Use of Spatial Analysis to Evaluate the Effect of Climate Change on numbers of Maui Parrotbill (*Pseudonestor xanthophrys*)

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Introduction

The Maui Parrotbill (MAPA) is a critically endangered honeycreeper endemic to Maui. Sub-fossil evidence suggests that MAPA once occurred throughout forested areas of Maui and Molokai (Olson and James 1982b, Scott et al. 1986). Habitat loss and alien diseases (e.g., avian malaria and avian pox) have dramatically reduced the species' range and population size; currently about 500 individuals comprise the sole population which occupies approximately 50 km^2 of wet, ohia-dominant forest on the windward slope of Haleakalā (Fig. 1). Climate change will likely increase the range of disease vectors (i.e., mosquitoes), and thus further reduce the amount of suitable MAPA habitat. Here we construct geospatial models to examine how predicted temperature increases will reduce suitable habitat for MAPA and use current home range sizes to estimate the number of pairs that this habitat could support. We also use similar methods to illustrate the potential benefits of reforestation efforts on the leeward slope of Haleakalā followed by the establishment of a second population.

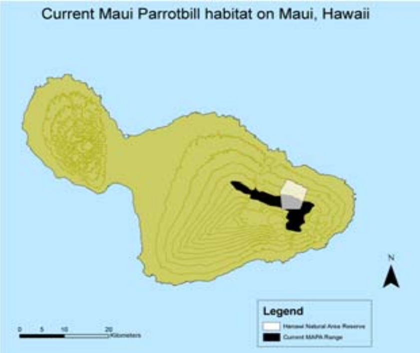

Figure 1. Hanawi Natural Area Reserve study area within current Maui Parrotbill habitat restricted by avian malaria.

Methods

Modeling Climate Change & Forest Restoration

The current range of MAPA is based on VCP (Variable Circular Plot) surveys conducted between 1980 and 2001, expert knowledge, and a lower elevational limit of 1200 m (Gorreson et al. In press). We input this information into ArcMap 9.2 to illustrate the species' current range. We clipped this general range polygon to the 1500 m contour line, the current known elevational limit of disease parasites and their vectors (Van Riper et al. 1986, LaPointe 2000, Benning et al. 2002). A geospatial prediction map was constructed based on the potential elevational movement of avian malaria by the year 2090 based on a 0.27°C/ decade temperature increase (Giambelluca et al. 2008) and a lapse rate of 0.55°C/ 100m (Loope and Giambelluca 1998). We constructed a second geospatial map using the same temperature change parameters to predict the amount of habitat that would be suitable for MAPA if all leeward, East Maui habitat was restored by 2090.

Home Range Analysis

We used four years of resight data from one pair of MAPA in Hanawi Natural Area Reserve (NAR; 3,125ha), to calculate a home range size. Using handheld GPS (Global Positioning System) units, locations of the pair were recorded and then downloaded into a GIS (Geographical Information System). Annual home range size was estimated by creating Minimum Convex Polygons using Hawth's Tools (Beyer 2004) and averaged to provide an overall home range size. This estimate was used to determine the number of pairs that could be supported in the two predicted MAPA ranges we calculated.

Results

Based on current data, about 40 km^2 of suitable MAPA habitat exists (Fig. 2). Within the Hanawi NAR, a pair of MAPA uses approximately eight ha, resulting in a range-wide population estimate of 500 pairs. Temperature increases associated with climate change and the concomitant increase in the elevational limits of malaria will reduce the amount of suitable habitat to 9 km^2 (Fig. 2). Based on our home range data, this area would support an upper limit of 100 MAPA pairs. Restoring leeward forests on East Maui would increase the amount of available habitat to 40 km^2 (Fig. 3), which could potentially support 500 pairs, based on homerange estimates from Hanawi.

The above analysis assumes that MAPA home ranges are constant throughout their range. Unfortunately, home range data does not exist for areas outside of Hanawi where MAPA density appears to be higher compared to areas outside the NAR: 35–49 birds/km^2 (Hanawi NAR [MFBRP unpub. data]) vs. 19 birds/km^2 (Kipahulu Valley, Haleakalā National Park [R. Camp pers. comm.]). Unpublished USGS data estimates a range-wide density of 16 birds/km^2. To illustrate the potential population size effects of variation in MAPA density due to forest type, we calculated population estimates based on the most recent density estimates from wet 'Ohia and mesic (Koa and 'Ohia) forests for the present day and for the year 2090 (Table 1).

Table 1. Range-wide MAPA density estimates calculated based on two forest types.

Study Area Used for Population Estimate	Forest Type	Present Population Estimate	2090 Population Estimate
Hanawi NAR	Wet, 'Ohia	1400 (35/km^2: 40km^2)	315 (35/km^2: 9km^2)
Kipahulu Valley	Mesic	760 (19/km^2: 40km^2)	171 (19/km^2: 9km^2)

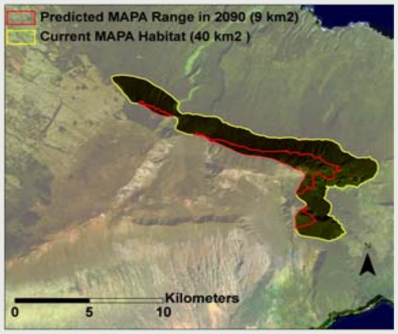

Figure 2. Model of Maui Parrotbill habitat restricted by avian malaria both presently (yellow contour) and for the year 2090 (red contour).

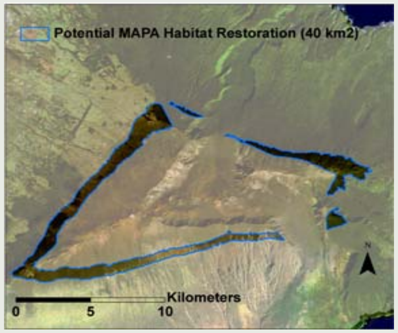

Figure 3. Predicted Maui Parrotbill habitat for 2090 if all leeward, East Maui habitat is restored.

Discussion

Our estimate of suitable habitat is 10 km^2 less than what has been traditionally reported; this difference is the result of using a 1200 m vs. 1500 m elevational limit. In contrast, our estimate of breeding pairs exceeds current population estimates, and is likely the result of habitat variation and how this variation affects MAPA density. Because Hanawi consists of a densely vegetated, wet-'ohia forest this suggests that MAPA in mesic and dry-forest habitats would require larger home ranges and thus our 2090 population estimates are likely biased high.

If current temperature trends continue habitat with a low-risk of disease could be reduced by as much as 75% leading to a dramatic loss of birds (Fig. 2). Unfortunately, disease moving upslope is not the only threat to native birds posed by climate change. It is likely that changes in frequency of occurrence and altitudinal location of the trade wind inversion (TWI) will also affect forest bird habitat. Although the TWI responds to sea surface temperature (SST), the relationship is ambiguous. If warming of SST causes the TWI to shift downslope, reduced cloud cover over upper elevation native forests will increase drought conditions and the risk of fire. If the TWI occurs more frequently, native bird habitats may suffer more frequent and damaging storms (Loope and Giambelluca 1998); currently, storms cause most MAPA nest failures in Hanawi (MFBRP unpub. data).

Efforts to reforest portions of the leeward slope of East Maui are being planned with the eventual goal being to establish a second MAPA population. MAPA survival into the next century may ultimately depend on the successful restoration of all leeward and windward habitats above the predicted avian malaria line. Unfortunately, these native habitats would be restricted to a narrow band of forest which would have a large surface to volume ratio. This would result in a number of potential management issues (e.g. edge effects), and these forests would support a population of MAPA that would continue to be highly vulnerable to extinction.

Acknowledgments

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