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Response: Commentary: Anthropogenic disturbances jeopardize biodiversity conservation within tropical rainforest reserves

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A commentary on

Commentary: Anthropogenic disturbances jeopardize biodiversity conservation within tropical rainforest reserves
by Arroyo-Rodríguez, V., and Melo, F. P. L. (2016). Front. Ecol. Evol. 4:73. doi: 10.3389/fevo.2016.00073

In their commentary on our recent paper (Martínez-Ramos et al., 2016), Arroyo-Rodríguez and Melo (2016, hereafter referred to as A-R&M) present imprecisions that need clarification to avoid misleading the readership of FEE regarding the contribution of our paper.

First, we focused on analyzing the effects of anthropogenic disturbances affecting a medium-sized (640 ha) tropical rainforest reserve (the Los Tuxtlas Research Station, protected by the National Autonomous University of Mexico, LTS). Our study was not designed to document landscape-level variation in the abundance of the palm *Astrocaryum mexicanum* among fragments in the Los Tuxtlas region (250,000 ha). Within LTS, we established a network of permanent plots to study this palm's demography, starting in 1975 when human impact, within and outside the reserve, was lower than in the subsequent years. Along 40 years, we observed a dramatic population outburst of the palm (**Figure 1**), with cascading consequences on biodiversity (reduction in abundance and diversity, and composition shifts of understory tree assemblages) and ecosystem functioning (changes in biomass and litter-fall processes). Using empirical, experimental, and modeling approaches, we show that such extraordinary palm population growth responded to anthropogenic activities (deforestation and defaunation) occurring in the surroundings of the LTS (Martínez-Ramos et al., 2016). This favored palm fecundity, seedling recruitment, and the survival and growth of juvenile and immature palms within a protected area immersed in a landscape of anthropogenic impact.

Second, we challenge A-R&M's comment regarding the robustness of our study. We employed eight plots (0.06 ha each), taking advantage of the high local abundance of *A. mexicanum* in LTS. Indeed, in 1975 we tagged (and then followed) more than 2300 individuals including seedlings, juveniles, and adults. Our plots were large enough to derive robust estimates of size-specific demographic rates (survival, growth, and reproduction) and of the population growth rate per plot

FIGURE 1 | In the Anthropocene, human impacts on tropical forests are threatening biodiversity, even inside reserves. In the Los Tuxtlas Station, SE Mexico, fragmentation and defaunation have conduced to the exponential growth of an understory palm with negative consequences for biodiversity conservation and ecosystem functioning. Image courtesy of Iván A. Ortiz-Rodríguez.

using matrix modeling. The plots were scattered in an area of 35 ha (not 10 ha, as mentioned by A-R&M), encompassing the natural variation in population densities of the palm (Piñero et al., 1984), variations in topography, structure and composition of the forest (Piñero et al., 1977), and forest regeneration stages (Martínez-Ramos et al., 1988). In sum, we base our study on copious and long-term data.

Third, the palm population densities within LTS reported by A-R&M are misleading as they counted palms with stems $\geq$ 1.3 m height. This is a critical drawback because we uncovered that the exponential growth of *A. mexicanum* is largely due to the extraordinary increase of palms $<$ 1.3 m high. These smaller palms, younger than 35–50 years (Piñero et al., 1984), are the ones mostly favored by the environmental changes (increased light availability due to edge effects) occurring inside the reserve over the past 40 years. On the other hand, the mean palm densities reported by A-R&M for the years 2003 (900/ha) and 2015 (1180/ha) correspond closely with ours, considering palms $\geq$ 1.3 m height (Martínez-Ramos et al., 2016) for the years 2005 (952) and 2013 (1129). Furthermore, with their data, it can be calculated that in 12 years (2003–2015) the palm population grew 31% [(1180–900)*100/(900)], corresponding to a finite population growth rate [$\lambda = (1180/900)^{(1/12)}$] of 1.023 ind ind^{-1} yr^{-1} (2.3% yr^{-1}). This rate is similar to that we report (2.9% per year) and would lead to a practically equal estimate of the population growth using our population density of palms $\geq$ 1.3 m height: $\lambda = 1.022$ for the 2005–2013 period. Considering that population density values of A-R&M were obtained in areas different from ours within LTS, these results support that the population outburst of *A. mexicanum* we report is becoming widespread throughout this small reserve.

Fourth, it is unfitting to compare our palm population densities within LTS with those in forest fragments outside the reserve, as done by AR&M. Theirs are unprotected fragments exposed to multiple anthropogenic impacts (human and livestock trampling, cattle grazing, fires, logging, fruit harvesting) that directly affect the population dynamics of *A. mexicanum*. For example, the palm's inflorescences are avidly consumed by local people, and are extensively harvested for sale in markets (Quero, 1992; Centurión-Hidalgo et al., 2009). Furthermore, people harvest the stems of large adult palms for use as agricultural tools, killing the single-stemmed palms. These activities have strong negative demographic consequences, reducing fruit production, seedling recruitment, and increasing adult mortality, thus reducing overall palm population density. By contrast, within the LTS these extractive activities are not allowed. It is therefore not surprising that in unprotected fragments, as those used by AR&M, palm population densities are varied, and often very low.

Fifth, it is also not surprising to find a positive relationship between tree species diversity and density of palms in the unprotected fragments studied by A-R&M. This relationship readily arises if tree species diversity varies across fragments while palm population density decrease with the intensity of anthropogenic disturbance in the fragments. The *A. mexicanum* populations of A-R&M were studied using single-time, static counts, making it impossible to know to what extent palm population density and tree assemblages have changed over time in their fragments. In contrast, we used a baseline population from 1975, followed for 4 decades, from which palm demography and the causes and consequences of the population explosion were assessed while we quantified the structure, composition and attributes of the ecosystem through time.

These arguments make it clear that A-R&M confused the essence of our article and, unfortunately, in so doing, provided a misleading view of the population dynamics of *A. mexicanum* both inside and outside the LTS reserve. Nevertheless, we concur with them that more efforts should be made to reach a comprehensive picture of the nuanced, frequently cryptic effects of anthropogenic activities on biodiversity. In this sense, studies like ours in PNAS and those mentioned by A-R&M are complementary and necessary to fully assess the condition of biodiversity in human modified landscapes. Finally, in accordance with Laurance et al. (2012) we emphasize the urgent need to monitor the health of ecosystems protected within reserves in the face of anthropogenic impacts occurring in their periphery.

AUTHOR CONTRIBUTIONS

MM, wrote the first version of the paper; IO, DP, RD, and JS reviewed and gave feedback on the writing of the paper.

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