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Conservation Strategies for the Akikiki for Preventing Extinction

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Abstract: The Akikiki (Oreomystis bairdi), a critically endangered Hawaiian honeycreeper, faces imminent extinction due to habitat loss, climate change, and the spread of avian malaria. Once abundant on Kauai Island, its population has dwindled to fewer than 50 individuals, with projections indicating extinction could occur between 2022 and 2025. Key conservation actions include captive care, conservation translocations, reduce mosquito abundance, translocation of native malaria-tolerant species to new areas, conservation breeding (mate choice program), protect alakai plateau from invasion of introduced plants and feral ungulates, and landscape-level mosquito control through the Wolbachia Incompatible Insect Technique. However, these methods either require significant time, resources, or present ethical concerns. This paper aims to explore the multifaceted threats to the Akikiki, summarize the existing urgent conservation strategies, and recommend captive care as the optimal conservation as it offers the highest probability of success in preventing the Akikiki's extinction, although it poses challenges related to cultural, social, and economic factors. To address these concerns, a collaborative approach involving local communities and stakeholders is recommended to ensure the long-term survival of the Akikiki.

Keywords: Akikiki; Preventing Extinction; Captivity Protection.

1. Introduction

The Hawaiian honeycreeper is a type of forest bird that lives on Hawaii Island. It used to have more than 50 species across the island, but due to the population decline that resulted from various environmental changes, only 21 species remain now [Fortini et al. 2015]. The Akikiki (Oreomystis Bairdi) is one of the native species of Hawaiian honeycreepers that was once very common on Kauai Island before 2000 [Paxton et al. 2022]. However, they have now been listed as a critically endangered species on the IUCN Red List, and are estimated to become extinct between 2022 and 2025 [Paxton et al. 2022]. They live at an elevation above 1500 meters on the Alakai Plateau of Kauai Island in Hawaii, where they used to be mosquito-free, and feed on the trunks, branches, and twigs of living and dead koa trees, insects, and arthropods [VanderWerf 2008].

2. Environmental Changes

The Akikiki's population size has decreased due to climate change, habitat loss, invasive species, and other environmental changes, putting it on the verge of extinction [Paxton et al. 2022]. As a result of hurricanes in 1982 and 1992, reduced plant cover caused by invasive plants like Himalayan ginger, and altered vegetation heights resulting from feral pigs, the Akikiki lost habitat and had fewer food resources, narrowing their range and reducing their occupancy [Behnke et al. 2016]. Until 2018, there were only around 454 Akikikis left and their range shrank from 88 square kilometers in 1973 to less than 25 square kilometers in 2012 [Paxton et al. 2018]. Nevertheless, the main reason for the population decline is Avian malaria, a mosquito-borne parasitic disease of birds [Paxton et al. 2022]. Mosquitoes breed in humid and warm environments, so large numbers of them live in low- to mid-elevation areas below 1,500 meters above sea level on Kauai Island [Dahlin and Feng 2019]. Because of climate change, the temperature in high-elevation forests, which used to be disease-free areas, increased, and mosquitoes could thus enter higher-elevation forests where the Akikiki lived, spreading avian malaria to disease-free zones [Paxton et al. 2022]. Since the Akikiki are vulnerable to malaria, a wider distribution of mosquitoes greatly increases disease transmission, infects the Akikiki, and kills their population, forcing them to move to even higher elevations with lower temperatures to avoid mosquitoes [Paxton et al. 2022].

With the predicted further intensification of climate change, there are potential risks of future natural disasters that destroy Akikiki's habitats to a greater extent [Behnke et al. 2016]. As the temperature rises, mosquitoes are expected to spread and bring Avian malaria to higher altitudes with cooler temperatures in the future [Behnke et al. 2016]. The existing disease spread cycle at lower altitudes will be strengthened and prolonged, resulting in highly vulnerable forests in mid- and high-elevation forests [Behnke et al. 2016]. Moreover, because the Akikiki have been forced to retreat to the refuge of the higher Ohia forest without their most common food, koa trees, if the situation continues to deteriorate, Akikiki's food and habitat will be further reduced, resulting in a more difficult living environment [Paxton et al. 2016]. According to a report published by the United States Geological Survey (USGS), U.S. Fish and Wildlife Service, and U.S. Office of Native Hawaiian Relations, the Akikiki are at risk of extinction within ten years, so necessary conservation measures need to be implemented in a timely manner [Paxton et al. 2022].

3. Conservation Goal

There are a range of common goals for the conservation of Akikiki that generally start from the perspective of protecting species themselves or protecting their habitat. Examples of conservation goals include preventing Akikiki‘s imminent

extinction, ensuring the species still exists in the wild in the long term (beyond 10 years), stabilizing the existing wild population of Akikiki, and managing the Alakai Plateau to ensure adequate habitat for remaining wild individuals in 10 years [Paxton et al. 2022]. Based on Akikiki's current situation, preventing them from imminent extinction would be the main focus right now. This means that immediate conservation actions are prioritized, and if successful actions are applied, the Akikiki's population will still exist under captive care or in the wild three years from now. Therefore, the Akikiki should be isolated from the biggest factor leading to their extinction, avian malaria.

4. Potential Conservation Actions

4.1. Captive Care

Scientists and experts are discussing several potential conservation actions that could prevent Akikiki from extinction. The first one is captive care, which is a popular way of protecting endangered species. It is immediate action that removes Akikiki from the wild to a controlled facility for caring and breeding until the threat of avian malaria mortality in the forest on the Alakai Plateau has been addressed [Paxton et al. 2022]. Captive care includes short-term holding, which releases Akikiki back to their original habitat after Wolbachia IIT (a method for controlling mosquito populations by identifying or giving different types of Wolbachia to the population than the wild population) breaks the malaria disease cycle in two to four years, and long-term breeding, in case the application of Wolbachia IIT is delayed [Paxton et al. 2022]. Captive care is insurance that prevents Akikiki's extinction in the short term by reducing the risk of disease mortality immediately [Paxton et al. 2022]. As of now, the success rate of captive breeding is uncertain, with success in increasing the population of some honeycreeper species but not others [Paxton et al. 2022]. For the Akikiki, there are two facilities managed by the San Diego Zoo Wildlife Alliance (SDZWA) in Hawaii that have successful cases in caring for honeycreeper species [Paxton et al. 2022]. However, space for facilities now is limited in Hawaii, so experts proposed options of expanding existing facilities managed by SDZWA, building new facilities managed by other organizations, or using the capacity of zoos outside of Hawaii, but each option comes with huge costs [Paxton et al. 2022]. In addition, after staying in managed facilities under human care for a long time, the Akikiki may gradually lose their natural behaviors over time, decreasing the success of reintroduction to the wild [Paxton et al. 2022].

4.2. Conservation Translocation

Conservation translocation is another method similar to captive care that intentionally moves the Akikiki outside their native forest to a disease-free area for conservation purposes [Paxton et al. 2022]. There are two potential methods for the translocation of Akikiki, direct translocation, which directly moves individuals to a disease-free site on the Island of Hawaii, and translocation from captivity, moving part of the population to a controlled facility for a while and waiting for translocation planning [Paxton et al. 2022]. Different from captive care, conservation translocation allows the Akikiki to remain in wild conditions to retain natural behavior and creates the potential source for repopulating after successful translocation and population growth in the new site [Paxton et al. 2022]. However, the uncertainty around the translocation of the Akikiki from Kauai Island to the Island of Hawaii is high [Paxton et al. 2022]. The impact of the new ecosystem is unknown, so a detailed plan, including site identification, suitability assessment, threats assessment and management, and regulatory compliance, before translocation is needed, which can take more than two years to design [Paxton et al. 2022]. Given the time needed for preparation work, it is also unpredictable how long the Island of Hawaii will remain disease-free since climate change is happening across the world, affecting the distribution of mosquitoes in all areas [Paxton et al. 2022]. Additionally, since there were only 45 Akikiki left in the wild in July 2023, there are not enough individuals available for multiple translocations, which results in a lower success rate if only conducted at a single location [Green and Chang 2023, Paxton et al. 2022].

4.3. Landscape-level Mosquito Control through the Wolbachia Incompatible Insect Technique

Landscape-level mosquito control through the Wolbachia Incompatible Insect Technique (Wolbachia IIT) is now the most popular technique among experts, which matches mosquitoes with different types of Wolbachia, a type of symbiotic bacteria, to mate and produce infertile eggs [Paxton et al. 2022]. It is a mosquito birth control method that releases tens to hundreds of thousands of male mosquitoes with a different type of Wolbachia than those in the wild to suppress the mosquito population at the landscape level in the forest where Akikiki lives [Paxton et al. 2022]. The continuous implementation of Wolbachia IIT can break the avian malaria disease cycle by reducing all mosquitoes in treated areas and thus preventing more Akikikis from being infected [Beebe et al. 2021]. In this way, the Akikiki can be kept in the wild to maintain their natural activities within their habitat, and are able to retain connections to the forest of origin [Paxton et al. 2022]. However, according to research, more than 90% of mosquitoes need to be eliminated in order to break the disease cycle so repeated implementation is needed [Paxton et al. 2022]. This also means that the Wolbachia IIT is a long-term process that requires a large amount of funding for the continuous release of mosquitoes, with an anticipated $6 million annual cost [Paxton et al. 2022]. If the process is paused, the mosquito population can recover in a short period of time, wasting the money and time spent in the past [Paxton et al. 2022]. Moreover, since Wolbachia IIT is a relatively new technique, its success rate is uncertain, and the research and development process require a significant amount of time and resources [Paxton et al. 2022].

4.4. Reducing Mosquito Abundance

Reducing mosquito abundance is another way to protect Akikiki from being infected with avian malaria [Hobbelen et al. 2012]. There are three common ways to reduce mosquito abundance: reduce larval habitat so fewer mosquitoes grow up and spread to different areas, use insecticides to increase larval or adult mortality rates, and introduce predators to mosquitoes to reduce the number of mosquitoes present in the forest where the Akikiki live [Hobbelen et al. 2012]. Through these methods, disease transmission can be limited, and the risk of avian malaria infection in the Akikiki can be reduced [Hobbelen et al. 2012]. However, there is potential harm to other native invertebrates when applying insecticides and biocontrol on a landscape scale, because they are highly toxic to them [Hobbelen et al. 2012].

4.5. Translocation of Native Malaria-Tolerant Species to New Areas

Although most of the honeycreepers are vulnerable to avian malaria, some of them, like the Hawaii Amakihi in low-elevation forests, are found to develop malaria tolerance since they have been coexisting with mosquitoes for a long time [Hobbelen et al. 2012]. They tend to disperse into higher-elevation forests and spread the disease, serving as a large disease reservoir for infecting mosquitoes [Hobbelen et al. 2012]. Therefore, some experts proposed translocating native malaria-tolerant species to new areas to facilitate disease tolerance in the native Hawaiian Honeycreeper community in mid- to high-elevation forests like the Akikiki [Hobbelen et al. 2012]. In this way, disease transmission can be reduced, but the success rate is uncertain, and the malaria-tolerant species may have negative impacts on other species in the new areas, such as transmitting disease to others who are susceptible [Hobbelen et al. 2012].

4.6. Protect Alakai Plateau from Invasion of Introduced Plants and Feral Ungulates

In order to mitigate habitat loss, ungulate fencing and invasive plant removal can be used to protect the Alakai Plateau from feral ungulates and invasive plants like Himalayan ginger that can alter the vegetation [Behnke et al. 2016]. Since feral pigs feed on native tree ferns in Hawaii, creating cavities that are ideal habitats for mosquito larvae, removing feral pigs can reduce the chance of malaria infection in Akikiki [Hobbelen et al. 2012]. In fact, the Hawaii Department of Land and Natural Resources has designed a plan to fence and remove ungulates in the 3000 acres surrounding the region with the highest Akikiki density, which can stop the degradation of Akikikis' population [Behnke et al. 2016]. These methods can all increase the resilience of the Alakai Plateau's forests, which are the Akikikis' habitat, and provide time for the Akikiki to adapt to avian disease [Kilpatrick 2006]. As the Akikiki have been experiencing a decline in occupancy and a narrow range in recent years, as well as increased disease transmission resulting from climate change, immediate conservation action is needed [Behnke et al. 2016]. However, these strategies take time and cannot protect the Akikiki left in a timely manner [Behnke et al. 2016]. If the Akikiki cannot get a higher availability of foods and suitable foraging and nesting habitat, the last group of individuals remaining can easily become extinct [Behnke et al. 2016].

4.7. Conservation Breeding (Mate choice program)

In addition to limiting negative factors, helping Akikiki reproduce quickly and successfully is also an important measure of conservation [Alverson et al. 2023]. The mate choice program for Akikiki under captivity recommends best mate pairings based on different genetics and considers the behavioral compatibility of potential mates, which helps the Akikiki to increase genetic diversity and improve the quantity and quality of their offspring [Alverson et al. 2023]. However, genetic pairings may be behaviorally incompatible, which compromises offspring production [Alverson et al. 2023]. Also, due to a lack of knowledge of Akikiki's reproductive biology and behavior, the long-term success rate for conservation breeding of Akikiki is low [Alverson et al. 2023]. Thus, extensive resources are needed to observe and study the behavior of Akikiki and proceed with the mating program [Alverson et al. 2023].

5. Optimal Conservation Action

Above all the potential conservation actions, the captive care method is the best solution regarding the current situation of Akikiki. Since there are only less than 50 Akikikis left now, taking conservation action in a timely manner is the priority to achieve the goal of preventing imminent extinction [Paxton et al. 2022]. Some experts now worry about whether there is enough time to respond to the declining Akikiki population, thus thinking that removing Akikiki as soon as possible from the wild to a controlled facility to cut off from the malaria disease threat is the best way to prevent imminent extinction [Paxton et al. 2022]. Captive care has the quickest implementation among all potential actions that need to be planned, initiated, and implemented, which can take several years before the actions even start [Paxton et al. 2022]. Immediate action is crucial for Akikiki to retain the remaining population, and captive care can serve as insurance to buy time for scientists to figure out and implement other ways like Wolbachia IIT to clear the threat of avian malaria in Akikiki's forest of origin before reintroducing them to the wild [Paxton et al. 2022]. Also, captive care is a matured technique that has been used worldwide on many endangered species and there was a successful case managed by SDZWA that helped to stabilize the Hawaiian Honeycreeper population [Paxton et al. 2022]. In the controlled facility, the environment is being managed so there are little to no threats to the Akikiki here to grow and reproduce. Another reason for choosing captive care is because there is room to choose short-term holding or long-term breeding depending on the external environment in the forest [Paxton et al. 2022]. If Wolbachia IIT successfully removes above 90% of mosquitoes from the forest on the Alakai Plateau, where Akikiki live, and reduces the threat of avian malaria mortality, scientists can choose short-term holding and release Akikiki back when the forest is safe, which usually takes two to four years [Paxton et al. 2022]. However, if the process of removing mosquitos is delayed, experts can build more facilities that are suitable for long-term breeding that typically enable Akikiki to live healthily for up to ten years, a relatively long life span for the species [Paxton et al. 2022]. No matter what option is chosen, the Akikiki can stay in a safe environment during the decision-making process, which guarantees their continuation of life.

The strategy of captive care is very likely to be adopted, although there are factors both supporting and hindering this action. First, captive care is a conservation tool used worldwide so institutions have successful experience in building facilities and controlling a suitable environment for the Akikiki to keep them in a low-risk environment [Paxton et al. 2022]. However, the previous outcomes of captive care for honeycreepers was mixed [Paxton et al. 2022]. The two facilities managed by SDZWA in Hawaii have been successful in caring for honeycreepers, but less successful in breeding to increase the population size and reintroducing healthy individuals back after the threats are cleared [Paxton et al. 2022]. It is unclear if the method works for the Akikiki and there is not a large enough population to estimate the probability of success in designing an effective captive care program [Paxton et al. 2022]. Also, scientists still need to use Wolbachia IIT to break the disease cycle in the forest [Paxton et al. 2022]. The time for reintroduction to the wild and success largely depend on the implementation of Wolbachia

IIT to remove the greatest threat to Akikiki, avian malaria [Paxton et al. 2022]. Nonetheless, captive care experts are confident in keeping Akikiki alive and increasing its population with sufficient resources and time. According to their estimation, there is a 78% probability of success in preventing them from extinction, the highest among most of the conservation strategies [Paxton et al. 2022]. In addition, since the issue Akikiki is experiencing is widely known by experts and environmentalists around the world, international concerns have led zoos outside of Hawaii to offer to help support long-term conservation, which provides extra capacity and skills at little cost [Paxton et al. 2022].

6. Concerns and Mitigations

However, there are some social, ethical, and economic concerns regarding the captive care program for the Akikiki.

6.1. Ethical Issue

Native Hawaiians want to maintain the Akikiki in the wild as much as possible, so they regard captive care as only a temporary solution to prevent its extinction in the short run because captive care cuts the Akikiki's connection to the wild [Paxton et al. 2022]. To mitigate this concern, scientists and organizations can design a cultural protocol during the planning process with the local Hawaiians [Paxton et al. 2022]. This would allow them to include cultural and ethical considerations to maximize the chance of success in capture and management, reducing the pain and suffering of captive individuals [Paxton et al. 2022]. In addition, scientists can also try to maintain Akikiki's connection to nature and provide high-quality care [Paxton et al. 2022].

6.2. Social Issue

Also, native Hawaiians consider moving Akikiki outside of Hawaii separating them from their historical, ecological, cultural, and familial ties [Paxton et al. 2022]. The consensus for international captive care is that it is only necessary when there is a higher possibility of success in facilities in other countries [Paxton et al. 2022]. Thus, scientists should coordinate the space for Akikiki to use facilities in various locations in Hawaii and expand the facilities within Hawaii Island not only managed by San Diego Zoo Wildlife Alliance, but also by other professional organizations with successful experience to ensure the control and maintenance of facilities and the caring process [Paxton et al. 2022].

6.3. Economic Issue

Finally, captive care requires an extensive amount of manpower and material resources that are associated with high costs [Paxton et al. 2022]. The Akikiki needs to stay in controlled facilities until avian malaria is cleared in their original habitat which takes at least two years [Paxton et al. 2022]. During this time, continuous management and control are needed for the Akikiki, not only ensuring their health but also boosting their reproductive rate [Paxton et al. 2022]. The estimated cost for temporary holding is $750,000 for starting the program and around $850,000 annual cost for maintenance and operation [Paxton et al. 2022]. Among the three options to cater to all Akikiki individuals under captive care, both expanding facilities under the management of SDZWA and building new Hawaii-based facilities are expected to cost $6,000,000 on average for the startup, with the slightly higher subsequent annual cost for the new facilities option, around $850,000 [Paxton et al. 2022]. The option of moving the Akikiki to Zoos outside Hawaii has a lower startup cost of $90,000 and a $100,000 yearly cost afterward [Paxton et al. 2022]. To solve the economic concern, scientists can expand facilities in the continental United States outside Hawaii to care for a small percentage of the population when there is not enough space in Hawaii to reduce the cost and move them back when there is space available to strengthen cultural, ecological, historical, and familial connections [Paxton et al. 2022]. In this way, there are also possibilities to access new expertise in different institutions that increase the rate of success [Paxton et al. 2022].

7. Conclusion

In conclusion, Akikiki's population has been declining rapidly during the last two decades because of various environmental changes like climate change, natural disasters, and invasive species, which all contribute to food and habitat loss and disease infection in the Akikiki [Paxton et al. 2022]. Among these factors, climate change is the major driving force that led to the sharp decline in the numbers of Akikiki, reaching a 5% annual population decline [Paxton et al. 2022]. Because of climate change, the mosquitoes that live in the lower- elevation forest on Kauai Island invade the higher elevation forest and bring avian malaria to the Akikiki, which are vulnerable to the disease [Paxton et al. 2022]. With the goal of preventing Akikiki from going extinct, several conservation actions can be taken, such as captive care [Paxton et al. 2022], conservation translocation [Paxton et al. 2022], Wolbachia IIT [Paxton et al. 2022], mate choice program [Alverson et al. 2023], reducing mosquito abundance [Hobbelen et al. 2012], ungulate fencing [Behnke et al. 2016], and removal of disease-tolerant species [Hobbelen et al. 2012]. But concerning the number of Akikiki population now, captive care would be the best choice because it can be implemented in the shortest period of time which cuts off the threats in the wild and keeps the Akikiki in a safe place to live and reproduce [Paxton et al. 2022]. It is also a mature method that has several successful cases in other honeycreeper species [Paxton et al. 2022]. Despite the unknown success rate of this method for the Akikiki, it is widely believed that with the help of experienced professionals, Akikiki are expected to have a high chance of surviving and reproducing to restore its population and achieve the goal of remain exist in the world in three years of time [Paxton et al. 2022].

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