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Symposium mini review

How Does Wood-inhabiting Fungal Community Affect Forest Recovery after Deforestation Events in Subalpine Coniferous Forest?

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Abstract

Typhoon disturbance is causing large impacts on subalpine forests in Far East Asia. The decay of dead wood generated by deforestation event is important for seedling regeneration. Moreover, wood decay type, traditionally categorized into white-rot and brown-rot reflecting the decay preference for wood structural components by fungal decomposers, determines successful colonization of the seedlings on dead wood. In this article, I did a brief review of current knowledge of the effects of fungal decomposition of wood on tree seedling establishment, and discussed a possible option for forest management to stimulate forest recovery after the disturbance from mycological point of view, by comparing two case studies took place in subalpine coniferous forests dominated by *Picea jezoensis* var. *hondoensis* (Hondo spruce).

Introduction

Typhoon disturbance is causing large impacts on subalpine forests in Far East Asia (Ida, 2000; Suzuki *et al*., 2013; Guo *et al*., 2015). While blowdown disturbance have direct, short-term effects on forest dynamics, microbial communities in the ground have indirect and usually gradual—but equally pivotal—effects on the dynamics of aboveground vegetation, of which little is known (Bardgett & Wardle, 2010).

The decay of dead wood lying on the ground is important for seedling regeneration in spruce forests with developed canopies (Bače *et al*., 2012; Ando *et al*., 2017; Tsvetanov *et al*., 2018) because the majority of seedlings that germinate on shaded ground will be killed by pathogenic soil fungi within a couple of years; only seedlings on logs (or stumps), where the density of pathogens present is smaller, can survive (Cheng & Igarashi, 1987; Mori *et al*., 2004). The wood decay activity of the fungal communities that deadwood harbours has significant effects on seedling performance and density (Bače *et al*., 2012; Fukasawa, 2012, 2016, 2018; Fukasawa & Komagata, 2018; Fukasawa *et al*., 2017). The density of spruce seedlings on deadwood is negatively affected by brown-rot fungi, which decay wood holocellulose selectively and modify lignin only slightly, probably due to the acidity or fragility of brown-rotted wood (Bače *et al*., 2012). In contrast, white-rot fungi decay wood holocellulose and lignin simultaneously or lignin selectively, and have positive effects on seedling density (Bače *et al*., 2012; Ando *et al*., 2017). Such differences between wood decay types of fungi are critical determinants of complex biotic interactions on deadwood associated with seedling regeneration (Fukasawa *et al*., 2015; Ando *et al*., 2017; Fukasawa & Ando, 2018).

In this mini-review, I discussed a possible option for forest management to stimulate forest recovery after disturbance by comparing two case studies in subalpine coniferous forest dominated by *Picea jezoensis* var. *hondoensis* (Hondo spruce) from mycological point of view. Both forest sites were severely damaged by a super typhoon (Category 5), named Vera or the Isewan typhoon in September 1959: one forest has recovered whereas the other has not recovered yet.

Case study 1: Forest RECOVERED after the past disturbance

Fukasawa *et al*. (2019a) evaluate the long lasting impact of the typhoon disturbance on communities of wood-inhabiting fungi, bryophyte, wood decay and tree seedling establishment on fallen logs of Hondo spruce in Yatsugatake Mountains, central Japan (36˚00’N, 138˚23’E, ca. 2200 m a.s.l.). The mean annual temperature is 2.1 ˚C and the mean annual precipitation is 1567 mm (Japan Meteorological Agency, 1981–2010 average). Before the typhoon disturbance, forest in this area was consist of *Abies veitchii* (basal area: 10–90%), *A. mariesii* (10–40%), *Tsuga diversifolia* (0–50%), *Picea jezoensis* var.

hondoensis (0–30%), and *Betula ermanii* (0–10%) (Kimura, 1963). Although the typhoon severely damaged the forest, a large part of the disturbed area is now covered by a coniferous forest dominated by *Abies veitchii* and *A. mariesii*, which mainly originated from saplings and seedlings that existed at the time of the original canopy damage (Kimura, 1963; Kimura *et al*., 1986). In this forest, Fukasawa *et al*., (2019a) found that forest disturbance has no clear effects on current fungal communities within logs and wood decay type as well, compared to that of surrounding undisturbed stands. However, disturbance affected bryophyte communities, which had strong effects on the seedling densities on the logs. Although they recorded poor regeneration of Hondo spruce, the bryophyte species and coverage on the logs seems suitable for spruce seedlings, and will host them near future as forest succession progresses.

Case study 2: Forest DECLINED after the past disturbance

Contrast to Yatsugatake Mountains, Hondo spruce stand in Odaigahara Mountains (34˚11'N, 136˚06'E, 1600 m a.s.l.) declined after the typhoon disturbance. Fukasawa *et al*. (2019b) evaluate the effect of forest decline on communities of wood-inhabiting fungi, bryophyte, wood decay and tree seedling establishment on dead wood of Hondo spruce by comparing those variables between stands with different dieback intensity (weak, mid, heavy). They found that forest decline promoted the frequency of brown-rot fungi in spruce dead wood. The frequency of brown-rotted wood increased with dieback intensity. In this site, forest dieback had a variety of indirect effects on *Picea* seedling density via wood decay type and bryophyte cover on dead wood. First, forest dieback reduced bryophyte cover on dead wood, which was important for spruce seedling colonization. Second, brown-rotted wood dominating the dieback forest negatively affected bryophyte cover. The results suggest that the function of wood decay fungal communities and their effects on interspecific interactions between bryophytes and spruce seedlings might be a key mechanism affecting the colonization success of spruce seedlings, which could be easily modified by the forest disturbance.

Conclusions

Although Yatsugatake and Odaigahara mountains are 290 km apart from each other, data from these two forest sites represents an interesting contrast regarding the forest recovery process and possible role of wood-inhabiting fungi and wood decay on it. An obvious difference between these forest sites is the rate of forest recovery. In Yatsugatake, the canopy of the disturbed stand was already closed to the same degree as an undisturbed stand because of the rapid regrowth of *Abies* spp., which had originally coexisted with spruce (Suzuki *et al*., 2013). In contrast, the heavily disturbed stand in Odaigahara, which had been almost pure spruce stand, had not yet recovered and the canopy was completely open (Shibata *et al*., 2008). Comparison of these two sites suggests that the intensive dieback site in Odaigahara seems to be staying in an alternative semi-stable state in the forest restoration process (Klotzli & Grootjans, 2001). The collapse of causal linkages between fungal decomposition of wood, bryophyte colonization, and spruce seedling establishment could be a mechanism by which the focal ecosystem has been staying in an alternative semi-stable state for a long time after the typhoon disturbance. Slow forest recovery reduces not only the seed supply from adult trees but also bryophyte cover on dead wood, which is important for spruce seedling colonization, and enhances the dominance of brown-rot in dead wood, which is not suitable for spruces seedling colonization. Therefore, a possible option for quick recovery of Hondo spruce forest after typhoon disturbance would be to stimulate stand regeneration not necessarily by spruce, but by other coexisting rapidly growing canopy tree groups such as *Abies*.

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