

# Differential leaflet mortality may influence biogeochemical cycling following tropical cyclones

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**I**ntensity of tropical cyclones is expected to increase in the coming century, and an improved understanding of their influence on biogeochemical cycles would benefit ecologists and conservationists. We studied the November 2013 Typhoon Haiyan damage to observe that numerous examples of partial leaf necrosis on intact leaves of trees in the Cycadaceae and Arecaceae families resulted, leaving behind a copious amount of arboreal dead leaf material attached to live leaves. The decay process of this form of arboreal litter has not been previously studied. When compared with decay of ground litter or detached litter suspended in the canopy, we predict the decay process of this form of arboreal litter will include increased photooxidation, leaching, and comminution by detritivorous insects and mites; but decreased catabolism of organic molecules by saprophytic organisms.

## Background

Predictions on the influence of climate change indicate that the number of intense tropical cyclones (known as typhoons or hurricanes) will increase.<sup>1,2</sup> Indeed, the United Nations Intergovernmental Panel on Climate Change reports that the average maximum wind speed of tropical cyclones will likely increase throughout the coming century (<http://www.ipcc.ch>). Reporting the details of case studies following contemporary tropical cyclones may improve our ability to predict how these changes will influence

ecosystem recovery following tropical cyclone damage. Toward that end, we recently compared long-term resilience of Guam's dominant arborescent species *Cycas micronesica* following the 1997 Supertyphoon Paka<sup>3</sup> and the 2004 Typhoon Chaba.<sup>4</sup> Results indicated that invasions of the armored scale *Aulacaspis yasumatsui* and the specialist butterfly *Chilades pandava* to Guam after the 1997 typhoon compromised the resistance to and resilience following the 2004 typhoon. The outcomes signified that studying the interactive aspects of the broad disciplines of invasion biology and climate change may inform future predictions and management decisions.

Understanding biogeochemical responses to disturbances such as tropical cyclones is viewed as a major theme that would benefit from international coordination among researchers. Pursuit of a useful understanding of long-term ecosystem responses to large-scale disturbances requires an understanding of short-term mechanistic processes during recovery.<sup>5</sup> In order to learn from ecosystem responses following the 8 Nov. 2013 damage of Typhoon Haiyan, a tropical cyclone reported to exhibit some of the highest tropical cyclone wind speeds on record, we followed its path across several eastern Philippine islands.

A widespread phenomenon became apparent in most of the habitats that were damaged by this severe tropical cyclone. Numerous examples of partial leaf necrosis on intact leaves of trees in the Cycadaceae and Arecaceae families resulted during the desiccating damage

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**Figure 1.** Arecaceae and Cycadaceae trees were uniquely damaged by Typhoon Haiyan in November 2013, leaving copious amounts of dead leaf material attached to partially live leaves. (A) Close-up of *Cycas* tree damage in Samar Island. Green surrounding vegetation was new regrowth after typhoon damage. (B) Group of *Cycas* trees in barrier island of Leyte exhibiting dead leaf material. (C) Heavily damaged *Nypa* trees in Leyte Island. (D) Grove of damaged *Saribus* trees in Leyte Island.

imposed by the typhoon (Fig. 1). The result was a copious amount of arboreal dead leaf material attached to live leaves.

Litterfall and litter decomposition have been extensively studied. However, the manner in which arboreal litter influences biogeochemical cycling has received much less attention.

### Tropical Cyclones and Litterfall

One of the most important effects of tropical cyclones is defoliation and the spatiotemporal influence of the resulting litter on subsequent geochemical processes.<sup>6-9</sup> Litterfall associated with tropical cyclones is so voluminous that it often explains the majority of variation in annual litterfall among years.<sup>7,10</sup> Tropical

cyclones also influence litter quality. Litter associated with tropical cyclones and other disturbances such as severe freeze events<sup>11</sup> is comprised of high quality green tissues that were detached before the typical nutrient resorption associated with the organ senescing processes. The combined effects of greater quantity and quality of litter indicate tropical cyclones exert a widespread and long-term influence on subsequent ecosystem processes.

### Arboreal Litter

The role of suspended or arboreal litter in ecosystem processes has not been well-studied, and the literature is comprised of eclectic publications. Some species have been shown to self-retain dead leaves

and branches,<sup>12</sup> and other understory species have been shown to intercept a disproportionately high amount of falling litter.<sup>13,14</sup> General quantity and traits of arboreal litter indicate the canopy location of suspended litter can be ephemeral as wind and branch movement repeatedly dislodge the litter, and decomposition of suspended litter that is artificially tethered in place is slow compared with litter on soil surfaces.<sup>15,16</sup> The composition and abundance of arthropods in arboreal litter may be highly contrasting to that of litter deposited on the forest floor.<sup>17-19</sup> Availability of arboreal litter is critically important for these specialist arthropods and insectivorous bird species that specialize on dead-leaf inhabiting arthropods.<sup>20,21</sup>

## Typhoon Haiyan

The dead leaflet material that was generated by the passage of Typhoon Haiyan (Fig. 1) may influence biogeochemical processes in a manner that is distinct from any previously published information concerning arboreal litter. We invoke known traits of the decay process<sup>22</sup> to formulate the following predictions. (1) The petiole, rachis, and many leaflets of the leaves on these damaged palm and cycad trees remained green and will likely retain the leaves on the trees for extended periods. The dead sections of these large leaves were not detached, they remained affixed to live leaves. Therefore, the routine dislodging by wind and branch movements that is characteristic of suspended, arboreal litter will not occur and the dead material will remain in place for extended periods of time. (2) Initial quality of this form of litter will be greater than the other forms of suspended litter that are generated by interception of naturally abscised leaves. The leaf sections killed by the forces of Typhoon Haiyan did not proceed through the typical resorption of nutrients

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