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Tropical Cyclones: Determinants of Pattern and Structure in New Zealand's Indigenous Forests[1]

W. B. SHAW[2]

ABSTRACT: Tropical cyclones usually form between 10° and 20° latitude but frequently move as far south as New Zealand. Cyclone Bernie, in April 1982, caused extensive damage in central North Island forests. Four other severe tropical cyclones since 1936, are known to have caused damage to indigenous forests throughout the North Island and in parts of the South Island.

Severe storms of extratropical origin also affect New Zealand, and many also result in significant forest damage. The storm regime to which New Zealand is subject is severe enough so that storms themselves could be a major factor in molding stand composition and structure in many, or even most, parts of the country.

THE DECISION TO INVESTIGATE in some detail the role of violent storms in the ecology of New Zealand's forests was taken after cyclone Bernie affected the North Island during April 1982, causing extensive forest damage with gusts of almost 100 knots. Tropical cyclones usually form between 10° and 20° latitude but frequently move as far south as New Zealand (lat. 34°30′–47°30′) during late summer or autumn (January–April). A few tropical cyclones other than Bernie are also known to have caused massive damage in New Zealand forests.

Severe storms of extratropical origin also reach New Zealand and may result in significant forest damage; for example, *Nothofagus* forests in the Canterbury region of the South Island have suffered blowdown from gales (Norton and Wilson 1981, Wardle 1983).

This paper discusses the significance of storms of tropical origin in molding stand composition and pattern.

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[2] Consultant to the Department of Lands and Survey. Present address: University of Waikato, Department of Biological Sciences, Private Bag, Hamilton, New Zealand.

TROPICAL CYCLONE BERNIE

On 9 and 10 April 1982, cyclone Bernie swept down the east coast of the North Island of New Zealand. This storm formed just below the equator, and Figure 1 records its path. Very high winds, generally from a northerly direction and gusting to 92 knots, were recorded in many parts of the North Island. Damage to both exotic and indigenous forest stands was often extensive, and sometimes severe, over approximately 30% of the North Island, particularly in central regions (Figure 2).

Urewera National Park Damage

Urewera National Park (Figures 2, 3) covers over 212,000 ha of highly dissected terrain from 150 to 1415 m altitude. The area is almost entirely covered by evergreen forests consisting of various mixtures of over 50 species of trees. Community patterns are often complex, reflecting the influences of altitude, slope instability, vulcanity, fire, humans, introduced animals, and past and present climatic extremes such as storm, frost, and snow damage.

At lower levels, *Beilschmiedia tawa* dominates along with *Weinmannia racemosa* and *Metrosideros robusta*. These hardwood species are often associated with podocarp species,

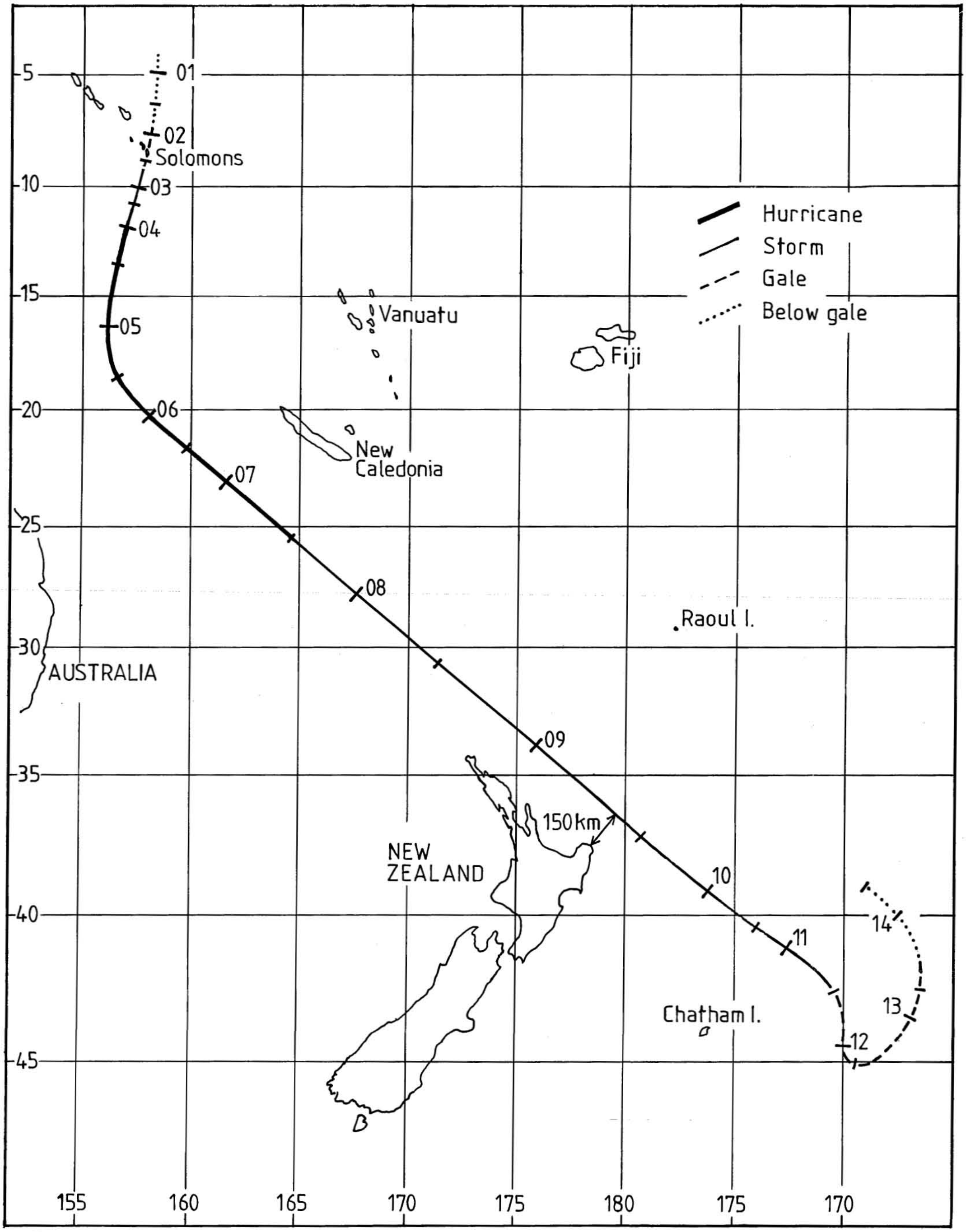

FIGURE 1. Track of cyclone Bernie 1–14 April 1982.

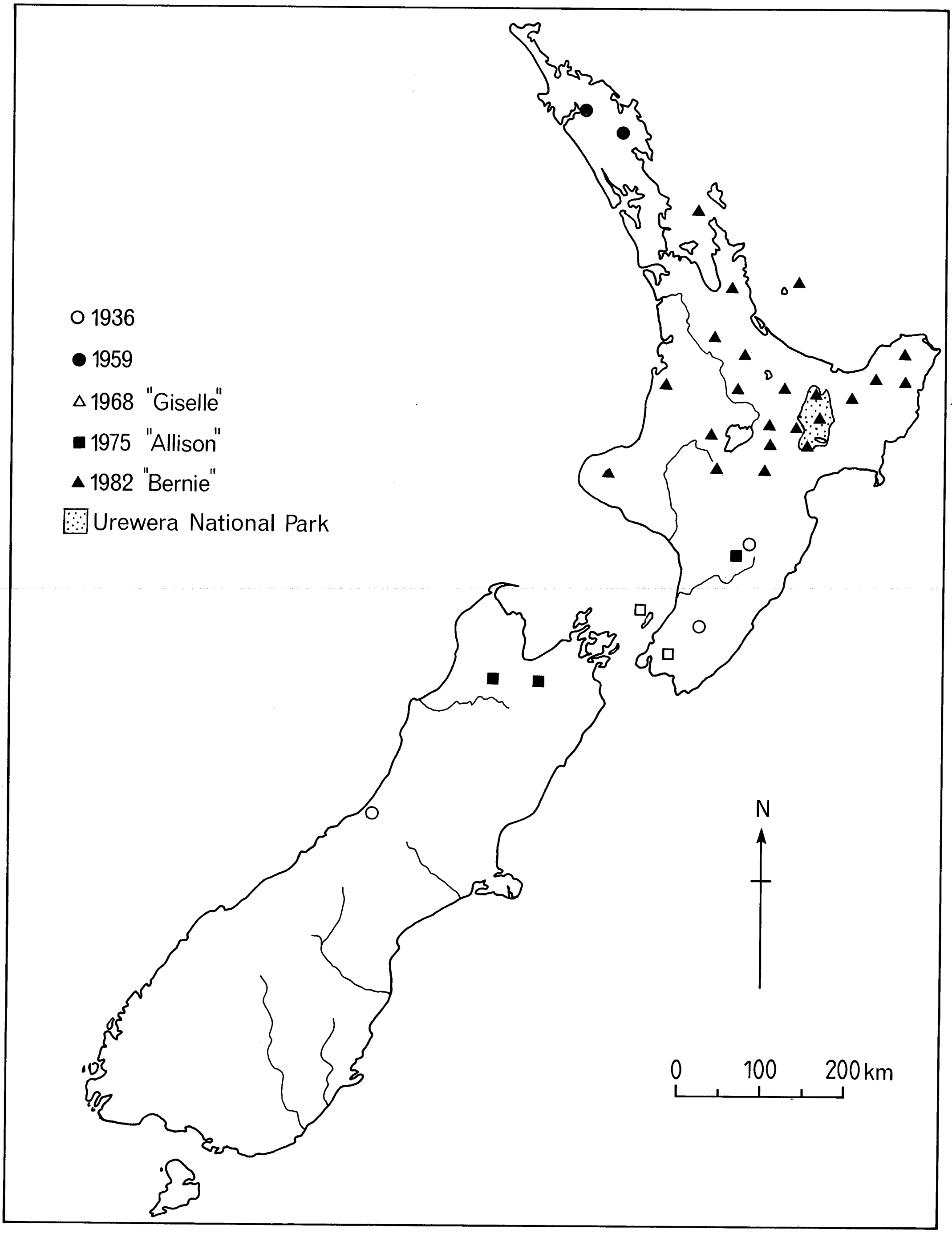

FIGURE 2. Currently known locations of damage to indigenous forest caused by tropical cyclones, for the period 1936–1982.

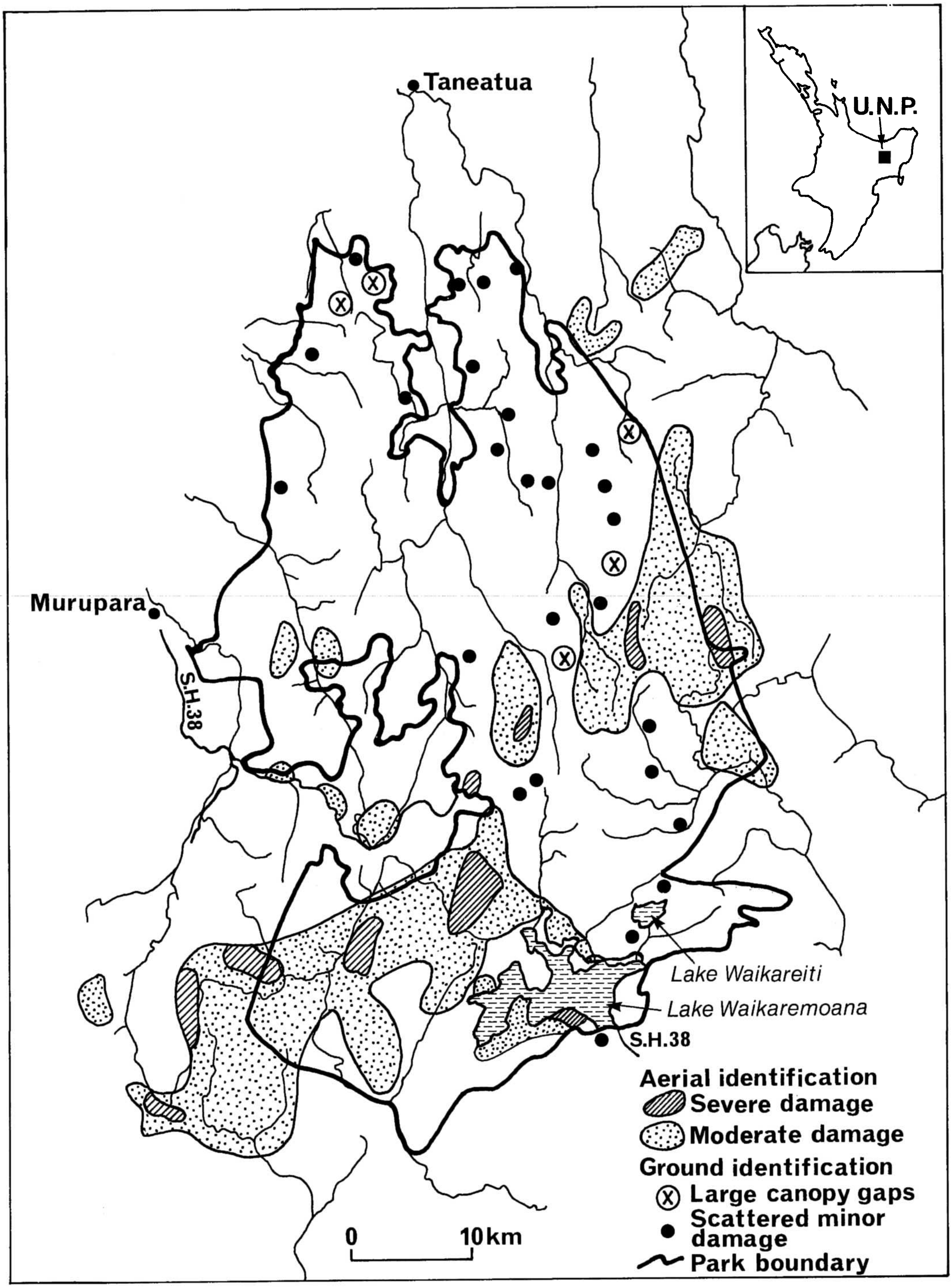

FIGURE 3. Damage caused by cyclone Bernie in Urewera National Park (after Knowlton 1982).

especially *Dacrydium cupressinum* on terraces and ridges, rarely forming pure stands in isolated pockets. At higher altitudes, the hardwood species change to *Nothofagus*, either associated with podocarps, or as pure stands of *N. fusca*, *N. fusca–N. menziesii* mixtures, or pure *N. menziesii*.

Damage has occurred throughout the park, with most, if not all, forest types suffering at least some damage. Reconnaissance surveys have been carried out from the air and on foot to map the storm's effects (Figure 3), and damage has been classified within three broad categories of severity.

SEVERE DAMAGE: 70–100% of the forest cover has suffered blowdown by either uprooting or stem breakage. This type of damage has created canopy gaps as large as 40 ha in a few places (Figure 4).

MODERATE DAMAGE: Obvious structural damage has occurred, but a modified canopy still survives (Figure 5).

MINOR DAMAGE: Nonfatal damage has occurred, such as defoliation, twig or branch breakage, and cracking of stems. Minor damage of this nature is probably to be found throughout the entire park.

FURTHER RECORDS OF DAMAGE BY TROPICAL CYCLONES IN NEW ZEALAND

A characteristic feature of tropical cyclones, probably resulting from irregular gusts, is the apparent lack of pattern in the distribution of damage (Anon. 1977). However, this apparent randomness of the blowdowns can usually be ascribed to local topographic features such as leading ridges, lee slopes, and valley funnelling and amplification, as well as biotic factors such as canopy gaps and tree health and vigor.

During the last 50 yr, there have been five major tropical cyclones (1936, 1959, 1968 Giselle, 1975 Allison, and 1982 Bernie) that have resulted in widespread damage in most of the forested areas of the North Island and even at a few locations in the South Island (Figure 2).

The 1936 storm occurred in February and reached its greatest force in the region of the Tararua Ranges, north of Wellington (Barnett 1938), where damage ranged from occasional blowdown to complete devastation over very large areas (Thomson 1936, Ure 1970, Zotov et al. 1938).

In a followup to his 1936 work, Thomson (1976) considers, from the size of the *Dacrydium cupressinum* and *Metrosideros robusta* trees blown down, that this storm must have been the worst to affect the area for some 300–400 yr. The destruction occurred in the very short time of about 2 hr (Zotov et al. 1938). Both Thomson (1936) and Zotov et al. (1938) make the interesting observation that mature *D. cupressinum* were left standing while everything else was smashed flat around them.

Some information on subsequent succession in the Tararuas can be gleaned from various later accounts (Elder 1963, Franklin 1967, Holloway et al. 1963, Mason 1950, Reid 1948), but the regeneration sequence is still only poorly documented. The same storm also caused damage in the Ruahine Ranges (P. J. Grant, personal communication) and in the Pukekura State Forest on the west coast of the South Island (Poole 1937).

The February 1936 storm was followed by another tropical cyclone in March of the same year (Barnett 1938). The impact of this storm was greater further north, in the vicinity of the Kaimai Ranges. Although there are no documented records of forest damage at the time, Jane and Green (1983) have recorded a seedling recruitment peak for the late 1930s in the Kaimais. This could well represent a regeneration event promoted by 1936 wind damage.

A large tropical cyclone in 1959 caused extensive blowdown in *Agathis australis* forests in Northland (Conway 1959). A feature of the damage was the much greater destruction of *Agathis* compared with species such as *Dacrydium cupressinum*, *Podocarpus ferrugineus*, and *P. totara*. *Agathis* is a canopy emergent (as it is in some tropical regions of the Pacific Islands and Southeast Asia) and is therefore exposed to wind gusts; Conway (1959) refers to the "driving effect of falling dominants." Windthrow of *Agathis* has also

FIGURE 4. Severe storm damage on a steep slope (55°). In many places, such damage has either caused mass movement to occur or reactivated an existing erosion scar. Waimana Valley, Urewera National Park.

been recorded in Northland and on the Coromandel Ranges by Cranwell and Moore (1936), although their observations were not based upon a known storm event.

Cyclone Giselle (known in New Zealand as the "Wahine Storm") of 1968 caused massive damage to property throughout the North Island and the northern half of the South Island. This was the worst storm in recorded New Zealand history. The strongest winds and the greatest damage again occurred in the Wellington area. The maximum gust recorded at Wellington airport during Giselle was 186 km/hr with a mean wind speed of 144 km/hr (Anon. n.d.).

Considerable damage occurred to the indigenous forests in the southern Rimutaka Ranges (D. Lowry, personal communication), on the Akatarawa Range (J. Maryatt, personal communication), on Kapiti Island (Dawson 1970), and in the Keith George Memorial Park near Upper Hutt (J. Maryatt,

FIGURE 5. Ground view of moderate damage to podocarp–*Beilschmiedia tawa* forest, Waimana Valley, Urewera National Park.

personal communication). Dawson (1970) has analyzed the storm impact on Kapiti Island and found that damage was related to both the degree of exposure and to the condition of the canopy crowns prior to the event.

Cyclone Allison in 1975 caused landslides in the Ruahine Ranges (Cunningham 1975) and extensive blowdown in the northwest Nelson area (G. N. Park, personal communication).

DISCUSSION

Tropical cyclone Bernie was a very severe storm that caused damage over a larger proportion of the North Island than many of the massive volcanic events for which New Zealand is renowned. Although Bernie caused widespread damage to forests, little was spectacular enough to reach the literature, and it is thus more than likely that similar damage caused by other storms has not been recorded. For instance, only one of the areas damaged by the Wahine Storm in 1968 has been recorded in the published literature (Dawson 1970).

It seems reasonable to expect a severe cyclone at least every 10 yr. However, the frequencies of such events may well alter dramatically with changes in regional macroclimate (Grant 1981*a*, *b*). Thus, many tree species may have experienced 50–100 severe storms during their life history, and therefore, forest communities are not likely to contain many "weaklings."

This observation also applies to forests such as those affected by relatively recent volcanic activity (e.g., the Taupo eruption c. 130 A.D.). It is now quite conceivable that the repeated imprint of severe storms has produced (at least in part) the mosaics of mixed age and species that are a feature of these forests (Cameron 1954, Herbert 1980, McKelvey 1953). For instance, Wardle (1970) notes that repeated disturbance of monospecific stands such as *Nothofagus* will produce a mixed-age structure on various scales.

It may be that only when other factors predispose individuals to wind damage that certain forms of damage occur. Senescence, and the resulting decline in the health of individuals or groups of trees, may increase the likelihood of blowdown. Overmature trees may survive a storm but not fully recover from it; they may even go into a rapid decline following minor damage of the type that a healthy tree would recover from (such as defoliation). Otherwise healthy trees may be rendered more susceptible to other disturbances following initially nonfatal storm damage. For instance, part of the area affected by cyclone Bernie suffered a severe drought during the summer immediately following the storm, and this may have resulted in enhanced mortality.

Thus, it needs to be emphasized that wind damage may be a critical factor both directly and indirectly. Initially minor damage may be followed by a later dieback and general deterioration of stand structure, although there are certainly many other factors promoting dieback. Mortality with no obvious cause is certainly a relatively common feature in many of the forests known to have been affected by severe tropical cyclones in New Zealand.

The storm regime to which New Zealand is subject is severe enough to mean that storms themselves could be major determinants of pattern and structure in New Zealand forests.

Thus, although New Zealand's forests are "warm temperate" in character, an extensive tropical literature (e.g., Richards 1952, Whitmore 1974, 1978) on gap-phase regeneration and forest succession is very relevant here—not because of taxonomic affinities, but because similar disturbance events bring about similar changes in forest structure and processes (c.f. Whitmore 1982).

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