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Using photomanipulation to facilitate the cross-matching of difficult species for dendrochronological research

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Introduction

This paper describes the procedure developed to apply dendrochronology to an endemic New Zealand tree species which presents several fundamental challenges (see figs 1&2). "Cross-dating is the most important principle of dendrochronology" (p.20, Fritts, 1976) and depends on the identification of similar variations of growth parameters, such as annual ring widths, within trees and between trees across an area. Although many approaches exist to achieve this, where New Zealand species are concerned, Norton & Ogden (1987) recommend a visual based approach to cross-dating because of the frequency of anomalous tree rings. This new approach to visual cross-dating is computerised, it uses scanned images of the prepared cores, and adapts the technique of skeleton plotting based on Schweingruber, Eckstein, Serre-Bachet & Bräker (1990).

There have been no published cross-dated chronologies using Kahikatea (*Dacrycarpus dacrydioides),* a New Zealand native *Podocarpaceae* species and authors, e.g. Bell & Bell (1958), Cameron (1960) and Stewart, Norton & Fergusson (1991) have all commented on the difficulties posed by lobate growth causing wedged and locally absent rings. Stewart *et al.*, 1991 avoided the annual resolution problem when investigating heavy metal accumulation in the species by using blocks of ten tree rings. Although not annually resolved, Stewart *et al.* (1991) showed the synchronous increase of heavy metals related well to the known historic increases in industrial activity. Stewart et al. (1991) thus support the assumption that the tree rings in this species are predominantly annual, albeit with anomalies.

Patel (1967) describes the growth rings themselves as "indistinct to slightly distinct, occasionally distinct" while Dunwiddie (1979) states that rings had good clarity. Dunwiddie (1979) notes that lobate growth is less with younger trees, and considered the species worthy of more detailed investigation. This current study used a range of tree size classes to control for the problem of lobate growth. We found sufficient variability in the samples to justify both of these opposing descriptions, although in general Dunwiddie's viewpoint is favoured. Often ring clarity was poor (see figures 1 & 2), either very faint or obscured within broad bands of late wood. Missing and wedged rings were identified and false rings (sub-annual rings), as described by Norton & Ogden (1987), were also observed. However these problems have not precluded dendrochronology but rather have catalysed the development of suitable and specific methods.

This digitalised approach to dendrochronology enables new methods and techniques. Photo-enhancement improves the visibility of faint tree rings (see figure 1), enabling ring border identification. Tree ring width measurements can be saved and reviewed against the image of the core, thus proof of every measurement is retained. Photo-manipulation can rescale images so that tree rings of different sizes can be compared directly. Skeleton plotting and tree ring measuring standardises data with respect to time, whereas this technique standardises the image size of the tree rings themselves so cores can be directly compared side-by-side. This helps by quickly identifying stretches of similar growth within cores from the same tree and from different trees, and provides the platform for visual cross-matching.

In addition to providing materials to evaluate the dendrochronological potential of this species, the motivation behind this project is to investigate the influence of hydrology on growth in the Wairarapa Valley in the southeast of The North Island of New Zealand. This area has a particular sensitivity to climate variation and the Southern Pacific Climate Oscillation (Watts, 2005). A complete tree ring network should help develop a fundamental understanding of the plant-water relationship and how river and groundwater management, including adjacent groundwater abstraction is influencing this riparian forest species.

The challenges posed by difficult wood morphology

The wood samples varied greatly, such as tree ring visibility and wood density. Wood texture affected the quality of preparation and hence the difficulty of identifying the ring borders and counting the tree rings. The species displays lobate growth, particularly with larger specimens which often have stout buttresses but lobate growth is present to some extent in most trees in all size classes. This growth habit poses problems for cross-matching because locally absent (missing) rings can often occur in one or more cores per tree or arcs of cross-sections. The corollary is that in other parts of a cross-section the rings are enlarged which makes microscope based comparison harder because the rings have such large size differences. Identifying the interannual variability can be difficult when wood samples have either very strongly or weakly growing regions.

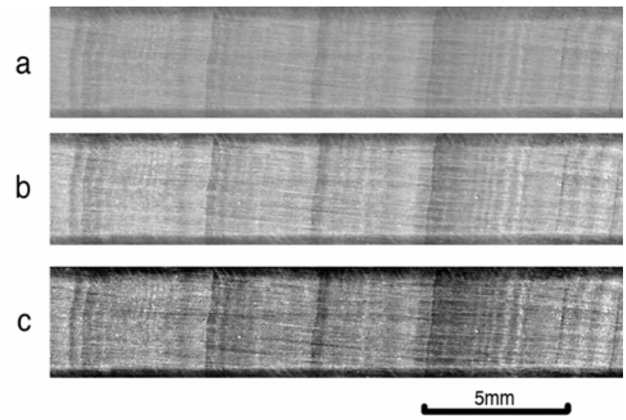

Figure 1. Faint ring borders with multiple density fluctuations and false rings. Adjusting the original scan (a) and enhancing the contrast and brightness (b) and 'blue channel only' (c) greatly improves visibility.

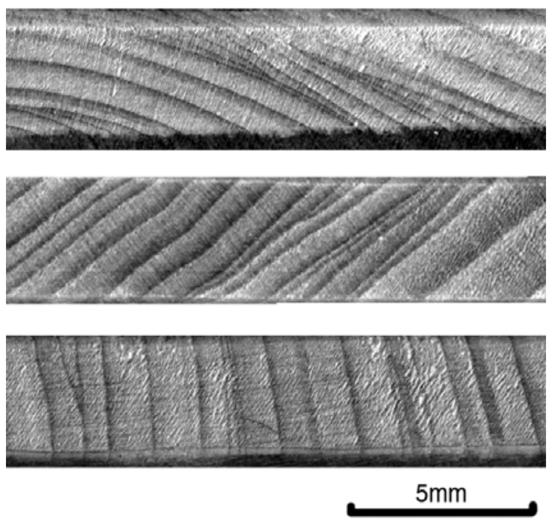

Figure 2. Examples of wedged and locally absent rings.

A further complication has been caused by false rings (see figure 1). These intra-annual structures were frequently encountered and can appear quite similar to normal ring borders (with regard to colour, morphology and size) but generally they were less well defined and the 'early-wood' between the false ring and the annual ring was comparatively very small. False rings tended to be less than 600 µm, occurring early in the growth season (possibly frost influenced) or at the end, when there could be a series (3 or more) of these anomalies. Occasionally, during cross-matching a faint ring which appeared similar to examples of false rings was, because of the context of the surrounding data, identified as an annual ring border. Conversely, extremely narrow (<600 µm) ring widths can be annual growth depending on the context. For example a series of small rings can occur under conditions of extreme competition, and across sections of lobate growth where rings are wedging (figure 2) and/or narrow but not appressed as where rings are locally absent. Narrow rings can also occur individually within a series of much larger rings and may represent a poor growth year.

Thus there seems to be no simple or fixed rules for determining whether an apparent tree ring is an annual ring border or not, and so all rings must be considered individually and within their chronological context, both within the tree and the sample site. These digital methods: using image files that allow repeated changes to counting without affecting the quality of the image; saving measurement tracks for review and the viewing of cores, side by side and of the same scale, really support the detailed and painstaking task of cross-matching.

Methodology

Core preparation

The cores were dried between absorbant kitchen-paper until thoroughly air-dry then packed for postage from New Zealand to Germany. The cores were glued to wooden mounts ready for the surface to be prepared by cutting or microtome. Several techniques have been tried but most often a WSL sledge microtome was used. Using a knife blade also provided a clean exposure but generally wasted more wood. After cutting, chalk dust was used to increase the contrast before scanning.

Scanning cores and file preparation

After preparation, the cores were scanned tree-by-tree using an Epsom Expression 10000 XL flatbed scanner with at least a resolution of 1200 dpi. Adobe Photoshop^{TM} (Adobe, 2005) was used to crop the files and the original image layer locked to prevent further changes. All markings, e.g. counting, decades or skeleton plots, were made in a new layer in the file and not on the original image itself. Separate copies of the images were kept for the different purposes, i.e. the files that would be measured were not altered from the original dimensions and the files that were used for the scaling plots were not measured.

Photoshop^{TM} offers several useful ways to adjust the image to be able to see faint structures (see fig 1.). The most useful of these has been to simply view the blue channel, meaning the blue frequencies in the image are shown in monochrome. This shows tree ring borders much more clearly and it is easy to switch between full colour and blue channel without making a change to the image. Other tools adjust the image itself and were only applied to copies of the original image saved as overlying layers. The most useful tools are found in the IMAGE tab, then ADJUSTMENTS. Changing the LEVELS, CHANNEL MIXER and BRIGHTNESS/CONTRAST can improve areas where tree rings are faint or ambiguous (see fig.1).

Counting and skeleton plots

Using Photoshop^{TM} every counted ring was marked below with a dot, decades were marked with two overlapping dots and one above using the traditional notation (1 dots for decades, 2 for 50 years and 3 for centuries). Skeleton plots (adapted from Schweingruber *et al.*, 1990) were marked in the space between cores against a white background to be more visible. Particularly large and small rings were identified by comparison to the 2 rings either side, and graded with either 3 dots for most extreme, 2 for strongly different and 1 dot for mild differences, either above or below a line to show relative magnitude. In a similar fashion skeleton plot data was recorded on paper.

Preparing files for measuring

The software Lignovision™ (Rinn, 2006) was used to measure the images. Lignovision™ supports jepg or bitmap formats but not file formats with layers so copies of each core were saved as jpeg files. Each core scan was cut into 2 or more overlapping sections. This was to provide multiple measurements of some of the rings and to reduce the size of file the computer had to handle. There is also the benefit when measuring because although measuring was conducted in the magnified window, the image is also shown in a navigation window and it was helpful to have the entire image large enough to see enough detail to help with orientation and perpendicularity while working on the magnified section.

Measuring and data treatment

Tree rings were measured using the continuous line function, i.e. clicking at each ring border and manually judging the most appropriate path across the early wood. The magnifier window was always used, most often at 3 times magnification but less if a structure appeared better defined at lower magnification. The measurement tracks and the tree ring widths were saved and the ring widths from each image section were checked and the data were saved for each complete core, and then collectively for each tree using TSAP™ (Rinn, 2005).

Scaling plot file preparation

Scaling plot files were prepared by having all the cores of a single tree as different layers in the same image file. This allows the TRANSFORM function to be conducted on each core individually and all the cores can be compared side by side on the same scale. Data of regions of cores showing strong similarities can be plotted on the paper skeleton plot of the tree's cores. Commonly the cores showed several phases or waves of larger and smaller growth rings and these can occur such that there is wide growth on one core and much less on another others. Repeatedly re-scaling the images allows for direct comparison and avoids the discomfort of extended microscope use, particularly the eyestrain from constantly switching between microscope, computer monitor and graph paper.
The favoured shorthand name for this technique is *ghost plotting* because it shows the presence of similarity in the bones of the skeleton plots without the fully resolved annual structure (see figure 3).

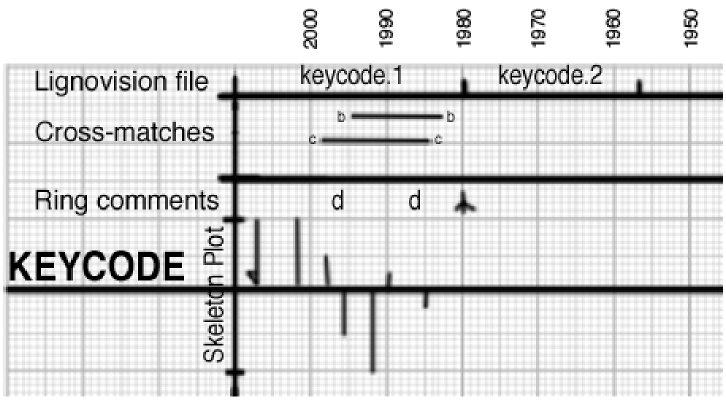

Figure 3. Example of how the data can arranged. 'Lignovision file' refers to the overlapping sub-sections of each core. 'Cross-matching' shows which regions of this core that strongly visually cross-match to regions of other cores. 'Ring Comments' would include density anomalies and missing rings etc. 'Keycode' is the core's reference code and here there is space for the skeleton plot. All cores of a tree are plotted on a single sheet of paper.

Cross-matching

The approach is incremental and acknowledges that it is practically impossible to ascribe the correct year to the tree rings in the first instance. In most cases it was possible to cross-match the pattern of tree ring growth using a series of pointer years (often groups) and directly compare each tree ring to the others in the tree until missing rings or false rings are identified. These changes are noted on the paper plot and then new versions of the images are made reflecting changes to the dating. Subsequent measurement adjustments are made and updated file versions are saved. Thus the ring width measurements are iteratively cross-matched and the data ready for analysis.

Although somewhat slower than other methods, for species that are new to dendrochronology and are proving challenging because of similar morphological features, this method's robust and practical approach to visual cross-matching could be helpful. Comparing these several representations of the cores, i.e. the scans and ghost plot files, the measurements, measurement tracks and paper skeleton and ghost plots, are very useful for managing the problems posed by the wood morphology in this species, for reducing human error as much as possible and most importantly provides a strong framework for identifying and rectifying discrepancies in the data.

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