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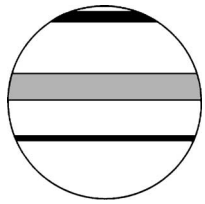
Holocene comment and reply



Determining the age of the mid-Holocene *Tsuga canadensis* (hemlock) decline, eastern North America: a comment on Bennett and Fuller

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Abstract: The new date provided by Bennett and Fuller (2002) for the mid-Holocene hemlock (*Tsuga canadensis*) decline in eastern North America is questioned in the light of recent advances in the palaeoecology of the decline. It is concluded that the 'new' date gives a false impression of the dating accuracy of a complex ecological event of relatively long duration.

Key words: *Tsuga canadensis*, Holocene, age-depth modelling, radiocarbon age determinations, pollen, eastern North America.

In a recent issue of *The Holocene*, Bennett and Fuller (2002) revisited the timing of the mid-Holocene hemlock (*Tsuga canadensis* L. (Carr.)) decline, one of the most important ecological events that took place in temperate forests of eastern North America (Davis, 1981; 1983). Twenty years after the first attempt to date as precisely as possible the hemlock decline (Webb, 1982), Bennett and Fuller (2002) have used a larger data set to suggest that the age of the decline is 4750 ^{14}C yr BP 'with a standard error of the mean of about 50 years'. They concluded that this date is slightly older than Webb's (1982) evaluation of 4634 ± 304 ^{14}C yr BP (with standard error of the mean of 43 years). The determination of the age of the hemlock decline is considered by Bennett and Fuller (2002) 'as an exercise to examine the problems with the determination of the age of any event'. Here I question the relevance of Bennett and Fuller's (2002) work in the light of recent advances in the palaeoecology of the decline closely associated with natural forest disturbances and, more particularly, I question the misuse and interpretation of radiocarbon dates that go beyond the limits of the method. This 'new' determination of the age of the hemlock decline gives a false impression of dating accuracy of an ecological event that is not properly described by the authors.

Using the North American Pollen Database, Bennett and Fuller (2002) selected 60 sites and divided them into three data sets based on the number of radiocarbon dates in pollen sequences: a, b and c. One data set (c) retained for the analysis included 20 sites (30%) having only one radiocarbon date! The other data sets had two or more (b) and three or more (a) radiocarbon dates. Data set b corresponds (Bennett and Fuller, 2002: Table 1) to pollen cores having two or more dates bracketing the decline, for example the Lac à St-Germain site (Savoie and Richard, 1979) with bracketing dates of 8060 ± 210 yr BP at 490–500 cm and 3990 ± 145 yr BP at 270–280 cm, and the Lac Marcotte site (Labelle and Richard, 1981) with bracketing dates of 6920 ± 85 at 185–195 cm and 4040 ± 80 yr BP at 90–100 cm. Radiocarbon dated bulk sediments (gyttja) were 10 cm thick in several cores examined for this study, thus reducing greatly the time resolution. AMS dating was not available or not used in most pollen cores listed. The determination of the age of the hemlock decline was based on different age-depth models, yielding a radiocarbon age far more precise than is justified. One can deplore the fact that the pollen and ^{14}C data set used by Bennett and Fuller (2002) was not filtered and validated to eliminate dubious material, problems of sampling intervals and quality and quantity of dated bulk sediments, as well as ill-dated pollen sequences. Whatever the validity of statistical treatments used to calculate the age of the hemlock decline, the procedure appears elusive in that it is based on a pot pourri of unchecked data.

In the introduction to their investigation, Bennett and Fuler (2002) state that the hemlock decline was an 'essentially synchronous event' throughout the species range during the mid-Holocene, and that 'there was no spatial pattern to the decline'. Whether these assumptions are good or false, it is a matter that deserves more work in sites yielding direct evidence of the decline. The seminal works of Davis (1981; 1983) pointing to the identification of the hemlock decline and its biotic origin in the Holocene records of eastern North America have influenced generations of pollen analysts, who were able to acknowledge the widespread occurrence of the mid-Holocene event across the species range. Pollen studies reporting on the palaeoecology of the hemlock decline have been most useful in providing a general temporal and spatial framework of the event, in particular those studies including well-dated pollen sequences. Unfortunately, the work of Bennett and Fuller (2002) does not go beyond this. Significant progress to pinpoint the timing, nature and magnitude of the hemlock decline must rely on the reconstruction of the event, in particular from direct macrofossil evidence, a condition rarely met because of the scarcity of well-drained sites harbouring mesophilous forest plants contemporaneous with the damaged hemlock stands represented by macrofossils preserved in mid-Holocene sediments.

The justification of the study was probably based on the assumption that the decline occurred at a 'single instant in time'. This important assumption was not verified and validated by Bennett and Fuller (2002), who preferred to calculate one single radiocarbon date for the event. Recent papers by Bhiry and Filion (1996a; 1996b; 1996c), not cited by Bennett and Fuller (2002), included detailed and well-dated macrofossil data sets documenting the hemlock decline as a major ecological event spanning 700 radiocarbon years from 4900 ^{14}C yr BP to 4200 ^{14}C yr BP (i.e., about 800 calendar years). The decline was shown to be associated with the activity of insect defoliators, particularly the hemlock looper (*Lambdina fiscellaria*) and the spruce budworm (*Choristoneura fumiferana*), occurring during at least three defoliation events. Direct evidence from insect remains (head capsules), chewed hemlock needles associated with feeding by hemlock looper, and several plant macrofossils was provided to describe the hemlock decline as a long-term event

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composed of successive stand disturbances (Bhiry and Filion, 1996a; 1996b). Confining the hemlock decline to a single point in time, as suggested by Bennett and Fuller (2002), without any other justification than the purpose to provide a 'revised' date for the event, is far from current expectations of palaeoecologists and field ecologists to document the nature and duration of the decline based on direct evidence and more appropriate methods.

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The mid-Holocene *Tsuga canadensis* (hemlock) decline, eastern North America — age versus causes: a reply to Payette

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Abstract: A reply is made to comments by Payette (2004) concerning the paper that attempted to determine the age of the *Tsuga canadensis* decline in eastern North America (Bennett and Fuller, 2002). It is pointed out that his criticisms of the methods used are all aspects covered in the original paper, and which make little, if any, difference to the result obtained. However, ecological aspects of the decline were outside the scope of the paper.

Key words: *Tsuga canadensis*, Holocene, age-depth modelling, radiocarbon age determinations, pollen, eastern North America.

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Introduction

Payette (2004) has questioned the relevance of our earlier paper (Bennett and Fuller, 2002) on the determination of the age of the *Tsuga canadensis* decline in eastern North America. He suggests that our results are insecurely founded because we did not filter and validate the basis data and used data with inadequate dating control. He points out that we neglected all mention of the ecological causes and consequences of the *Tsuga canadensis* decline, and failed to cite relevant papers in this area. We discuss these points below, in the context of the overall scope of our work and the rationale for site selection.

Overall scope

Radiocarbon dates are not accurate measurements of age: they are estimates of a true (but unknown) age, and consequently have an error associated with them. This matter is additionally complicated by the question of calibration, which we leave to one side for the purposes of this discussion. Because a single radiocarbon date is not accurate, it is unwise to rely to single measurements. The *Tsuga canadensis* decline has been dated many times (hundreds, probably). No one has ever felt able to assert that the dating accuracy of any one site is better than others. No one has ever detected consistent patterns of spatial or temporal variability in the available dates. Nearly all studies of the *Tsuga canadensis* decline, to our knowledge, have assumed that it was both synchronous and short-lived (e.g., Davis, 1981; Webb, 1982) (but see below).

Dating the *Tsuga canadensis* decline requires radiocarbon dates. It also requires an accurate location of the *Tsuga canadensis* decline horizon in sediment. Even the most accurate dates are useless if the sampling resolution is coarse.

Putting these aspects together, we adopted a strategy that would enable us to obtain as much information as reasonably possible about the age of the decline in the form of raw data that we could then treat evenly and consistently. The collection of data in the North America Pollen Database (NAPD) is not complete or perfect, but it is substantial, and it is consistently organized and searchable. Few, if any, really poor sites have been entered. We checked that the sites selected according to our criteria (Bennett and Fuller, 2002: 422) were continuous sequences of sediment and that they were relevant for the *Tsuga canadensis* decline, both in terms of recognizing its existence and in terms of dating it. We are aware of additional sites, not in NAPD, that might have been included. However, we also realized that obtaining such data might well be time-consuming and laborious, especially if it was not already in NAPD format. We felt that this extra work was unlikely to be worth it: adding five more sites (or even 20) to a data set of 68 would be scarcely noticeable in the final results.

Some of the sites have only one radiocarbon date. However, it is also possible to assume an age for top sediment, and this we did. All the sites thus had at least two points with an independent age estimate. Dividing the data set into sets with different quality made little difference to the overall results (e.g., Bennett and Fuller, 2002: Tables 3, 4 and 5; additional unpublished analyses). There is in fact a trade-off: being more demanding of site quality results in a smaller database, and hence greater statistical errors. Relaxing the demands gives a larger database, which reduces statistical errors but increases the risk of large errors through including inaccurate data. We chose the latter option, but did check what was happening by subdivision of the data.