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ORIGINAL ARTICLE

Adverse implications of misdating in dendrochronology: Addressing the re-dating of the "Messiah" violin

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Abstract

A recent report by Mondino and Avalle (2009) was widely distributed that demonstrated a re-dating of the famous "Messiah" violin, a violin attributed to Antonio Stradivari with a label date of 1716. An outermost ring date of 1844 is instead suggested rather than dates in the 1680s reported in previous studies. Mondino and Avalle suggest that this outermost ring date supports the attribution of the violin to Jean-Baptiste Vuillaume, a prolific French instrument maker who was well known for his copies of famous instruments. The statistical techniques and exercises used by Mondino and Avalle, however, are problematic and do not support this revised outermost date for the "Messiah" violin. Raw measurement data with original trends are used in their statistical crossdating, properties previously shown to hinder precise crossdating. They then substantiate their re-dating with polynomial trend curves, which has ever been accepted practice in dendrochronology. Furthermore, the authors use re-scaled correlation coefficients and *t*-values which artificially inflate the strength of the relationship between tree-ring series that are being statistically crossdated. Using the exact same tree-ring data, but using accepted techniques in statistical crossdating (e.g., the removal of all low-frequency trends and autocorrelation), we could not verify the revised dating of the "Messiah" violin. We urge caution for those who intend to use the SynchroSearch software, book, and lesson plans developed and distributed by Mondino and Avalle. This study illustrates the adverse effects possible in dendrochronology when investigators do not adhere to accepted and time-tested techniques, and are not versed in the extensive literature that highlights issues commonly encountered in statistical crossdating.

Keywords: Tree rings; Dendrochronology; Musical instruments; "Messiah" violin; Antonio Stradivari

Introduction

In early 2009, many dendrochronologists received by email a communication that announced a soon-to-be-published book titled "Course of Applied Dendrochronology to Musical Instruments Dating for the

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Violin-Making Scools [*sic*], Museum Curators and Experts'' (Mondino and Avalle, 2009). In the document reside 11 exercises on tree-ring dating techniques applied to various musical instruments, including instruments previously dated by Elio Corona (1991) (''Il Cremonese'') and Grissino-Mayer et al. (2005) (the ''Karr-Koussevitzky'' double bass). Mondino and Avalle use these case studies to showcase the usefulness of tree-ring dating for verifying or refuting the accepted year of construction of musical instruments, as well as to demonstrate new software (''SynchroSearch'') for cross-dating tree-ring series obtained from musical instruments. Additional instruments are listed in the Table of Contents that were analyzed by Mondino and Avalle.

Particularly noticeable is Exercise 5, titled ''The Messiah Case.'' For this exercise, Mondino and Avalle chose to analyze the treble and bass side raw measurements derived from the ''Messiah'' violin by Henri D. Grissino-Mayer and archived with the International Tree-Ring Data Bank (ITRDB) as BRIT050 (the ''Messiah'' is housed at the Ashmolean Museum in Oxford, United Kingdom). To crossdate the Messiah measurements, they selected the Obersaxen/Meierhof, Switzerland (46°44′N, 9°05′E) Norway spruce (*Picea abies* (L.) H. Karst.) reference chronology spanning 1537–1995, created by Fritz H. Schweingruber (WSL, Birmensdorf, Switzerland) and archived with the ITRDB as SWIT173.

Mondino and Avalle highlight the re-dating of the ''Messiah'' violin, made by Antonio Stradivari with a label date of 1716 and considered by many to be the archetype of Stradivari's remarkable achievements (Draley, 1990; Pollens, 1999; Pieters, 2001; Kass, 2001). Mondino and Avalle demonstrate how their SynchroSearch software points to an alternate end year of 1832 (for the treble side measurements) and 1844 (for the bass side measurements) rather than the end years obtained by both Topham and McCormick (2000) and Grissino-Mayer et al. (2004) of 1682 and 1687, respectively (the latter researchers were able to measure additional rings). Mondino and Avalle (2009, p. 96) contend further that the 1832–1844 outermost years confirm ''Pollen's [*sic*] organological analysis sustaining that the violin housed in the Ashmolean Museum in Oxford cannot have been built by Antonio Stradivari beeing [*sic*] a work of Jean-Baptiste Vuillaume.'' This statement refers to the assertion by Stewart Pollens (1999) that the violin was not made by Stradivari based on discrepancies in stylistic traits, but instead could have been made by the eminent luthier Jean-Baptiste Vuillaume, who was well known for his famous copies of previously constructed instruments.

We feel compelled to examine the re-dating of the ''Messiah'' violin because a tree ring can date to one and only one position in time. There should be no competing dates provided for tree rings once they are absolutely dated. We found major issues with the statistical analyses of Mondino and Avalle that are counter to well-established and time-tested conventions in dendrochronology, and we demonstrate how their analyses lead to erroneous results and damage the reputation of the discipline. We begin first by discussing the basic foundations of dendrochronology to which tree-ring scientists must adhere.

Foundations of dendrochronology

The most basic foundation in dendrochronology is crossdating. Development of the concept and techniques of crossdating are the most essential contributions of Douglass (1920, 1941) to the field of dendrochronology (Stokes and Smiley, 1968; Fritts, 1976). Crossdating, as Douglass developed it, matches patterns of conspicuously wide and narrow rings (relative to their immediate neighbors) caused by climatic variation (Stokes and Smiley, 1968). If the time series is long enough, the patterns caused by random climatic variation will be unique so that there can only be one correct placement in time of each tree-ring series. Both graphical pattern matching and statistical crossdating depend on high-frequency climatic variation. Accurate statistical correlation especially depends on time series with a prominent high-frequency signal. Anything that obscures the high-frequency signal (such as parallel trends), or that dilutes the high-frequency signal (such as autocorrelation), will degrade crossdating and possibly lead to erroneous conclusions. When graphical and statistical crossdating are not rigorously applied, it may lead to two conclusions: (1) a tree-ring series that should crossdate does not, or (2) worse yet, a series is ''dated'' at an erroneous temporal position.

A second basic foundation in dendrochronology, related to crossdating, is that a tree ring can date to one and only one year (Baillie, 1982, p. 263). This premise is necessary to protect the integrity of the field and the integrity of those who practice it. Misdating tree rings can cause adverse repercussions that eventually can reverberate throughout the field of dendrochronology and the sciences that rely on it. This premise was so important in the early years of the science of dendrochronology that Andrew Ellicott Douglass, who established many of the basic principles of dendrochronology, was required to personally scrutinize and verify all absolute tree-ring dates, especially those concerning the dating of archaeological sites, as stipulated by the First Tree Ring Conference held 11–12 June 1934: ''Dr. Douglass consented to the requests of the assembled scientists that he take sufficient of his time to check all dates before they are published with finality'' (Glock, 1934, p. 5). Douglass took this charge very seriously. He counseled his former student, the eminent archaeologist Florence Hawley: ''It would be a mistake to publish any dates until several fundamental items are fully checked'' (Nash, 1999, p. 221). This tradition is continued today by:

- carefully conducting rigorous statistical techniques (complemented by long-established graphical procedures; see Douglass, 1928, Glock, 1937);
- collaborating with others to strengthen the quality of the overall research and to ensure the veracity of the results via peer-to-peer exchange;
- ensuring our research is peer-reviewed before publication; and,
- eventually making tree-ring data available to others for scrutiny and re-analysis, whether through the International Tree-Ring Data Bank, data repositories for peer-reviewed journals, or via inter-laboratory requests (for example, the Euro Catalogue of European tree-ring chronologies).

A third basic foundation in dendrochronology, and in much of the sciences, is verification, which forms the nucleus of logical positivism (Ayer, 1959), an approach to inquiry that ''recognizes the significance of logic and mathematics as systems of symbolic representation in scientific thinking'' (Peet, 1998). Outcomes of scientific tests and experiments can be repeated and the same results should be obtained. If repeated verification attempts do not provide the same results, then the original test or experiment must have been faulty in some respect. For example, in the late 1990s, researchers were unable to replicate the results published by two cancer researchers who subsequently admitted to fabricating data that were reported in more than 40 peer-reviewed publications (Abbott, 1997, 1998). In dendrochronology, ''dates should be repeatable, i.e. any laboratory should give the same result'' (Baillie, 1982, p. 262). Thus, dendrochronologists adhere to the verification principle. To achieve verification, the test itself must be replicable and enough information must be supplied in any publication by the original researchers to ensure the test can be replicated.

Finally, a fourth foundation concerns the legacy of literature. The development of a discipline takes considerable time as new methods and procedures emerge and new ways to interpret the results from tests conducted become available. Dendrochronology has evolved over a greater than 100-year period to be the quantitative, rigorous, and well-accepted science that it is, with an impressive body of literature that currently numbers over 11,700 publications (Dendrochronology Bibliographic Database, 2009). During this period, the science has withstood several challenges that were subsequently resolved by applying the principle of verification. Tree-ring series that were believed to date in a certain temporal placement by faulty means were subsequently found to date correctly in time by graphical and statistical crossdating procedures (Douglass, 1941; Bråthen, 1993; Nash, 1999, pp. 93–141; Grissino-Mayer et al., 2004; Henderson et al., 2009). Adhering to established time-tested methods and principles is critical for the success and continued acceptance of a discipline, while at the same time maintaining flexibility to adopt newly discovered techniques that advance the discipline. Dendrochronologists must be well aware of issues previously raised in the literature or else risk repeating mistakes previously pointed out by others. Ignoring the extensive body of literature in dendrochronology (especially those publications that concern a fundamental technique of dendrochronology—crossdating—and sound statistical methodology) can lead to erroneous dating and interpretations and damage the reputation of our discipline. This latter foundation is especially critical and demonstrated with several issues we observed with the re-dating of the ''Messiah'' violin by Mondino and Avalle.

Issue one: the graphical crossdating in SynchroSearch is not convincing

Crossdating in dendrochronology is as much a graphical process as it is a statistical process—graphical crossdating must accompany statistical crossdating and vice versa (Grissino-Mayer, 2001). The graphical crossdating, whether by skeleton plots or superimposed line graphs, must be visually convincing by inspection of how well the narrow and wide rings align between the two series. Mondino and Avalle supply several graphs that should demonstrate the crossdating between the Messiah ring measurements and the Obersaxen/Meierhof chronology, but these graphs are not convincing and even hinder the graphical crossdating task by the series being plotted. In their Fig. 1 (p. 89), they plot the Messiah treble side measurements against the Obersaxen/Meierhof chronology, essentially plotting a raw measurement series with a downward linear trend against an index chronology with a flat trend. In no way is this graphical comparison convincing or even interpretable. Similar figures that plot raw measurement series against an index chronology (with mean 1.0) are given in their Fig. 3 (p. 91) and Fig. 4 (p. 92). Lastly, Mondino and Avalle (2009, p. 88) state ''The graph in Fig. 1 shows the excellent values of the statistical values…'' but make no mention of their assessment whether graphical crossdating is confirmed or not.

Issue two: crossdating non-detrended series may result in spurious relationships

Mondino and Avalle demonstrate crossdating between the Obersaxen/Meierhof chronology and the Messiah

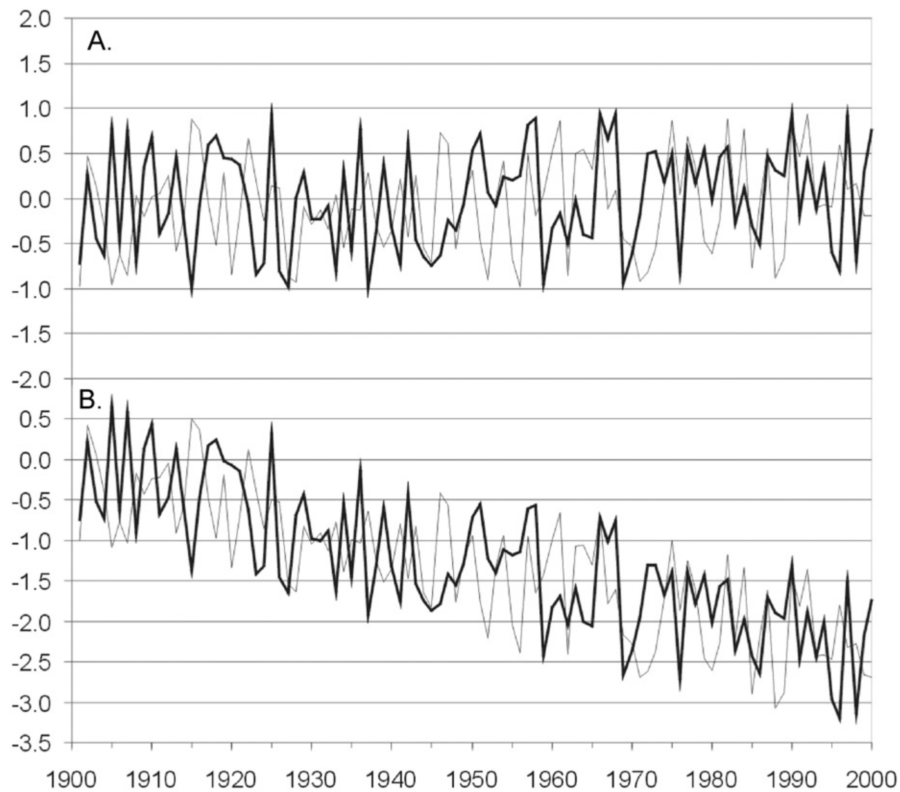

Fig. 1. (A) Two randomly generated time series with no statistically significant correlation ($r=0.01$, $t=0.12$, $P>0.80$). (B) The same time series with a downward linear trend added, now with a statistically significant correlation ($r=0.58$, $t=6.99$, $P<0.0001$). Units on the y-axis are dimensionless.

measurements using undetrended data. The Messiah measurements, as do most tree-ring width series, contain obvious age trends because tree growth generally declines from one year to the next caused mainly by geometric constraints during year to year wood production (Fritts, 1976). As such, "raw ring width series do not lend themselves to crossdating, except in the case of people comparing graphs by eye" (Munro, 1984, p. 18). The "Messiah" raw measurements clearly show the linear downward age trend common in tree-ring series. Such trends should be removed prior to statistical crossdating because they could lead to spurious relationships between two data series when in fact none exists. Hence, when testing the "Messiah" raw measurements (or any tree-ring measurement data sets) against other tree-ring data sets (including those with autocorrelation but no downward linear trend), the correlations will be spuriously high.

The effect of using undetrended data in statistical crossdating is best illustrated with an example. Two data sets of random data were generated with values between −1.0 and +1.0. Both have means near zero, no autocorrelation (r_1 for series 1 = –0.03, r_1 for series 2 = 0.12), and similar standard deviations, as expected (sd = 0.56 and 0.53, respectively). The correlation between these two series is statistically insignificant ($r=0.01$, $n=100$, $t=0.12$, $P>0.80$) (Fig. 1A).

A simple linear trend was then added to each series via: $Y_t=0.025(X_t)+B_t$ where t is the year, Y is the generated (predicted) value for year t, X represents the age of the tree in year t, and B is the actual measurement in year t (Fig. 1B). The correlation between the two series jumps remarkably to 0.58 ($n=100$, $t=6.99$), a value that is now statistically significant ($P<0.0001$). This example illustrates the adverse effect possible when attempting to crossdate tree-ring series using undetrended data because one is actually correlating the similarity in the low-frequency trend and not the similarities in the high frequency, year to year data. Statistical crossdating should be conducted on tree-ring series that have been detrended first.

Issue three: crossdating autocorrelated series results in spurious relationships

Mondino and Avalle demonstrate crossdating between the Obersaxen/Meierhof chronology and the Messiah measurements, but both these time series contain significant autocorrelation. The "Messiah" raw measurements contain an extraordinary amount of first-order autocorrelation, r_1 (treble) = 0.95 and r_1 (bass) = 0.94, which imparts a considerable autoregressive trend that can cause spurious correlations. ARMA modeling (Meko, 1981; Guiot et al., 1982) shows both to be an AR(2) process, in fact. The Obersaxen/Meierhof standard chronology also has a large amount of first-order autocorrelation ($r_1 = 0.81$). Autocorrelation arises in tree-ring series because the influence of growth in one year is carried over to the next year (i.e., ''biological inertia'') when trees fix photosynthates in the current growing season for growth in the following growing season (Fritts, 1976). Further, standard index chronologies have autocorrelation simply because they are created by averaging individual index series together (and therefore their individual autoregressive properties) using a mean value function.

Autocorrelation should be removed prior to statistical crossdating because it can lead to spurious relationships between two data series when in fact none exists (Yamaguchi, 1986). Current software in use for statistical crossdating, such as COFECHA (Holmes, 1983; Grissino-Mayer, 2001), removes autocorrelation and all low-frequency trends because ''it is to our advantage to consider only those high-frequency variations'' (Wigley et al., 1987). The effects of autocorrelation on statistical crossdating, and in dendrochronology in general, have been carefully analyzed and published on extensively (Fritts, 1976, pp. 324–325; Barefoot et al., 1978; Munro, 1984; Monserud, 1986; Wigley et al., 1987; Yamaguchi and Allen, 1992; Yamaguchi and Grissino-Mayer, 1993).

These effects are best shown with an example using the ''Messiah'' treble side measurements and the SWIT173 Standard chronology. Running correlations were computed dating the ''Messiah'' treble side raw measurement series at all possible positions against the SWIT173 Standard chronology, essentially replicating what we believe the SynchroSearch software does (Mondino and Avalle, 2009, p. 89), and these correlations were plotted by the various first years of the ''Messiah'' chronology. A t-value of 3.5, often the minimum considered indicative of a possible statistical match (Baillie, 1982; Orton, 1983; Wigley et al., 1987; Laxton and Litton, 1989; Grissino-Mayer, 2001), for $n = 99$ would require a correlation coefficient of 0.34 ($P < 0.001$).

We found a statistically significant correlation of 0.43 at the 1734–1832 placement (Fig. 2, marked by the arrow) suggested by Mondino and Avalle, but also found a similarly significant correlation of 0.43 at the 1721–1819 position. In fact, all 99-year-long overlaps with beginning years from 1720 to 1735 have statistically significant correlations with t-values > 3.5, as well as beginning years from 1636 to 1638, resulting in 19 possible placements at two different locations in time for the ''Messiah'' treble side measurements. Because tree rings can date to one and only one position in time, this approach cannot confirm the exact placement of the treble side measurements in time. Nevertheless, SynchroSearch reports only one of the possible 19 possible placements, 1734–1832, which does not have the highest correlation (the 1724–1822 placement has a correlation of 0.48).

Once the autocorrelation was removed using program ARSTAN to create Residual tree-ring chronologies (Cook, 1985), we do confirm a statistically significant correlation of 0.36 at the 1734–1832 position that barely exceeds the minimum threshold t-value of 3.5, but this low correlation is not convincing enough to state that the ''Messiah'' is conclusively dated at this position. Higher and more convincing t-values were obtained for 40-year segments of the Residual (i.e., no autocorrelation) chronologies between the ''Messiah'' and two other instruments, the ''Kux/Castelbarco'' and ''Archinto'' (Grissino-Mayer et al., 2004). Topham and McCormick (2000, p. 190) reported higher t-values of 10.0 and 11.1 between the ''Messiah'' treble and bass sides, respectively, when tested against instrument Vn278 which had already been conclusively dated (1584–1686), suggesting that the wood from these two instruments may have been procured from the same tree (pp. 190–191).

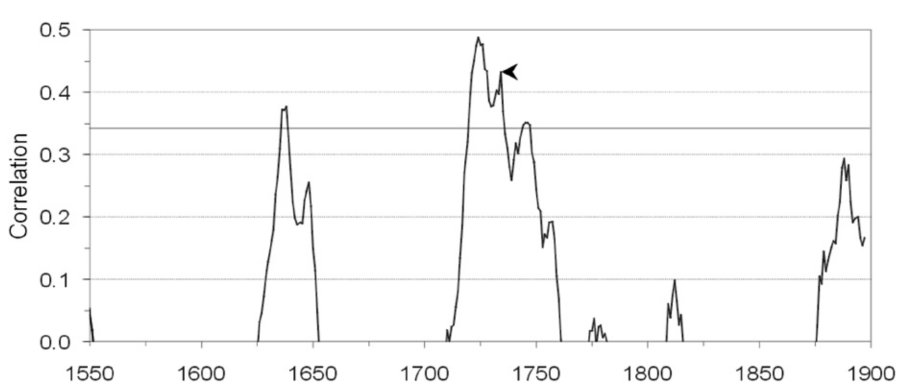

Fig. 2. Correlation coefficients between the ''Messiah'' treble side raw measurements and the SWIT173 Standard chronology, replicating the crossdating conducted by Mondino and Avalle. The arrow points to the 1734 beginning year they suggest as the correct dating of the ''Messiah,'' ignoring many statistically significant correlations elsewhere. The line at $r = 0.34$ ($P < 0.001$) indicates possible significant dating with a minimum t-value of 3.5.

Issue four: SynchroSearch produces extraordinarily high correlations and *t*-values

Another issue concerns correlation coefficients and their respective *t*-values that are exceedingly high when conducting crossmatching between two tree-ring time series using the SynchroSearch software. Mondino and Avalle use the SWIT173 Standard chronology in all analyses as indicated in their Fig. 1 (p. 89). The correlation obtained between the SWIT173 Standard chronology and the non-detrended (i.e., raw) treble measurements is an astounding 0.86 with an associated *t*-value of 16.51. They also obtained a correlation of 0.61 ($t = 7.46$) using "detrended" versions of both data sets (p. 90). The bass side measurements also showed an unusually high correlation of 0.75 with a *t*-value of 11.22, with $r = 0.80$ and $t = 13.85$ for the "detrended" data sets. Such high correlations and *t*-values are exceedingly rare (and perhaps unheard of) in dendrochronology. The probability of error associated with a *t*-value of 16.51 is nearly 0.0. In fact, measurements of the same rings by two different researchers yield comparably high correlations (Grissino-Mayer et al., 2004, see their Table 2), so obtaining *t*-values this high between two different tree-ring data sets is extraordinary and doubts arise on the validity of the crossdating.

We attempted to verify these correlations using both COFECHA and the correlation procedures available in Microsoft Excel, but we obtained an *r*-value for the treble side of 0.43 ($n = 99$, $t = 4.69$), a value that was statistically significant ($P < 0.001$) but half that obtained by Mondino and Avalle. We next detrended the treble side measurements using routines available in COFECHA that remove low-frequency trends, and compared this to the SWIT173 Standard chronology used by Mondino and Avalle. We obtained a correlation of 0.22 ($t = 2.22$), a value that would not be considered statistically significant by dendrochronologists. A similar correlation was obtained between the Messiah treble side Residual chronology and the SWIT173 Standard chronology (0.23). We therefore could not confirm the alternate dating positions obtained by Mondino and Avalle using the SWIT173 Standard Chronology.

Issue five: polynomials cannot prove relationships exist between series

As supporting evidence, Mondino and Avalle suggest that the 3rd-order polynomial curve of the Obersaxen/Meierhof chronology is "perfectly similar" [*sic*] (p. 95) with the 3rd-order polynomial curve for the "Messiah" treble side measurements, and that "the similarity in the trend of these curves justifies the choice of the crossdating 1736–1832 … and the feasibility of the correlation." While the similarity in curves is appealing, such similarities are inherently subjective and in fact, we see little similarity in the curves in their Figs. 5 and 6 (p. 93) as the regression coefficients on the 1st-, 2nd-, and 3rd-order regressors (basically, the age of the ring) are vastly dissimilar, as are the r^2 values generated by fitting the data with the 3rd-order polynomial (0.46 for the Obersaxen/Meierhof chronology, and 0.81 for the Messiah treble side measurements). In no way do similarities in polynomial curves for two series corroborate a correlation coefficient when testing the strength of the statistical association between two series.

Issue six: suggested guidelines should adhere to established principles

Mondino and Avalle (2009, pp. 80–83) provide guidelines that are counter to many of the well-established principles long-adopted in dendrochronology. These established principles are based on close examinations over the years of statistical properties of tree-ring data that can interfere when attempting to date a tree-ring chronology that is floating in time.

Detrending tree-ring measurement series

Mondino and Avalle (2009) state: "The use in the first instance of standardized detrended series by indexing is to be avoided because crossdating is considerably facilitated when the chronologies being examined are not standardized and trendings [*sic*] are not cancelled out" (p. 81). As we have demonstrated, similar to what many before us have demonstrated, tree-ring data contain inherent statistical properties that can cause spurious correlations when trend and autocorrelation are not removed first. Mondino and Avalle found what they believe to be statistically significant correlations for measurements from the "Messiah" violin and a regional reference chronology. These correlations are all inflated because of trends and autocorrelation, both of which should be removed using linear and log-linear functions, autoregressive modeling, and flexible cubic smoothing spline fitting. The last method removes complex trends in tree-ring data better than polynomial functions (Cook and Peters, 1981).

Correlation coefficients are apparently re-scaled

The greatly inflated correlation coefficients can be explained by a purposeful and misleading re-scaling of the distribution of these coefficients (M. Avalle, email communication to P. Ratcliff, 3 March 2009, on file). Correlations normally range in value from –1 to +1, with –1 indicating a perfect inverse relationship, 0.0 indicating no relationship whatsoever, and +1.0

indicating a perfect positive relationship (Fritts, 1976, p. 257; Sokal and Rohlf, 1994; Walford, 1995; Chen and Popovich, 2002). The null hypothesis used in hypothesis testing states that no statistical association exists between two tree-ring time series, i.e., r is below the threshold required for statistical significance. Significance is tested using the t-distribution after conversion of r to t. This distribution is two-tailed, similar to the distribution of r-values.

Mondino and Avalle apparently have re-scaled the r-values: "[T]ale discrepanza, infatti, è in parte dovuta ad una differente implementazione dell'algoritmo di calcolo dell'R di Pearson" ("Such a discrepancy is, in fact, partially due to a different implementation of the algorithm used to calculate Pearson's R") (M. Avalle, email communication to P. Ratcliff, 3 March 2009, on file). This re-scaling appears to increase all positive r-values substantially and could result in positive values for otherwise negative correlations. Mondino and Avalle justify the use of this re-scaled r: "[I]n quanto la curva di crescita del nostro parametro R è praticamente identica a quella del parametro calcolato con le formule standard" ("as the incremental curve of our R is practically identical to the one obtained from standard formulae") (M. Avalle, email communication to P. Ratcliff, 3 March 2009, on file). This does not in any way validate this re-scaling. Further, when r is squared (for use in the t-value calculation), the comparative curves of r and the re-scaled r are not identical. This re-scaling of r-values is so counter to existing statistical convention that it essentially misleads users of Synchro-Search, especially beginners unfamiliar with statistical tests. Further, t-values associated with these re-scaled r-values are much inflated and therefore should not be considered statistically valid for crossdating.

Climate response in trees

The claim that "straight tendency lines… are proxy evidence of local temperature trends" (Mondino and Avalle, 2009, p. 82) is an oversimplification of the climate response found in Norway spruce trees. Temperature certainly affects growth of Norway spruce found in central Europe, but the statement by Mondino and Avalle is not necessarily true in all cases (Cherubini et al., 1996). For example, Wilson (2003) observed that a network of Norway spruce chronologies along an elevation transect in the lower Bavarian forest had variable climate responses, with lower elevation sites responding more to precipitation. Büntgen et al. (2006) found that Norway spruce growing in three high elevation Swiss sites (Lötschental, Goms, and Engadine) responded to previous year August–September precipitation, and also that the climate–tree growth relationship was unstable back in time. Pichler and Oberhuber (2007) found that April–June precipitation was most strongly associated with growth of Norway spruce at an alpine site in Tyrol, Austria. These and many other studies demonstrate that precipitation can also significantly affect growth of Norway spruce in high elevation areas of central Europe.

Dissimilar trends in tree-ring series

Mondino and Avalle further note that for tree-ring series with dissimilar trends "matching is to be rejected" because it is not conceivable that temperature trends should be opposite (p. 82). Again, this is an over-simplification because internal stand dynamics indeed can cause an increasing trend (or more complex trends) in a tree-ring series that is dissimilar to the trend exhibited by other trees collected from the same stand (Cherubini et al., 1998, 1999, who analyzed subalpine trees growing in the "violin forest" in Paneveggio, Italy). These linear or more complex trends can be removed using established detrending methods that enable crossdating of series with dissimilar trends in the raw data (Fritts, 1976; Graybill, 1982; Cook, 1985, 1990; Cook and Peters, 1981; Cook et al., 1990). Furthermore, Mondino and Avalle make no attempt to distinguish what constitutes "dissimilar trends" between two series.

Verification of trends using polynomials

In Guideline IV, Mondino and Avalle (p. 83) stress the importance of visual verification of crossdating by inspection of the polynomial approximation, but this verification is a subjective assessment because no statistical tests are performed to evaluate the similarities of the coefficients obtained in the polynomial (multiple) regression. Furthermore, we reiterate that the use of polynomials as indicators of trend in tree-ring series is "not recommended" because of "problems in order selection, potentially severe end-fitting problems, and poor local goodness-of-fit" (Cook et al., 1990).

Combining tree-ring series into one chronology

Mondino and Avalle (2009, p. 83) recommend in Guideline VI that the bass and treble side measurements not be combined into a single chronology unless the wood comes from the same tree. This requirement is not necessary because the whole point of sampling two or more cores from a living tree and sampling many trees in a stand for any kind of dendrochronological study (e.g., climatic, ecological, or archaeological) is to acquire the climatic signal common to all trees that imparts the necessary properties for crossdating. Trees respond individually to the surrounding environment, causing differences (some slight, some major) in the growth patterns among trees. Even within a tree, growth patterns seen on two radii can be dissimilar because of (1) physiological functions within the tree, (2) the architecture of the tree, and (3) asymmetric effects of local disturbances on tree growth, all of which contribute to "within-tree variability" (Schweingruber et al., 1990). If the bass and treble side measurements do crossdate, the growth indices are averaged together within and between trees via a mean value function after detrending. This process "… has the desired goal of decreasing the random error (E) associated with each series, resulting in a final chronology with a relatively high ratio of climatic signal to non-climatic noise" (Graybill, 1982).

Discussion

The importance of peer review cannot be overstated because it "represents the *status quo* within which we currently work as practicing scientists, and, importantly, upon which we rely for continuous dissemination of high quality and reliable information that allows us to move our fields forward" (Grainger, 2008, p. 5200). Peer review essentially provides a mechanism by which experts can monitor research in their field to ensure its validity and ensure that it adheres to established guidelines. Distributing literature that has not been evaluated by experts can have detrimental effects on the field, can lead to faulty research that produces erroneous results, can lead to conclusions that have no scientific basis, and can mislead students and novices who wish to learn how the field operates within an established scientific framework.

We saw no indication that the SynchroSearch software, its book, and the lesson plans were peer-reviewed. For example, the first exercise in the lesson plans concerns the re-dating of the Karr–Koussevitzky double bass, originally dated by Grissino-Mayer et al. (2005). Fig. 6 in this exercise shows the dating of the bass side measurements ("Karr06") against the Obergurgl, Austria master chronology developed by Veronika Giertz-Siebenlist in the mid-1970s. Curiously, the SynchroSearch software shows a correlation of 0.06 ($n=298$, $t=1.04$) between the two undetrended data sets, and yet Mondino and Avalle assert that the "1464–1761 dating is confirmed" (p. 2). Peer review would most certainly have caught the erroneous fact that a correlation of 0.06 does not confirm dating.

Peer review of the SynchroSearch literature might also have alerted Mondino and Avalle to a major issue concerning their dating of the "Charles IX" violin made by Andrea Amati ca. 1566, shown in their Chapter 11, section 11.4, titled "Dating instruments from images" (see http://www.synchrosearch.org/english/data/118-122ing.pdf). Their Fig. 11.4.2 shows the location on the instrument from where the measurements (listed in the sidebar across from their Fig. 11.4.1) were obtained from a photographic image shown in Carlson and Chiesa (2000, p. 76). Recognizable is the fact that the ring widths on this violin decrease towards the outer edges of the instrument, indicating the near-pith rings are near the centerline on the spruce top. This particular construction is opposite that used for other musical instruments in that the near-pith rings are nearly always found on the outer edges of the instrument top because of the way the wood is split and glued together (Topham, 2003). High-resolution photographs of the wood from the 1566 Amati (kindly supplied by Bruce Carlson) clearly show the growth direction is towards the edge of the instrument, indicated by the earlywood to latewood transition and the sharp latewood boundaries. However, Mondino and Avalle measured the ring widths from the edge to the centerline, opposite the growth direction, essentially providing meaningless tree-ring data. Yet, they were able to date these 59 rings to the period 1436–1494 against the Obergurgl Norway spruce chronology that spans 1274–1976 (Mondino and Avalle refer to this as the "Oetztal" chronology, but it is archived in the ITRDB as "Obergurgl").

We attempted to replicate this dating using the original data given in the sidebar of this chapter, despite these measurements being reversed. For $n=59$ years, a correlation coefficient of 0.42 is required to obtain a t-value≥ 3.5. We found a statistically significant r-value of 0.49 at the 1436–1494 suggested placement (arrow, Fig. 3), considerably lower than the reported r-value of 0.83 (their Fig. 11.4.4). However, we found many higher and statistically significant correlation coefficients elsewhere in three temporal positions: outer date ranges of 1433–1448, 1518–1534, and 1803–1813 (Fig. 3). We next reversed the measurements to the correct order and created a Residual chronology from the corrected measurements to compare with the Obergurgl Residual chronology, and found no correlation coefficient that approached 0.42 (highest $r=0.34$ at first year of 1383, $t=2.73$).

We therefore have three major concerns with this exercise: (1) not recognizing that the growth direction of the wood is opposite that found on other instruments; (2) the many possible dating positions that demonstrate the ambiguity of any suggested temporal placement; and, (3) discarding many competing temporal placements because these would place the outer ring of the "Charles IX" Amati after its ca. 1566 construction date. Had the maker of this instrument been unknown, no firm dating conclusions could have been reached based on these ambiguous results. Furthermore, discarding possible dating positions because they do not fit some *a priori* idea on where the dating position is removes objectivity in statistical crossdating.

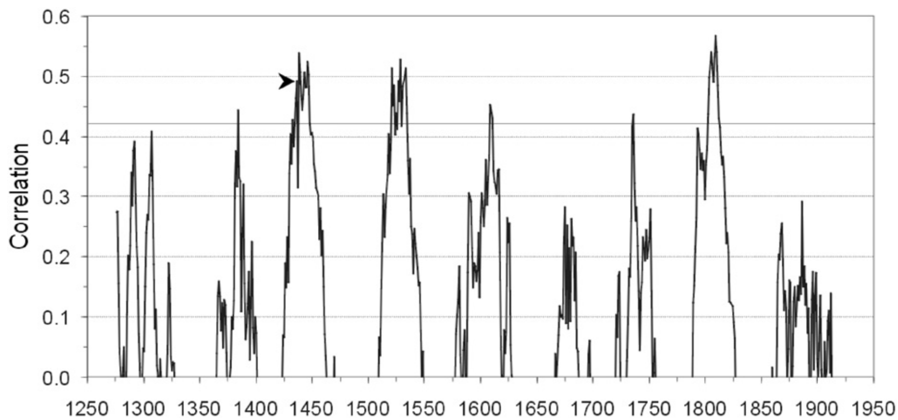

Fig. 3. Correlation coefficients between the ''Charles IX'' treble side raw measurements (*reversed*) and the AUST003 Standard chronology for Obergurgl, Austria, replicating the crossdating conducted by Mondino and Avalle. The arrow points to the 1436 beginning year they suggest as the correct dating of the instrument based on the reversed measurements. The line at $r = 0.42$ indicates possible significant dating with a minimum t-value of 3.5.

Lastly, Mondino and Avalle (2009, p. 85 and p. 96) contend that their outermost date for the ''Messiah'' violin of 1844 supports the attribution of the violin to Jean-Baptiste Vuillaume because the instruments made by Vuillaume were made from wood located in Switzerland, specifically, as he would buy beams from ''old chalets'' (Millant, 1972). However, to make the ''Messiah'' violin in the mid-1800s as suggested by Mondino and Avalle, Vuillaume would have had to salvage wood from a chalet that was not old at all because the outermost ring they contend is 1844, and the ''Messiah'' did not appear in Vuillaume's possession until 1855 (Hill 1891). This 12-year period does not give Vuillaume much time to find an ''old chalet'' (it would not have been old in the 1850s), select the wood, purchase the wood, remove the wood, transport the wood to Paris, build an exquisite instrument from the wood, label it a Stradivari made in 1716 (with a convincing label), then never take credit for his work. Furthermore, we can assume that the cutting date of the tree was later than the 1844 date proposed by Mondino an Avalle because portions of the sapwood are usually removed when making musical instruments. To support their contention, Mondino and Avalle (2009, p. 97) cite Grissino-Mayer et al. (2002), who found a conspicuous black dot (among several marks found) on the ''Messiah'' centerline under the bridge, a trademark of instruments made by Vuillaume (Editions Montparnasse, 2007). However, nowhere do Grissino-Mayer et al. (2002) suggest that the instrument was made by Vuillaume. Instead, the black dot (which was on top of the varnish) suggests only the ownership of the ''Messiah'' violin by Vuillaume, at the most.

Concluding remarks

We recommend that SynchroSearch software, web site, book, and lesson plans should not be used until these have undergone peer review, as have all other suites of software used in dendrochronology. Mondino and Avalle tout SynchroSearch as ''Do It Yourself'' dendrochronology (see: http://www.synchrosearch.org/english/index.asp), but dendrochronology is no more a ''Do It Yourself'' science than other sciences such as chemistry or physics. As do all fields of inquiry, dendrochronology requires training in several different disciplines, especially basic and advanced statistics, botanical foundations of tree growth, climatology, ecology, and human–environment interactions. Without this training, one can make very basic mistakes that can lead to erroneous conclusions, such as not identifying correctly the direction of tree growth.

Mondino and Avalle (2009, p. 79) claim that our original research on the dating of the ''Messiah'' violin had looked under the wrong ''lamppost'' because that particular lamppost was where the light was shining most brightly, and later state that ''we think it is a pity that our friend Henri did not find the lamppost that would have illuminated his search'' (p. 104). We hope that this rebuttal to the re-dating of the ''Messiah'' violin shows that we did indeed look under the right lamppost, as well as in the shadows around the lamppost and beyond, as if illuminated by the sun itself, to ensure the veracity of our research.

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