembrandt was responsible for the work. The use of dendrochronology to authenticate artists and to detect forgery is accepted today as an established science for museums and galleries and has spurred the construction of oak chronologies for the

Fig. 3. Dieter Eckstein first measured tree-ring widths with a hand lens as for this panel.

Netherlands (Eckstein et al., 1975).

Musical instruments made of wood also held promise for dendrochronological dating. In 1980, Elio Corona in Viterbo, Italy, dated two violins made by Giovanni Battista Gabbrielli (1716–1771). As the top plates of stringed instruments are usually made of Norway spruce (*Picea abies*) and the first famous violins were made in Italy during the 1600 s and 1700 s, reference chronologies needed to be developed for spruce and other important wood species (Siebenlist Kerner, 1984).

As with historical paintings, the monetary value of stringed musical instruments greatly depends on the identification of the geographic source of materials, on the historical period of construction, and ideally the workshop or individual artisan responsible. In the 1980 s many string instruments were investigated in the tree-ring laboratory in Hamburg (Klein, 1985; Klein et al., 1986). As with panel paintings, the authenticity of string instruments is often controversial, which stimulated dendrochronological dating of hundreds of instruments to prove their authenticity (Beuting, 2004, 2022; Klein, 2022). Micha Beuting (2004) demonstrated that dendroprovenance techniques can determine the source of woods used in instrument construction in his thesis supervised by Eckstein and supported by Peter Klein (Fig. 4). This helped to develop dendrochronology as a key method for instrument authentication (Cherubini, 2021; Cherubini et al., 2022). Development of networks of reference chronologies to serve scholarship and the conservation of art is constantly improving.

5. Dendrochronology 1.0

When Eckstein began his career, the acquisition and analysis of dendrochronological data was decidedly analog and manual. Eckstein readily realized how statistical comparisons would be greatly facilitated by digital computing techniques. As early as 1969, he developed software to calculate the *Gleichläufigkeit* (coefficient of concordance), often referred to as the "Eckstein value", to evaluate the statistical similarity between chronologies (Eckstein and Bauch, 1969). Eckstein also inspired Roland Aniol to develop a user-friendly work station that included a measuring table, stereomicroscope, and personal computer loaded with the Computer Aided Tree Ring Analysis System (CATRAS) software package (Aniol, 1983, 1987). With this system, the dendrochronologist could measure tree-ring width, visually and statistically cross-date ring series, and produce presentation graphics. In the 1980 s, Richard Holmes, author of the COFECHA program (Holmes, 1983), worked to improve COFECHA and other tools during his year-long stay in Eckstein's laboratory in Hamburg (Eckstein et al., 1991; Richter et al., 1991).

In 1983, Eckstein organized a symposium on dendrochronology in Hamburg, and invited Peter Ian Kuniholm from the USA to contribute. Leone Fasani and Alessandra Aspes from Verona, Italy, who attended the meeting as well, were so impressed with the potential of dendrochronology that they founded the "Istituto Italiano di Dendrocronologia" and the journal "Dendrochronologia" (Sass-Klaassen et al., 2022). "Dendrochronologia" Volume 1 was published in 1983 under Editor-in-chief Elio Corona, Editor-in-charge Leone Fasani, and Secretary Alessandra Aspes. The very first article was dedicated to dendrochronology in Europe (Eckstein and Wrobel, 1983) and reported, among other things, on the establishment of the multimillennial South German oak chronology based on the work of Huber, Becker, Delorme, Hollstein, Schmidt, and Schwabedissen (Eckstein and Wrobel, 1983). This chronology enabled dendrochronological dating in Germany, and a large area between then Czechoslovakia, Switzerland, and northern Italy. In 1983 Eckstein was appointed Corresponding Member of the "*Istituto Italiano di Dendrocronologia*" and since the release of Volume 2 of Dendrochronologia in 1984 served as a very active member of the editorial board for nearly 20 years. The journal provided opportunities for early-career scientists to publish their results. Dendrochronologia started as a European journal, but quickly opened up to contributions from around the world (Eckstein and Schweingruber, 2009). Since 2003, Dendrochronologia has been published by Elsevier and continues to be a high-quality journal for all topics within tree-ring science.

6. Dendrochronology spreads east and south

Climatic teleconnections between regions affect the common growth signal and development of tree-ring chronologies. To understand these relationships, dendrochronologists had to network and collaborate with each other (Eckstein et al., 1984a; Lambert et al., 1979). Given the historical trade connections evident from dendroprovenancing, cooperation with scientists in Eastern Europe and beyond was essential to understand ancient trade patterns (Fig. 5).

To support the development of dendrochronology in Eastern Europe, Eckstein and his team assisted and trained numerous, primarily early-career dendrochronologists first from Poland and then from the Baltic countries of Estonia, Lithuania and Latvia.

Poland was expected to be a country that could solve the nagging problem of floating art-historical chronologies. Numerous panels painted by prominent Flemish and Dutch artists did not correspond to the few available oak chronologies for the Netherlands constructed in 1970 s. The tree-ring patterns were clearly divided into two main groups but there did not exist any correlation between them (Eckstein et al., 1975). One of these groups was represented clearly by local Dutch timbers while the other, approximately within the time range AD 1100–1650, was used to construct the "NL" floating chronology. During the 1970 s and 1980 s an intensive search was conducted to find the

Fig. 4. Dieter Ekstein, PhD supervisor, Micha Beuting, and adviser Peter Klein at the party after Beuting's successful PhD defense in October 2003.

Fig. 5. Dieter Eckstein with fellow dendrochronologists in 1984 in Athens, Greece. From left to right: (front row) Francoise Serre-Bachet, Helene Neuss-Aniol, Nili Lipschitz, Dieter Eckstein, Sigrid Wrobel and (second row) Roland Aniol, unidentified researcher, Fritz Schweingruber, Peter Ian Kuniholm, Mike Baillie, Klaus Richter.

forest region that could have been a source of high-quality oak timber in late medieval and early modern times. Eckstein suggested Poland and the Baltic area as the most probable areas of origin.

The first results of the cooperation with Tomasz Ważny from Poland led to many, often spectacular, new results and insights. As an intern at the Hamburg Institute in 1980, Ważny was required to serve each laboratory in rotation. However, he stayed in Eckstein's dendrochronology lab for months and the full duration of the internship. In 1981, Ważny returned to Poland with a strong motivation and vision to introduce dendrochronology as a means to date historic objects in his home country.

In 1984, Eckstein traveled to Poland under the German Academic Exchange Service program to lecture in Warsaw, Gdańsk, and Cracow. Eckstein's mission was two-fold: to introduce and inspire others with the art and science of dendrochronology and to assess the potential of Poland to contribute the missing pieces of the long European oak chronology. Eckstein returned to Poland the following year with sampling equipment and together with Ważny, collected samples from over 20 previously selected churches and cathedrals at archaeological excavations in the Hanseatic city Elbląg/Elbing and the early medieval Slavic-Viking settlement of Wolin. The Gdansk-Pomerania oak chronology covering 1000 years was built based on these collections that resolved the long-standing problem of floating art-historical chronologies from the time of Rembrandt and Rubens. Additionally, dendroprovenance analysis supported the reconstruction of past timber trade in finer detail than previously had been possible (Eckstein et al., 1986; Ważny and Eckstein, 1987a; b; Ważny, Eckstein, 1991). Eckstein continued to support Ważny and other Polish colleagues, until the closure of Eckstein's dendrochronological laboratory in Hamburg (Fig. 6).

In 1987, Eckstein met Estonian dendrochronologist Alar Läänelaid at Lake Baikal while both participated in the first international conference on dendrochronology in the Soviet Union. Eckstein invited Läänelaid to visit Hamburg and his dendrochronology laboratory in 1989. Läänelaid became a regular guest at the Hamburg laboratory to study Estonian wood. He defended his PhD at the University of Helsinki (with Eckstein as examiner) on tree-ring dating in Estonia (Läänelaid, 2002). The collaboration with Eckstein, and his support of the Estonian laboratory, continued with Kristina Sohar in 2010.

Eckstein's mission to connect dendrochronologists across western and eastern Europe occurred in difficult political times. In 1990, shortly before the collapse of the Soviet Union, Eckstein proposed an international dendrochronological meeting to be held in Estonia, which took place in late August 1991 in already independent Estonia. Dendrochronology has a long history of practice in the Baltic countries. Eckstein chose to support early-career dendrochronologists who began their research careers in 1990 and later. Rūtilė Pukienė and Adomas Vitas (Lithuania), and Māris Zunde, Guntis Brumelis, Didzis Elferts, Iluta Dauškane (Latvia), have conducted diverse research on a wide range of dendrochronological topics (Vitas et al., 2012).

Despite the uncertain situation, Eckstein continued working visits to Estonia and to support the strong research network driven by friendship and common interest in science. Three dendroprovenancing workshops in the Baltics, Moletai, Lithuania (2005), Sigulda, Latvia (2007), Saaremaa Island, Estonia (2009) (Fig. 7), provided the basis for regular regional and international meetings including the EuroDendro 2017 conference in Tartu, Estonia (Sohar et al., 2017).

Eckstein and Läänelaid coauthored a series of articles on Estonian dendrochronology including a pine chronology (Läänelaid, Eckstein, 2003), the effect of underground mining on pine growth (Läänelaid, Eckstein, 2006; Läänelaid, Eckstein, 2010; Läänelaid et al., 2009), comparative analyses of pine chronologies around the Baltic Sea (Läänelaid et al., 2010), and dendroclimatology of Norway spruce (Läänelaid and Eckstein, 2012; Läänelaid et al., 2015). With the research of Kristina Sohar, the focus shifted to oak dendroclimatology (Sohar et al., 2011, 2012a; b; Sohar et al., 2014).

Eckstein also collaborated with colleagues in the Czech Republic on forest dieback studies. Together with his PhD student Constantin Sander, they participated in studying tree-rings and wood properties of affected Norway spruce in the Krkonoše Mountains (Dobry et al., 1992; Sander et al., 1995). The development of dendrochronology here was also influenced by recognition that the oak tree-ring pattern was related to that of the south German oak chronology, which was confirmed by systematic studies almost two decades later (Dobrovolný et al., 2016; Kolář et al., 2012).

Eckstein also inspired and supported Rupert Wimmer to establish dendrochronology at the University of Natural Resources and Life Sciences (BOKU) in Vienna, Austria. In collaboration with Michael Grabner, they produced the first long oak chronology for Austria (Wimmer and Grabner, 1998). The Austrian multi-centennial regional oak chronology and Eckstein's personal support stimulated the development of oak dendrochronology in Hungary with Andras Grynaeus (Grynaeus, 1996).

In contrast, oak grown south of the Alps in Slovenia seemed to have a unique dendrochronological growth signal with no apparent teleconnection with central and western European oak. Eckstein also supported the establishment of dendrochronology at the University of Ljubljana in Slovenia, first with support of studies related to silver fir (*Abies alba*) dieback (Čufar, 2021; Torelli et al., 1986) and studies of old-growth silver fir (Levanič and Čufar, 1997; Schichler et al., 1997). The dating of many built structures in Slovenia was facilitated by the discovered teleconnection of silver fir with growth elsewhere in Europe. With much support from Eckstein, a 548-year regional oak chronology that clarified teleconnection of Slovenian oaks with those of neighboring countries was constructed that could be used successfully to date

Fig. 6. December 21, 2018. The last "pre-Christmas" meeting of Dieter Eckstein, Tomasz Ważny and Sigrid Wrobel (left to right) in Eckstein's laboratory in Hamburg. A few days after this meeting Wrobel retired and the laboratory was closed.

Fig. 7. Dendroprovenancing meeting in Saaremaa, Estonia, 2009 with Eckstein. From left to right: (front row) Thomas Bartholin, Kristina Sohar, Dieter Eckstein, Rūtilė Pukienė, Marta Domínguez-Delmás, Pascale Fraiture, Sigrid Wrobel, and (second row) Alar Läänelaid, Tomasz Ważny, Māris Zunde, Maxim Yermokhin, Martin Bridge, Niels Bonde, Severin Sagaydak, Adomas Vitas.

historical artifacts and to reconstruct climate (Čufar et al., 2008a, 2008b, 2010).

Analysis of prehistoric oak chronologies connected patterns of growth in Slovenia to the combined Swiss-Southern German chronology (Čufar et al., 2015). This helped to absolutely date prehistoric pile dwellings (3771–3330 BC) in the Slovene moorland.

This development affected dendrochronology south of the Alps and enabled numerous applications, including the studies of wood formation, with strong participation by Eckstein (Schmitt et al., 2016a; b). Wood formation proved to be critical to understanding how and when trees incorporate environmental signals into their wood structure.

In Italy, oak chronology development was hampered due to inadequate sample density to represent the time period and geographic area. Eckstein supported Olivia Pignatelli to establish the Dendrodata laboratory in Verona, which offers regional dendrochronological support for nearly four decades.

As a PhD student of Eckstein's, Klaus Richter constructed a long chronology composed of living and historic pine trees from southeast Spain and presented it as a proxy of summer rainfall. The chronology was based on samples of *Pinus sylvestris, P. nigra, P. pinaster, P. mugo,* and *P. uncinata* collected from 31 mature or old-growth pine stands. This research supported the delineation of dendrochronologically similar areas within nine mountainous regions of Spain (Richter and Eckstein, 1990; Richter et al., 1991).

7. Forest decline provided the opportunity to further develop dendroecology

Hamburg researchers including Eckstein were among the first to study forest dieback, which became a major research focus of a broad international and interdisciplinary community in the 1970 s and 1980 s

In the 1970 s, a decline in silver fir (*Abies alba* Mill.) stands was observed in Germany, the so-called *Tannensterben* or silver fir dieback. Some of the decline outbreaks were near point sources of air pollution, and were evidently caused by those local emissions. Later, a more widespread decline of other tree species (*Waldsterben* or forest dieback) was observed in European forests. Research on forest decline provided the opportunity for a number of labs to determine the relationship of ring width to visible symptoms of dieback and decline in living trees. Various methods included tests of the relationship of ring width to categories of crown transparency. While many of these studies did associate decreased growth with higher crown transparency, others showed no such relation, or no relationship at low to moderate levels of transparency (Cherubini et al., 2021). Interest in tree species affected by forest decline stimulated dendrochronological and wood anatomical studies by Eckstein and collaborators on Norway spruce (Eckstein, 1988; Eckstein et al., 1981b; Greve et al., 1983, 1985, 1986), silver fir (Eckstein et al., 1983), Scots pine and Douglas-fir (Lorenz and Eckstein, 1988), and European beech (Eckstein et al., 1984b). Influenced by multiple factors, the decline was likely incited by drought and aggravated by airborne pollutants directly as well as indirectly through acid rain and altered soil chemistry.

Although the relationship of ring width to contemporaneous decline symptoms was weak or unclear, Eckstein recognized that dendrochronology had the potential to predict or assess forest damage, even before development of crown symptoms. He was invited by the International Union of Forestry Research Organizations (IUFRO) to present possibilities of using dendrochronology to assess forest damage (Eckstein, 1985). The long-term perspective provided by tree growth and climate relationships advanced understanding of the mechanism of tree disease and recovery from disturbance (Eckstein, 1989; Eckstein and Krause, 1989; Eckstein et al., 1989; Eckstein and Sass, 1989; Krause, 1992).

One feature of the regional decline of European conifer forests appeared to involve premature shedding of needles. In the early 1990 s, Finnish forest pathologist Risto Jalkanen developed the needle trace method to determine the duration of needle retention (Aalto and Jalkanen, 1996). Each tree leaf or needle is anatomically connected to the tree vascular system. The connection leaves a remnant of vascular tissue that can be visually identified and used to assign the calendar year of needle formation. After Jalkanen's visit to Eckstein's laboratory in 1992, the Hamburg team successfully adopted this method to study dynamics of needle mass in Norway spruce (Sander and Eckstein, 1994). The method was applied to spruce from the Giant Mountains of the Czech Republic, and showed that the number of needle primordia and shoot length were correlated with each other but not correlated to radial growth (Sander, 1997; Sander et al., 1995). Shoot length, needle production, and needle shedding were primarily influenced by the weather of the previous year. Needle retention showed a clear age trend, with older trees having a shorter period of needle retention (Sander and Eckstein, 1997).

8. Histometry and development of quantitative wood anatomy

Dendrochronology was initially developed from the analysis of annual series of tree-ring widths. Research on conifers identified tree-ring density and tracheid dimensions as additional features that contained a common growth signal and that corresponded to environmental conditions preceding and during the period of wood formation (Liese et al., 1975; Schweingruber et al., 1978). Analysis of these latter features introduced the concept of quantitative wood anatomy at the cellular and tissue level of organization. However, the prevailing methods of sample collection and examination were inadequate to fully apply cellular characteristics to dendrochronological sequences. To meet this technical challenge, Eckstein and colleagues in the 1970 s-1980 s began to develop histometric methods to quantify wood anatomy (Eckstein and Frisse, 1979; Eckstein et al., 1977, 1981b; Frisse, 1977; Greve et al., 1983, 1985). Histological techniques to prepare thin-sections over a wide cross-sectional area were developed (Sass and Eckstein, 1994). The histology research coincided with the development of automated image analysis techniques for quantitative analysis on a large scale (Sander et al., 1996). This combination of histology and image analysis made possible the development of long chronologies of vessel size in beech earlywood (Sass and Eckstein, 1995). These finding also supported the use of earlywood vessel chronologies of oak to reconstruct past climate beyond the instrumental weather records (García González and Eckstein, 2003).

Research on the interrelationships of processes of tree growth, wood anatomy, and climate deepened (Fonti and García González, 2004, 2008; Fonti et al., 2007; García González and Fonti, 2006) as modern quantitative wood anatomy (QWA) continued to develop (Fonti et al., 2010).

9. Tree rings as an archive for retrospective analyses of environmental and climatic conditions - keeping an overview

Through his work, Eckstein became a world-leading scientist in the complex field of tree rings as a qualitative and quantitative archive for retrospective analyses of environmental (Eckstein, 2004; Eckstein et al., 1976; Petersen et al., 1982; Schmitt et al., 2000) and climatic conditions (Eckstein et al., 1974; Greve et al., 1986; Haeseler et al., 2007). Eckstein had the ability to keep an overview of interesting developments in tree-ring sciences and connect new insights in a way that leads to new knowledge of tree function. Quantitative wood anatomy, for example allowed both precise reconstruction of past climate conditions as well as to predict the ecophysiological impact of adverse conditions, such as drought for wood formation and tree performance (Eilmann et al., 2011).

In the 1990s, emphasis of forestry and tree biology research shifted from assessment of regional growth declines to predictions of the anticipated effects of climate change. Eckstein and colleagues contributed to two large EU projects (FOREST and PINE) through pilot studies of dendroclimatic relationships, in part through the pinning technique of sensitive and vulnerable *Pinus sylvestris* and other trees in northern Finland (Schmitt et al., 2004) and other tree species from different environments (Gričar et al., 2007; Larson, 1994; Nobuchi et al., 1995; Seo et al., 2007; Wolter, 1968). The pinning of pine trees in northern Finland determined that wood formation began around the middle of June at the Arctic Circle and distinctly later at sites closer to the Arctic tree line, with the greatest rate of wood formation in July (Schmitt et al., 2004; Seo et al., 2011, 2013). Extreme weather such as temporary drought stress during the weeks before onset of wood formation could be correlated with reduced wood formation (Seo et al., 2011). For the boreal zone in Finland, Eckstein and colleagues demonstrated through the heat-sum approach that while temperature contributed to the timing of the onset of cambial division, cessation of cambial activity was distinctly less correlated with the temperature (Seo et al., 2008). Eckstein favored research strategies based on the evaluation of previously described multiproxy data pools (McCarroll et al., 2003). There was clear evidence that bioindicators of climate change would involve wood formation as well as phenological indicators, such as bud break and intra-annual height growth, as well as intra-annual variables of cellular anatomy (Seo et al., 2010, 2012a, 2012b). The first author of these papers, Jeong-Wook Seo, returned to Korea a few years after receiving his PhD in Hamburg and remembers Eckstein not only as a great PhD advisor (Fig. 8) but also as a role model in his scientific endeavors and in his life as a human being (for details, see Sass-Klaassen et al., 2022). Seo was the first author of the last publication in which Eckstein was actively involved (Seo et al., 2020).

Analyses on cambial dynamics played a crucial role in Eckstein's scientific career in Europe and in Asia (Bhattacharyya et al., 2007; Liang et al., 2009b; Oladi et al., 2011).

A challenge that arose from these anatomical and developmental studies of boreal and temperate zone trees is how best to visualize the reactivation of cambial cells after winter dormancy and prior to the first cell divisions of the growing season. Eckstein and his team also studied the fine structure of cambial cells by means of transmission electron microscopy. For ring-porous ash, cambial reactivation had clearly started some weeks before the first new derivatives were formed. The reactivated cambial cells differed from cells in winter dormancy by a number of ultrastructural features (Frankenstein et al., 2005a). Consequently, the term "cambial activity" should not be restricted to xylem and phloem cell production, as cellular activity of the cambium begins much earlier. The period of cellular activity also extends beyond the production of new xylem and phloem, as cambial cells continue to be modified after cell production ceases and prior to the onset of dormancy.

Fig. 8. Dieter Eckstein was always attentive and helpful to his students. Here in 2004, Eckstein worked with his PhD student Jeong-Wook Seo during a project meeting near Rovaniemi.

Eckstein and collaborators also studied the form and function of rays in the wood, which have important physiological and accessory functions in trees but are under-represented in ecophysiological studies. Rays contain parenchyma cells involved in active radial transport processes, starch storage, defense mechanisms, and heartwood formation. In addition, rays contribute significantly to the radial stiffness and strength of wood.

Wood tensile strength conferred by axial fibers and conducting elements is greatest for forces applied parallel to the stem axis ("with the grain"). Detailed studies of the mechanical function of rays in the living tree by Eckstein's team, with significant participation of the PhD student Ingo Burgert, showed that rays of deciduous trees strongly contribute to the strength of green wood (Burgert et al., 2001) and exhibit much higher tensile strength in the radial direction than axial tissues (Burgert et al., 1999, 2001; Burgert and Eckstein, 2001; Eckstein et al., 1998). In the living tree, this reinforcing effect of wood rays is particularly important in curved stems and branches, which are subjected to radial stress during bending.

Years later, Eckstein wrote a valuable commentary on the study (Olano et al., 2013) of the relationship between the annual amount of ray parenchyma (more specifically, the percentage of cross-sectional ring area occupied by ray parenchyma) and climate in Spanish juniper (*Juniperus thurifera*) (Eckstein, 2013). Eckstein noted that the study deserves recognition and should be applied to other species with more complicated ray structure.

Since the 1970 s, Eckstein and his team studied cellular aspects of callus formed in response to wounding of differentiating cells as well as the vascular cambium (Eckstein et al., 1979). Both light and electron microscopy revealed that during the growing season, cambial cells close to the wound and some of the youngest still differentiating phloem cells start forming parenchyma which later undergoes oriented cell divisions to produce young callus tissue at the wound edge. Within the young callus a wound cambium then develops, the derivatives of which form wound xylem, wound phloem, and a new periderm (Frankenstein et al., 2005b; Schmitt et al., 2016b). Another phenomenon studied was a surface callus occasionally formed when large areas of bark were mechanically removed (Stobbe et al., 2002b). Such research conducted in cooperation with arborists Dirk Dujesiefken and Horst Stobbe was regularly presented to the professional arborist community and is well-accepted in tree care (Dujesiefken et al., 1998, 1999; Stobbe et al., 2002a, 2003, 2015).

10. Dendrochronology in the tropics

Dendrochronology was initially developed from wood obtained from trees grown in the temperate climatic zone with well-defined growing and dormant seasons and annual ring boundaries that are more-or-less readily identified with proper sample preparation. Ring boundaries are not usually seen in the wood of tropical trees for which wood production was considered to be continuous through the year. Eckstein and some other pioneer researchers recognized that tropical trees likely respond to seasonal variation in tropical climate.

To compile new findings, evaluate conclusions, and stimulate research on tropical dendrochronology, Harvard and Yale Universities sponsored the 1981workshop on "Growth Rate Determination of Tropical Trees" (Mariaux, 1995). Eckstein and co-authors presented a study of possible applications of dendrochronological methods to tropical tree species (Eckstein et al., 1981c).

However, Eckstein did not have the opportunity to systematically study tree-ring formation in tropical tree species until Nathsuda Pumijumnong from Thailand received a scholarship from the German academic exchange service (DAAD) in 1991 and began her doctoral studies in Germany under his supervision (Fig. 9). Pumijumnong was very motivated to gain experience in dendrochronology and to understand climate-growth relationships in teak (*Tectona grandis* L.) from northern Thailand (Pumijumnong, 1995). With the assistance of Eckstein and Thai collaborators, the team collected teak samples from several provinces in Thailand.

Samples from more than 200 teak trees were collected and brought to the Hamburg dendrochronology laboratory for laborious measurement and painstaking visual and statistical cross-dating. At that time, ring-width series were still printed on transparent paper and compared on a light table, as Eckstein believed that this was the best method to detect convincing matches between time series, followed by statistical verification. Pumijumnong's work resulted in a network of tree-ring chronologies for northern Thailand. In her dissertation she showed that teak growth in northern Thailand was dependent on precipitation during the rainy season, from April to June (Pumijumnong et al., 1995a; b). The results were presented at an international meeting in Kuala Lumpur, Malaysia (1994) and also published in a special issue of the IAWA Journal devoted to the dendrochronology of tropical trees (Eckstein et al., 1995; Mariaux, 1995). The same special issue included another study by the Hamburg group on wood formation in two Dipterocarpaceae from Malaysia, Kapur (*Dryobalanops sumatrensis*) and Tembaga (*Shorea leprosula*) (Sass et al., 1995).

The influence of climate on teak growth in Thailand was later confirmed by a wood-anatomical study which showed that initial divisions in the cambium of teak started at the end of April and were stimulated by April rainfall as was also shown for Myanmar teak (Pumijumnong et al., 2001). In this way, southeast Asian teak proved to be optimal to study tropical monsoon variation and climate history. This was presented at the workshops (Pumijumnong et al., 1998) and in a special issue of the IAWA Journal on Dendrochronology in the Asian Monsoon (Eckstein and Baas, 1999). A few years later, Bhattacharyya developed earlywood-vessel chronologies to further specify climate-growth relationships for teak from southern India (Bhattacharyya et al., 2007).

In 2011, dendrochronological work in Thailand was extended to tropical pines, *Pinus merkursii*, *P. latteri*, and *P. kesiya* from more than 16 study areas and a reconstruction of temperature from March to May for the period 1834–2011 (Pumijumnong and Eckstein, 2011). The development of tree-ring research in Thailand and Southeast Asia has also encouraged the study of teak from archaeological sites (Buajan et al., 2020; Pumijumnong, 2015) and cambium studies of other tropical tree species with less distinct growth rings.

11. Dendrochronology in Japan

Eckstein also built up close relations with colleagues from Japan, especially Takumi Mitsutani, Terutaka Katoh, Yasuharu Hoshino, Motonari Oyama, Hitoshi Yonenobu and many others. Many of them visited his laboratory in Hamburg (Fig. 10). Dendrochronology has a long tradition in Japan, dating back to the early 20th century, as shown in the report on dendrochronology in Japan published by Mitsutani's institute (Nara National Research Institute for Cultural Properties, 1990). The first attempts to introduce modern dendrochronology began in 1979 and continued in 1985 with the first research project with archaeologist Migaku Tanaka and archaeobotanist Mitsutani of the Nara National Cultural Properties Research Institute and Tadanobu Sato of the Disaster Prevention Research Institute of Kyoto University (Nara National Research Institute for Cultural Properties, 1990). As part of this project, they studied several of Japan's major tree species and developed tree-ring chronologies. This enabled the dating of several early historical buildings and numerous artefacts. With the help of tree-ring research it became even possible to date the eruption of Mount Fuji based on a buried standing Hinoki cypress (*Chamaecyparis obtusa*) with the outer ring dated to 833 AD.

Eckstein collaborated to build a well-replicated tree-ring chronology of Hinoki cypress with early-career scientist Yonenobu. The resulting chronology was used to reconstruct spring temperatures during the Little Ice Age in central Japan (Yonenobu and Eckstein, 2006). These and other dendroclimatic studies enabled the large-scale climate reconstruction for northeast Asia by the late Won-Kyu Park of South Korea (Ohyama et al., 2013). Eckstein also contributed to the development of guidelines on producing tree-ring dates for Japanese tree species using Monte Carlo simulations (Yonenobu et al., 2010). Mitsutani's dated wood samples were valuable as evidence to detect the cosmic Miyake event (Miyake et al., 2012). These past efforts still contribute to extend the chronology network to reconstruct climate and to date cultural objects (Ura and Hoshino, 2019).

Fig. 9. Dieter Eckstein extracts samples of teak with local foresters in northern Thailand (1992).

12. Dendroecology and innovation in northern and western China

Eryuan Liang (research professor at the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, and adjunct professor in Lanzhou University) (Fig. 11) received a 2004 Humboldt Research Fellowship to work with Eckstein after completing his PhD at the Institute of Botany, Chinese Academy of Sciences. Thereafter, Liang regularly visited Eckstein who coordinated his academic visits with connections to other scientists. In this way a fruitful cooperation started which resulted in at least 17 joint publications of Liang and Eckstein (Scopus, 2023), which through the involvement of other scientists, introduced dendroecological research into northern and western China. In this way, the scope of classical tree-ring research was widened to include the dendrochronological records from woody shrubs that grow beyond the treeline.

Eckstein and Liang investigated wood formation in Chinese pine (*Pinus tabulaeformis*), an endemic and widespread conifer species in northern China, where cell division started in third week of May and ended around mid-August, while cell-wall formation was not yet completed by mid-September (Liang et al., 2009b). This enabled monitoring of wood formation in other regions where growth variation was largely related to May-July precipitation/PDSI. It was shown that warming-induced moisture stress due to higher evapotranspiration contributes to variation in tree radial growth (Liang et al., 2007, 2008). Chinese pine also contained locally absent and light rings in wood associated with severe drought which could be used to indicate past drought events in climate reconstructions (Liang and Eckstein, 2006; Liang et al., 2006b; Liang et al., 2016a,b).

Similarly, growth of birch (*Betula utilis*) was related to the effect of pre-monsoon precipitation in the central Himalayas (Liang et al., 2014; Li et al., 2021). In semi-arid grassland, both tree growth and above-ground biomass productivity (as indicated by NDVI) are strongly influenced by precipitation for May-July and tree-ring width can be used as a proxy of past growth dynamics in grasslands (Liang et al., 2009a).

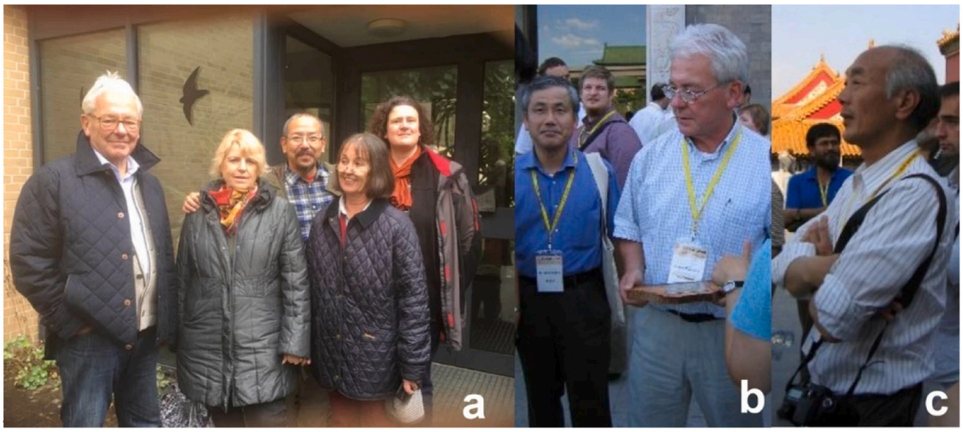

Fig. 10. Cooperation with Japanese colleagues: (a) Hitoshi Yonenobu visiting the Hamburg team in 2016, (b) Terutaka Katoh and Dieter Eckstein and (c) Takumi Mitsutani at the WorldDendro conference in Beijing in 2006.

Fig. 11. Dieter Eckstein with Eryuan Liang (left) and Constantin Sander (right) at the WorldDendro conference in Beijing in 2006.

The Tibetan Plateau is characterized as a region of rapid warming. Growth of Qilian juniper (*Juniperus przewalskii*) and Qinghai spruce (*Picea crassifolia*) proved to be mainly driven by topography-dependent microclimates (Liang et al., 2006a). Tree growth was sensitive to drought stress on west-facing slopes with a dry microclimate and sensitive to summer temperature on the east-facing slopes. These findings were also supported by diverse bioclimatic signals observed in a network of 16 tree-ring chronologies along a 520-km precipitation gradient in the Qilian Mountains (Liang et al., 2010). Thus, spatial variability in tree growth was shown to be an important component of climatic responses.

The Tibetan Plateau hosts the world's highest treeline in elevation above sea level. According to some expectations, the elevation of treeline would have increased during the last decades of regional climatic warming. To test that expectation, Liang and Eckstein investigated Smith fir (*Abies georgei* var. *smithii*) which forms a natural alpine treeline at 4250–4400 m. They found increased tree recruitment after the 1950 s which was positively correlated to both summer and winter temperatures. However, treeline positions did not show a significant upward movement, despite warming (Liang et al., 2011). Furthermore, tree-shrub competition above treeline slowed the warming-induced treeline shifts (Liang et al., 2016b) and cambial reactivation under warmer spring conditions proved to be advanced in Smith fir trees but delayed in rhododendron shrubs. Such a phenological mismatch gives trees a competitive advantage over shrubs (Li et al., 2023). Treeline tended to move upslope due to warming while the shift rates were driven by precipitation, on both regional (Sigdel et al., 2018, 2020) and hemispheric (Lu et al., 2021a) scales.

Details of needle phenology (e.g., bud burst, shoot elongation, and needle expansion) for Smith fir were monitored weekly along an elevational gradient on the southeastern Tibetan Plateau (Li et al., 2013, 2017; Wang et al., 2012, 2013). Shoot growth and needle expansion started increasingly later with increased elevation which suggested an important role of growing season temperature (Wang et al., 2013). However, the variation of the length of the growing season from 1960 to 2010 did not exhibit any significant effect on the radial growth of Smith fir at timberline (Liu et al., 2013). For the temperate zone of the northern hemisphere, earlier onset of the growing season promoted growth in more mesic sites but had little effect in cold and dry regions (Gao et al., 2022).

Forest cover is primarily confined to the eastern margin of the Tibetan Plateau. The presence of woody alpine shrubs (primarily rhododendron and juniper) elsewhere on the plateau provided an opportunity to extend the dendrochronological network into extreme environments beyond the survival limit of trees (Liang and Eckstein, 2009). Tree-ring series from rhododendron shrubs showed similar dendroclimatic relationships to timberline trees of the Tibetan plateau (Liang and Eckstein, 2009; Liang et al., 2009c). The team established the longest rhododendron ring-width chronology (401 years) (Lu et al., 2015). Alpine *Cassiope fastigiata* shrubs also form distinct annual growth rings and recorded similar climatic signals as nearby timberline trees (Liang et al., 2015). The widely distributed Wilson juniper (*Juniperus pingii* var. *wilsonii*) forms the highest elevation limit of woody shrubs in the plateau. A 537-year standard shrub-ring chronology from crossdated living and dead Wilson junipers was established and growth of Wilson juniper was related to May-June moisture (Liang et al., 2012; Lu et al., 2020), while rhododendron shrubs positively responded to above-average growing season temperature. On the other hand, high temperatures in May-June negatively affected shrub growth even at high elevations (above 4740 m). In addition, Wilson juniper formed the highest elevation shrub-line at 5280 m in the south-central Tibetan Plateau (Lu et al., 2021b). Growth of Wilson juniper was reduced due to warming-induced moisture stress as well as reduced regeneration on the Tibetan Plateau (Lu et al., 2019; Wang et al., 2015), the central Himalayas (Sigdel et al., 2021), and willow shrubs on the Tibetan Plateau (Wang et al., 2021) as well as in Greenland (Lu et al., 2022). In this way dendrochronological research in China supported by wood biology opened new ways to understand tree- and shrub-ring chronologies as climate proxies.

13. Communication leads to successful science

This survey of Eckstein's scholarly accomplishments is a story of cooperation and networking, of assembling teams and developing new techniques that would guide and support far more researchers than those with whom he directly collaborated or taught.

We have listed over 280 publications authored by Dieter Eckstein including peer-reviewed articles in scientific journals, monographs and monograph chapters, articles and some of the abstracts in conference proceedings, editorials, and other published works (Supplement S1), most of the dissertations and graduation theses he supervised (Supplement S2), and EuroDendro conferences he supported through membership in scientific, advisory, and organizational committees and editorial assistance in the preparation of the proceedings (Supplement S3). The publications were found in various bibliographic sources. For example, Scopus lists 104 articles published between 1967 and 2020 (Scopus, 2023), Web of Science lists 76 articles published between 1974 and 2020 (Web of Science, 2023), and the Bibliography of Dendrochronology (WSL, 2023) lists 184 articles published between 1967 and 2006. In addition, a "manual" search of the Thünen Institute Library (Jacoby, 2022 personal communication) yielded a total of 328 titles published between 1965 and 2020 including works where Eckstein was a supervisor or advisor and about 90 titles which were not listed in any other bibliographic source and are not available online.

However impressive, the share number of publications is perhaps less significant than that he presented research with at least 137 different co-authors, 43 with whom Eckstein published 2–25 articles. The top co-authors with more than 10 articles are: Josef Bauch, Sigrid Wrobel, Uwe Schmitt, Eryuan Liang, Walter Liese, and Ute Sass-Klaassen (Supplement S1, Fig. 12).

Fig. 12. A word cloud of coauthor names with whom Dieter Eckstein published two or more works.

Eckstein's work and publications were driven by a curiosity to try new approaches, to promote a deeper understanding of science, and to connect the research community through new findings and novel techniques. Although he worked with wood, microscopes, and analytical machinery, his commitment to science was strongly linked to an interest in people and different cultures. A bright star of his career was the establishment and maintenance of scientific networks, first with colleagues throughout Europe, and then extended to the United States and Russia, to bring together scientists from both sides of the "Iron Curtain" as well as virtually every continent. He understood the importance of connection across cultures and academic generations through conferences, workshops, and field research campaigns.

Eckstein was a long-time president of the worldwide "Tree Ring Society" (1974–1993) and a very active member of "International Association of Wood Anatomy (IAWA)" and the "Association for Tree-Ring Research (ATR)" and its annual "Tree Rings in Archaeology, Climatology and Ecology (TRACE)" meetings in Europe. In the early 1990 s, he initiated and chaired the informal "European Working Group on Dendrochronology", which hosts the "EuroDendro" meetings (Supplement S3). This model of ideas spread to the other continents, where it took the form of "AmeriDendro" and "AsiaDendro" conferences.

Eckstein built his personal research network as he hosted, trained, and collaborated with scientists from all generations and various career stages from Europe and around the world. With many of them he shared a lifelong friendship that enabled them to carry on and spread the "Eckstein spirit" of collaborative curiosity and innovation in discovery. That is the real legacy of Eckstein's work to promote the science and practice of dendrochronology around the world.

Eckstein's network shared openness and friendship as well as academic discipline and technical expertise. Eckstein gave his colleagues and scholars the opportunity to become a "dendrofamily". The challenge and responsibility is to continue to advance the "Eckstein spirit" of collaborative discovery.

CRediT authorship contribution statement

KČ, EL, KTS, TW, SW, PC, and USK designed the paper; KČ, EL, SW, and GK collected and organized the bibliographic database; KČ, EL, KTS, TW, SW, PC, and USK compiled and edited the manuscript; all authors contributed parts of the manuscript text, references, and photographic material from their personal archives, commented on the original version of the manuscript, and approved the published version.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The compiled bibliography in *docx, *pdf and *ris format, as well as the theses and Eurodendros supervised and supported by Dieter Eckstein in *docx format are publicly accessible in the Mendeley Data powered by Digital Commons Data repository. They can be accessed via dhttps://data.mendeley.com/datasets/h5gc8t3wc9/1 and cited as Čufar et al. (2024) doi: 10.17632/h5gc8t3wc9.1.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.dendro.2024.126165.

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