

Megafans and Trumpeter Bird Biodiversity—*Psophia* Phylogeography and Landscape Evolution in Amazonia

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Similar geographic evolution of land surfaces and bird paleogeography

Based on geomorphic character and mapped geology, geologists have interpreted the landscape surrounding the Andes Mountains as becoming progressively younger to the East. These sedimentary materials filled the late Miocene swampland that formerly occupied central and western Amazonia. Apart from the ancient landscapes of the Guiana Highlands (top right, figure 1a), Zone Ac is the oldest, followed by Zone Aw, within which megafan Jw is older than megafan Je (figure 1a).

DNA-based paleogeography of the trumpeters shows that younger clades diverge from parent lineages with increasing distance from the Andes chain. Thus, *Psophia napensis* diverges from the *P. crepitans* parent, and *P. ochroptera* diverges from *P. napensis*. The *P. ochroptera* population is confined solely to the Je megafan (figure 1a). The same trend is seen on the south side of the Amazon depression.

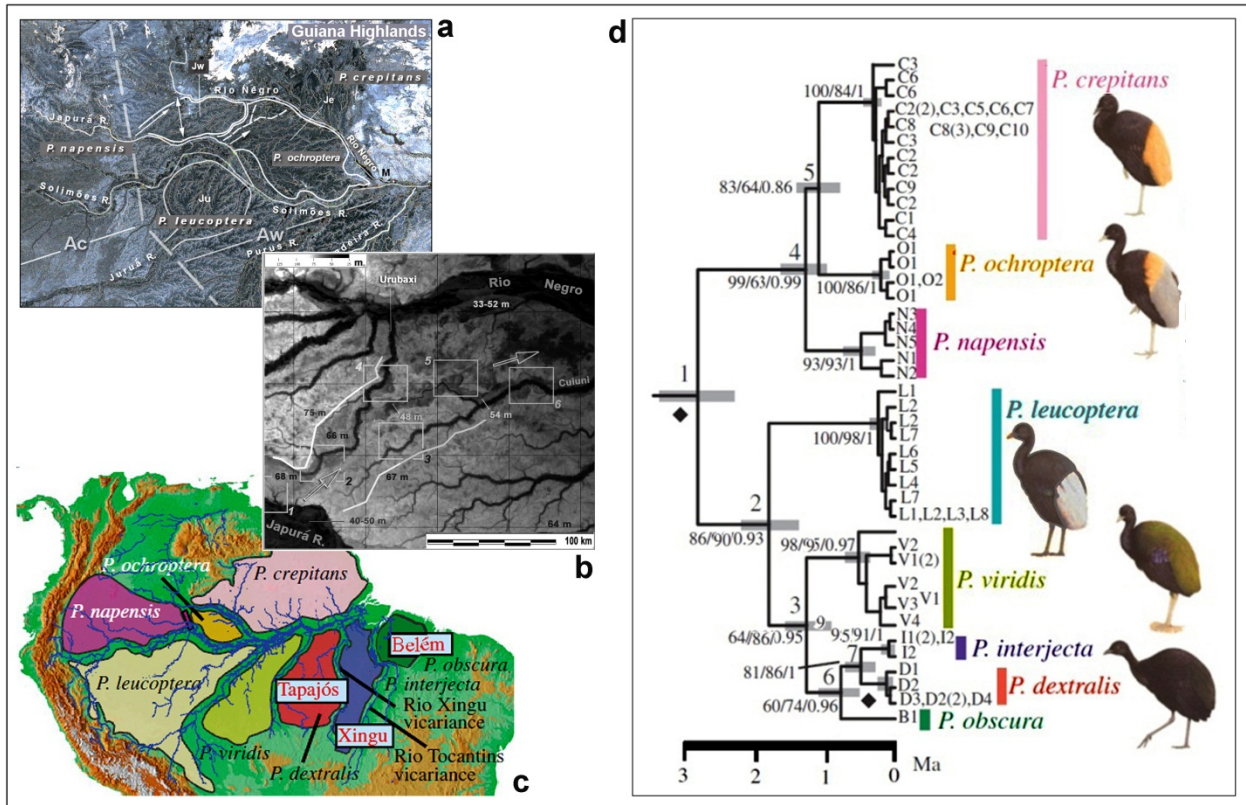
Since the timing of the events seems to be of exactly the same order [post-Miocene for the land surfaces and trumpeter divergence within the last 3 million years (figure 1d)], it seems reasonable to think that the megafans provided the substrate on which new bird lineages could speciate. Such physical controls of evolution are becoming more important in the understanding of biodiversity.

Major past rivers identified on the basis of bird paleogeography

In five of the seven trumpeter populations, most boundaries between the lineages are strikingly located at major modern rivers (figure 1c). However, along two of these boundaries – between *P. napensis* and *P. crepitans* and between *P. napensis* and *P. ochroptera* – no modern river exists. We examined megafan margins for the existence of past large rivers that might occupy these locations indicated by the trumpeter phylogeography.

Both locations showed prominent signs of very large rivers (*i.e.*, especially large meanders scars), on floodplains trending in directions that act as boundaries between the abovementioned clades – along two prior courses indicated by single-headed arrows in figure 1a. These paleo-rivers suggest, in effect, that the Japurá River has at different times in the past been oriented toward the Rio Negro.

This is a remarkable instance of geological understanding being advanced through interpretation of a DNA-based biogeography.



a—Topographic roughness map of South America. Roughness map (based on SRTM data and algorithms developed for Mars) shows well-developed modern megafan landscapes to the north and south of Amazonia and the preferred location of major trunk rivers located furthest from the Andes Mountains; *i.e.*, against margins of the Guiana and Brazilian shields (resulting from megafan progradation eastward). The map shows the rough and steep landscapes (*lightest tones*) and the smooth, lowest-sloped lowland landscapes, dominated by megafan plains and floodplains (*darkest tones*).

b—Newly identified paleo-river. SRTM-based topographic altitude map – lighter tones are higher surfaces, darker tones are lower surfaces. Paleo-river floodplain (between angular lines) connects the lower Japurá R. (near its confluence with the Solimões R.) to the middle Rio Negro, a distance of ~200 km. Open arrows show the direction of paleo-river flow. Spot heights show that the paleo-river floodplain lies at an altitude between that of the modern Japurá R. (40–45 m) and the upper surfaces of megafan *Jw* (75 m) due west.

c—Palaeobiogeographic model of terrestrial environments of Amazonia, showing successive clades of *Psophia*. Map shows trumpeter phylogeography at 0.8–0.3 Ma, in which *Psophia crepitans* represents the parent. Thereafter, *P. leucoptera* and *P. napensis* diverge from this parent (at 2.0–1.0 Ma and 1.3–0.8 Ma, respectively); followed by divergence of *P. ochroptera* at ~1.0–0.7. Each lineage is separated by a major river. (In other parts of Amazonia the Tapajós, Tocantins, and Xingu rivers are established, isolating three successively younger endemic trumpeter species.) From Ribas et al. (2011).

d—Phylogeny and phylogeography of *Psophia* lineages in approximately the last 3 million years. Chronogram derived from Bayesian analysis of *cyt b* and *ND2* sequences (2181 bp). Calibration derived from analysis of *RAG2* nuclear gene. Adapted from Ribas et al. (2011).

Figure 1.— Amazonia—topography and trumpeter bird DNA.