Palynological Evidence of Vegetation Dynamics in Relatively Undisturbed and Disturbed Sites in New Zealand

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Abstract

New Zealand forest has been affected by both natural and anthropogenic disturbances. Protecting and restoring indigenous forest is one of the focal issues in conservation of New Zealand, and understanding vegetation dynamics is a key part of management strategies. The longevity of most of New Zealand trees impedes short-term vegetation dynamic studies. Instead fossil pollen records provide one of the most valuable sources of long term data to trace vegetation development. In this study, pollen records are used as proxies of vegetation population to test the roles of long-term climate change and transient environmental disturbances in vegetation dynamics. Two sediment cores, from Sponge Swamp, Haast, and Tiniroto Lakes, Gisborne, were collected as representatives of undisturbed and disturbed sites, the former being used as a reference site to separate out the effects of climate and evaluate the impact of disturbance on the vegetation.

Pollen data were inspected using Tilia, and zones defined. Principal component analysis (PCA) was performed on pollen data to summarise the change in species composition over time, and the sample scores of the first PCA axis were exploited as an index of vegetation dynamics for further comparison. Redundancy analysis (RDA) is also applied to help interpretation of the vegetation change with respect to environmental factors.

The result of this study indicates that the vegetation development in both sites is characterized by non-equilibrium dynamics, in which vegetation composition is changing continually through time. In Sponge Swamp, this change is steady and consistent over the whole time span, with a consistent decline of *Ascarina lucida* and a progressive increase of cold tolerant or moisture-stressed taxa, like *Gleichenia* and *Lycopodium australianum*. Subsequently there is a partial replacement of swamp forest taxa such as *Dacrycarps dacrydioides* and tree ferns by *Prumnopitys taxifolia*, and further expansion of *Nothofagus* and *Phyllocladus* is distinguished. A climate gradient, from mild and wet to cooler and/or drier is suggested from the pollen evidence, and appears the driving force for the vegetation dynamics at that undisturbed site. At Tiniroto, however, the vegetation

development is divided into two stages. Before c. 2300 yr BP, the vegetation change is steady and consistent which is comparable to that from Sponge Swamp. A forest invasion, a process of gradually replacing open land and light-adapted taxa, such as *Dodonaea viscosa, Coprosma, Pseudopanax, Schefflera digitata, Pteridium, Hebe* and members of the family Fabaceae and Asteraceae, by increasing proportions of forest taxa, characterise this change. Climate amelioration with increased rainfall is responsible. After c. 2300 yr BP, this trend was frequently punctuated by disturbances, in which sudden changes of vegetation occur, generating substantial fluctuations about the trend.

From RDA, sample age explains more than 20% of the variance of species data at both sites. The long-term directional climate change derived from pollen evidence of Sponge Swamp and at least partly at the Tiniroto site, may be represented by the explanatory variable age. At Tiniroto, additional variance is also explained by the explanatory variables charcoal and pollen taxonomic richness, suggesting the impact of disturbance on vegetation dynamics. The impact of disturbance on vegetation dynamics becomes clearer after the climate gradient is removed. Autocorrelation analysis on detrended sample scores of the first PCA axis suggests further differences between the two sites, in response to local disturbances. There is little dependence of the present state of vegetation composition on its past state in the Sponge Swamp site; instead, the vegetation composition is affected by various "random" events, implying small disturbances such as floods, or landslides caused by earthquakes etc. At Tiniroto, the change of vegetation composition is more "successional", and the present state of vegetation depends only on the immediate past state, due to the impact of catastrophic disturbance.

Despite the Tiniroto site having been subjected to a long history of disturbance, the climate gradient, which is distinct at the earlier stage, becomes less identifiable and partially masked by outbreaks of disturbances only since c. 2300 yr BP. This implies that the relative role of disturbance on vegetation dynamics with respect to climate is depended on different types or different levels of disturbances and different responses by the vegetation.

Short-term vegetation responses to different types of disturbance were examined by fine resolution pollen analyses around five disturbance episodes, including the Taupo (1850±10 yr BP), Waimihia (3280±20 yr BP), Whakatane (4830±20 yr BP) eruptions, and two charcoal peaks (c. 1100 yr BP and c. 2300 yr BP). Almost no vegetation change occurred relative to the eruption within the Whakatane and Waimihia episodes, except that a temporary rise of shrubs and ferns corresponded with intermittent occurrence of charcoal particles. Substantial vegetation change relative to disturbance was found within both the Taupo episode and the fire episode around c. 2300 yr BP, in which establishment of ensuing semi-open vegetation was encouraged for decades. The fire c. 2300 yr BP transformed part of the forest into fernland, while the Taupo eruption turned part of the shrubs and tree ferns into bracken field. Although it is difficult to judge the effect of the fire around 1100 yr BP as the result was unreliable due to contamination, the vegetation at Tiniroto is suggested to be more vulnerable to fire than tephra.

Non-equilibrium dynamics are common in New Zealand forests, even at stable sites such as Sponge Swamp, due to climate change. Locally these non-equilibrium dynamics appear highly responsive to disturbances, esp. at Tiniroto. Even disturbances at Tiniroto are dynamic and a change of disturbance regime is suggested around the later disturbance episodes. This change is possibly due to climate increasing the fire frequency, but an alternative explanation is the presence of humans earlier than currently accepted. Forests and forest ecological studies in New Zealand are very dynamic, and forest management needs to improve to incorporate these dynamics.

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