A tale of two species: the importance of native ecosystems for long-term conservation on Príncipe Island, Gulf of Guinea

Guilherme R.V. Rebelo, Filipa C. Soares, Martina Panisi
Yodiney dos Santos, Tania L.F. Bird, Frazer Sinclair
Jorge Palmeirim and Ricardo Faustino de Lima

Abstract Since it was first described in 1901, the Príncipe thrush *Turdus xanthorhynchus* has been rare and restricted to the native forest in the south of Príncipe Island. The Obô giant land snail *Archachatina bicarinata*, however, was widespread across the island and at least locally abundant until the 1990s. Since then its population has collapsed, and now, like the thrush, it is also restricted to the native forest in the south of the island. Using species distribution modelling, we show that both species are currently strongly associated with rugged and remote areas of native forest at high altitudes. We argue that their current distribution might be negatively affected by anthropogenic pressures, as both are harvested, and also because invasive alien species are expected to have deleterious effects on these species, although further studies are needed to clarify interactions between these native and introduced species. The diachronic stories of these species highlight an overlooked value of native ecosystems: their role in the conservation of widespread species that might be unable to use anthropogenic landscapes in the future. They also reinforce the need for protected areas that strive to exclude most human activities in the context of particularly sensitive biodiversity, as is often the case on oceanic islands.

Keywords Endemism, Gulf of Guinea, native forest, Obô giant land snail, oceanic islands, Príncipe thrush, São Tomé and Príncipe, species distribution modelling

Guilherme R.V. Rebelo*† (Corresponding author, orcid.org/0000-0001-6161-7731, guilhermervrebelo97@gmail.com), Filipa C. Soares*† (orcid.org/0000-0002-7579-2538), Martina Panisi*†‡ (orcid.org/0000-0001-6132-5974), Jorge Palmeirim*† (orcid.org/0000-0003-4734-8162) and Ricardo Faustino de Lima*† (orcid.org/0000-0002-0184-3945) Centre for Ecology, Evolution and Environmental Changes, Faculty of Sciences, University of Lisbon, 1749-016 Lisbon, Portugal

Yodiney dos Santos (orcid.org/0000-0002-6158-8667), Tania L.F. Bird§ (orcid.org/0000-0002-5795-1750) and Frazer Sinclair§ (orcid.org/0000-0001-5017-3215) Fundação Príncipe, Santo António, São Tomé and Príncipe

*Also at: CHANGE–Global Change and Sustainability Institute, Faculty of Sciences, University of Lisbon, Lisbon, Portugal
†Also at: Department of Animal Biology, Faculty of Sciences, University of Lisbon, Lisbon, Portugal
‡Also at: CIBIO (Research Center in Biodiversity and Genetic Resources), University of Porto, Vairão, Portugal
§Also at: Fauna & Flora, Cambridge, UK

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The small volcanic island of Príncipe (136 km²) in the Gulf of Guinea (Central Africa; Fig. 1a) is home to a remarkable number of endemic species (Jones, 1994), including at least 11 bird species (de Lima & Melo, 2021) and 24 terrestrial molluscs (Holyoak et al., 2020). Amongst the most charismatic are the Critically Endangered Príncipe thrush *Turdus xanthorhynchus* (BirdLife International, 2021) and the Endangered Obô giant land snail *Archachatina bicarinata* (Panisi et al., 2022). The thrush is restricted to an extremely small population in the south of Príncipe, and it is susceptible to alien species, hunting and habitat degradation (Dallimer et al., 2010; BirdLife International, 2021). The snail also occurs on the nearby island of São Tomé, and its population and distribution are shrinking (Dallimer & Melo, 2010; Panisi et al., 2020, 2022). Here we use novel data to assess and compare the distribution and habitat associations of these two species on Príncipe.

Príncipe Island comprises a relatively flat, low-lying basalt platform in the north and a mountainous south. Temperature varies little across the island, whereas annual rainfall ranges from c. 2,000 mm in the north to > 5,000 mm in the south-west (Chou et al., 2020). The whole island remains largely forested, especially in the south, where a substantial area of native forest has been protected since 2006 by Príncipe Natural Park (Fauna & Flora, 2018). Native forest (27% of the land cover) refers to relatively undisturbed areas that have never been fully cut, whereas secondary forest (52%) refers to the results of regeneration, mainly after agricultural abandonment. Most of the human population and agricultural land are in the north, including a wide diversity of non-forested areas (12%) and shade plantations (9%); the latter is an agroforestry system in which cash and food crops are grown under the canopy of large trees (D'Avis, 2022).

We compiled presence–absence data to model the distribution of the two target species. We determined presences in January 2020 from all available records of live individuals of the thrush gathered since 2014 and of the snail since 2018 (Fig. 1b,c). Many of these records were made during an island-wide survey in 2018–2019 that encompassed five sampling points in each 1-km UTM grid cell (760 points), with the remaining records resulting from monitoring activities and occasional sightings (Fundação Príncipe, 2019). We excluded some records (mostly older ones), so

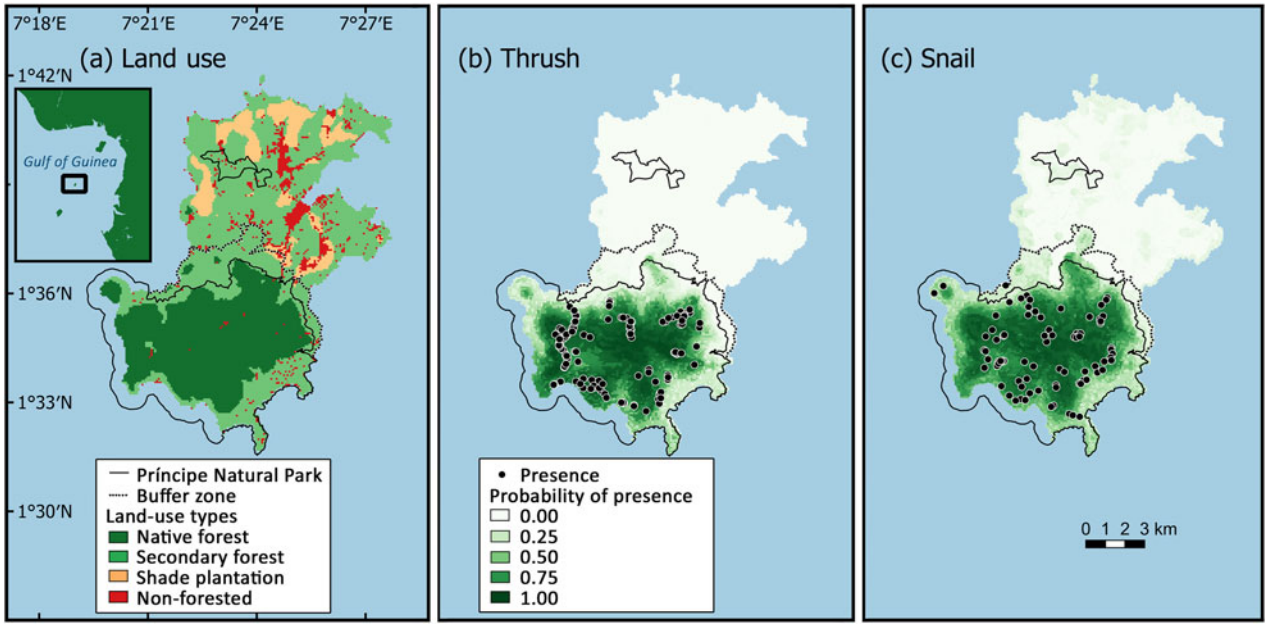

FIG. 1 Distributions of (a) land-use types, (b) Príncipe thrush *Turdus xanthorhynchus*, and (c) Obô giant land snail *Archachatina bicarinata* on Príncipe Island, São Tomé and Príncipe, with the boundaries of Príncipe Natural Park and its respective buffer zone and, in (b) and (c), records of the two species and their modelled potential distributions (see text for details). (Readers of the printed journal are referred to the online article for a colour version of this figure.)

that presences were at least 50 m apart. For absences we used sampling points from the island-wide survey that were at least 300 m from any thrush presence or 100 m from any snail presence. For each presence and absence point we used pre-existing geographically explicit variables to characterize land use (Fundação Príncipe, 2020), altitude, ruggedness, slope, topography, distance from the coast, rainfall and remoteness (Soares et al., 2020). To avoid multicollinearity, we excluded slope, distance from the coast and rainfall because they were highly correlated with other explanatory variables (Spearman's $\rho > 0.7$) whilst having lower correlations with the presence of the species. All remaining variables had low variance inflation factors (i.e. < 2).

We assessed the relationships between species presence and the environmental variables using a multi-model inference approach (Bartoń, 2019) and generalized linear models with a binomial distribution. We ranked the models with all possible combinations of environmental variables without interactions, based on the Akaike information criterion corrected for small sample sizes (AICc) with 1,000 bootstrap replicates, and we identified the relative variable importance from the sum of the AICc weights. We assessed the goodness of fit using McFadden's index and model performance using area under the curve (Sing et al., 2005). We mapped the distribution of each species from the model with the lowest AICc. We performed all modelling in *R 3.6.2* (R Core Team, 2019), and extracted environmental values and visualized the results in *QGIS 3.8.1* (QGIS Development Team, 2019).

The presence of the thrush was strongly and positively correlated with altitude and remoteness (both relative variable importance = 1), and the best model (AICc weight = 0.30) included altitude, land use, remoteness and topography (McFadden's index = 0.48, area under the curve = 0.90; Fig. 1b). The presence of the snail was strongly and positively correlated with altitude, remoteness (both relative variable importance = 1) and land use (relative variable importance = 0.98), and the best model (AICc weight = 0.50) included altitude, remoteness, land use and topography (McFadden's index = 0.47, area under the curve = 0.90; Fig. 1c).

Both species were strongly associated with native forest in the south of the island (Fig. 1b,c), which has been attributed to anthropogenic pressure: the thrush actively approaches humans, making it an easy, opportunistic target for hunting (Dallimer et al., 2010), and the snail is collected for food and traditional medicine (Dallimer & Melo, 2010). The tameness of the thrush makes it vulnerable to alien predators (Guedes et al., 2021), and there is evidence the snail has been significantly affected by the introduction of the giant West African land snail *Archachatina marginata* in the 1990s, although the exact mechanism underlying this remains unclear (Panisi et al., 2020). The ecology of both species remains poorly known, so it is possible they are also reliant on ecological features of the native forest, namely in terms of food availability. However, although the thrush has been restricted to native forest since the species was described in 1901, the snail was abundant throughout the island until a few decades ago, including in the north, which has experienced greater anthropogenic disturbance (Dallimer & Melo,

2010), suggesting that ecological features of the native forest are less likely to provide a direct causal explanation for the current habitat preferences of these species.

The example provided by these two species underlines the value of native ecosystems, which are known to be important for biodiversity (Newbold et al., 2015) and to be declining, particularly in the tropics (Hansen et al., 2013). Furthermore, it shows that the dependence of species on native ecosystems is not necessarily synchronous, and that some species become immediately reliant on those ecosystems, whereas others demonstrate a delayed response. This study reinforces the need to protect native ecosystems from anthropogenic pressures because of their role as species refuges (Selwood & Zimmer, 2020), not only in the present but also in the future. Although the integration of human activities in such habitats could be a feasible way to protect biodiversity in some contexts (Phalan, 2018), we argue that here and in similar cases involving oceanic islands or other ecosystems that are particularly sensitive to anthropogenic disturbance, striving for reduced human interference may be needed, at least in key locations. Considering ongoing environmental changes and the limited resources allocated to conservation, ensuring the effective protection of remaining native ecosystems should thus be a top priority for long-term conservation (Le Saout et al., 2013), as this could halt extinctions and prevent the disruption of ecosystem functioning (Watson et al., 2018).

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Conflicts of interest None.

Ethical standards Our research abided by the *Oryx* guidelines on ethical standards and no specific approval was required.

Data availability The data that support the findings of this study are available from the corresponding author, GRVR, upon reasonable request.

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