Defaunation shadow on mutualistic interactions

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Tregidgo et al. (1) show that size-selective overfishing has drastically depleted and downsized populations of tambaqui (*Colossoma macropomum*) along the Purus River, Amazonia. Because fishers have historically targeted the largest individuals, tambaqui ∼1,000 km upriver are twofold larger than those near the Manaus rainforest metropolis (1). Here, we demonstrate that this overfishing shadow has cascading consequences, reaching beyond the sustainability of this fishery. By effectively dispersing seeds of >100 species, tambaqui plays a major role in the natural regeneration of Amazonian floodplain forests (2–5). However, due to gape limitation, only large-bodied tambaqui can disperse large-seeded fruits (3). Thus, we hypothesize that the tambaqui's key ecological function as a seed disperser is diminished by the striking fisheries-induced downsize.

We constructed a niche model of food web structure (6), using the statistical relationship between tambaqui body size and fruit size, to infer losses in seed dispersal potential. First, we measured the fruit or seed (for dehiscent species) size of 264 species from Purus floodplain forests (7). We then used fish and fruit size data from 629 individual-level feeding records to model the upper boundary of the tambaqui's feeding range, using a 95% quantile regression (6). A decrease of 1 kg in body weight leads to a reduction of 3 mm in the maximum size of a fruit that a tambaqui can ingest ($\log_{10}$-transformed; intercept = 0.39, $\beta = 0.29$; Fig. 1). Finally, we used this relationship to calibrate our niche model and predict which plant species from the Purus regional pool could be dispersed by tambaqui near Manaus versus ∼1,000 km upriver.

The downsizing of tambaqui near Manaus leads to a substantial reduction in its seed dispersal potential (Fig. 2). The largest tambaqui caught upriver in the fisher's lifetime (1) can consume fruits (while ingesting seeds intact) up to ∼6 cm long, which is ∼90% of the Purus River floodplain species pool. In contrast, the largest tambaqui near Manaus are biomechanically unable to consume fruits >4.4 cm in length (Fig. 2*A*). However, given the mean fish size caught recently (1), tambaqui near Manaus can only consume fruits <2.8 cm in length. Our model indicates that tambaqui reaching the maximum body size for the species (2) would even be able to disperse megafauna fruits (∼7 cm) (8).

Our results illustrate that the defaunation shadow around Manaus, driven by the urban demand for food, may collapse not only the harvested species but also its ecological function. Historical overfishing of tambaqui has already removed the largest seed dispersers, indirectly affecting mutualistic interactions with plants. Large-seeded floodplain taxa (e.g., Arecaceae, Sapotaceae) are usually disperser-limited and do not float, relying on large-sized fish to disperse their seeds (5). Moreover, these taxa significantly contribute to carbon stocks in Neotropical rainforests (9). Because body size is also positively associated with long-distance seed dispersal (10), the downsizing of tambaqui can also reduce the genetic diversity of floodplain plant populations (1). Our results add an additional level of complexity to Tregidgo et al.'s (1) conclusions, highlighting that the legacy of overharvesting can scale-up to ecosystem-level impacts, potentially affecting the structure and function of floodplain forests.

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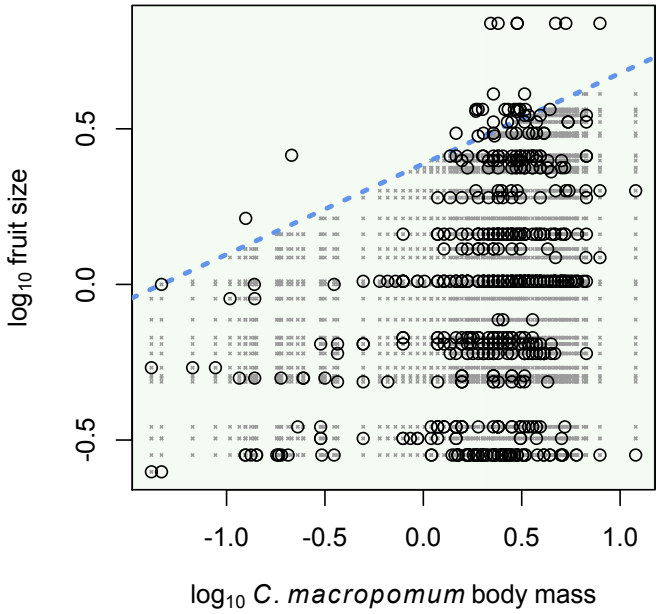

Fig. 1. Relationship between tambaqui body mass and fruit size. Open dots are observed trophic interactions, while small "x" symbols are predicted interactions based on the parameterization of the niche model. The dotted blue line represents the upper boundary of the feeding range (i.e., maximum fruit size consumed by a fish of a given size) obtained by fitting a 95% quantile regression of fruit size (log_{10}) as a function of fish size (log_{10}).

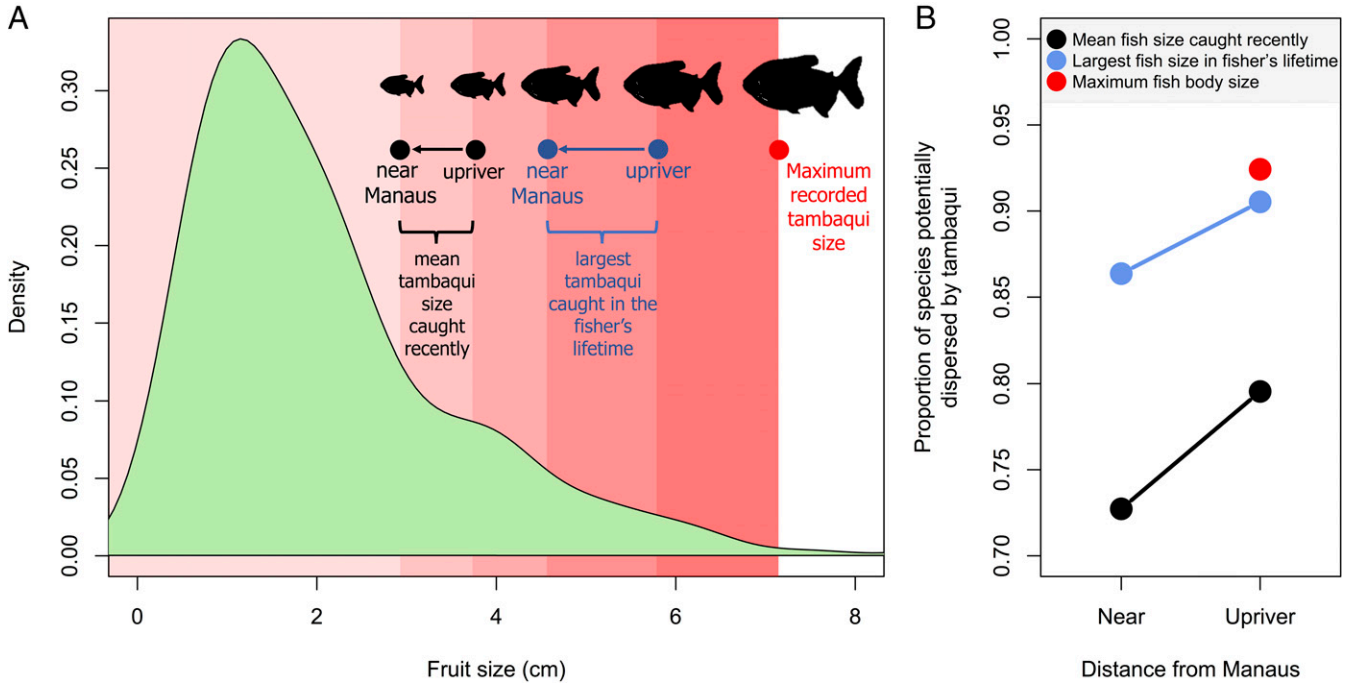

Fig. 2. (*A*) Size distributions for fruits for Purus River floodplain forest species (green) and the predicted subset of species that could be dispersed by the tambaqui, *C. macropomum* (mean and maximum body sizes), nearby Manaus versus ~1,000 km upriver. Seed size distributions were used for dehiscent fruits. Dots inside the panel represent the upper boundary of fruit sizes potentially dispersed by each tambaqui size class as defined by Tregidgo et al. (1). (*B*) Proportion of the plant species from the Purus floodplain regional pool potentially dispersed by tambaqui along the defaunation shadow from Manaus.

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