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Using ecological niche models to infer the distribution and population size of parakeets in New Caledonia

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ABSTRACT

Knowing the distribution and abundance of species is critical for conservation, yet field surveys are often limited in their spatial extent. In this study, we use ecological niche models to infer the current and future distribution of New Caledonian Parakeets (*Cyanoramphus saisseti*), Horned Parakeets (*Eunymphicus cornutus*), and Ouvéa Parakeets (*Eunymphicus uvaeensis*) in New Caledonia. In addition, we present a new method of assessing the population size of each species based on the relationship between local abundance and modelled habitat suitability. According to our estimates, there are 5708 (5048–6174) New Caledonian Parakeets on the main island of New Caledonia, distributed over an area of 2783 km^2, of which 1939 km^2 is forested. We estimate there to be 8690 (7934–9445) Horned Parakeets, and their distribution extends over 3482 km^2, including 2162 km^2 of forest. In comparison, the Ouvéa Parakeet has a very restricted range of 34 km^2 (most of which is forested), and a population estimated at 1730 (963–3203) individuals. Projections involving simulated climate change suggest that populations of New Caledonian Parakeets and Horned Parakeets may recede into areas at higher altitudes in the future, primarily along the central mountain chain of the mainland. It is difficult to predict how the Ouvéa Parakeet will respond to the climatic changes forecast for Ouvéa, as the species is expected to face climatic conditions in the future that are different from any of those currently experienced on the island. Our research demonstrates that the current reserve system in New Caledonia is unlikely to provide sufficient protection for parakeets. Hence, we believe that existing Important Bird Areas (IBAs) should be evaluated for their current and future potential as reserves.

1. Introduction

Knowledge of a species' distribution and abundance is critical for assessing conservation status, determining current levels of threat, and developing conservation strategies (IUCN, 2011). However, field surveys are often limited in their spatial extent, even in relatively well-studied regions of the world (Wilson et al., 2005). Field research is costly and labour intensive, thus detailed information about the distribution of species is difficult to obtain, let alone keep current. One way to overcome this problem is to estimate species' distributions using ecological niche models, which quantify the relationship between a species and its habitat (Guisan and Thuiller, 2005). By correlating the spatial coordinates of field observations with information about the surrounding environment, such models can be used to infer a species' ecological requirements and predict suitable habitat in unsurveyed regions (Peterson, 2006). The reliability of ecological niche models has advanced in recent years as a result of the increased availability of high-resolution geospatial data and improvements in predictive algorithms (Elith et al., 2006; Phillips et al., 2006). While models are typically used to estimate a species' current distribution (e.g. Buermann et al., 2008), they also have the potential to predict future distributions (e.g. Araujo et al., 2004; Rodder and Weinsheimer, 2009), amongst a variety of other applications (Guisan and Thuiller, 2005; Peterson, 2006).

Given the ability of ecological niche models to predict where a species may occur, they may also provide an indication of a species'

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relative abundance in a particular habitat. In theory, a highly suitable habitat should support a large number of individuals, but this assumption may not hold under all circumstances (Van Horne, 1983). Furthermore, the conceptual link between abundance and habitat suitability has proven difficult to establish for certain taxa (Jiménez-Valverde et al., 2009; Nielsen et al., 2005; Pearce and Ferrier, 2001), leading some authors to conclude that the relationship may not be generally applicable (Jiménez-Valverde et al., 2009), or that the factors limiting a species' distribution may differ from those that influence abundance (Nielsen et al., 2005). However, recent research, involving novel modelling algorithms and relatively fine-scale environmental variables, has revealed that a positive relationship exists between spatial patterns of abundance and habitat suitability for a wide range of species (VanDerWal et al., 2009). These findings have important implications for conservation, as they suggest that models of habitat suitability have potential for monitoring population trends (e.g. Real et al., 2009) and for estimating population size (e.g. Long et al., 2008).

Identifying priority areas for conservation is important for species protection, yet distribution data are rarely available at the scale or resolution necessary to determine which areas have the greatest potential for conservation. Ecological niche models provide a means of extrapolating incomplete distribution data to a wider area, which is useful for evaluating the suitability of reserves (e.g. Anderson and Martinez-Meyer, 2004), and estimating the proportion of a species' range that is protected (e.g. Carroll, 2010). There is an increasing need to incorporate predictive models into conservation strategies as descriptive studies alone cannot keep pace with the ongoing loss of biodiversity and the degradation of ecosystems around the world, and this situation looks likely to worsen as the risks associated with climate change become more apparent (Walther et al., 2002).

New Caledonia is considered a global hotspot of biodiversity, on account of its high level of species endemism, and in view of the fact that a substantial proportion of its original vegetation has been lost (Myers et al., 2000). Despite the dire need to conserve species and habitats in New Caledonia, the region has not been adequately surveyed. Thus, predictive models are likely to prove useful as conservation tools, by maximising the utility of existing data. Here, we use ecological niche models to infer the current and future distribution of New Caledonian Parakeets (*Cyanoramphus saisseti*), Horned Parakeets (*Eunymphicus cornutus*), and Ouvéa Parakeets (*Eunymphicus uvaeensis*) in New Caledonia. Ouvéa Parakeets are categorised as 'endangered', while New Caledonian Parakeets and Horned Parakeets are both considered 'vulnerable' by the IUCN (2011). Using ecological knowledge gathered in previous studies (Barré et al., 2010; Legault et al., 2011, 2012, 2013; Robinet et al., 2003; Theuerkauf et al., 2009), we establish the relationship between local abundance and habitat suitability, and then draw on this relationship to estimate the population size of each species. Furthermore, we examine whether the existing reserve system provides sufficient long-term protection for parakeets, and analyse the relative suitability of Important Bird Areas (IBAs) in New Caledonia, as defined by Spaggiari et al. (2007).

2. Methods

2.1. Surveys

We carried out our study throughout New Caledonia (18,500 km^2), which is located in the southwest Pacific Ocean (20–22°S, 164–168°E). We based our analysis on encounters with parakeets, which we recorded during targeted searches, auditory point counts, and distance sampling from 2002 to 2011.

Searches were carried out at various locations on the main island of New Caledonia (Fig. 1), and involved locating parakeets by their calls and recording their position using GPS. The vocalisations of each species are distinct, so we had little difficulty identifying birds. The GPS error associated with parakeets encountered during searches was usually 20 m or less, and not more than 50 m (95% probability). At 39 survey sites on the mainland, we assessed daily encounter rates by recording the number of parakeets encountered during two days of searches. At two of these sites, we established the relationship between encounter rates and density estimates from distance sampling (Legault et al., 2013).

We performed point counts throughout mainland New Caledonia during several extensive surveys (Chartendrault and Barré, 2005, 2006; Desmoulins and Barré, 2004). Points were spaced at intervals of about 500 m, and we spent 15 min at each point listening for bird calls. We undertook counts from dawn to 09:30, and from 15:30 to dusk. Only the location of the observer was recorded during point counts. We did not record the distance or direction to birds, but we presume that most locations were within a radius of 250 m or less, due to limitations of audibility. We consider this to be a conservative estimate, as we rarely detected parakeets beyond 80 m during distance sampling (Legault et al., 2013), and the accuracy of these records was sufficient for our purposes.

On the mainland, we used point counts and daily encounter rates as indices of parakeet abundance because they offered a convenient means of surveying multiple species over large areas in a relatively short period. Both of these methods yield important information about the distribution and abundance of parrots, yet they are of limited use for estimating population size on their own. On the island of Ouvéa (20°36'S, 166°34'E), we used line transect distance sampling methods (Buckland et al., 1993) to estimate parakeet numbers (Barré et al., 2010; Legault et al., 2013). Distance sampling is useful for estimating bird densities, but few areas on the mainland have been surveyed using this approach (Legault et al., 2013). Assuming a search radius of 250 m at each of the locations visited, we estimate that we surveyed 510 km^2 (3%) of the mainland (using searches, point counts, and distance sampling), and 40 km^2 (29%) of Ouvéa (using distance sampling). All estimates of density and population size are provided with 95% confidence intervals.

2.2. Model variables

We assessed habitat suitability for parakeets in New Caledonia using the maximum entropy niche modelling approach, as implemented in Maxent version 3.3.2 (Phillips et al., 2004, 2006). Given the varying detectability of parakeets in their natural environment, some individuals are likely to have remained undetected during surveys. Considering the difficulty in distinguishing between inconspicuous behaviour and true absence, we felt that a presence-only modelling approach would suit our study better than an approach requiring accurate absence data.

During the initial testing phase, we generated models using various combinations of variables. We examined the relative contribution of each variable and performed a jack-knife test to evaluate variable importance. We also measured the degree of spatial correlation between potential model variables by calculating Pearson's correlation coefficient (r) in ENMTools 1.1 (Warren et al., 2010). To improve interpretability and to minimise the possibility of over-fitting, we removed highly correlated variables ($r > 0.90$), and retained only those that we considered to be biologically relevant to parrots in New Caledonia, as described below. Additional variables did not appear to improve predictive performance, and the probability distributions generated by the chosen models were very similar to those produced by more complex alternatives.