Estimating the date of a single bole scar by counting tree rings in increment cores

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Received March 22, 1989
Accepted June 9, 1989

MEANS, J. E. 1989. Estimating the date of a single bore scar by counting tree rings in increment cores. Can. J. For. Res. **19**: 1491-1496.

This paper describes a method of estimating the date of single bole scars, evaluates its accuracy, and describes circumstances suited and unsuited to its use. This technique involves counting tree rings in cores taken through and on either side of a scar so that the ring including or preceding the scar can be identified and dated. Twenty-five single scars ranging in age from 9 to 247 years were dated by this technique, by counting rings in wedges cut with a saw and by crossdating prescar growth as the standard of comparison. Sixteen of 21 dates obtained by counting rings in increment cores were equal to those based on crossdating; errors ranged from −2 to +3 years, with one exception. This core counting technique should prove useful for estimating scar dates when crossdating is infeasible because of infrequent marker rings or insufficient prescar growth (e.g., caused by rot) and cutting boles is not convenient or allowed. However, it should be evaluated for each species and locale to determine if estimated dates will be accurate enough to meet study objectives.

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Cette étude présente une méthode pour estimer l'âge d'une blessure au tronc, évalue sa précision et décrit les conditions qui rendent ou non son utilisation possible. La technique consiste à compter les cernes sur des carottes prélevées dans et de chaque côté d'une blessure, de telle sorte que les cernes formés antérieurement et subséquemment à la blessure puissent être identifiés et datés. Vingt-cinq blessures âgées de 9 à 247 ans ont été datées par cette technique en comptant les cernes dans des entailles pratiquées à la scie et en utilisant comme standard de comparaison les cernes existants au moment de la blessure. Seize des 21 dates obtenues, en comptant les cernes sur des carottes, étaient identiques à celles déterminées par datage comparé. À l'exception d'un cas, l'erreur variait de −2 à +3 ans. Cette méthode, basée sur le comptage à partir de carottes, devrait être utile pour évaluer l'âge des blessures quand le datage comparé est impossible, dû au manque de cernes repères ou à l'absence de cernes antérieurs à la blessure à cause de la carie par exemple, ou lorsqu'il n'est pas facile ou permis de couper le tronc. Cependant, la méthode devrait être évaluée pour chaque espèce et chaque endroit afin de déterminer si l'évaluation est suffisamment précise pour atteindre les objectifs de l'étude.

[Traduit par la revue]

Printed in Canada / Imprimé au Canada

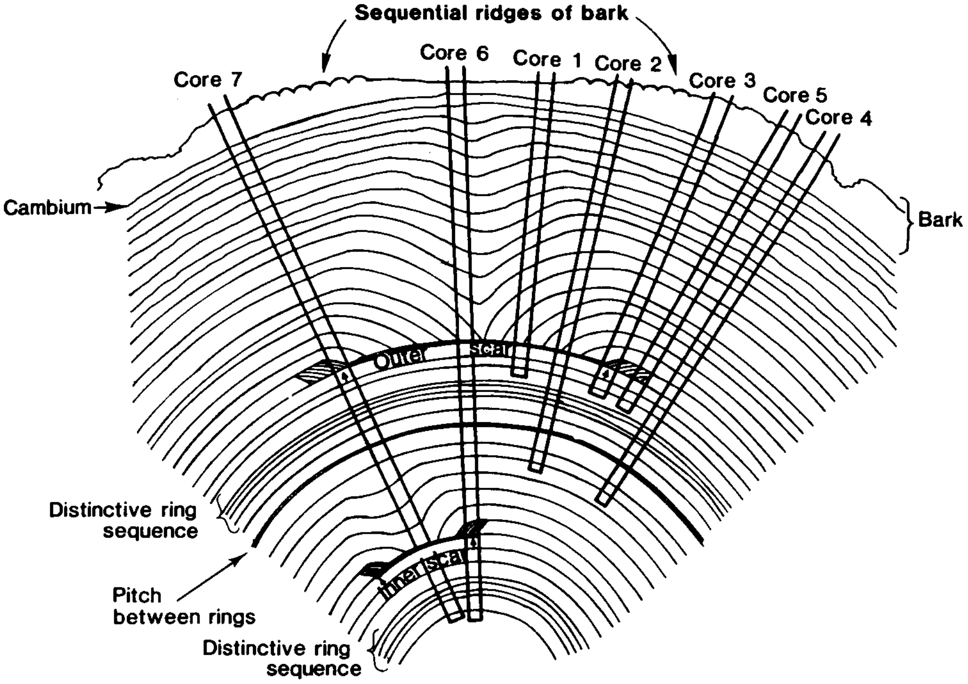

FIG. 1. Tree cross section showing two bole scars and the increment cores used to date them by counting rings. The scar (delineated by arrows) is the zone where the cambium was killed. Part of each first postscar ring is shaded darker to indicate a shock ring that is short in circumference. In Douglas-fir, scars can be identified 50–200 or more years after the wound has closed, by the pattern created by sequential ridges of bark that heal over the wound.

Introduction

Several fire history researchers have found that counting rings in increment cores is a helpful technique for dating bole scars (Spurr 1954; Frissell 1973; Heinselman 1973; Tande 1979; Greenlee and Moldenke 1982; Means 1982; Agee *et al.* 1986; Barrett and Arno 1988), though the most common method involves cutting cross sections or wedges (e.g., McBride and Laven 1976; Arno and Sneck 1977; Madany *et al.* 1982). In contrast, other researchers have found that counting rings in increment cores may result in large errors in scar dates (e.g., Fritz 1940; Cwynar 1977; Zackrisson 1980; Romme 1982; McBride 1983). Of those who claim to have obtained acceptable scar ages by counting core rings, only Barrett and Arno (1988) published descriptions of the technique, but they do not present any dates obtained with the technique or evaluate its accuracy.

Thus, two important questions are unanswered: What level of accuracy can be expected from the technique? What circumstances are appropriate for its use and what are not?

The purposes of this paper are (*i*) to describe a technique (including several variations) for estimating the date of single bole scars by counting rings in increment cores; (*ii*) to evaluate the accuracy of this technique using crossdating that is highly accurate (Stokes 1980); and (*iii*) to discuss its advantages and disadvantages and the conditions under which it gives acceptable dates. Others present and discuss methods for determining dates of disturbances such as fires when single scar dates do not agree exactly (Madany *et al.* 1982; Arno and Sneck 1977). Crossdating (as opposed to ring counting) prescar rings in increment cores can provide scar dates accurate to the year (Swetnam 1984; Sheppard *et al.* 1988), but is infeasible when marker rings or sequences are far apart or there is insufficient prescar growth for crossdating due, for example, to rot.

Terminology

A scar is defined as the portion of the cambial zone where the cambium is killed by one injury. A single scar is defined as a scar separated from other scars (if present) by uninterrupted rings when viewed in cross section. A tree may have more than one single scar if, for example, the first scar completely heals over before a second injury occurs. A closed scar is one that has healed over completely; an open scar is one that has not. Scar age is the number of rings counted in the postscar xylem produced after the scarring injury.

When a tree was injured during the growing season, the scar ring is defined as the ring that includes the scar. For dormant season scars (which occur between rings) in the Pacific Northwest, I define the scar ring as the ring that precedes the scar (ring with adjacent late wood). This definition is appropriate for this region because (*i*) natural fires commonly occur in late summer (Burke 1979) during late wood formation (Emmingham 1977; Griffith 1960); (*ii*) they may also occur in the fall after ring formation is complete; and (*iii*) scars in late wood cannot reliably be distinguished from dormant season scars in cores, In contrast, for dormant season scars in other areas, the scar ring may be defined as the ring with adjacent early wood in fire history studies, if for example, fires commonly occur before the initiation of ring growth in the winter or spring of the same calendar year. The scar date is the year of the scar ring.

The edge of the scar is the boundary between the scar and the zone where cambium was not killed. When viewed in a core (core 3, Fig. 1) part of the first postscar ring will be anatomically connected to the prescar xylem and part will not.

A shock ring is sometimes produced immediately in response to scarring and is often darker than other rings, especially adjacent to the scar (Shigo and Marx 1977). Alexander (1980, p. 101) shows a jack pine (*Pinus bank-*

siana Lamb.) cross section with what appear to be distinct shock rings. Shock rings may include longitudinal traumatic resin canals (Panshin and De Zeeuw 1980, p 148).

Description of the technique

The basic technique

Cores should be taken from close to the base of the tree, where possible, to avoid partial or missing rings that may be more common near breast height (Zackrisson 1980). Increment borers should be kept sharp and clean (Agee and Huff 1986), and cores extracted carefully (Phipps 1985). The basic technique for collecting and counting core rings is described as follows for the outer scar in Fig. 1.

Core the scar where it has been grown over (core 1, Fig. 1). This provides a ring count that underestimates scar age. The scar can be identified in the core by the slanted, postscar rings that end abruptly at the scar and by the lack of anatomical connection between the pre- and post-scar xylem.

Take one or more cores successively closer to the edge of the scar to obtain successively closer estimates of scar age (core 2, Fig. 1).

Take at least one core that intersects the edge of the scar or is outside the scar to identify the scar ring.

Identify the scar ring by one of several methods, listed here in order form most to least reliable:

(*a*) A core that includes the edge of the scar and an area where the cambium was not killed (i.e., to the side of the scar) provides certain identification of the scar ring (core 3, Fig. 1). This method often requires taking 10 or more cores to date deeply buried scars in large-diameter, old-growth Douglas-fir (Means 1982).

(*b*) A distinctive ring sequence (see example in Fig. 1) that predates the scar can be used as a bench mark to identify the scar ring by counting the number of rings from this sequence to the scar ring, in a core through the scar (core 2, Fig. 1). Then the scar ring can also be identified in a core that does not include the scar (core 4, Fig. 1) by counting toward the cambium from the distinctive sequence. This is a powerful method because changes in ring width or in early wood : late wood ratio from all causes, including those that obscure climatic sensitivity (e.g., changes in competitive stress, herbivory, other injuries), produce useful distinctive ring sequences.

(*c*) The scar ring can be identified if it has the appearance of a shock ring near the scar. Shock rings in Douglas-fir may be identifiable in cores (core 5, Fig. 1) by their darker color, but this darker color is short in circumference and may be missed when boring (core 4, Fig. 1).

(*d*) Pitch may be deposited immediately outside the scar ring between the pre- and post-scar xylem, as may occur in old-growth Douglas-fir.

Some rings when viewed in a core, e.g., if darker like a shock ring or if separated by pitch (Fig. 1), could be mistaken for the scar ring if method *a* or *b* were not used. The true scar ring can be distinguished from these others because it is just 1 or a few years older than the greatest age counted to the scar (core 2, Fig. 1). Thus, preliminary ring counts should be made in the field, to be certain the scar ring can be identified and dated in the laboratory.

Transport cores carefully, e.g., in straws (Maeglin 1979), then dry, mount on boards, and surface as needed for making accurate counts in the laboratory (Phipps 1985).

Estimate the scar date by counting inward from the cambium to the scar ring, using more than one core, if possible.

Variations on the basic technique

This technique, initially described for closed scars, is easily adapted to single open scars, in which case all cores can be taken through the live cambium. Overlapping single scars (inner and outer scars, Fig. 1) can be dated if the inner scar healed over before the outer scar occurred (Table 1). The outer scar is dated first as previously described; then the inner scar is dated similarly, except counting is done inward from the outer scar in cores that intersect the outer scar (cores 6 and 7, Fig. 1, using method *a* or *b*). A clear mental image of the two scars is required, and unusual scar-healing growth or inexperience can make this image difficult or impossible to visualize.

Verification of dates

Methods and results

Scars sampled to evaluate this technique were in trees on hot, dry sites on the H.J. Andrews Experimental Forest. Generally, 2–6 cores were required to date a scar. Probable cause of the scar was identified when possible (Table 1): logfall scars had the scarring agent (log) present at the scar, no prescar bark present over the scar, and were occasionally orientated at an angle from the vertical. Logging scars were adjacent to past logging activity (e.g., old landings or roads), faced the logging activity, had no prescar bark present over the scar, and were dated to the known period of logging activity. Fire scars (all of which were on Douglas-fir) had several of these characteristics: they occured on the uphill side of the tree, were extended to or near the ground, had charred prescar bark present near the scar, were located under deep crevices in the bark, and had some prescar bark over the scar. Scars up to 235 years old were almost all grown over, but were usually easily identified by the parallel vertical ridges of bark produced by annual progression of new growth over each wound (Fig. 1); the thick bark of Douglas-fir can apparently accumulate for centuries.

After mounting and sanding cores and sanding wedges, the samples were dated by (*i*) counting postscar rings in cores under a 10–40× microscope using the core counting technique described here, (*ii*) counting postscar rings on wedges, and (*iii*) crossdating prescar rings as the highly accurate standard for comparison (Sheppard *et al.* 1988). The dates from these methods allow partitioning the errors from the core counting technique into those caused by using cores instead of wedges and those caused by counting rings instead of crossdating (Table 1).

Sixteen of 21 scars were dated accurately with the core counting technique as verified by crossdating (Table 1), including two pairs of overlapping single scars (trees DFJ5 and DF15). Errors were caused by nonoccurrence of 9 partial and 19 missing rings in cores, and by counting in cores three false rings within shock rings near scars in western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), a common occurrence in this species. Most errors were corrected by counting rings in wedges instead of cores, but the largest error and one other were only detected by crossdating.

In previous work (Means 1982), fire dates obtained with the core counting technique ranged from 1844 to 1847 in 16 trees apparently scarred by one fire in a 1-ha stand and were accurate to within 2 years; crossdating of a wedge cut from a nearby fire scar gave a date of 1846 (tree DFJ1, Table 1). Counting core rings under a binocular microscope in the laboratory as recommended in this work, rather than with a hand lens in the field as was done, might have improved the precision.

Discussion of verification work

Data from the verification study suggest that the core counting technique will meet the needs of some studies. For example, errors of 1 to 3 years would have been acceptable for dating scars caused by falling logs to estimate residence

TABLE 1. Accuracy of dating bole scars by counting postscar rings in increment cores (core-counting technique) for scars from trees on the H.J. Andrews Experimental Forest, Cascade Range, western Oregon

		Year of scar-dating technique			Error (years)	
Tree No. by species	Probable cause of scar	Counting cores	Counting wedges	Crossdating	Using cores instead of wedges[a]	Counting instead of crossdating[b]
Pseudotsuga menziesii						
DF1	Log fall	1975	1975		0	
DF2	Unknown		1923	1923		0
DFJ1	Fire	1847	1847	1847	0	0
DFJ2	Unknown	1947	1947	1947	0	0
RDF2	Fire	1798	1798	1795	0	+3 (2, 1, 0)
DFJ4	Log fall	1933	1930	1930	+3 (3, 0, 0)	0
DFJ5	Log fall	1948	1948	1948	0	0
DFJ5	Fire	1911	1911	1911	0	0
DF11[c]	Logging	1975	1975	1975	0	0
DF12	Fire	1839	1839	1839	0	0
DF13	Fire	1839	1839	1839	0	0
DF14	Fire	1849	1849	1849	0	0
DF15	Fire	1849	1849	1849	0	0
DF15	Fire	1828	1828	1828	0	0
DF16	Logging	1957	1957		0	
DF17	Log fall	1950	1950	1950	0	0
DF19	Fire	1868	1864	1846	+4 (4, 0, 0)	+18 (0, 18, 0)
DF20	Fire	1889	1889	1889	0	0
DF21	Fire	1738	1738	1738	0	0
DF22	Fire	1889	1889	1889	0	0
Tsuga heterophylla						
WHJ1	Unknown	1934	1934		0	
WHJ2	Logging	1960	1962	1962	−2 (0, 0, 2)	0
WH5	Log fall	1953	1953	1953	0	0
WH6	Logging	1963	1963	1963	0	0
WH7	Logging	1961	1962	1962	−1 (0, 0, 1)	0
Castanopsis chrysophylla						
CACH1	Log fall	1975	1975		0	

NOTE: Dates from counting cores are compared with dates from counting wedges and from crossdating prescar rings on cores and wedges (standard of comparison; Sheppard *et al.* 1988). Positive errors indicate omission of partial or missing rings in counts of postscar growth; negative errors indicate counting of false rings in the first postscar ring in cores near the scar. Causes of error are given in parentheses as number of partial rings, number of missing rings, and number of false rings, respectively.

[a] Error in core-count date corrected by counting rings in wedge.

[b] Error in wedge-count date corrected by crossdating.

[c] This scar was caused by logging activity known to have occurred in the spring and summer of 1975.

times of logs decomposing on the forest floor, where unexplained variation was high and residence times ranged from 0 to 313 years (Means *et al.* 1985). Errors of up to 2 years were acceptable for a stand development study (Means 1982) because they were small relative to the mean fire interval of 103 years and minor differences in dates almost certainly were not caused by a short fire return interval.

In other contexts, however, errors from the core counting technique of even a few years would be serious; for example, in studies of fire history in forests with fires frequent enough that inaccurate dates of the same fire could be judged to be separate fires (e.g., Dieterich 1980). An error of 22 years (tree DF19, Table 1) would be serious in most studies. It could, for example, be interpreted as a separate fire, underestimating the mean fire interval. Clearly, if highly precise dates are required, then crossdating of cores (Sheppard *et al.* 1988) or wedges (Madany *et al.* 1982) will be necessary.

Missing or partial rings (Table 1) were found only in sequences of very narrow rings (from 0.5 mm to less than 0.05 mm wide) that were decades within the xylem or adjacent to the vascular cambium. Large numbers of missing rings (18 in tree DF19) are previously reported for Douglas-fir on the west side of the Oregon or Washington Cascades only in response to volcanism (Yamaguchi 1983), and are probably caused by poor vigor due to rot, crown breakage, and thin gravelly soils in a climate with summer drought. I expected partial or missing rings to be associated with the initial trauma of scarring, but they were not. It seems reasonable to assume that most errors in the core counting technique could be avoided if Douglas-firs with narrow rings (<0.5 mm) are not sampled on these sites.

Conclusions and recommendations

The technique of counting rings in increment cores described in this paper can provide useful estimates of scar dates when it is not convenient or possible to take wedge or cross sections, and when the errors expected are small enough to allow a study to meet its objectives. Therefore, before the technique is used, its accuracy must be determined for the locale and species under study by comparing its scar dates with those based on crossdated cores (Sheppard *et al.* 1988) or wedges (Madany *et al.* 1982). In addition to guiding the selection of the core counting technique, this comparison will help determine sources of errors and may make possible their reduction or avoidance. If this comparison indicates serious errors will be unavoidable, then crossdating will be necessary.

Advantages and suitable circumstances

Using increment borers to extract cores, in contrast to cutting wedges, does little damage to the appearance or strength of the tree. Strength is important, for example, where trees are exposed to strong winds. Increment-borer holes heal closed more rapidly than do wedge cuts and so reduce the opportunity for disease or insect entry. Also, heavy motorized equipment is not needed. These advantages indicate the technique may be well suited for use in parks, wilderness, and nature preserves.

This technique will work when there are insufficient prescar rings for crossdating; for example, if rot has destroyed some rings or if the tree was young when scarred. This situation occurred with trees DF1, DF16, WHJ1, and CACH1 (Table 1).

This technique will provide dates on sites where limits to tree growth do not vary much from year to year, so the marker rings used for crossdating are unavailable behind some scars.

Disadvantages and unsuitable circumstances

This technique is not well suited for dating multiple scars, i.e., scars without intervening continuous rings. Heinselman (1973) and Frissell (1973) dated up to quintuple the fire scars using increment cores, identifying the shock ring with method *a*. These dates, however, supplemented those from cross sections and wedges to map the extent of fires first dated in cross sections. Other scar-coring techniques may be used to date multiple scars by counting rings (Barrett and Arno 1988), but potential errors have not been evaluated. Cutting wedges and counting rings (Arno and Sneck 1977) when the resulting errors are known to be acceptable, or crossdating (Madany *et al.* 1982), will probably be necessary where multiple scars are common.

Using the core counting technique, it is impossible to correct individual dates for missing rings. Partial rings (tree DFJ4, Table 1) and false rings (tree WHJ2) may also cause errors. For example, partial rings in coast redwood (*Sequoia sempervirens* (D. Don) Endl.) may be so common that some radii have more than 100 missing rings (Fritz 1940).

Dating a scar by increment boring requires identification of the scar ring. When rot or insects have destroyed wood near the scar, this may not be possible, or many borings may be required to find intact wood. Such scars can sometimes be dated with wedges or cross sections if intact xylem can be found by cutting.

Extracting the cores needed for dating usually takes longer than cutting a wedge with a chainsaw. However, the coring technique may be faster if trees must be felled or a handsaw used to obtain cross sections or wedges.

Acknowledgements

I thank Leland Miller and Rob Morrow for help with sample collection. Jim Agee, Steve Barrett, Mark Huff, Fred Swanson, and Tom Swetnam provided helpful reviews. This work was supported by grants DEB 80-12162 and BSR-85-14325 to Oregon State University from the National Science Foundation.

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