TRADE-OFFS BETWEEN THE USE OF TREE-RING COUNTING AND DENDROCHRONOLOGY IN ECOLOGICAL STUDIES

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ABSTRACT

In most situations, dendrochronological techniques are superior to ring-counting techniques because of the accuracy of the resulting data. However, depending on the objectives of a particular study, ring-counting may be an acceptable, and in some cases, the only feasible approach. Both methods require considerable amounts of time and effort when done properly. Once an individual is familiar with the techniques and a species' ring characteristics, the only "extra" time required by either approach involves the crossdating procedure in dendrochronology. For determining tree or stand age, crossdating will produce more accurate estimates particularly for older trees, but when using standard procedures, neither approach produces exact ages. Information on growth rates can be obtained with both approaches, but growth trends related to tree age must be removed or considered when comparing different individuals or sites. The value of ring-counting for identifying environmental events decreases over time. Only very major environmental changes or events in the recent past are detectable with ring-counting techniques.

INTRODUCTION

A major point of discussion among people conducting studies which utilize tree-rings is whether it is necessary to develop a chronology before one can attempt to interpret information contained in the ring patterns. It is clear that without first developing a chronology, it is difficult to make precise statements about the date when a particular ring was formed. However, there are circumstances when approximate dating of rings may either be sufficient or the only feasible approach, particularly when working with material which does not crossdate. In this situation, is it better to give up and say there is nothing we can do with tree rings? Or should one be willing to make an attempt at ring counting to see if it is possible to develop at least some information that may contribute to the resolution of important environmental questions? Our feeling is that there is a place for both approaches, as long as there is a realistic understanding of 1) the level of effort required to generate valid data and 2) the appropriate use of any data which result from the effort.

Problems begin when researchers, particularly those new to tree-ring analysis, are not willing to put the necessary level of effort into either dendrochronology or ring counting. Individuals experienced in these two approaches have developed procedures to assure the quality of the data generated and its appropriate interpretation (Duever and Riopelle 1984a, Fritts and Swetnam 1986, Hughes et al. 1982, Phipps 1985, Schweingruber 1982, Stokes and Smiley 1968, Swetnam et al. 1985). However, for some reason tree-ring analysis is frequently viewed as a relatively simple and straightforward technique which requires little experience or training. The results of this attitude have varied. Where the ring patterns have been clear and relationships with environmental variables fairly simple, valuable information has been generated (Duever et al. 1978, Duever and Riopelle 1983, Nessel et al. 1982, Schweingruber 1982). Unfortunately, this situation is frequently the exception rather than the rule. At the other extreme, where the ring patterns are difficult to identify and environmental relationships complex, results have been poor. All too often the response to the latter situation has been that the techniques do not work, rather than we didn't know what we were doing, and that is the reason they didn't work. Even worse, invalid conclusions have sometimes been drawn from tree-ring data generated using inadequate techniques, with the result that the field has developed an undeservedly poor reputation in some quarters. One of the goals of this meeting and the subsequent publication is to maximize the dissemination of information that will help researchers avoid pitfalls which can waste their time or lead to inaccurate interpretation of their data.

Most of our work with tree rings over the past 12 years has involved ring counting, and during this period we have been able to successfully address a number of significant environmental questions using this approach (Duever et al. 1978, 1984, Duever and Riopelle 1983, 1984b, McCollom et al. 1985). However, since we have not been able to crossdate most of our materials, there are a number of objectives we have not been able to attain. Since crossdating has not been possible, we have spent a great deal of time working to assure the quality of our data by other means (Duever and Riopelle 1984a). In this paper we will try to identify some of the trade-offs between the two approaches to tree-ring analysis using experience gained during our ring counting work, and that of others who have utilized dendrochronology.

DATING OF RINGS

In some cases the trade-offs are fairly clear (Table 1). By definition, chronologies are extremely precise and there is no error associated with a date assigned to a particular ring. In ring counting, the dates are only approximate, and the associated error is a function of the level of effort a researcher puts into studying the reliability of ring patterns of a particular species at a particular site.

Table 1. Summary of trade-offs between ring counting and dendrochronology.

	RING COUNTING	DENDROCHRONOLOGY
DATING OF RINGS:		
ACCURACY	APPROXIMATE	PRECISE
ERROR (*Taxodium*)	($\pm$ 5%)	(NONE)
SAMPLE SIZE:		
NUMBER OF TREES	>50	$\geq$20
NUMBER OF CORES PER TREE	1	2
APPROPRIATE APPLICATIONS:		
AGE	++++	+
GROWTH RATES	++++	+
SITE CHARACTERISTICS	++++	+
CORRELATION WITH ENVIRONMENTAL EVENTS OR VARIABILITY	+	++++
LENGTH OF RING SERIES	SHORT (< 100 YRS)	LONG (> 50 YRS)
TYPES OF DETECTABLE CHANGES	GROSS	SUBTLE-GROSS
	DISCRETE	DISCRETE-CONTINUOUS
	(YES OR NO)	(MORE OR LESS THAN)

When we first began our work with bald cypress, *Taxodium distichum*, in the early 1970's, the general attitude was that you could not do anything with cypress tree rings. As a result of this attitude and the potential value to our research of being able to generate at least some useful information from cypress, we put a great deal of effort into studying its ring characteristics, initially in Florida and eventually throughout its range. We now feel we can date cypress rings in Florida and nearby areas with an accuracy on the order of $\pm$ 5% (Duever et al. 1978). However, we have seen material from trees growing on poor sites which we feel is too difficult to attempt even approximate dates, and other material from young trees on good sites in the northern parts of the species' range, where counts are likely to approach 100% accuracy.

The techniques we utilize to determine the accuracy of dates, for either a new species or a species we have worked with but at a new site, have become fairly well standardized over the years (Duever and Riopelle 1984a). Our first step is to obtain slabs from at least 6 different trees. These can be from dead logs or branches of live trees, and we normally try to get samples on the order of 10-15 cm in diameter. What we are looking for initially is (1) how distinct are the ring boundaries and (2) are they continuous around the sample. If these criteria are satisfied, we then make ring counts along three radii around the slab and compare them to try to understand the reasons for any discrepancies between the counts. This provides us with a preliminary quantitative estimate of how much confidence we can put in cores taken from this species at this site, and gives us an idea of how difficult it will be to work with the material. The examination of slabs to provide this preliminary information has been one of the most valuable procedures in our research, and unfortunately, one frequently ignored by novices in the field. In some cases, we have found unusable species with beautifully distinct rings that combine frequently with adjacent rings as you proceed around the slab. In other cases, we have found useful species whose rings are very indistinct, but still consistent around the slab. These are types of information that cannot be easily detected by simply using cores, and skipping the examination of slabs.

The next step normally involves determining whether the rings are produced annually. This is accomplished by identifying sites where there are trees which were severely impacted by some known event or where there is a possibility of getting known aged trees. In the latter case, it might be possible to find trees that were planted at a known size on a known date. Alternately, we might be able to say that some individual trees could be no older than some known date because conditions were not suitable for their colonization prior to that date. Examples could include stump sprouts on logged sites, newly created habitats, or sites for which old photographs are available. In these cases, current stems could have sprouted anytime after a certain date, but not before it. This then provides a maximum number of possible rings that can be present if a species produces annual rings. Also if one selects specimens carefully, it is possible to obtain samples from trees that are more likely to have been the first colonizers on a site, which further increases the usefulness of the samples for verifying the annualarity of rings.

In a more detailed study at one of our early research sites, we took short cores from 20 trees monthly for a full annual cycle. In addition to providing us with information on the occurrence of missing and false rings, we were able to ascertain the seasonal timing of ring formation. In our subtropical region, this has been helpful in other studies for making decisions about the date of the outermost ring on samples taken from living specimens.

LEVEL OF EFFORT

The level of effort involved in tree-ring analyses is almost always large, regardless of the approach taken. The above comments document our approach to the development of a rigorous method for determining the suitability of a species at a particular site for ring-counting. There are numerous sources of information on the approaches used in dendrochronology (Ferguson 1970, Fritts 1976, Fritts and Swetnam 1986, Hughes et al. 1982, Phipps 1985, Schweingruber 1982, Swetnam et al. 1985, Stokes and Smiley 1968). Since tree ring analysis often appears simple, novices to the field characteristically underestimate the large amount of effort necessary for the development of useful information from tree-ring analyses, unless they happen to be extremely lucky with the material they start with.

Another problem that frequently occurs is that regardless of the original objectives of a study, a researcher often decides to try to do more with the data than was initially intended, or someone else will decide that this is a really nice data set to use for some other purpose. When the material has not been crossdated, even if the techniques utilized were adequate for the original objectives, they frequently are not adequate for the additional studies. The necessity for reworking the data, or possibly collecting additional samples to bring the data up to a level of accuracy appropriate for the new objectives is frequently not taken into consideration when the new studies commence. All too often great frustration, if not outright disaster, ensues from this approach.

One of the first considerations at the beginning of any tree-ring study is the sample size required. As with many things, there is no simple answer because of species-to-species and site-to-site variability. In dendrochronology, a minimum of 15-20 trees is a frequently heard response, at least as a starting point at sites that are not excessively difficult to revisit and where the material is reasonably good. This sample size is required to overcome variability in ring width patterns associated with the individual genetic or environmental factors influencing specific trees. In our experience with ring-counting of cypress, we have normally needed samples of 50-100 trees to obtain useful information on ring width patterns associated with even major environmental events. This large sample size is primarily due to the existence of missing and/or false rings which almost invariably occur in any data set produced by ring-counting techniques. However, if there are distinctive patterns common to many trees on the site, a sample size of 50-100 trees has been sufficient to make them apparent.

While an increased number of trees is necessary when one relies on ring-counting, we normally only take one core per tree rather than two as is the common practice with dendrochronology. The reason for this is that we are trying to maximize information about the site rather than account for variability within individual trees.

Thus, while the total amount of effort expended in ring counting may appear to be less than for producing a chronology, there is really little difference between them. In both cases, developing the initial expertise, first with the basic techniques and subsequently with each new species and site, requires a great deal of time and effort when done properly. Ring counting requires substantial time to locate, sample, and analyze trees of known or approximately known age to verify the existence of consistently recognizable annual rings, while dendrochronology requires similar expenditures of effort to learn how to crossdate. After this initial period, most of the remaining sample processing and data analysis procedures are similarly routine and time consuming for both techniques. The greatest difference at this stage is associated with crossdating, which does represent an additional sample processing step and one that can become significant when samples do not readily crossdate. (Madany et al. 1982).

APPLICATIONS

In most situations dendrochronological techniques are superior to ring-counting techniques because of the accuracy of the resulting data. However, in some situations ring-counting may be an acceptable alternative depending on the objectives of a particular study. This approach may be particularly appropriate in situations where the researcher is already quite familiar with the ring characteristics of a species to be sampled, the time period of interest is relatively short, missing and/or false rings are relatively infrequent, crossdating is excessively difficult, or the degree of precision needed is not great.

Tree Age

One the most frequent uses of tree-ring information is in the determination of the age of individual trees or stands of trees. Aging requires that a researcher be able to recognize rings on the individuals to be sampled, and that he is able to demonstrate that these trees regularly produce one and only one ring each year. Neither of these requirements are significant problems when dealing with many species at most sites where they occur. However, these same species at some sites, and other species wherever they occur, require at least a preliminary examination of their ring characteristics before even an experienced person can identify annual rings with a reasonable degree of confidence. Still other species or sites are impossible to work with because of excessive numbers of missing and/or false rings.

When a species is shown to have identifiable annual rings, ring counts can normally provide age estimates that are sufficiently accurate for many purposes, particularly since standard sampling techniques already introduce small errors into our estimates. One type of sampling error occurs when cores do not include the pith at the center of a tree, thus precluding any possibility of a complete count. This problem is most severe with larger trees, many of which have eccentrically placed centers. A second type of error results from cores normally being taken at breast height (approximately 1.5 m above the ground), so that the number of years which it has taken the tree to initially reach breast height must be estimated. A third type of error occurs when the main stem of small or even large trees is killed, and a new stem develops from the same root system or from a surviving portion of the tree at a point below breast height.

If one is interested in the age of a forest stand, there are additional errors associated with different dates of germination as the site is initially colonized by a species or with differential growth rates among individuals before they attain breast height.

While all of these differences between ring counts and actual age may be small, they do add a certain amount of uncertainty to any estimate of the age of an individual tree or forest stand which cannot be compensated for by the use of dendrochronological techniques.

Growth Rates

Growth rates of woody plants, as indicated by their annual ring widths, are always to some degree a function of both natural and anthropogenic environmental conditions (Fritts 1976). Comparisons of ring widths within the same species over time or on different sites, or between different species on the same site, can provide valuable information on how woody plant growth varies temporally or spatially with a variety of environmental conditions. In addition, it is possible to evaluate the relative productivity of species or sites, or how a species' growth is affected by various management practices or impacts.

When one is able to successfully age trees, the only additional requirement associated with determining variations in annual growth rates is an ability to accurately measure individual ring widths. Again, for those species and sites where one is able to demonstrate that excessive numbers of missing and/or false rings do not occur, it is often possible to obtain adequate results with ring-counting techniques. However, one important constraint must be kept in mind.

This constraint involves the change in growth rates which occurs as a function of age (Fritts 1976). Under constant environmental conditions, annual rings are widest when a tree is young, they gradually become smaller as the tree ages, and at some point in time their size stabilizes until just prior to death. Thus, a person may fairly study growth rates during different portions of the life span of an individual tree, but must be cautious when comparing growth rates of different aged trees. This problem increases as we deal with progressively greater disparities in ages among trees. Some methods for minimizing this problem include comparing different individuals only over similar portions of their life span (Duever et al. 1984) or standardizing the series to compensate for age-related changes in growth rates (Cook and Peters 1981, Fritts 1976, Graybill 1982, Swetnam et al. 1985).

Detecting Environmental Events

Virtually all ring width series have some missing and/or false rings that are undetectable with ring-counting techniques, and the magnitude of this error increases as the length of the ring width series increases. As a result, we have found it very difficult to detect effects of even major environmental events in cypress much over 100 years old. This is a function of different trees having different numbers of missing and/or false rings between the outer ring and the ring corresponding to the year of the event. Even though all of the trees may be responding to the same environmental event, the ring in which it is exhibited in the uncrossdated samples is scattered over such a broad range of "dated" rings that it is difficult to identify it as a single event. Thus, the value of ring-counting for identifying the occurrence of even major, much less minor, environmental events decreases over time, although the period over which "reliable" ring-counting can be done will vary from species to species and from site to site.

Since dendrochronology precisely dates all rings, its ability to accurately date past events is limited only by the length of the chronology. The only exception to this is for ring width series that are shorter than about 50 years. The reason for this is that crossdating depends on being able to match ring width patterns among a number of specimens. Unless a group of samples exhibits excellent crossdating, series much less than 50 years are too short for crossdatable patterns to be apparent. While series this short are frequently of little interest in traditional dendrochronology, they can be of great interest to ecologists with little or no other historical data on environmental conditions on a particular site.

Detecting Subtle Variations in Environmental Conditions

The ability to detect subtle variations in environmental parameters is also much greater using dendrochronology as compared to ring-counting techniques. This is because with precise dating of individual rings, it is possible to relate year to year variations in growth to year to year variations in environmental conditions. This allows the development of precise statistical relationships between the tree-ring and environmental data which can be used to make statements about how growth responds to various combinations and degrees of environmental change (Eckstein and Frisse 1982, Fritts 1976, Thompson 1981). Use of these precisely determined relationships between ring widths and environmental conditions is also the basis upon which otherwise unavailable information on past environmental conditions can be reconstructed (Cropper 1982, Holmes et al. 1982, Meko 1982, Swetnam 1983).

With ring-counting, the ever-present missing and/or false rings allow only approximate dating of any individual ring. This precludes the possibility of developing precise statistical relationships between year to year ring-width and environmental data. As a result, only very major environmental changes or events in the recent past are detectable with ring-counting techniques.

CONCLUSIONS

Of the two major approaches to tree-ring analysis, dendrochronology is generally preferred. This is because of the accuracy with which rings can be dated, and the precise relationships which can then be developed between ring width and environmental data. Where long chronologies can be developed, there is also the possibility of reconstructing certain environmental parameters for the length of the chronology. The primary drawback of depending strictly on dendrochronology is that for those species and sites where crossdating is not feasible for one reason or another, valuable information contained in tree rings will be unavailable indefinitely.

Ring counting provides an alternate approach to dendrochronology. There are situations where it is more appropriate than dendrochronology given the objectives and constraints of a particular study, and many other situations where it is the only feasible approach. The primary problems with the past use of ring counting have been a lack of awareness on the part of researchers of (1) the amount of effort required to produce accurate ring counts and (2) the limitations of analyzing a data set that is not precisely dated.

There appears to be a general impression that tree-ring counting requires less effort than dendrochronology. In reality, there is relatively little difference between them in the total amount of effort required when they are done properly.

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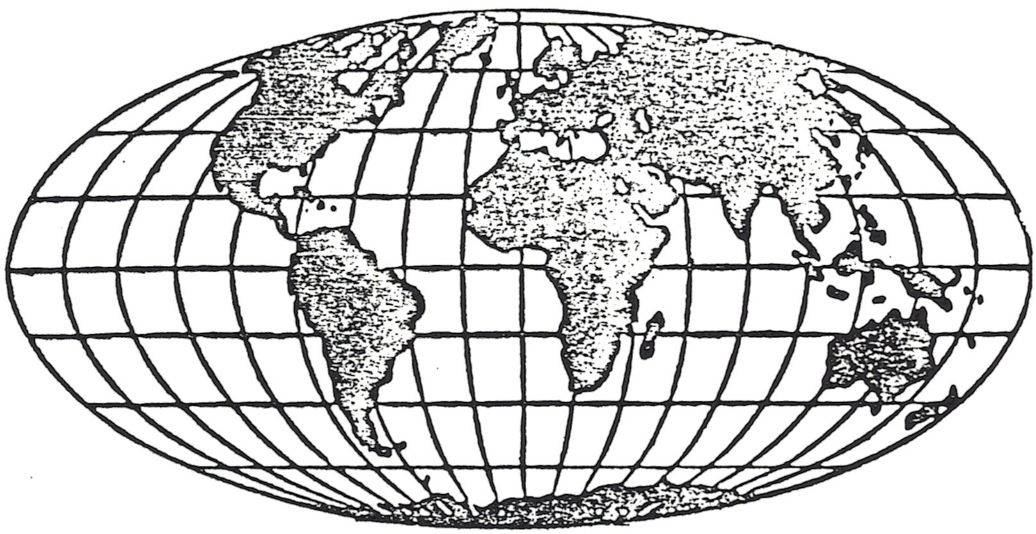

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