

## Biodiversity and ecosystem functioning: Effects of the loss of salamander species richness

The effects of species loss on ecosystem processes has attracted substantial research efforts over the last 2 decades (1, 2), partly motivated by rapid declines in global biodiversity. The value of this research to practical conservation is, however, yet limited (ref. 3, but see ref. 4), partly due to the lack of clear evidence from natural systems. In a recent study in PNAS, Rovito et al. (5) provide information that enhances our understanding of the potential consequences of biodiversity loss. They report dramatic declines of many species of salamander in Central America and Mexico between the 1970s and 2005–2007. Even though not explicitly discussed in their article, Rovito et al. show that declines in species richness of salamanders (e.g., from 7 in the 1970s to 3 in 2005–2007, El Rincon site, see Table 1 in ref. 5) are associated with large declines in encounter rates: 6.2 salamanders per person per hour in the 1970s and 1.27 in 2005–2007 at El Rinco. If biomass is assumed to correlate

with encounter rates, species loss has a negative effect on the production of biomass.

There is no data in the paper (5) to evaluate whether other species that were not included in the survey compensated for the large declines in the counted salamander species. Compensation or not is key to evaluate the ecosystem consequences of species loss. Provided there was no substantial compensation, the results presented by Rovito et al. provide strong evidence from the field that biodiversity loss can have serious consequences for ecosystem processes.

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## Reply to Gamfeldt: Biodiversity and ecosystem functioning

In his letter (1), Gamfeldt asks questions concerning broader aspects of our study (2). In response, salamander biomass has been substantially reduced. In the upper cloud forest habitat at El Rincon, San Marcos, Guatemala, 3 formerly abundant salamander species and a 4th relatively rare species were not found. Although 3 other species were found as often or slightly more so than in the past, the overall salamander density at El Rincon is much lower compared to previous decades. These 7 species constitute the entire salamander community at this site, and no species were found on our recent surveys that were not present in the 1970s. The total salamander biomass at the site is only a fraction of what it once was; vastly fewer amphibians and reptiles (specifically salamander-eating snakes) were encountered than in the past. Similarly, forest habitat with formerly dense populations of *Pseudoeurycea* and *Thorius* on Cerro San Felipe, Oaxaca, Mexico, now contain no *Pseudoeurycea* (based on our surveys) and very few *Thorius* compared with previous decades, although suitable habitat remains. All salamander species have declined at this site, with no compensation from any other salamander species.

These results suggest that ecosystem processes involving salamanders have been substantially affected by the decline in salamander abundance and species diversity. Salamanders are important mid-level predators that participate in ecosystem processes and represent a critical store of energy and nutrients for tertiary consumers (3). Although the ecological role of tropical salamanders is not well understood, the formerly high density of these species and the importance of salamanders for ecosystem processes in temperate forests imply that these declines have consequences for ecosystem function.

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