Population estimate of Trindade Petrel *Pterodroma arminjoniana* by the use of Predictive Nest Habitat Modelling

LUCAS KRÜGER, VITOR H. PAIVA, MARIA VIRGINIA PETRY, ROSALINDA C. MONTONE and JAIME A. RAMOS

Summary

The Trindade Petrel *Pterodroma arminjoniana* is a vulnerable species that breeds on Trindade Island, 1,100 km away from the Brazilian coast, and on Round Island in the Indian Ocean. Recent population estimates for Trindade Island by nest counts in accessible areas, and extrapolated to the whole island provided a figure of 1,130 breeding pairs. Using topographic variables and Predictive Nest Habitat Modelling from known breeding sites, we estimated the potential area of nesting and estimated the size of the breeding population. Nests were associated with low to intermediate elevations in areas of steep slopes and high runoff, which limited the distribution of potential breeding sites to the edges of the Island. By extrapolating the density of nests in the known breeding sites to the overall potential breeding area, we estimated 1,228 nests. We discuss the potential implications of our findings in relation to the population status based on the scenario of intense habitat modification of the island over the few last centuries. This species may have suffered declines due to habitat alteration by human activities and introduction of exotic species. Furthermore, we generate an overview of potential areas for nesting and establish relationships with habitats that may be useful for the conservation of the Trindade Petrel, and restoration actions for Trindade Island in the future.

Introduction

The Trindade Petrel *Pterodroma arminjoniana* is a vulnerable species that breeds on Trindade Island, 1,100 km away from the Brazilian coast, and on Round Island, in the South Indian Ocean (Brown and Jordan 2009, Brown *et al.* 2010, BirdLife International 2015). Trindade Petrel breeds in natural cavities on rocky and steep slopes of Trindade Island (Antas 1991, Luigi *et al.* 2009), with two main populations breeding in at different seasons, one breeding in austral summer and the other in austral winter, with a few individuals probably breeding in between (Luigi *et al.* 2009). The breeding habitat hampers access to most of the breeding sites on the island. Consequently, the few population estimates of the species have a large degree of uncertainty. The population was estimated at c.15,000 individuals (BirdLife International 2015), but Fonseca-Neto (2004) estimated 6,500 individuals, based on counts of incubating adults, plus flying individuals sighted at the breeding areas. However, Fonseca-Neto (2004) did not specify any correction to prevent recounting of flying individuals. Using an extrapolation of nest counts per area to the total number of areas where Trindade Petrel was recorded, Luigi *et al.* (2009) obtained an estimate of 1,130 breeding pairs and doubled this number for the non-breeding population. They counted 377 nesting pairs, assumed that the unmapped nests corresponded to twice this value and that half the nests were occupied by two pairs within a given year, thus producing an estimated breeding population of 1,130 pairs.

Censusing seabird populations breeding on cliffs and steep slopes is often difficult or highly imprecise due to accessibility constraints. Thus, several authors developed habitat suitability maps for predicting nest/colony locations of a given species (e.g. Catry *et al.* 2003, Rayner *et al.* 2007, Scott *et al.* 2009). Such Predictive Nest Habitat Modelling is based on (1) census of nesting birds in accessible areas, (2) modelling the habitat preferences of the species in accessible areas and (3) predicting the location and numbers of breeders for the remaining unsurveyed potential breeding area. In this study we provide the first breeding population estimative of Trindade Petrel based on nest-site mapping and nest counts in accessible breeding areas, and extrapolated the results to the whole area by the use of predictive nesting habitat modelling. Specifically, we tested the null hypothesis that predictive nest habitat modelling provides a similar population estimate to that of direct nest count methods used previously.

Methods

Study area

Trindade Island is one of the islands that rise from the Victoria-Trindade Ridge, a group of seamounts that originates at the coast and extends 1,100 km towards the Mid-Atlantic Ridge (Miloslavich *et al.* 2011). The island is highly mountainous and the relief ranges from sea level to 600 m in a relative small area, thus the overall slope of the island is above 80° (Alves 1998). The vegetation of the island was highly impacted by introduction of large herbivores, intensive logging and fire since its discovery by the year 1700 (Olson 1981, Alves 1998, Silva and Alves 2011). Olson (1981) reports eventual sightings of feral cats and mice *Mus* sp. There are no records of any rats *Rattus* spp. on Trindade Island in the past (Olson 1981) or presently. There is also a dense population of terrestrial crabs *Johngarthia lagostoma* that predate heavily upon seabird eggs (Fonseca-Neto 2004, Luigi *et al.*2009).

Nest mapping and density estimates

Trindade Petrel breeds on large rock cavities, and in contrast to most *Pterodroma* species which are ground burrowing breeders, nests of Trindade Petrels are quite exposed on the surface of such cavities. We searched for nests in areas described by Luigi *et al.* (2009) and its surroundings. We used flying individuals as cues to find nesting sites. The distribution presented by Luigi *et al.* (2009) was an outcome of a joint effort of several research surveys on Trindade Island between 1987 and 2007. They reported the locations of breeding areas found after exhaustive searching and exploration of the whole Island. After several years of inspection, they did not find breeding birds at high elevations (i.e. above 300m). Nevertheless, on two opportunities, we made excursions to the higher elevations of the island in search of nests.

We mapped the accessible breeding sites of the Trindade Island with a hand-held GPS receiver GARMIN GPSMAP® 60CSX (average precision ±4 m) and counted the active nests in those areas between September and November 2014, during the incubation period. Active nests were considered as those with adults, chicks or eggs, following Luigi *et al.* (2009). Additionally, we used the areas and the number of nests given by *Luigi et al.* (2009) for the other areas that we could not access (Figure 1). Luigi *et al.* (2009) counted 377 active nests with adults, eggs or chicks, between December 2006 and April 2007. In ArcGis 10.2 we created polygons from the mapped areas, and randomly added the number of nests of each breeding sites within the polygons. We excluded the South Islet presented by Luigi *et al.* (2009) because it has the higher density of nests in a relatively small area; probably the isolation from the main island resulted in a protection against past threats. This islet would bias the result towards those characteristics that are not representative of the rest of the island.
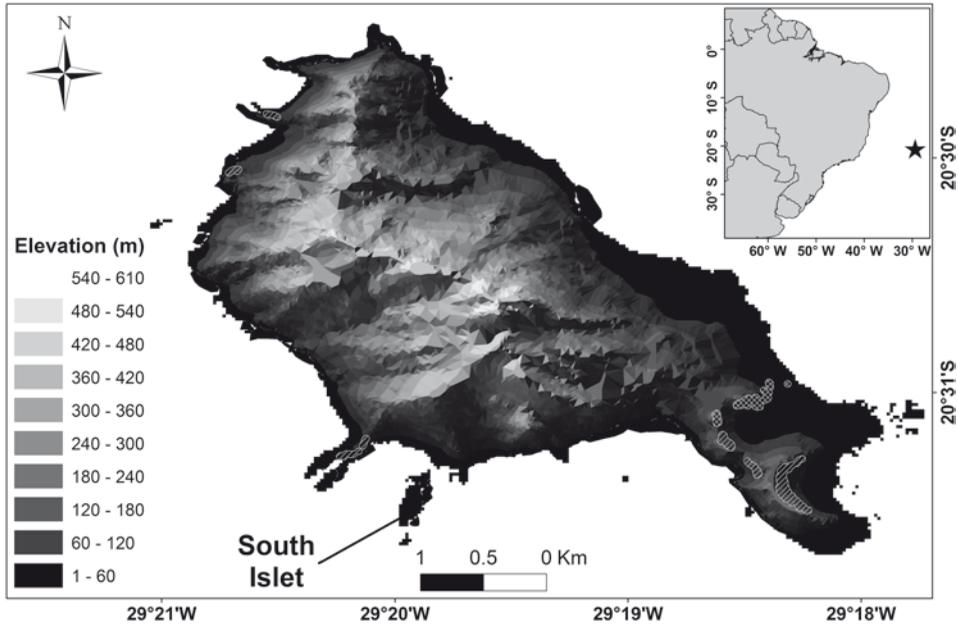
Figure 1. Location of Trindade Island (star) above, on the right, and the Trindade Petrel *Pterodroma arminjoniana* nesting areas mapped during this study (cross hatch) and by Luigi *et al.* (2009) (simple hatch), overlapped on a 3D Digital Elevation Model topography.

Geographic information system data

Trindade Petrel nests are associated with steep slopes and cliffs from low to intermediate elevations (Fonseca-Neto 2004, Luigi *et al.* 2009). Hence, we used topography to evaluate nest habitat suitability. A contour line shapefile was provided to us by the Brazilian Navy through the "Secretaria da Comissão Interministerial para os Recursos do Mar" (SECIRM). We created a Digital Elevation Model (DEM) through a Triangulated Irregular Network (TIN) 3D interpolation of the contour lines on ArcGis v10.2 (Figure 1). TIN interpolation allows for a more detailed estimation of elevation in comparison to other methods (Ewans *et al.* 2001, Tucker *et al.* 2001). Altitude, slope (terrain inclination) and aspect (the direction, in degrees) images were generated from the DEM. The altitude raster was used to evaluate finer measures of relief inclination associated with precipitation movement and soil runoff, the flow length and the flow drop, using the hydrology toolbox of the Spatial Analyst on Arc Gis 10.2 (Figure 2). Flow length measures the downstream distance for precipitation moving from one grid cell to another, and flow drop is a measure of the probability of precipitation movement to a given grid cell. These variables should be important in characterising breeding areas because sites with severe runoff and high precipitation speed may be unsuitable or disadvantageous for nesting.

Predictive nesting habitat modelling

There are several methods of modelling species distribution (e.g. Peterson *et al.* 2007, Oppel *et al.* 2012). We chose to use the Maximum Entropy (MaxEnt) approach (Phillips *et al.* 2006) as it is regarded one of the best mechanistic methods for modelling species distributions based on presence-only data (Elith *et al.* 2006, Oppel *et al.* 2012), and it relies on non-linear relations of presence-only data and habitat variables (Elith *et al.* 2011, Merow *et al.* 2013). For instance, Austin (2002, 2007) emphasises the need to use non-linear methods in habitat modelling.
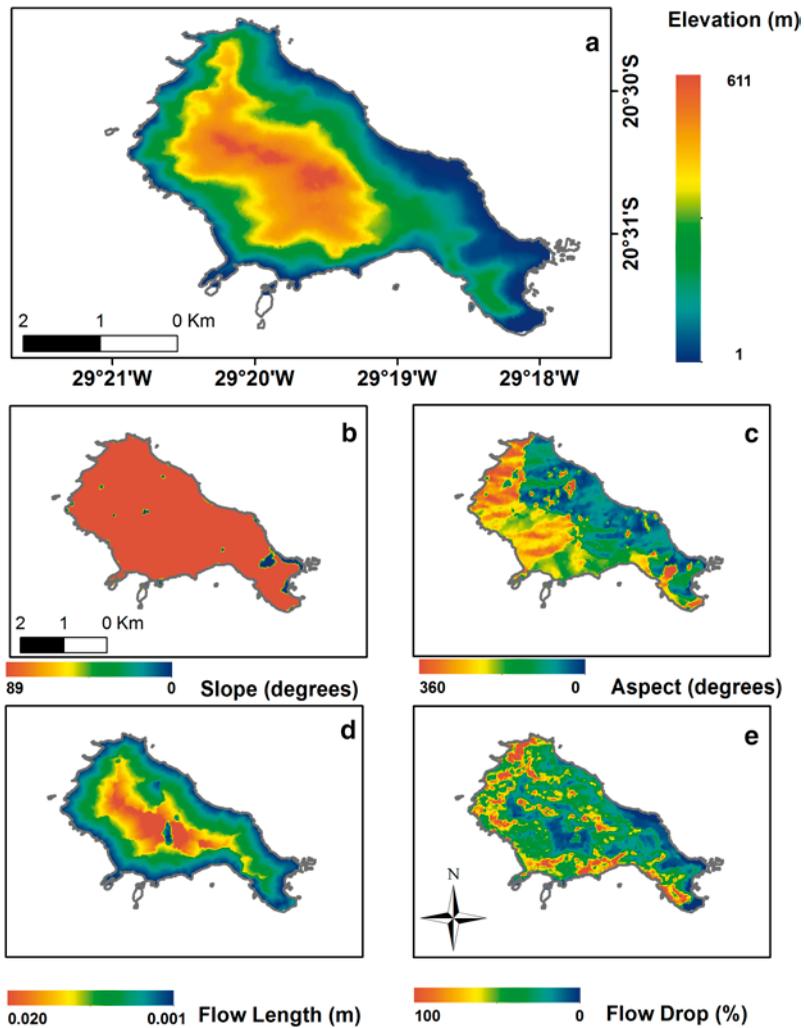
Figure 2. Environmental variables used to evaluate the Predictive Nest Habitat Modelling of Trindade Petrel *Pterodroma arminjoniana* with the MaxEnt modelling technique.

Furthermore, MaxEnt is robust to the use of correlated variables in the modelling procedure to predict probability of presence in each cell (Royle *et al.* 2012), as it is a machine learning method (Elith *et al.* 2011, Merow *et al.* 2013). We set aside 10% of presence localities as set points to calculate model accuracy. The multidimensional environmental similarity surface method (MESS) was used to evaluate where the environment had values out of range (Merow *et al.* 2013). We used a bootstrap resampling procedure ($n = 50$) to obtain a prediction of the average distribution (Edrén *et al.* 2010). The MaxEnt model produces a logistic output as a measure of habitat suitability (from 0 to 1) for predicting nest locations of breeding Trindade petrels, as proposed by Merow *et al.* (2013).

Predicting breeding areas

We inspected how the resultant entropy (as a measure of how the final presence probabilities differentiate from those expected using the model) of the 50 resamplings was related to the
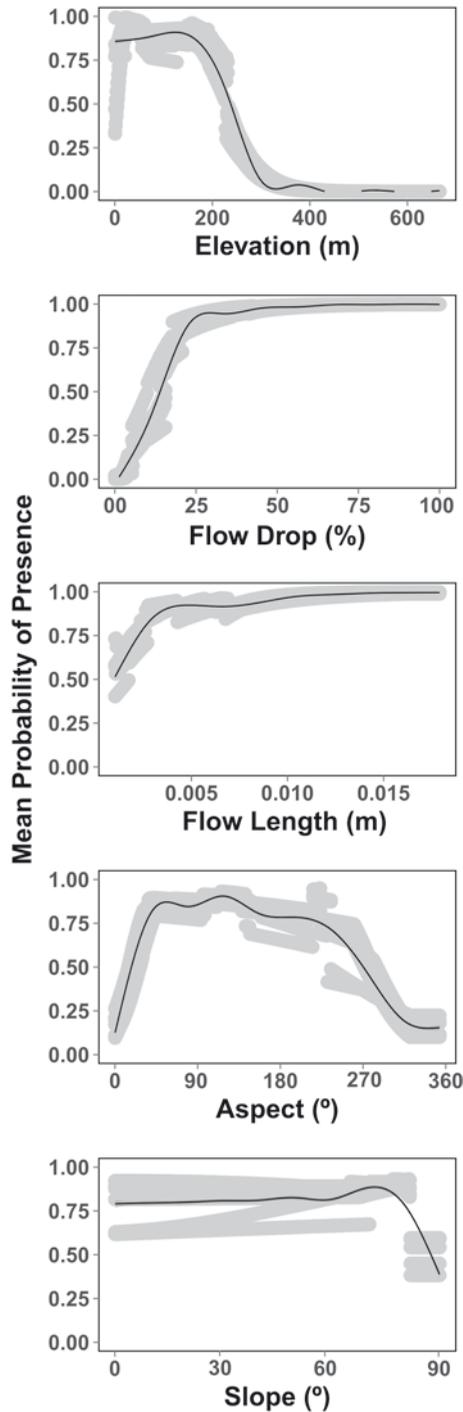
Figure 3. Estimated probability of Trindade Petrel *Pterodroma arminjoniana* nest presence in relation to the different environmental variables included in the MaxEnt Predictive Nest Habitat Modelling (grey areas) and a smoothed loess tendency (black line).

maximum sensitivity plus specificity threshold outputs, and chose the higher threshold value that minimised the entropy. Then we selected only the pixels that were above this threshold value to calculate the area of the island where we expected the Trindade Petrel nests to occur. We extrapolated the density of nests in the known and mapped nesting sites to the area calculated using this threshold.

Results

The accuracy of the models was high (bootstrap mean AUC = 0.977 ± 0.004) meaning that the model was able to predict almost all of the 10% of data set aside for testing. The variables with higher contribution to the models were elevation and flow drop, which together represented 67.6% of the contribution to models and 82.9% of permutation importance (the percentage of AUC reduction on models without the variables) (Table 1). The Trindade Petrel had a higher estimated probability of presence in low to medium elevations, in areas where slope varied from flat to steep, but the probability of presence decreased considerably on slopes above 80° (Figure 3). Such factors indicated that the higher presence probabilities were restricted mostly to the outer edges of the island (Figure 4).

The entropy on the 50 bootstrapped models described a parabola in relation to the maximum sensitivity plus specificity thresholds (Figure 5). The minimum entropy would match a threshold near zero, but this would use almost the entire area of the island, which is an unreal assumption. As the estimated entropy starts to decrease when the threshold reaches 0.20 of presence probability, we chose to use the higher value of 0.29, rounded to 0.30. By applying a threshold value of 0.30 the potential nesting area of Trindade Petrel on the island (Figure 6) occupied 5,346 m^2 (Table 2). Within this area 1,048 nests are expected to occur. Adding the numbers from the South Islet which were previously excluded, we reached an estimate of 1,228 nests for Trindade Island.

Discussion

We found a breeding population value relatively similar to the value given by Luigi *et al.* (2009), thus corroborating the size of the breeding population proposed by them. They suggested a population of 1,130 breeding pairs, while our modelling resulted in 1,228 breeding pairs. Information regarding species abundance in the past (Murphy 1936, Olson 1981) is mostly anecdotal, but a population decline between the mid-1970s and mid-1990s can be inferred from a reduction of sightings in the non-breeding areas (Lee 1999, 2000). It is worth noting that our count was conducted during the austral summer (September–November). Luigi *et al.* (2009) included year-round data in their counts, so by using their data we reduced any potential error due to Trindade Petrels having subpopulations with different breeding periods. However, we would be cautious and assume that our population values are a potential minimum population size. Furthermore, this species shows nest site fidelity; e.g. Fonseca-Neto (2004) observed that seven out of 18 individuals returned to the same nests, and eight to the same cavities. Krüger *et al.* (2016) found that 16 out of 40 birds returned to the same cavities.

Table 1. Mean ± SD percentage contribution and permutation importance of the environmental variables (for explanation of variables see methods) from the 50 bootstrapped MaxEnt model, predicting the probability of presence of Trindade Petrel *Pterodroma arminjoniana* nests in Trindade Island.

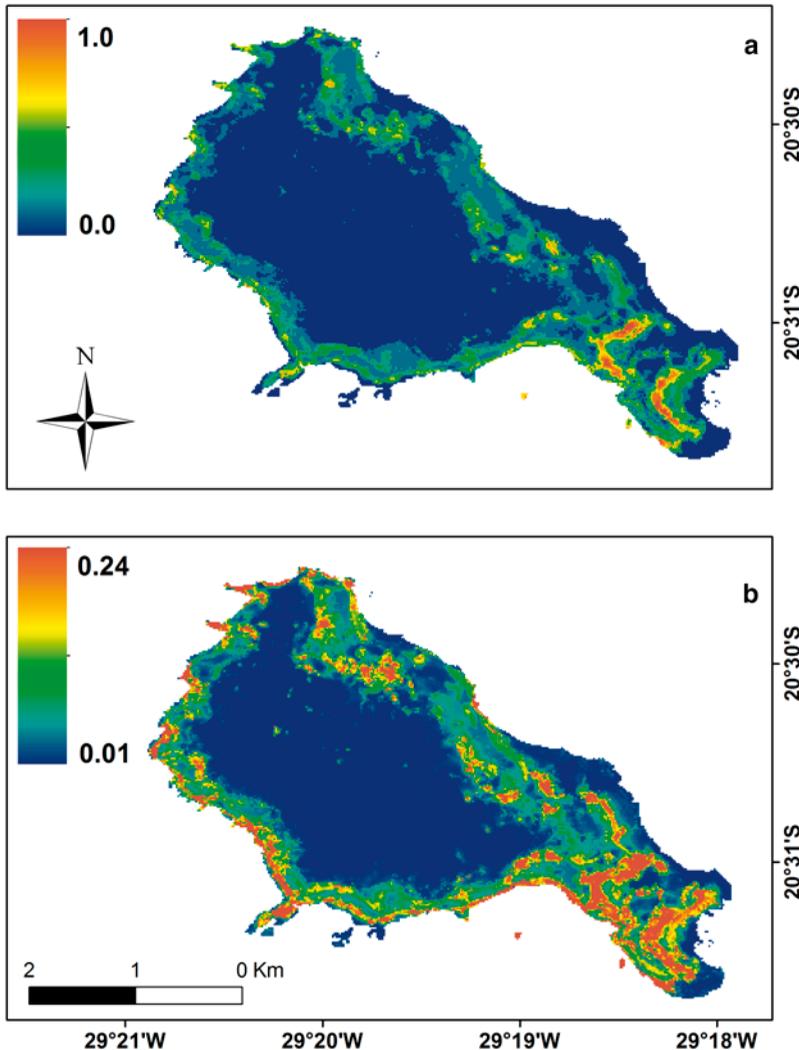| Variable	Percent contribution	Permutation importance
Elevation	34.9 ± 2.36	46.3 ± 2.84
Flow Drop	32.7 ± 2.31	36.6 ± 3.31
Flow Length	13.0 ± 1.77	8.1 ± 0.94
Aspect	12.0 ± 1.57	4.5 ± 1.20
Slope	3.1 ± 1.18	3.25 ± 1.12

Figure 4. Mean predictive probability of presence (a) and standard deviation (b) of the predictions of Trindade Petrel *Pterodroma arminjoniana* nests locations at Trindade Island. Outputs of a MaxEnt Predictive Nest Habitat Modelling.

As with other species of gadfly petrels (*Pterodroma* spp.) (Harris 1970, Bretagnolle and Attié 1991, Zino *et al.* 2001) Trindade Petrel nests on steep slopes and cliffs, but unlike other species (Zino *et al.* 2001, Rayner *et al.* 2007, Pinet *et al.* 2009), they do not associate with higher elevations. Species such as Zino's Petrel *Pterodroma madeira* (Zino *et al.* 2001), Cooks's Petrel *Pterodroma cookii* (Rayner *et al.* 2007) and Barau's Petrel *Pterodroma baraui* (Pinet *et al.* 2009) breed in association with remnant vegetation restricted to higher mountain areas and cliffs where human activity, trampling and grazing by introduced large herbivores are restricted. The nesting distributions of these three species have had limited habitat modification, as they are associated with vegetation at higher elevations where native vegetation remains. Trindade Petrel seems to present the opposite response, as it is a surface breeder not associated with dense vegetation, therefore avoiding higher elevations (Luigi *et al.* 2009).
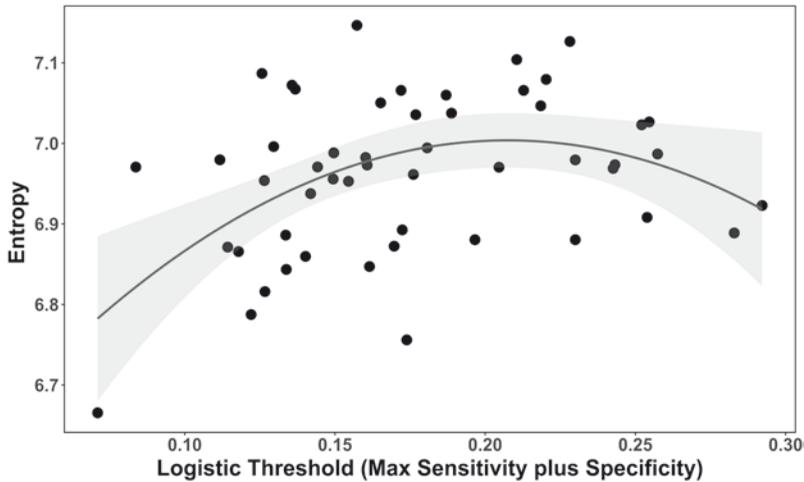
Figure 5. The entropy in relation to the logistic threshold values of the 50 bootstrapped models. We chose the higher value of threshold with the potential lower value of entropy (Logistic threshold = 0.30).

It has been suggested that Trindade Petrels were limited to cliffs and slopes due to the combined effects of feral goat trampling, feral cats and intense egg predation by crabs (Alves 1998, Fonseca-Neto 2004, Luigi *et al.* 2009). In pristine conditions Trindade Petrels were probably able to nest on the ground close to the coast, but there is no description of the nesting habitat before habitat modification on the island. On two occasions during field surveys, one of the authors (LK) was able to participate in exploration of the high peaks of the island, and found no signs of Trindade Petrels there or near the remnant patches of vegetation, something also highlighted by Luigi *et al.* (2009).

Lee (1999, 2000) suggested that this species has suffered a severe decline, after analysing historical sightings in the North Atlantic. This suggestion, added to the population size of 15,000 individuals (BirdLife International 2015), raised some questions concerning the current population
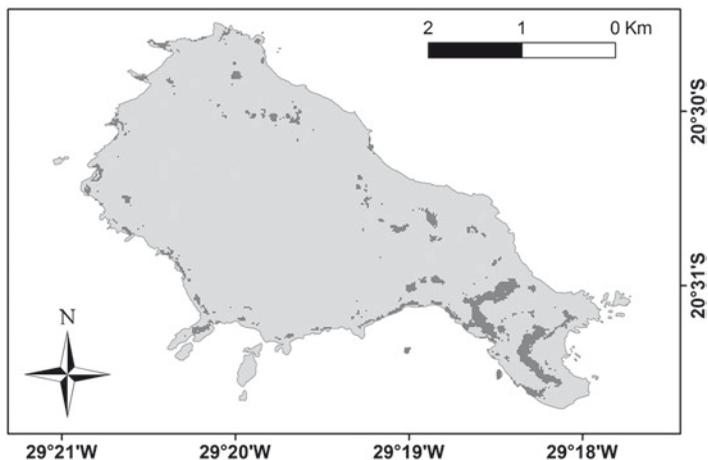

Figure 6. Expected distribution of Trindade Petrel *Pterodroma arminjoniana* colonies based on a logistic threshold of 0.30. See the methods section for the full MaxEnt Predictive Nest Habitat Modelling procedure.

Table 2. Number of Trindade Petrel *Pterodroma arminjoniana* nests on the mapped areas and extrapolation to the estimated areas using the Predictive Nest Habitat Modelling (excluding the South Islet) with a logistic threshold (probability of occurrence) of 0.30.

Method	Area (m²)	Nests
Mapped	2,096	411
Logistic Threshold	5,346	1048

status of this species and a possible negative effect of the feral goats inhabiting the Island for two centuries, occasional feral cats and egg predation by crabs (Alves 1998, Fonseca-Neto 2004, Luigi *et al.* 2009). Furthermore, researchers on early expeditions recorded the presence of feral cats at very low densities (Olson 1981, Williams 1984), which may also have contributed to the decrease of the Trindade Petrel, and for the restriction of breeding sites to steep cliffs of the island. There are several examples of feral cat predation reducing populations of seabirds (Carlile *et al.* 2003, Pinet *et al.* 2009, Ratcliffe *et al.* 2009), but this type of impact over Trindade Petrel is only implied, since there is no confirmation of cat predation in the past, and currently cats are absent from the Island.

Conclusion

To our best knowledge, this is the first study evaluating the population size of Trindade Petrel using the Predictive Nesting Habitat Modelling technique. We found that our up-to-date estimate of the breeding population likely matches another recently reported figure (Luigi *et al.* 2009). Furthermore, we were able to generate a picture of the distribution of breeding areas that can be verified in future field studies, and can be used to guide decisions for the protection of the breeding habitat of this vulnerable species.

Acknowledgements

References

Alves, R. J. V. (1998) *Ilha da Trindade e Arquipélago Martin Vaz, um ensaio geobotânico*. Rio de Janeiro, BR: Serviço de Documentação da Marinha.

Antas, P. T. Z. (1991) Status and conservation of seabirds breeding in Brazilian waters. Pp. 141–158 in J. P. Croxall, ed. *Seabird status and conservation: a supplement*. Cambridge, UK: International Council for Bird Preservation.

Austin, M. P. (2002) Spatial prediction of species distribution: an interface between ecological theory and statistical modelling. *Ecol. Modell.* 157: 101–118.

Austin, M. P. (2007) Species distribution models and ecological theory: a critical assessment and some possibly new approaches. *Ecol. Modell.* 200: 1–19.

BirdLife International (2015) Species factsheet: *Pterodroma arminjoniana*. Downloaded from http://www.birdlife.org on 16/11/2015.

Bretagnolle, V. and Attié, C. (1991) Status of Barau's Petrel (*Pterodroma baraui*): colony sites, breeding population and

taxonomic affinities. *Colonial Waterbirds* 14: 25–33.

Brown, R. M. and Jordan, W. C. (2009) Characterization of polymorphic microsatellite loci from Round Island Petrels (*Pterodroma arminjoniana*) and their utility in other seabird species. *J. Ornithol.* 150: 925–929.

Brown, R. M., Nichols, R. A., Faulkes, C. G., Jones, C. G., Bugoni, L., Tatayah, V. Gottelli, D. and Jordan, W. C. (2010) Range expansion and hybridization in Round Island petrels (Pterodroma spp.): evidence from microsatellite genotypes. *Molec. Ecol.* 19: 3157–3170.

Carlile, N., Priddel, D., Zino, F., Natividad, C. and Wingate, D. B. (2003) A review of four successful recovery programmes for threatened sub-tropical petrels. *Marine Ornithol.* 31: 185–192.

Catry, P., Campos, A., Segurado, P., Silva, M. and Strange, I. (2003) Population census and nesting habitat selection of Thin-Billed Prion *Pachyptila belcheri* on New Island, Falkland Islands. *Polar Biol.* 26: 202–207.

Edrén, S. M. C., Wisz, M. S., Teilmann, J., Dietz, R. and Söderkvist, J. (2010) Modelling spatial patterns in harbour porpoise satellite telemetry data using maximum entropy. *Ecography* 698–708.

Elith, J., Graham, C. H., Anderson, R. P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R. J., Huettmann, F., Leathwick, J. R., Lehmann, A., Li, J., Lohmann, L. G., Loiselle, B. A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J. McC., Peterson, A. T., Phillips, S. J., Richardson, K. S., Scachetti-Pereira, R., Schapire, R. E., Soberon, J., Williams, S., Wisz, M. S. and Zimmermann, N. E. (2006) Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29: 129–151.

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., and Yates, C. J. (2011) A statistical explanation of MaxEnt for ecologists. *Divers. Distrib.* 17: 43–57.

Ewans, W., Kirkpatrick, D. and Townsend, G. (2001) Right-triangulated irregular networks. *Algorithmica* 30: 264–286.

Fonseca-Neto, F. P. (2004) Aves marinhas da ilha Trindade. Pp. 119–146 in J. O. Branco, ed.

Aves marinhas insulares brasileiras: bioecologia e conservação. Itajaí, BR: UNIVALI.

Harris, M. P. (1970) The biology of an endangered species, the Dark-Rumped Petrel (*Pterodroma phaeopygia*) in the Galápagos Islands. *The Condor* 72: 76–84.

Krüger, L., Paiva, V. H., Colabuono, F. I., Petry, M. V., Montone, R. C. and Ramos, J. A. (2016) Year-round spatial movements and trophic ecology of Trindade Petrels (Pterodroma arminjoniana). *Journal of Field Ornithology* 87: 404–416.

Lee, D. S. (1999) Pelagic seabirds and the proposed exploration for fossil fuels off North Carolina: a test for conservation efforts of a vulnerable international resource. *J. Elisha Mitchell Sci. Soc.* 115: 294–315.

Lee, D. S. (2000) Color morph bias and conservation concerns for a tropical *Pterodroma*. *The Chat* 64: 15–20.

Luigi, G., Bugoni, L., Fonseca-Neto, F. P. and Teixeira, D. M. (2009) Biologia e conservação do Petrel-de-Trindade, *Pterodroma arminjoniana*, na ilha da Trindade, Atlântico sul. Pp. 223–263 in: L. V. Mohr, J. W. A. Castro, P. M. S. Costa and R. J. V. Alves, eds. *Ilhas oceânicas brasileiras: da pesquisa ao manejo*. Brasília, BR: Ministério do Meio Ambiente.

Merow, C., Smith, M. J., and Silander Jr, J. A. (2013) A practical guide to MaxEnt for modelling species' distributions: what it does, and why inputs and settings matter. *Ecography* 36: 1058–1069.

Miloslavich, P., Klein, E., Díaz, J. M., Hernández, C. E., Bigatti, G., Campos, L., Artigas, F., Castillo, J., Penchaszadeh, P. E., Neill, P. E., Carranza, A., Retana, M. V., Astarloa, J. M. D., Lewis, M., Yorio, P., Piriz, M. L., Rodríguez, D., Yoneshigue-Valentin, Y., Gamboa, L. and Martín, A. (2011) Marine biodiversity in the Atlantic and Pacific coasts of South America: Knowledge and gaps. *PLoS One* 6: e14631.

Murphy, R. C. (1936) *Oceanic birds of South America*. New York: American Museum of Natural History.

Olson, S. L. (1981) Natural history of vertebrates on the Brazilian islands of the mid South Atlantic. *Nat. Geogr. Soc. Res. Reports* 13: 481–492.

Oppel, S., Meirinho, A., Ramírez, I., Gardner, B., O'Connell, A. F., Miller, P. I. and Louzao, M.

(2012) Comparison of five modelling techniques to predict the spatial distribution and abundance of seabirds. *Biol. Conserv.* 156: 94–104.

Peterson, A. T., Papes, M. and Eaton, M. (2007) Transferability and model evaluation in ecological niche modelling: a comparison of GARP and Maxent. *Ecography* 30: 550–560.

Phillips, S. J., Anderson, R. P. and Schapire, R. E. (2006) Maximum entropy modelling of species geographic distributions. *Ecol. Modell.* 190: 231–259.

Pinet, P., Salamolard, M., Probst, J. M., Russel, J. C., Jaquemet, S. and Le Corre, M. (2009) Barau's Petrel *Pterodroma baraui*: history, biology and conservation of an endangered endemic petrel. *Marine Ornithol.* 37: 107–113.

Ratcliffe, N., Bell, M., Pelembe, T., Boyle, D., Benjamin, R., White, R., Godley, B., Stevenson, J. and Sanders, S. (2009) The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. *Oryx* 44: 20–29.

Rayner, M. J., Hauber, M. E. and Clout, M. N. (2007) Breeding habitat of the Cook's Petrel (*Pterodroma cookii*) on Little Barrier Island (Hauturu): implications for the conservation of a New Zealand endemic. *Emu* 107: 59–68.

Royle, J. A., Chandler, R. B., Yackulic, C. and Nichols, J. D. (2012) Likelihood analysis of species occurrence probability from presence-only data for modelling species distributions. *Methods Ecol. Evol.* 3: 545–554.

Scott, D., Moller, H., Fletcher, D., Newman, J., Aryal, J., Bragg, C. and Charleton, K. (2009) Predictive habitat modelling to estimate petrel breeding colony sizes: Sooty Shearwaters (*Puffinus griseus*) and Mottled Petrels (*Pterodroma inexpectata*) on Whenua Hou Island. *New Zealand J. Zool.* 36: 291–306.

Silva, N. G. and Alves, R. J. V. (2011) The eradication of feral goats and its impact on plant biodiversity – a milestone in the history of Trindade Island, Brazil. *Rodriguésia* 62: 2011.

Tucker, E. G., Lancaster, S. T., Gasparini, N. M., Bras, R. L. and Rybarczyk, S. M. (2001) An object-oriented framework for distributed hydrologic and geomorphic modelling using triangulated irregular networks. *Computers and Geosciences* 27: 959–973.

Williams, A. J. (1984) Breeding distribution, numbers and conservation of tropical seabirds on oceanic islands in the South Atlantic Ocean. Pp. 393–401 in J. P. Croxall, P. G. H. Evans, and R. W. Schreiber, eds. *Status and conservation of the world's seabirds*. Cambridge UK: International Council for Bird Preservation.

Zino, F., Oliveira, P., King, S., Buckle, A., Biscoito, M., Costa Neves, A. and Vasconcelos, A. (2001) Conservation of Zino's Petrel *Pterodroma madeira* in the archipelago of Madeira. *Oryx* 35: 128–136.

LUCAS KRÜGER*, VITOR H. PAIVA, JAIME A. RAMOS
MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, University of Coimbra, 3000-456 Coimbra, Portugal.

MARIA VIRGINIA PETRY
Laboratório de Ornitologia e Animais Marinhos, Universidade do Vale do Rio dos Sinos, São Leopoldo, Brasil.

ROSALINDA C. MONTONE
Instituto Oceanográfico da Universidade de São Paulo, Universidade de São Paulo, São Paulo, Brasil.

Author for correspondence; e-mail: biokruger@gmail.com