LETTER

REPLY TO PINCHEIRA-DONOSO AND HODGSON:

Both the largest and smallest vertebrates have elevated extinction risk

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Pincheira-Donoso and Hodgson (1) discuss vertebrate endangerment patterns in their response to our recent article (2). They reassessed our conclusion of a bimodal body size distribution of endangerment for all vertebrates but did so using only data on body mass for amphibians. In our study, we collectively analyzed patterns of endangerment across six classes of vertebrates. Contrasting patterns specific to amphibians with results that pertain to all vertebrates fails to compare like to like and as such is perhaps an exercise of unclear value. Pincheira-Donoso and Hodgson (1) suggest that our vertebrate model is inadequate because "increases in endangerment of smaller vertebrates are heavily biased by a single class (Amphibia) . . . " We investigated this potential bias by refitting our vertebrate model without amphibians and compared these results to the model with amphibians that we published for all vertebrates in Ripple et al. (2). The exclusion of amphibians did not substantially alter our findings (Fig. 1), refuting the notion that amphibians are driving our model results.

Pincheira-Donoso and Hodgson (1) do not report the source of their amphibian data or the methods for determining body masses. Furthermore, they use a quadratic slope term to test for a turning point in the mass–extinction risk relationship for amphibians. However, this approach can fail to detect U-shaped relationships, even for large sample sizes (3).

Pincheira-Donoso and Hodgson (1) indicate that we used improper phylogenetic analyses. We respectfully disagree and suggest that the approach we employed to account for phylogenetic dependence (random effects based on taxonomy) is commonly used to account for more closely related species tending to be more similar (4–6). In our paper, we also noted that "full phylogenetic trees were unavailable for some of the classes in our analysis, precluding the use of more complex modeling techniques like phylogenetic logistic regression."

Pincheira-Donoso and Hodgson (1) also raise concerns about the influence of geographic range size on our results. However, figure 2A in ref. 2 illustrates that the overall U-shaped relationship for all vertebrates' extinction risk generally holds across geographic range sizes. In any case, we explicitly acknowledged other drivers of extinction risk, especially geographic range size, as having "central relevance to the patterns we report."

Our results, both with and without considering amphibians, provide strong evidence that extinction risk increases for the largest and smallest vertebrates (Fig. 1). Although we recognize that there is both pure and applied value in describing patterns of extinction vulnerability specific to taxa like amphibians, we feel it may be more constructive and accurate to present such patterns as a potentially insightful compliment to those patterns observed for all vertebrates, rather than suggesting that these more taxonomically constrained analyses somehow invalidate the results observed in analyses for all vertebrates. Finally, we repeat our earlier remarks that the vulnerability of smaller vertebrates has been underestimated, highlighting an urgent need to increase conservation efforts for both the heaviest and lightest vertebrates.

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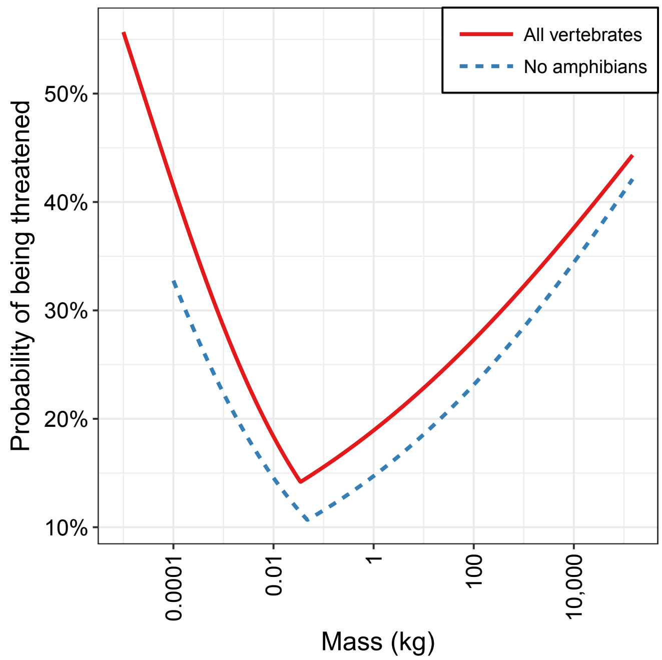

Fig. 1. **Estimated probability of being threatened versus body mass according to the original "All vertebrates" model given in Ripple et al. (2) and the "No amphibians" model, which is identical, except amphibians were removed from the dataset. In both cases, the model was a generalized linear mixed model with random intercepts based on taxonomic order and a segmented relationship with respect to mass (base 10 log-transformed). As before, all slope parameter terms were highly significant ($P < 0.001$). Removing amphibians from the dataset increased the pseudo-R^2 from 0.317 to 0.323. These model results show that excluding amphibians from the dataset has little effect on our overall conclusions.**

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2 Ripple WJ, et al. (2017) Extinction risk is most acute for the world's largest and smallest vertebrates. *Proc Natl Acad Sci USA* 114:10678–10683.

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