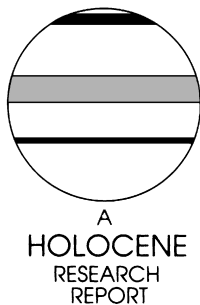


The late-Holocene decline of Casuarinaceae in southeast Australia

S.J. Gale¹ and P.C. Pisanu²

(¹*School of Geosciences, The University of Sydney, Sydney, New South Wales 2006, Australia;* ²*Division of Ecosystem Management, School of Rural Science and Natural Resources, The University of New England, Armidale, New South Wales 2351, Australia*)

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Abstract: In a seminal paper, Crowley (1994a) attributed the decline of Casuarinaceae in Australia during the period of European contact to soil salinization, itself the product of vegetation clearance and raised groundwater levels. However, the post-contact Casuarinaceae decline in the New England area of northeast New South Wales was not associated with salinization. Instead, there is strong evidence that the decline was caused by the preferential use and clearance of these trees by European settlers. Direct human impact must therefore be added to the list of causes of the late-Holocene diminution of Casuarinaceae in Australia.

Key words: Casuarinaceae, vegetation history, Australia, Holocene, Quaternary, human impact.

Introduction

The widespread decrease in the incidence of Casuarinaceae in Australia during the Quaternary has long been a source of controversy among palaeoecologists. The most recent contribution to the debate is that of Crowley (1994a; 1994b) who has argued that the Casuarinaceae decline was the result of increased soil salinity and/or rising groundwater levels. She has extended this thesis to the period of European contact, interpreting the frequently observed late-Holocene diminution in Casuarinaceae as the product of soil salinization, itself a consequence of vegetation clearance and raised groundwater levels (Crowley, 1994a: 18). Crowley acknowledged that Casuarinaceae were cleared by the European settlers and that their wood was valued for fuel (Crowley, 1994a: 18). Nevertheless, she has contended that there is no evidence that the clearance of Casuarinaceae was any more extensive than that of other trees and, by implication, that there was no preferential use of this taxon by the European colonists.

At least in some circumstances, however, the post-contact Casuarinaceae decline was not associated with soil salinization. Instead, there is compelling evidence that the decline was a direct consequence of the preferential use and clearance of these trees by European settlers.

The study site

Little Llangothlin Lagoon is a shallow, internally draining lake basin, lying 18 km northeast by north of Guyra at an altitude of

1360 m on the highest part of the New England Tablelands of northeast New South Wales (Figure 1). The catchment is largely made up of basalt, although the underlying granite is exposed along the northern divide. The lagoon is dammed by a 1 km long sand lunette on its eastern side. The lake has no outlet and consequently acts as an efficient trap for sediment mobilized on the catchment surrounds.

The mean annual rainfall just to the north of the catchment is 1051 mm (White, 1986: 186), with a minor summer maximum. Mean daily maximum temperatures at Guyra range from 10.2°C (July) to 22.8°C (January), while mean daily minima vary from –1.0°C (July) to 11.6°C (February) (Bureau of Meteorology, 1995: 302). The climate falls within the Cfa category of the Köppen classification.

The natural, post-contact vegetation in the vicinity of the catchment may be subdivided into three types on the basis of topography. The hilltops and upper slopes support a closed *Eucalyptus viminalis*-*E. pauciflora* grassy forest, with a herb layer dominated by *Poa* sp. (snow grass) and *Themeda australis*. The lower slopes possess an open *E. stellulata* dwarf woodland, and the valley bottoms are characterized by open *E. nova-anglica* taller woodland (Williams, 1963: 44–47).

The history of early colonial land use in the catchment is summarized by Gale *et al.* (forthcoming). Briefly, the Llangothlin run was originally taken up by Thomas Augustus Perry in 1837 (Gardner, 1854a: 70). Perry built his homestead at Ben Lomond, 2 km northwest of Llangothlin Lagoon and within a few

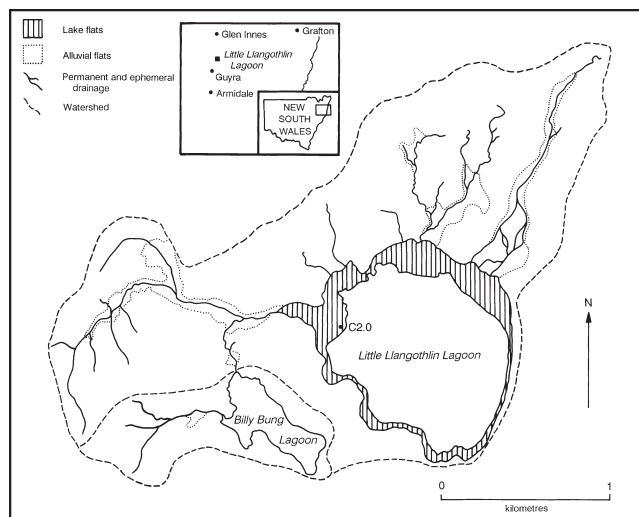


Figure 1 The catchment of Little Llangothlin Lagoon, Guyra, northeast New South Wales. Mapping based on field surveys and 1984 aerial photographs.

kilometres of Little Llangothlin (Russell, 1888: 236). Perry left Llangothlin sometime in the early 1840s (Walker, 1963: 1) and the station appears to have been owned first by Arthur Joseph Maister (Gardner, 1844–46: 5; 1846), who went bankrupt in 1844 (Kerr, 1844), and subsequently by William Rawson, who occupied the run until at least 1847 (Abbott, 1972: 15–16). The squat-terage was taken up by Charles F. Codrington sometime between 1847 and 1851 (Galloway, 1851; Massie, 1851a; 1851b), from whom it was purchased by Christopher Thomas Bagot in 1861 (Walker, 1963: 1–2).

The first squatters ran sheep on the property. By November 1845, Rawson grazed 6000 sheep on 50 000 acres (Thomson, 1848; Abbott, 1972). Cattle may also have been run on the catchment, although the earliest known reference to this is from 1848 (Massie, 1851b). Unfortunately, we have little direct knowledge either of the nature of the vegetation in the catchment at the time of contact or of the impact of the settlers on the vegetation cover. There is evidence from elsewhere on the Tablelands that trees were cleared, swamps were drained and land was cultivated, but there is no mention in the historical literature of the preferential use or removal of particular vegetation types.

Methods

Extensive coring of Little Llangothlin Lagoon has shown that the longest and highest-resolution sedimentary record in the basin comes from site C2.0, located on the distal edge of the delta formed by the largest stream flowing into the lake (Figure 1). A 1.44 m deep core was taken from this site. The core was sampled in a continuous series of spits, each 40 mm thick. With the exception of the basal sample, all these were analysed for pollen following the palynological procedures adopted by Gale *et al.* (1995). Lead-210 analysis was used to obtain a high-resolution record of sediment chronology, dating back over 180 years. Details of the methods used and the chronology obtained are given by Gale *et al.* (1995).

It is not possible using conventional light microscopy to establish the identity of the particular Casuarinaceae species that have contributed to the pollen assemblage at the lagoon. Three species of Casuarinaceae currently occur in the region (Doran and Hall, 1983). These are *Casuarina cunninghamiana*, *Allocasuarina littoralis* and *A. torulosa*. It is not unreasonable to assume that these were also the species growing on the Tablelands at and immediately after European contact. Some support for this thesis comes

from nineteenth- and early twentieth-century vegetation records. In 1877, Christie recorded *A. torulosa* on the central and northern parts of New England. In 1884, Maiden noted *A. littoralis* on the Tablelands and *A. torulosa* along the escarpment that forms the eastern edge of the Tablelands (Maiden, 1898: 595, 598, 601). As part of the first systematic census of the vegetation of the New England Tablelands, made in 1890–1903, Turner (1903) recorded scattered specimens of *A. littoralis* over this region. Finally, in the later part of the nineteenth century, Campbell (1907: 155) noted the occurrence of *A. littoralis* and *A. torulosa* in the southern part of New England.

There is a suggestion that *C. glauca* may also have been present on the Tablelands during the nineteenth century, but further evidence is required before this can be substantiated.

The Casuarinaceae grains in the Little Llangothlin sediments fall into two discrete size populations (Figure 2). Grains 30–40 μm in diameter are assigned to Casuarinaceae 1; grains 20–25 μm in diameter are assigned to Casuarinaceae 2. On the basis of Kershaw's (1970) measurements of the size ranges of modern Casuarinaceae pollen, Casuarinaceae 1 are very unlikely to represent either *C. cunninghamiana* or *A. torulosa*, but are highly likely to be *A. littoralis*. Similarly, Casuarinaceae 2 are very unlikely to be derived from either *A. littoralis* or *A. torulosa*, but are highly likely to be from *C. cunninghamiana*.

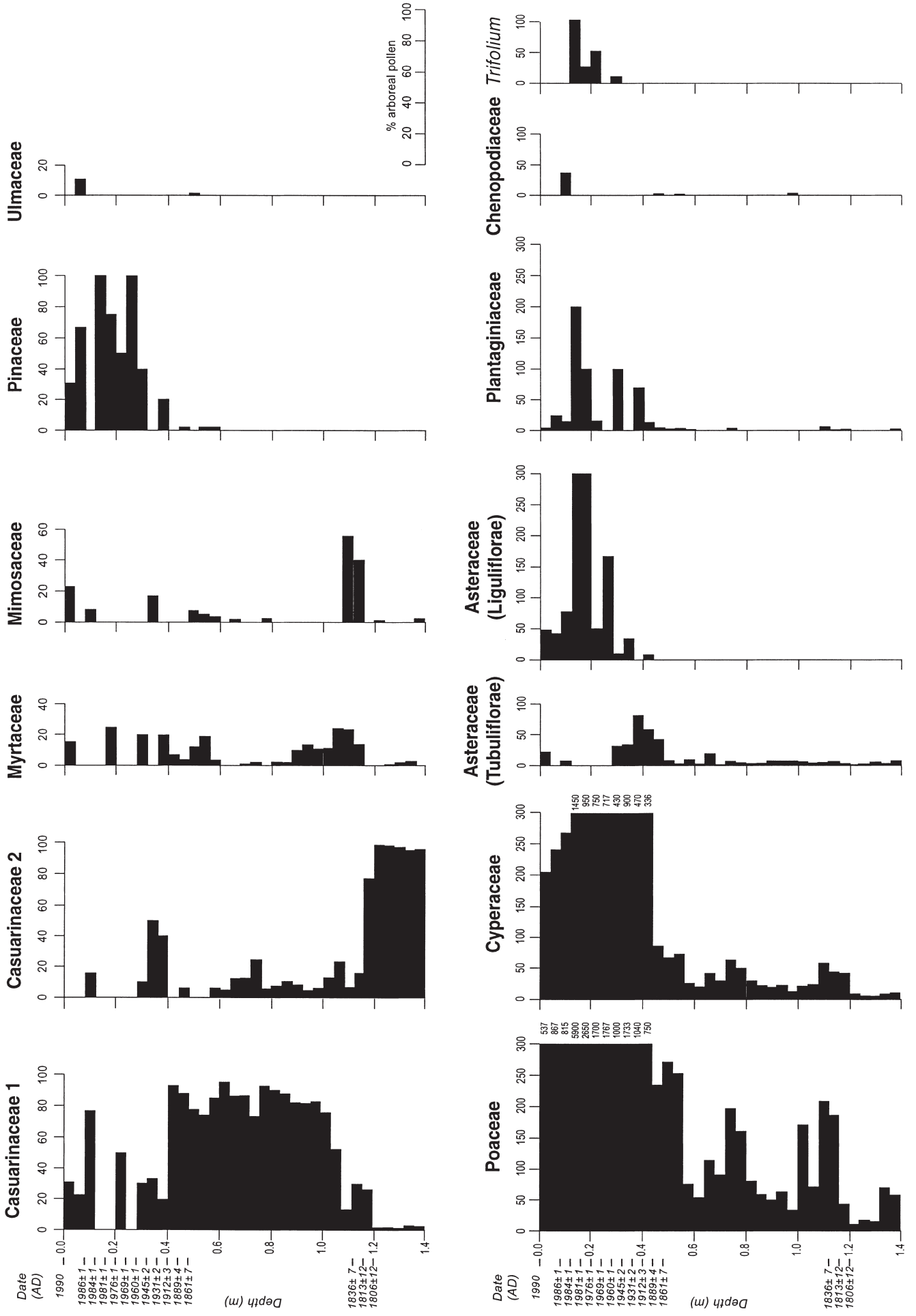
Results

The focus of this paper is on the early colonial decline in the incidence of Casuarinaceae. Detailed interpretation of the pollen data is therefore confined to the nineteenth-century part of the sequence.

The tree and shrub pollen assemblage from the base of the core is dominated by Casuarinaceae 2, with a low incidence of Casuarinaceae 1 and Myrtaceae, and occasional Mimosaceae (Figure 2). This picture changes dramatically at a depth of 1.20 m, where the abundance of Casuarinaceae 1 begins to rise markedly, and then at 1.16 m, where Casuarinaceae 2 decrease significantly, and Myrtaceae and Mimosaceae both rise steeply. The increase in Mimosaceae is short-lived, however, and, above 1.08 m, pollen of this type occurs only rarely and sporadically. The expansion of Myrtaceae is rather more protracted, although this taxon occurs less frequently above 0.88 m. By contrast, the increase in the incidence of Casuarinaceae 1 above 1.20 m is large and dramatic, with an equally sharp fall above 0.40 m. Finally, above ~0.6 m, the pollen of exotic trees such as Pinaceae and Ulmaceae appears for the first time in the record.

The ^{210}Pb chronology shows that the arrival of Thomas Perry to take up the Llangothlin run coincided with the deposition of material at a depth of 1.16–1.12 m in the core (Gale *et al.*, 1995). This is the position at which the massive fall in the incidence of Casuarinaceae 2 pollen occurs and the point at which Casuarinaceae 2 begin to be replaced by Mimosaceae and Myrtaceae, and, finally, by Casuarinaceae 1. Between 1.08 and 0.40 m, the arboreal pollen assemblage is dominated by Casuarinaceae 1. The grains that make up this peak are largely broken and crumpled (Figure 3). Such grains are diagnostic of mechanical damage sustained during the reworking of pollen from the catchment to the

Figure 2 Pollen diagram, core C2.0, Little Llangothlin Lagoon, Guyra, northeast New South Wales. Pollen counts are expressed as a percentage of the total tree and scrub (as defined by Dodson, 1974) pollen frequency in each sample. The Casuarinaceae are divided into two groups on the basis of size. Grains 30–40 μm in diameter are assigned to Casuarinaceae 1; grains 20–25 μm in diameter are assigned to Casuarinaceae 2.



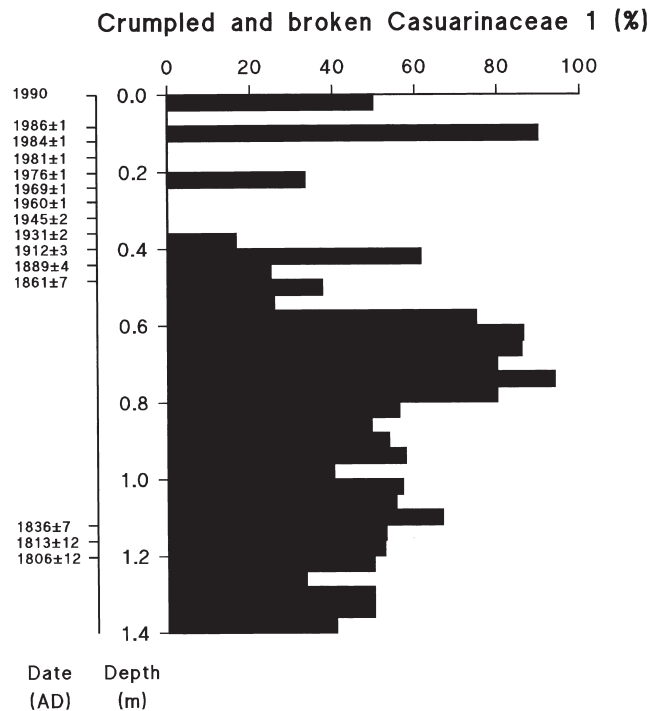


Figure 3 The percentage of Casuarinaceae 1 pollen grains that are crumpled and broken, core C2.0, Little Llangothlin Lagoon, Guyra, north-east New South Wales.

deposition site (Delcourt and Delcourt, 1980). This interpretation is supported by the deficit of excess ^{210}Pb in this part of the core. This is suggestive of a phase of intensive erosion during which subsoil was transported into the basin from the catchment slopes (Gale *et al.*, 1995: 402). It is also supported by the relatively high mass-specific magnetic susceptibility and zero to low frequency-dependent magnetic susceptibility of these sediments (Gale and Hoare, 1991: 221). This combination is strongly indicative of a magnetic mineral assemblage dominated by single and multidomain ferrimagnetic grains, and thus by the primary magnetic minerals characteristic of unweathered igneous rocks (Gale and Hoare, 1991: 201–15). The only source of such material in the area is the relatively unweathered basalt and its associated regolith found beneath the catchment surface. Such material can only have reached the lake as a result of deep erosion of the regolith and the bedrock. The high incidence of Casuarinaceae 1 between 1.08 and 0.40 m in the sequence may therefore be a consequence of the reworking of pollen into the lake during an episode of intensive erosion rather than a change in vegetation in the catchment.

Hypotheses of Casuarinaceae decline

What caused the dramatic and selective diminution of Casuarinaceae in and around the catchment? Crowley (1994b) has reviewed the hypotheses previously advanced to explain this phenomenon. These include increased fire activity, a change to a wetter climate, the competitive replacement of Casuarinaceae by *Eucalyptus*, and increased soil salinity and/or higher groundwater levels. We review each of these hypotheses here and assess their capacity to explain the Casuarinaceae decline at Little Llangothlin Lagoon.

Increased fire activity

Workers such as Hooley *et al.* (1980: 360–61), Singh *et al.* (1981: 43, 46) and Singh and Geissler (1985: 429–39) have argued that Casuarinaceae are largely fire-sensitive and that increasing fire frequency and/or intensity results in a decrease in their incidence.

There is frequent reference in the historical literature to the Aboriginal use of fire on the New England Tablelands both prior to and during the European takeover of the region (see, for example, Oxley, 1820: 290; Marsh, 1867: 41–42; Irby and Irby, 1908: 41). Aboriginal burning must have decreased markedly in the years after contact as the Aborigines moved off or were forced away from the newly established properties. Burning would also have declined as Aboriginal populations fell as a result of disease and war, and as their traditional way of life was modified by contact with European society. An exhaustive search of diaries, station records, letters, etc. from the first few decades of European settlement has revealed not a single reference to the use of fire by the colonists. Charcoal occurs only rarely within the sediments of Little Llangothlin Lagoon, suggesting negligible burning within the catchment, at least since the time of European settlement. In general, European pastoralists appear to have distrusted and feared the use of fire, at least in the very early days of colonization. Fire was used in the management of grazing lands (Mitchell, 1848: 413), but, looking back, Hamilton (1892: 200) was able to write: 'And although at the present time (and still more in older days) the settlers burn off long dry grass so that their stock may have the fresh, young feed which so soon appears, yet on the whole it has been their aim to fight the fires and keep them down.' The evidence thus strongly points to a decrease in fire activity on the Tablelands during the time of the decline of Casuarinaceae 2 in the pollen record.

Change to a wetter climate

It has been argued that a shift to moister conditions will favour *Eucalyptus* over Casuarinaceae (D'Costa *et al.*, 1989; Luly, 1993). There is strong evidence, however, that the Tablelands experienced drought-dominated conditions throughout the first half of the nineteenth century; that is, from well before to well after the time when the decline in Casuarinaceae 2 occurred. Thus, Cunningham (1828) recorded exceptionally dry conditions during 1827 on his journey across the Western Slopes of northern New South Wales. Similarly, Hall (1927) and Foley (1957) have provided evidence of drought conditions further south in the colony in the first half of the nineteenth century. Most significantly, Gardner (1854a: 55–56), writing about the Liverpool Plains, just to the south of New England, in the early 1850s, commented: 'Who will deny that great changes have taken place since the white man took possession of Australian soil. The native tribes are unanimous on this position, that the seasons are altered to the "dry way" in Comparison of what they were antecedent to that eventful period.'

Competitive replacement of Casuarinaceae by *Eucalyptus*

At first sight the evidence from Little Llangothlin Lagoon appears to support the argument that Casuarinaceae are replaced competitively by *Eucalyptus*. Thus, above 1.16 m, the decline in the incidence of pollen of Casuarinaceae 2 is reciprocated by an increase in Myrtaceae. However, the Myrtaceae themselves begin to decline above 1.04 m. More importantly, this thesis has been developed in the context of the more rapid migration of Casuarinaceae from glacial-stage refugia than *Eucalyptus* (Dodson, 1977: 112–13; D'Costa *et al.*, 1989: 480; Edney *et al.*, 1990: 337–38). Yet the historical records show that eucalypts had already achieved a broad regional distribution throughout New England by the early nineteenth century (Oxley, 1820: 288–96; Everett, 1838: facing p. 19; Marsh, 1867: 55) and it seems unlikely that the mid-nineteenth-century replacement of Casuarinaceae 2 around the lagoon could have been the result of the final stages of migration of *Eucalyptus* from refuges elsewhere on the Tablelands.

Soil salinization

Support for the argument that the decline in Casuarinaceae is the result of soil salinization has been obtained from the inverse relationship observed between Casuarinaceae and salt-tolerant Chenopodiaceae in many Australian Quaternary pollen diagrams (Crowley, 1994a; 1994b). Chenopodiaceae pollen occurs only rarely within the Little Llangothlin Lagoon sequence, however, and its incidence is quite unrelated to that of Casuarinaceae (Figure 2). Rather more importantly, New England does not suffer from soil salinization (Northcote and Skene, 1972; Graham *et al.*, 1989), nor is there any history of salinization in the region. This therefore cannot be the explanation of the late-Holocene decline in Casuarinaceae in the area.

Higher groundwater levels

There are few clues to the nature of groundwater conditions either in the catchment or across the Tablelands as a whole in the early years of European colonization. Nevertheless, the evidence of drought-dominated climates at this time is indicative of a fall in groundwater recharge and a long-term decline in groundwater levels throughout the early nineteenth century. Higher groundwater levels are therefore unlikely to be the cause of the Casuarinaceae decline.

Discussion

None of the hypotheses advanced by Crowley (1994b) to explain the decline in Casuarinaceae is applicable to the record from Little Llangothlin Lagoon. In particular, none is capable of explaining the preferential decline of Casuarinaceae 2 (?*C. cunninghamiana*). Nevertheless, several other explanations are possible. First, the wood of all three species found in the region provides excellent fuel (Maiden, 1889: 397, 400; Anderson, 1968: 67, 120; Doran and Hall, 1983: 26, 40, 48) that is likely to have been preferentially selected by the squatters. Second, the foliage of *C. cunninghamiana* and *A. littoralis* may be used as drought fodder (Maiden, 1889: 122; Anderson, 1968: 67), while the seedlings of *C. cunninghamiana* are relished by stock with the result that natural regeneration rarely occurs in areas to which domestic livestock have access (Anderson, 1968: 67). Third, there is contemporary documentary evidence that Casuarinaceae were cleared for timber by the European immigrants (Gardner, 1854a: 54; 1854b: 49). The wood of *C. cunninghamiana*, for example, was favoured for shingles, staves and bullock yokes (Maiden, 1889: 397; Anderson, 1968: 67; Doran and Hall, 1983: 26). *A. littoralis* was used for shingles, farm buildings and in furniture-making (Maiden, 1889: 400; Anderson, 1968: 120; Doran and Hall, 1983: 40). *A. torulosa* was used for shingles, flooring and cabinet work (Maiden, 1889: 400; Anderson, 1968: 120; Doran and Hall, 1983: 48). Finally, there is strong evidence that early clearance efforts in New England focused on wetter areas (Cane, 1949: 26, 28, 71), exactly those places favoured by *C. cunninghamiana* (Doran and Hall, 1983: 26).

There are thus convincing grounds for believing that particular species of Casuarinaceae may have been felled preferentially by the early colonists. Furthermore, the farming practices of the European settlers may have caused the preferential loss of certain types of Casuarinaceae (particularly *C. cunninghamiana*) and prevented their regeneration. In this context, it should be noted that, unlike the other two species, *C. cunninghamiana* occurs as pure stands in narrow riverine belts (Doran and Hall, 1983: 26, 40, 48). It is therefore relatively easy to eradicate. More speculatively, it is possible that the failure of *C. cunninghamiana* to re-occupy riverine habitats after clearance may be linked to the introduction of *Salix alba* 'Tristis' to the area by the early colonists. *S. alba* occupies an environment similar to that required by *C.*

cunninghamiana. Moreover, it was introduced to the Tablelands at exactly the time that the first clearances were taking place (Young, 1923: 403). The widespread occurrence of *S. alba* along watercourses in New England (although not in the catchment of Little Llangothlin Lagoon) may therefore be a result of the displacement of *C. cunninghamiana* from its former habitat.

Conclusions

The arguments put forward by Crowley (1994a; 1994b) to explain the Late Quaternary decrease of Casuarinaceae in Australia are compelling ones. Nevertheless, the decline of Casuarinaceae 2 at Little Llangothlin Lagoon during the late Holocene cannot be a result of soil salinization. Nor are any of the other mechanisms advanced by her to explain this phenomenon adequate. Instead, the close relationship between vegetational disruption at the site and the arrival of the squatters and their sheep argues strongly for a human-induced cause. Although the precise mechanism by which this may have operated is unknown, there is good evidence of the preferential use of particular Casuarinaceae species by the early European settlers and the preferential loss of certain species as a result of early colonial practices. That this conclusion may be applied more generally across southeast Australia is indicated by findings hinted at elsewhere. For example, D'Costa *et al.* (1989: 479) speculated that the decline of Casuarinaceae in the vicinity of Tower Hill, western Victoria, after 1850 was the result of land clearance and the collection of firewood. Similarly, Kershaw *et al.* (1994: 91) showed that there had been a substantial decrease in the incidence of Casuarinaceae pollen across southeast Australia within the period of European settlement. They argued that this was because of the preferred use of Casuarinaceae for firewood in the early days of settlement and because Casuarinaceae were more affected than *Eucalyptus* by intensive firing practices, although no specific evidence was offered in support of these statements. Direct human impact must therefore be added to the list of causes of the Australian Casuarinaceae decline, at least within the context of late-Holocene environmental history.

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