



The tolerance of *Sequoia sempervirens* to sedimentation, East Coast region, New Zealand

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Abstract

The health of three redwood (*Sequoia sempervirens*) stands on alluvial terraces at Waipare, East Coast Region, New Zealand, was monitored for three years after flooding during Cyclone Bola in March 1988. Overall, 27 trees of a population of 402 died, all in the stand where sediment deposits were the thickest and the most extensive.

Anaerobic conditions developed where 60-90 cm of sediment was deposited, causing death of some trees within 10 months. Where sediment depth was 30-60 cm, many trees had unhealthy crowns after the first year and some of these subsequently died. However, where less than 20 cm of sediment was deposited, trees were unaffected.

In contrast, redwood trees in hillside plantations were unaffected by the aggradation of landslide-derived materials around their base. Landslide deposits rarely exceeded 50 cm depth, and materials remained loosely compacted and free-draining. Redwoods may therefore be suitable for planting on free-draining eroding hillslopes in the East Coast Region, but not on terrace sites where deep sediment deposits may lead to anaerobic conditions.

Introduction

Certain biological characteristics allow redwood (*Sequoia sempervirens*) in its natural habitat in California to exploit alluvial flats subjected to periodic flooding and coarse sediment deposition (Stone and Vasey 1968). A second root system develops adventitiously from the buried portion of the stem, which allows redwood to survive successive burials by up to 9 m of flood-deposited sediment (Stone and Vasey 1968). This edaphic tolerance suggests that planting redwood may be a possible long-term solution to erosion problems in the East Coast Region of the North Island, New Zealand (Burdon 1975).

Two storms in 1985 (Ngatapa) and 1988 (Cyclone Bola), affecting different parts of the East Coast Region, caused severe hillslope erosion, with subsequent flooding and sedimentation of alluvial flats. After both storms, redwood stands subjected to flooding initially showed signs of stress and some trees eventually died. This paper records and interprets redwood mortality at Waipare after flooding and sedimentation in 1988.

Study Area

At Waipare, 61 km north of Gisborne City (Fig. 1), three stands of 67-year-old redwood (an area of 1.18 ha) are located on an alluvial terrace 5 m above river bed level between State highway 35 and the Hikuwai River. All three stands were in good health in 1976 when stands B and C were experimentally thinned. Growth and yield figures measured in 1985 are given in Table 1. In 1987 these stands were gazetted 'Scenic Reserve B' status.

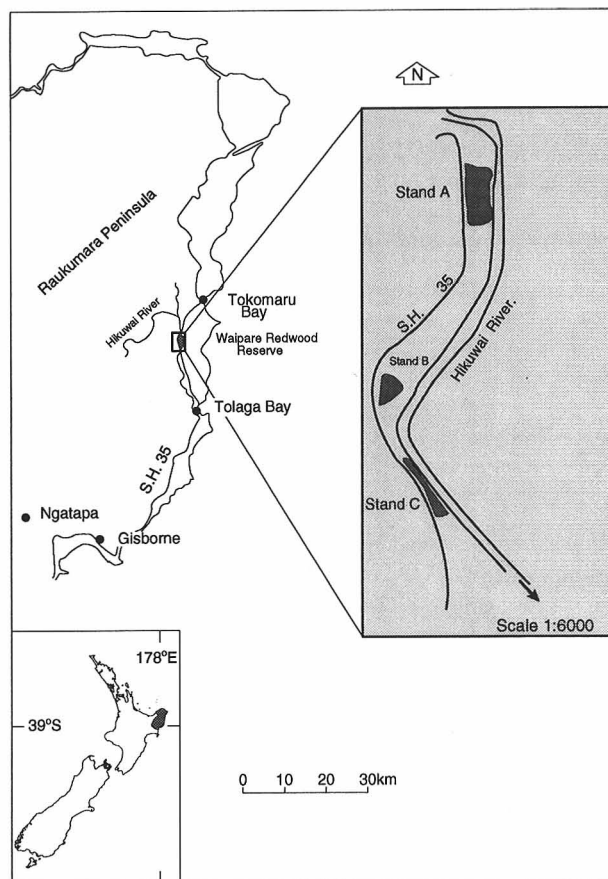


Figure 1: Location of three stands of *Sequoia sempervirens* comprising Waipare Redwood Scenic Reserve.

Table 1: Growth and yield figures (1985) of redwoods at Waipare Reserve (Source: Lands and Survey File 13/163, DOC File RSN 035).

	Area (ha)	Age	Ave. height (m)	Ave. diam. (cm)	No. of trees	Vol. (m ³)	Vol/ha (m ³)	M.a.i. per ha
Stand A	0.25	61	34.1	52.3	234	477	1908	31
Stand B	0.73	61	38.9	82.6	111	579	793	13
Stand C	0.20	61	38.0	93.6	57	381	1905	31
Totals					402	1437		
Means			37.0	76.0			1218	

The terrace has two levels, with 0.5 m vertical separation, and slopes gently toward the river. Soils are fertile, well-drained Waipaoa Silt Loam (Rijkse and Pullar 1978), with a weakly

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developed profile of shallow topsoils low in organic matter and a clay content of 22-47%, overlying alluvium.

The East Coast Region has a history of severe storms, many of which are cyclones of tropical origin. South-eastward movement of these cyclones is sometimes stalled, resulting in heavy rainfalls. These extra-tropical cyclones occur about once every 12 years (New Zealand Meteorological Service, 1988). Cyclone Bola (5-9 March 1988) yielded five-day rainfall totals in excess of 900 mm in the headwater catchment areas drained by the Hikuwai and its tributary streams. The estimated return period of this event was greater than 100 years (pers. comm. Gisborne District Council). Debris lodged in the trees showed that flood levels reached 3 m in the Waipare redwood stands during Cyclone Bola.

Results

Ten months after Cyclone Bola, all three redwood stands showed signs of canopy yellowing. This was worst in Stand C, particularly in parts closest to the river where three trees had died. Coppicing at the base of the trees with yellow crowns was also affected, though to a lesser degree.

In March 1990, two years after Cyclone Bola, the appearance of the canopy foliage within the two least affected stands (A and B) had changed little. However, Stand C had deteriorated markedly (Fig. 4). Canopy foliage had thinned to the extent that the once shaded ground was now sunlit. Coppicing around root crowns had died, and the number of dead or stressed trees had increased to 19. There was no adventitious root development, but approximately half of the stressed trees showed signs of new foliage sprouting from their lower trunk. The reddish tinge of the cambium layer indicated that these trees were still alive.

In February 1991, three years after Cyclone Bola, the trees in Stand C that had shown signs of recovery had died and a further eight trees showed advanced stages of decline. The signs of stress present initially in Stands A and B were no longer apparent.

Augering showed that there were no accumulations of flood-deposited material that could be attributed to historical storm events before Cyclone Bola. The depth of sediment deposited after flooding in 1988 in Stands A and B was less than 10 cm, but in Stand C it varied from 10 cm close to S.H.35 to over 90 cm close to the river (Fig. 2). The shallowest deposits were moist but not saturated. In the deepest deposit, the sediment was uniformly moist between ground level and 60 cm depth, but between

60 and 80 cm depth it was saturated. The texture of the sediment was predominantly medium to fine-grained sand. However, in the saturated zone fine to very fine-grained sand contained a higher proportion of silt and clay-sized material and had a pungent smell indicative of anaerobic conditions. Beneath this saturated zone another layer of moist sediment up to 20 cm thick overlay a 10-cm-thick horizon of rich black humus, which represented the pre-Bola ground surface (Fig. 3). By summer 1990 the zone of moist sediment immediately above the buried humus became progressively more saturated and anaerobic as the saturated zone migrated downward. Below the humus was coarser, buff-coloured Waipaoa Silt Loam which, together with the humus, remained dry and friable throughout the period of observation.

Mapping the distribution of individual trees in Stand C relative to depth of siltation (Fig. 2) showed that dead and dying trees occurred where sedimentation was thickest (30-90 cm), i.e., on the lower of the two terrace levels. In contrast, live trees and vigorous coppice growth were almost wholly confined to the upper terrace level where sedimentation was less than 25 cm.

In contrast to the terrace stands, hillside plantations of redwood remained unaffected by the aggradation of landslide materials around their base. Soil and rock remained loose and free-draining after deposition. Redwood showed no short-term signs of stress even where landslide deposits exceeded 0.5 m depth.

Discussion

Before Cyclone Bola the redwoods at Waipare survived flooding during at least three major storm events in 1936, 1938 and 1948. However, none of these flood events resulted in sedimentation.

Although redwood in California can survive extensive burial by coarse sediment (Stone and Vasey 1968) redwood growing on alluvial flats at Waipare did not survive sedimentation involving fine-grained deposits. The fine-grained, clay-rich mudstones of the East Coast Region are typically of low porosity and permeability. As a consequence, water is entrapped within the deposit, and the lack of gradient on low-lying alluvial terraces also hinders drainage. Oxygen is thus unable to diffuse through the sediment and anaerobic conditions develop.

At Waipare a saturated and anaerobic zone developed at 60-80 cm depth in the thickest sediment deposits. The original root

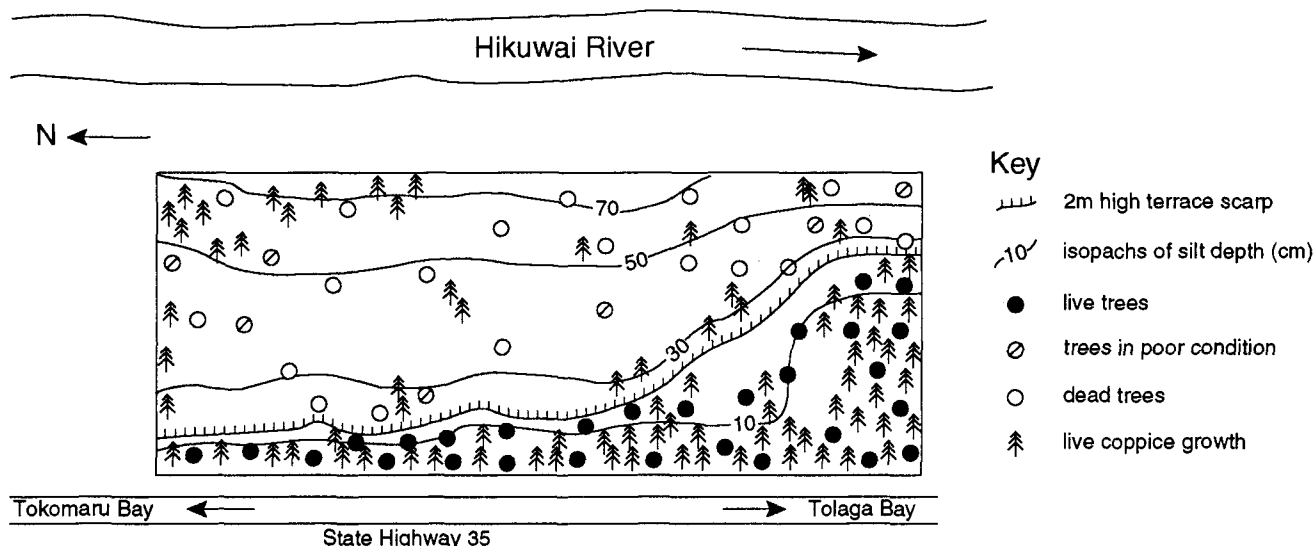


Figure 2: Plan view of Stand C showing distribution of individual trees relative to depth of siltation as at February 1991. Not to scale.

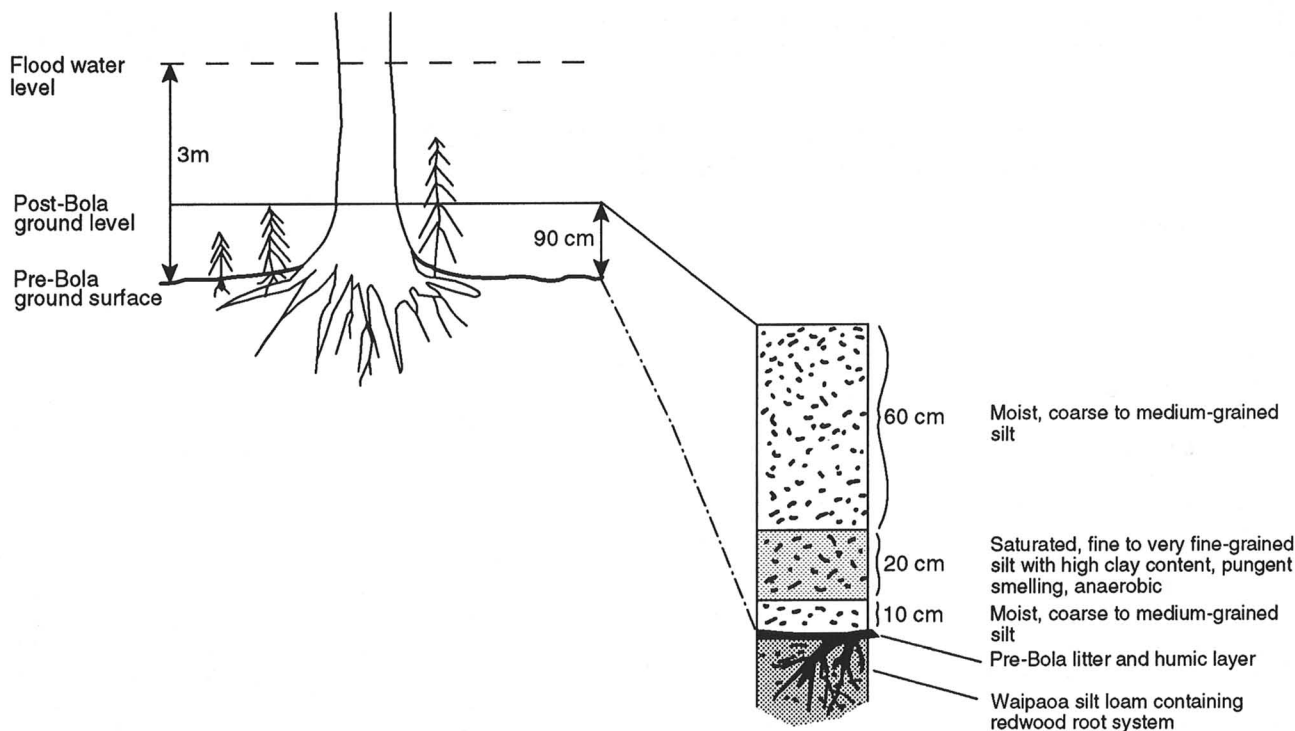


Figure 3: Schematic soil profile at Waipare Redwood Reserve.

systems became deprived of oxygen and in the absence of the development of adventitious roots, three redwood died within 10 months. Mortality was slower (one-three years) where sediment depth was 30-60 cm, as oxygen was able to diffuse through the sediment, but at a much reduced rate. The stressed redwoods eventually died. Only where sedimentation was less than 20 cm thick were redwoods relatively unaffected.

The contrasting survival of hillside redwood plantations after inundation by free-draining coarse landslide materials supports the conclusion that anaerobic conditions developing in deep deposits of fine-grained sediment were the cause of redwood mortality at Waipare.

An examination of other possible causes ruled out foliage disease or insect infestation. Redwood is notably free from diseases and insect pests (Hepting 1971) and no evidence of either was found (Aard Zandvoort, Senior Forest Health Officer, Ministry of Forestry, Rotorua, pers. comm.)

Cyclone Bola has shown that low-lying alluvial flats subject to sporadic flooding should be considered as high-risk sites for redwood establishment, despite the potential for excellent growth rates on such sites. Such an event may occur only once in 100 years, but when accompanied by deep deposits of fine-grained sediment, it is sufficient to kill even mature redwoods. However, the severely eroding hill country of the East Coast Region offers potential for redwood plantings. Redwood tolerance to the aggradation of free-draining, landslide-derived materials could be exploited more fully to combat the erosion problems of this region.

Acknowledgements

Thanks are due to field companions including D. Rowan R. Coker, R. Jackson, and J. Galilee, for the valued discussions during visits to this site. Mr Aard Zandvoort (Senior Forest Health Officer, Ministry of Forestry) kindly inspected the redwood reserve for disease. Diagrams were draughted by T. Farndon. This script was edited by J. Orwin.



Figure 4: Post-Bola photograph (March 1990) of Stand C showing effects of sedimentation on redwood trees nearest to Hikuwai River (left of photo).

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