Eradication Efforts for Hybrid-Mouflon Sheep in Palila Critical Habitat on Mauna Kea

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ABSTRACT: Palila were listed as a federal endangered species in 1967, primarily due to two centuries of habitat destruction by non-native ungulates. The United States Fish and Wildlife Service designated Critical Habitat for palila in 1977, and federal court rulings in 1979, 1987, and 1998 mandated Hawai'i Department of Land and Natural Resources (DLNR) to remove all sheep and goats from Critical Habitat. In 2010, over 30 years since the original ruling, DLNR initiated construction of a 6-foot-tall ungulate-proof fence around Mauna Kea to eliminate ingress of feral sheep, hybrid-mouflon sheep, goats, and cattle. Twenty-four miles of fence were completed around the southern portion of Mauna Kea by 2013. DLNR also developed a strategic plan for the permanent removal of non-native ungulates from palila critical habitat (PCH) and received a Competitive State Wildlife Grant to fund eradication efforts. Implementation of the plan and dispersal of the funds began in April 2013. A population estimate was conducted in May 2013 using distance sampling that produced a point estimate of 2,046 hybrid-mouflon sheep with a 95% confidence interval of 482- 3,614 sheep. From January 1 2003 to February 6 2014, 3,270 sheep and 26 goats were removed from PCH by aerial shooting (2,150), aerial drives (228), and public hunting (792). Of the 2,147 sheep shot during aerial shooting, 2,081 were shot when not tracking Judas sheep (sheep fitted with radio collars that facilitate locating herds from the helicopter), and 66 were shot when tracking Judas sheep. With the population reduction, aerial shoot efforts are now dependent upon tracking the 17 Judas sheep currently equipped with radio-collars to find herds that have learned to avoid aerial hunting by hiding under the forest canopy. Future aerial shoots will be conducted on a monthly basis and missions will likely to be 2 days. To reach the goal of sheep eradication in PCH prior to the depletion of remaining funds, it is essential to track all Judas sheep every mission to increase removal rates. Otherwise, the sheep population will likely recover and continue to damage the remaining forest in PCH that palila depend upon.

KEY WORDS: aerial shooting, eradication, fences, Judas animals, *Loxioides bailleui*, mouflon sheep, *Ovis gmelini musimon*, palila, sheep, ungulates

Proc. 26th Vertebr. Pest Conf. (R. M. Timm and J. M. O'Brien, Eds.)
Published at Univ. of Calif., Davis. 2014. Pp. 56-60.

INTRODUCTION

Palila (*Loxioides bailleui*) is a forest bird species that is endemic to the Hawaiian Islands. They belong to a group of birds referred to as the Hawaiian honeycreepers, included in the sub-group called finch-billed honeycreepers that primarily eat seeds. Palila are specialists that depend on māmane (*Sophora chrysophylla*) trees for 90% of their diet (Banko et al. 2002). Māmane, a leguminous tree, provides seeds, flowers, young leaves, and larvae found in the seed pods that palila eat. Historically, palila occupied māmane forests on Hawai'i Island on the upper slopes of Mauna Loa, Hualālai, and Mauna Kea.

Due to the isolation of the Hawaiian Islands, the native vegetation did not evolve with mammalian herbivory. In the late-1700s, Europeans arrived in Hawai'i and released sheep (*Ovis aries*), goats (*Capra hircus*), and cattle (*Bos taurus*) (hereafter "ungulates") (Tomich 1986). Hawaiian royalty forbade the harvest of the new food source to allow the populations to grow. The non-native ungulates expanded their range across Hawai'i Island and within 3 decades, sheep and cattle were found in large numbers near the summit of Mauna Kea. Over the next century, the exploding populations of ungulates browsed on the defenseless native flora and destroyed much of the forest on which palila depended. Fortunately, some native ecosystems in Hawai'i have the capacity to recover when ungulates are removed from the landscape (Scowcroft and Giffin 1983, Hess et al. 1999, Cole et al. 2012, Reddy et al. 2012).

The Territorial foresters recognized the destruction that was occurring to the forests on Mauna Kea. In the 1930s, they began addressing the problem with the help of the Civilian Conservation Corps. They built 55 mi of fence around the base of Mauna Kea in 20 months with the goal of eradicating ungulates above the fence (Bryan 1937a). In a 10-year period, they removed nearly 50,000 ungulates from Mauna Kea (Bryan 1937b).

After World War II, there was a shift in management goals from watershed conservation to sustainable yield for recreational hunting by promoting ungulate population growth (Banko et al. 2014). In the 1960s, the Hawai'i Division of Fish and Game introduced mouflon sheep (*O. gmelini musimon*) to Mauna Kea with the intention of improving hunting opportunities and minimizing the impacts of feral sheep browse damage by hybridizing mouflon sheep with feral sheep. The rationale was that browsing damage would be reduced because mouflon sheep are less gregarious than feral sheep and occur in smaller herds. Instead, a more athletic and intelligent breed of sheep displaced feral sheep, continued to damage native forest, and is more difficult to eradicate from a rugged mountain with limited access.

Palila were listed as an Endangered Species in 1967 due to a severe population decline and a drastic loss of habitat (USFSW 1967). They were last observed on Hualālai in the late 1800s, on Mauna Loa in the early 1950s, and now they only occur on a small portion of Mauna Kea's southwestern slope (Camp et al. 2014), referred to as Palila Core Area (Figure 1). Palila Critical Habitat (PCH; 60,187 acres) was designated on Mauna

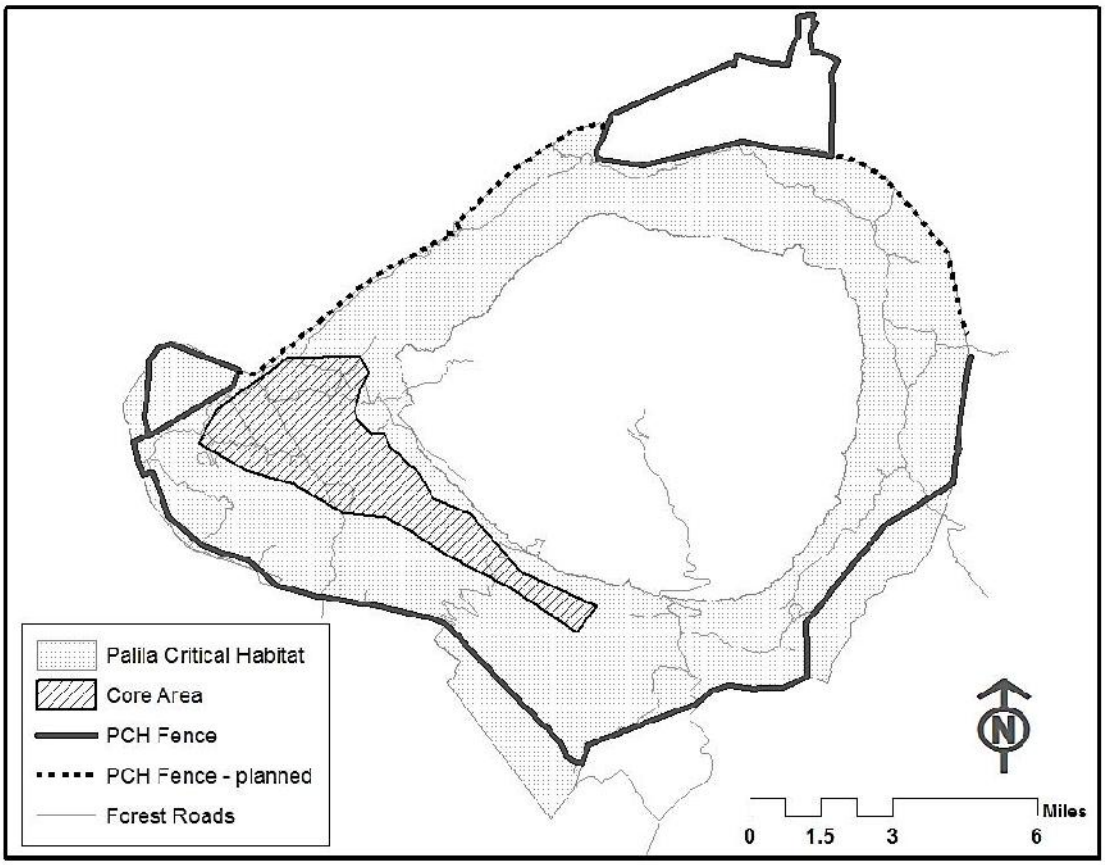

Figure 1. Map of Palila Critical Habitat, Core Area and Fences on Mauna Kea, Hawai'i Island.

Kea in 1977 (USFWS 1977), and in 1979 the palila was named as a plaintiff under the Endangered Species Act in *Palila v. DLNR*. A federal judge ordered all feral sheep and goats removed from PCH. *Palila v. DLNR* was reconvened in 1987, 1998, and 2009. In 1987, DLNR was ordered to remove all hybrid-mouflon sheep from PCH as well. In 1998, the federal judge stipulated that DLNR must a) eliminate ungulate ingress into PCH by repairing or building new fence along the PCH boundary, b) continue using public hunting to remove sheep from PCH, and c) conduct aerial shoots in PCH at least semi-annually. In 2009, DLNR assured the court they would complete the fence and removal of all sheep from PCH in a timely manner. The palila population is estimated at 1,328-1,802 (point estimate = 1,549), which represents a 68% decline since 1998 when intensive survey efforts were implemented (Camp et al. 2014).

ERADICATION PLANNING AND RESULTS (2010-2014)

Palila Critical Habitat Fence

DLNR initiated construction of a 6-ft-high ungulate-proof fence around PCH in 2010 with funding provided by the United States Fish and Wildlife Service (USFWS). Twenty-four mi were completed by March 2013, protecting a 29-mi boundary along the southern portion of Mauna Kea from ungulate ingress (Figure 1). Two sections (14 mi) remain to be completed. A 9-mi section of 55-inch-high fence built in the 1930s along the northwestern boundary with Parker Ranch is still functional. The threat of ungulate ingress along this border is negligible. A 5-mi segment along the northeastern border of PCH is in disrepair and ungulate movement does occur across this border, but the level of ingress in uncertain. Construction of the 6-ft-high fence has been delayed due to native Hawaiian burial sites located along this corridor, which require further surveys and consultation to minimize impacts to burial sites.

Eradication Plan

Prior to 2013, little information was collected during aerial shoots documenting the methods used or to assess the effectiveness of those efforts. However, in 2012 DLNR drafted an Ungulate Removal Plan for PCH (DLNR 2013) to facilitate the removal of all sheep using aerial shooting and public hunting. The plan included the following guidelines: 1) conduct an aerial survey to determine the size and distribution of the sheep population in PCH; 2) increase the frequency of aerial shoots to occur approximately every 5 weeks; 3) capture 25 hybrid-mouflon sheep, attach radio-collars to each animal, and release them in PCH to use as 'Judas sheep' focusing on the area occupied by palila and areas with the highest densities of sheep ('Judas sheep' will flock with other sheep and enable the aerial shoot crew to efficiently locate sheep groups from the helicopter); and 4) collect data to assess effectiveness and refine methodology in order to eradicate the remaining sheep.

As a result of initiating construction of the PCH fence and drafting an eradication plan, DLNR was awarded a

Competitive State Wildlife Grant from the USFSW with $250,000 budgeted for aerial shooting.

Sheep Population Estimate

In May 2013, an aerial survey was conducted from a Bell Jet Ranger helicopter flown at 45 knots and 75 m above ground level along 280 km of transects spaced 1 km apart using distance sampling (Buckland et al. 2001). The two observers on each side acted as a team and estimated distances with a TruPulse laser rangefinder (Laser Technology Inc., Centennial, CO). Observers detected 482 sheep in 53 clusters. The point estimate was 2,046 sheep with a 95% confidence interval of 482-3,614. The estimate has an unknown level of bias due to a low sample size (n = 53) and a violation of the one of the underlying assumptions of distance: there were fewer detections closer to the line than further away. The average distance of sheep observed from transects was only 240 ft in the palila Core Area on the southwestern slope of Mauna Kea, compared to 567 ft outside of the Core Area. Detectability was lower in the Core Area because forest is much thicker there than in the rest of PCH. The sex ratio was 42 rams per 100 ewes.

Aerial Drives and Shooting Results

DLNR conducted aerial drives and herded 228 sheep into a corral in 2013. The sheep were then transported to Pohakuloa Training Area, where they were eventually released with the goal of establishing a herd that would provide sustainable hunting opportunities.

There were seven 2-day and two 4-day aerial shoot missions (22 total days) from April 22 2013 through February 6 2014. There were 2,147 sheep (44 rams per 100 ewes) and 26 goats shot. Sheep shot per day decreased from 193/day to 55/day from the April 2013 to February 2014 missions. The majority of effort occurred in the Core Area. Minimal effort occurred at the northeastern portion of PCH. The aerial shoot crew salvaged 35.6% of the sheep shot, which were given to the public. Total flight time for the 22 days of aerial shooting was billed at 107.2 hours (aerial shooting: Judas sheep capture = 99.1 hours, sheep salvage = 8.1 hours). Average flight time was 4.9 hours per day.

Twenty-six Judas sheep (14 rams and 12 ewes) were captured and collared between July 15 2013 and February 6 2014. Twelve Judas sheep were translocated from the capture site and 14 were released at the capture site. At the end of this period, 17 of the Judas sheep were still alive, 4 rams were accidentally shot by the aerial shoot crew, 2 ewes were harvested by hunters, and signals from 2 ewes and 1 ram had not been received in over 4 months. More effort was put into searching for sheep visually from the helicopter than was dedicated to tracking Judas sheep. Of the total sheep removed by aerial shooting, 2,081 were removed without tracking Judas sheep and 66 were removed when tracking Judas sheep. Fifty-four sheep were shot in 15 encounters (3.6 sheep/encounter) with Judas rams and 12 sheep were shot in 6 encounters (2 sheep/encounter) with Judas ewes. After being deployed with radio collars, Judas sheep had an average relocation by radio telemetry and observation rate of 36% (range = 0-67%) during aerial shooting missions from August 2013 to February 2014. As of March 2014, Judas sheep were evenly distributed across PCH, except for the northeastern side of Mauna Kea where no Judas sheep were present.

Public Hunting Results

Annual hunter harvest for 2013 was 913 sheep. Harvest decreased progressively throughout the year, from 155 sheep in February to 18 sheep in December 2013.

DISCUSSION

Increased funding and effort greatly improved annual sheep removal rates by DLNR from PCH. There were 2,147 sheep shot in less than one year (April 2013 to February 2014), compared to an average of 355 sheep/year between 1998 and 2012 since DLNR was mandated to conduct aerial shoots semi-annually starting in 1998 (Banko et al. 2014). However, several steps should be implemented to further increase ungulate removal rates from PCH while funding is available, and also to better assess the progress of the eradication effort.

Most of the effort from August 2013 through February 2014 was dedicated to searching PCH for sheep without tracking Judas sheep. Removal rates would have been higher if Judas sheep were relocated more consistently than the average 36% radio telemetry monitoring and observation rate per Judas sheep per aerial shoot mission. For example, only 55 sheep were shot during the February 2014 mission and none of those were with Judas sheep. In March 2014, an aerial survey limited to 2 hours was conducted, and 10 of 13 (77%) of the active Judas sheep present during the February 2014 mission were tracked and observed, resulting in a total of 127 sheep counted; 72 more sheep than were shot during the February 2014 mission.

Deploying a larger number of Judas sheep in PCH should also facilitate higher removal rates of sheep. The original Ungulate Removal Plan for PCH called for 40-50 Judas sheep in PCH, but it was reduced to 25 Judas sheep to minimize exposure of the aerial shoot staff to dangerous aspects of "Aerial Capture, Eradication and Tagging of Animals" work. However, deploying fewer collars ultimately increases overall risk to staff by extending the duration of the eradication program through reduced removal rates.

Target areas for deploying more Judas sheep should be on the northeastern aspect of Mauna Kea and in the Core Area of PCH, since both areas are underrepresented with Judas sheep. As of February 2014, no Judas sheep were present in the northeastern quadrant of PCH and based on track logs of each flight, little effort was expended searching this area for sheep. This area is important to survey during aerial shoots because 1) the fence there is dilapidated and the level of immigration occurring into PCH is uncertain, and 2) it is critical not to leave any reservoirs of sheep present in PCH because of the potential for rapid repopulation. A study of mouflon sheep demographics in response to eradication efforts at Hawai'i Volcano National Park highlights the importance of maximizing annual removals rates (Stephens et al. 2008). After 2 years of control and a 30% population decrease, there was a significant increase in the number of lambs

per ewe (±95% CI), from 0.484 (0.412-0.558) in 2005 to 0.667 (0.587-0.750) in 2007, consistent with a density-dependent response. Increasing the density of Judas sheep in the Core Area should also increase annual removal rates by facilitating sheep detection in thick vegetation. The Core Area has the greatest density of trees and canopy cover (Scott et al. 1984), making it difficult to detect sheep from a helicopter, as indicated by the average sighting distance of only 240 ft there during the population estimate.

Increasing the flight time of aerial shooting beyond the average of 4.9 hours/day should also increase annual removal rates. The average duration of aerial control missions from May 1999 to November 2011 (n = 57) was just over 7 hours per mission (DLNR 2013).

Finally, although 3,270 sheep have been removed from PCH, it is difficult to assess how effective the eradication effort has been thus far because the trends in kills per unit time when 1) tracking Judas sheep and 2) not tracking Judas sheep cannot be calculated. To facilitate this, it is necessary to record time in the helicopter dedicated to each of the following activity classes: 1) searching for and hunting sheep without radio telemetry, 2) searching for and hunting sheep with radio telemetry, 3) capture of Judas sheep, 4) salvage, and 5) ferry time.

Failure to maximize removal rates allows reproduction by more sheep, which increases the amount of time, effort, and money necessary to complete the eradication of sheep from PCH. All remaining funds from the Competitive State Wildlife Grant for the eradication program are projected to be spent by December 2014 and no additional funds are presently available. Therefore, the goal of this assessment is to refine the current methodology in hopes of removing all sheep from PCH while funds are still available. The implications of not removing all sheep are that remaining sheep can repopulate PCH quickly. For reference, a population of mouflon sheep was established on a Kerguelen Island in the Southern Ocean in 1957 when 2 mouflon sheep were introduced. The population increased by 46.3% per year until 1969, when the population reached nearly 130 sheep (Chapuis et al. 1994).

It is likely that there are currently fewer sheep in PCH now than at any other time in the past two centuries. Even if all sheep are eradicated, the difficulty of preventing reinvasion poses a persistent threat (Hess and Jacobi 2011); chronic vandalism along the new PCH fence makes this scenario likely. To minimize the potential for reinvasion, it is necessary to regularly monitor and maintain the current PCH fence while continuing to build the remaining sections. Concurrent maintenance and monitoring of sterilized Judas sheep distributed across PCH will allow DLNR to minimize the potential for ingress and eliminate the possibility of reproduction by Judas sheep. DLNR will need to seek new funding to implement these future efforts and continue aerial shooting at least twice a year, as mandated under the 1998 ruling.

ACKNOWLEDGEMENTS

Funding and support for this work came from USFWS, DLNR, and the American Bird Conservancy. Thank you to the Vertebrate Pest Conference for the opportunity to present and publish these efforts and also to the editors and reviewers for their comments.

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