CASE STUDY: Climate change threatens Hawaiian forest birds

In Hawai'i, geographic isolation has prevented the natural establishment of mammals, reptiles, amphibians, and many insect species, such as biting mosquitoes. Isolation has also facilitated the spectacular evolutionary radiation of Hawaiian honeycreepers from a single small flock of North American finches into more than 50 species and subspecies of endemic forest birds (Pratt, 2009).

With the arrival of humans came the clearing of forests and the introduction of non-native species and their diseases. More than 40 mosquito species have been intercepted in Hawai'i, and six have become established, most recently in 2004 (LaPointe & Burgett, 2005). The southern house mosquito was the first to arrive in Hawai'i in 1826 (Atkinson & LaPointe, 2009b). It is the vector for avian malaria and avian pox. The malaria parasite arrived later with the introduction of non-native birds, probably around 1871. These introduced birds are the perfect avian malaria host: They show no signs of infection and remain infectious for long periods of time.

The *'Apapane* honeycreeper, seen here at Hawai'i Volcanoes National Park, is one of the only remaining, relatively abundant species of Hawaiian honeycreepers. Photo courtesy of Simon Bisson.

Habitat loss, predation and competition have taken their toll on Hawaiian honeycreepers, but this trio of invasive species—alien birds, malaria, and mosquitoes—were, and still are, a major threat to the honeycreepers' long-term survival. Almost all of these birds are vulnerable to avian malaria, with mortality rates as high as 65% to 90% after being bitten by a single infective mosquito (Atkinson & LaPointe, 2009a, 2009b). Of the 50 species and sub-species of endemic Hawaiian honeycreepers, only 22 have survived the combined effects of habitat loss, disease, predation, and competition from alien species). The most recent victim, the *Po'ouli* became extinct in 2004 (Pratt, 2009).

Mosquitoes and avian malaria do not do well in Hawai'i's cooler high elevations. Below 13^{o}C (about 55^{o}F), the malaria parasite cannot complete its maturation cycle, so the disease cannot be transmitted. In addition, the southern house mosquito, which transmits avian malaria, is active at night when temperatures are cooler. Consequently, the prevalence of avian malaria in native forest birds is low above 1,500m (about 5,000 feet) (Atkinson & LaPointe, 2009a). At lower elevations, mosquitoes and malaria are abundant, and most honeycreepers can no longer survive in the warm mesic and wet forests that were once ideal habitats. Hawai'i's cool, high mesic and wet forests have become their last refuge. But today, climate change threatens to open up these refuges to avian malaria.

As climate change warms the air, the range of mosquitoes will expand upslope, and infective malaria parasites will develop at high elevations. Currently, at higher elevations, avian malaria transmission is seasonal, occurring during the warm summer and fall when mosquito populations are at a maximum. Thus the cooler winter months and night temperatures are critical to the survival of honeycreepers.

As global warming raises air temperatures, their seasonal high elevation refuge will shrink and eventually disappear (Benning et al., 2002; Atkinson & LaPointe, 2009a). It is likely that the spread of mosquitoes and avian malaria (as well as avian pox) into the high elevations of Hawai'i will eventually lead to the extinction of many, perhaps all, of the honeycreepers that currently survive in these areas.

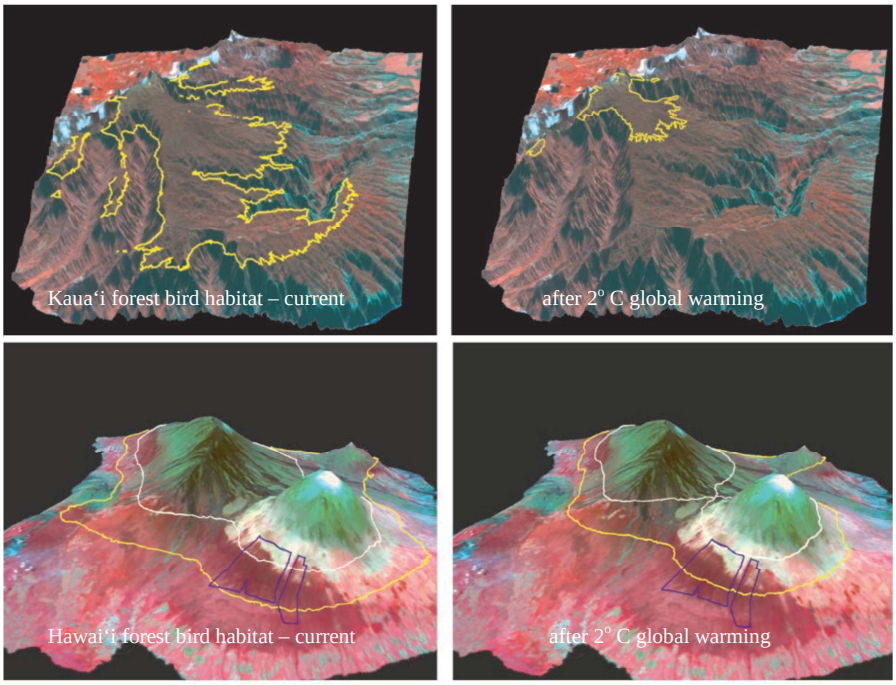

Figure 4.14. Projected changes in forest cover in relation to 17°C (yellow) and 13°C (white) isotherms under current and 2°C warming conditions. Changes are shown for Hakalau Forest National Wildlife Refuge (blue boundary) on Hawai‘i, and the Alakai swamp region on the island of Kaua’i. Figure from (Benning et al., 2002).

Current temperatures at high elevations in Hawai`i have risen about 0.26° C per decade averaged over the day and night. But of greater concern is the rise in night-time temperatures when the southern house mosquito is most active. These have risen about 0.44° C (0.79 °F) per decade since 1975 (Giambelluca et al*.,* 2008). As a result, the prevalence of avian malaria in Hawaiian forest birds at Hakalau Forest National Wildlife Refuge (1,500 to 2,000 m; 5,000 to 6,500 feet elevation) on the island of Hawai‘i has risen from 2.1% to 5.4% over the past decade (Freed et al., 2005). The prevalence of avian malaria at high elevations on Kaua‘i has risen as much as 30% over the past decade (Atkinson & Utzurrum, 2010).

High-elevation forest restoration is needed to expand the upward range available to these forest birds. This will require addressing long-standing problems with invasive plants and animals. And there is hope for some Hawai‘i honeycreepers. Natural resistance to avian malaria has developed in one species, the *Hawai’i amakihi,* which is now more abundant in low-elevation forests with high levels of mosquitoes and avian malaria than at disease-free high-elevation sites (Woodworth et al., 2004; Kilpatrick et al., 2006). The hope is that good habitat management can help other honeycreepers developing resistance to avian malaria (Kilpatrick, 2006). Unfortunately, the rate of warming in Hawai‘i may not give these birds enough time to develop resistance. Without human assistance, global warming combined with avian malaria may overwhelm Hawai‘i honeycreepers and other forest bird species.