

Messages from Population Models: Implications for Recovery of Endangered Maui Parrotbill

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INTRODUCTION

Small populations, especially those on islands, are extinction prone (Gilpin and Soulé 1986, Steadman 2006). Such populations are vulnerable to chance events like hurricanes, anthropogenic threats, the transport of new diseases and predators, and to demographic and genetic problems. All can contribute to extinction (Banko *et al.* 2001).

Population viability analysis is often used to quantify the risk of extinction and to examine the relative benefits of alternative management actions (Ellner & Fieberg 2003). Predicting the risk of and time to extinction under a variety of scenarios can inform conservation decisions and management efforts (Clark *et al.* 1990). If a species is expected to go extinct within a decade, management priorities would need to differ substantially from those for a species predicted to slowly decline over a century.

Here we present results of population viability analyses (PVA) for the Kiwikiu or Maui Parrotbill (*Pseudonester xanthophrys*, MAPA), a federally endangered species restricted to a single population occupying less than 50 sq km on windward east Maui. We compare estimates of extinction probability and time to extinction for MAPA under different demographic, threat, and management scenarios.



METHODS

MAPA demographic data (Table 1) were collected in mature ohia (*Metrosideros polymorpha*) forest between 1700 and 2300 m elevation in the Hanawi Natural Area Reserve on windward Haleakala volcano, Maui. We used Vortex 9.99 to predict extinction risks and in all simulations we assumed a stable age distribution, even sex ratio, and a carrying capacity supportive of growth ($K=3000$). In all simulations we started the population at its current estimated size, 500 individuals (Camp *et al.* 2009), and kept annual adult mortality constant at 16%. After evaluating two estimators for the percentage of adults breeding in the population (nest success and pair success), we calculated a value that would result in population stability, referred to as "reverse engineer". Next, we compared the effects of increasing juvenile mortality or the number of years that adults breed (i.e. reproductive years).

We modeled the influx of avian malaria expected as a result of climate warming (Benning *et al.* 2002, Harvell *et al.* 2002) as steady or catastrophic (Table 3). In the steady influx model the harvest feature in Vortex was set at 1% per year (5 birds), based on the annual loss of disease free habitat in climate change models (Giambelluca *et al.* 2008). The harvest took two females (a juvenile and an adult) and three males (two juveniles and one adult) per year. We then modeled catastrophic influx of malaria by reducing survival by 50% once every 10 years.

RESULTS

Demographic Scenarios

PVA models based on nest success data suggest that MAPA are declining faster than models based on pair success (Table 2). The productivity value associated with population stability, defined here as maintaining 500 individuals over the next 100 years, was 57.25% (Table 2). In the stable population models, a near doubling of juvenile mortality increased extinction risk from 5% to 100%, while reducing the time to extinction by 34 years (Table 2). Increasing reproductive years from 15 to 20 caused the population to more than double, while reducing it to 10 resulted in a substantial decline.

Threat & Management Scenarios

A gradual influx of malaria increased extinction probability to 48%. With pulses of high mortality the probability of extinction increased to 99% with an average time to extinction of 48 years (Table 3). The increase in pair success associated with rodent reduction (Table 1) allowed the population to increase 6-fold under the gradual malaria influx scenario, but was unable to mitigate population losses in the catastrophic malaria scenario (Table 3).

Table 1. Demographic values and their sources

Variable	Values Used	Source or Publication
Juvenile mortality	24% ± 9	Garvin 2008
Second yr mortality	20% ± 5	Extrapolated for model
Adult mortality	16% ± 4	Garvin 2008
Life Span	15+ years	MFBRP unpublished data
Nest success	36%	Becker <i>et al.</i> 2010
Pair success	55%	Becker <i>et al.</i> 2010
Pair success, PC*	80%	MFBRP unpublished data
Age 1st reproduction	2 (ASY)	MFBRP unpublished data
Reproductive years	10,15,20	Model

* PC refers to a predator control grid where predation risk by rodents is reduced

Table 3. Effects of malaria influx and rodent reduction on extinction and MAPA population size

Model	Treatment	P Extinct.%	Yrs to Extinct.	N100±SD
Gradual malaria influx	Harvest 5/yr	48	79 ± 13	300 ± 35
Catastrophic malaria influx	↓ 50% survival 1/10yrs	99	48	0
Rodent Reduction w/ gradual influx	↑ % Breeding to 80%	0	0	2986 ± 47
Rodent Reduction w/ catastrophic influx	↑ % Breeding to 80%	55	91	296 ± 540



DISCUSSION

Population viability analysis is sensitive to model parameters emphasizing the need for caution when interpreting results, and for high quality data. For example, our estimate of juvenile survival is based on a small sample (N=7); a larger sample would be informative. However, in absence of new threats, Kiwikiu juvenile mortality is probably low and fairly stable due to intense parental care exhibited by this species (Becker *et al.* 2010).

Both methods of calculating productivity (nest success and pair success) indicate that the Kiwikiu core population may be declining, contrary to population surveys suggesting that the Hanawi population is stable (Camp *et al.* 2009). However, a small increase in the number of pairs producing a fledgling (pair success) results in a stable population, if environmental variables remain similar, which is unlikely.

Increasing pair success is the demographic parameter most likely to be influenced by management. With predator control, pair success has been increased significantly at Hanawi. Reducing rodents favors population growth ($\lambda > 1$), and should facilitate the evolution of resistance to malaria, especially at mid-elevations (Kilpatrick 2006).

This positive scenario is tempered by the likelihood that large influxes of malaria caused by extreme climate events would cause high pulses of mortality at higher elevations where resistance is not expected to evolve.

An understanding of genetic variability of Kiwikiu will help better determine the potential the species has for adapting to the challenges of climate induced upslope migration of avian malaria.

Given that we did not include other stochastic events (i.e., hurricanes) our results call attention to the serious vulnerability of Kiwikiu and highlight the importance of rapidly restoring forest habitat and establishing a second population. Fortunately, work is underway by the State of Hawaii Department of Land and Natural Resources-DOFAW to re-establish native koa (*Acacia koa*) forest and a second Kiwikiu population on the drier leeward side of east Maui where mosquitoes are less prevalent than in the wetter windward forests. In addition, some private landowners are restoring high elevation native forest on Haleakala. These actions will reduce the risk of extinction by increasing carrying capacity, and favor the recovery of Kiwikiu populations.

ACKNOWLEDGEMENTS

We would like to thank all field technicians who collected the field data underlying these analyses. We would also like to thank Haleakala National Park, Hawaii Department of Land and Natural Resources, Pacific Cooperative Studies Unit, U.S. Fish and Wildlife Service, Haleakala Ranch, Pacific Helicopters and Windward Aviation who also made this work possible.



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